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Archaeology

War, Wounds, and Medicine:
A Re-Examination of the Crew of the Mary Rose

by

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Abstract

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The Mary Rose sank in the Solent on 19th July 1545. Only a few dozen of the 450+ crew survived, the rest, trapped beneath anti-boarding netting and on the lower decks, went down with the ship. Despite numerous attempts to salvage and explore the wreck site over the centuries, it was not until excavations in the 1970s and 80s that revealed the starboard side of the Mary Rose, preserved beneath the silts of the Solent. Along with the ship, the contents were similarly preserved, including an undisturbed medical chest. The excavation not only revealed the material contents of the ship, but additionally the remains of at least 179 crew members, 92 of which were deemed as 'Fairly Complete Skeletons' and form the basis of this study.

This thesis aims to examine the medical care available to a military crew in the mid-16th Century. The Mary Rose provides a unique case study with the human remains being closely associated with evidence of medical practice, through the presence of the medical chest found in the Surgeon's Cabin. The known date of the sinking places the site firmly within the wider context of Tudor medicine. Alongside the excavated evidence from the ship, the practice of surgery is examined through the texts available in the 16th century. The texts offer an understanding as to how a surgeon on board the Mary Rose may have treated the crew under his care.

This thesis provides an insight into the types of injury and trauma that affected a living and working naval crew. The pathology found within the skeletal material was not the cause of death, but rather a representation of injuries with which they lived. The results show that alongside traumatic fractures and dislocations, the crew also suffered from degenerative changes to their joints and spines. The

medical chest demonstrates that the Surgeon on board the Mary Rose would have been prepared with a wide range of equipment to perform everyday tasks, such as barbery, to the more extreme surgical procedures, such as amputation. This thesis provides a deeper insight into the health of the Mary Rose crew, and the medical treatment available to them as a living, fighting force of the Tudor navy.

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Research Thesis: Declaration of Authorship

Print name: Emily Sarah Jocelyn Mitchell

Title of thesis: War, Wounds, and Medicine: A Re-Examination of the Crew of the *Mary Rose*

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission

Signature: ....Date:

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Abbreviations

A-M	Ante-mortem
EN	Enthesopathy
FCS	Fairly Complete Skeleton
OA	Osteoarthritis
OC	Osteochondroma
OD	Osteochondritis Dissecans
OLF	Ossified Ligamentum Flavum
OLS	Ordinary Least Squares
OP	Osteophytes
OsA	Os Acromiale
PD	Periodontal Disease
P-M	Post-mortem
RMA	Reduced Major Axis
SBO	Spina Bifida Occulta
SCFE	Slipped Capital Femoral Epiphysis
SEE	Standard Estimation Error
SN	Schmorl's Nodes

U	Upper Deck (numbered 2-11)
M	Main Deck (numbered 1-11)
O	Orlop Deck (numbered 1-11)
H	Hold (numbered 1-11)

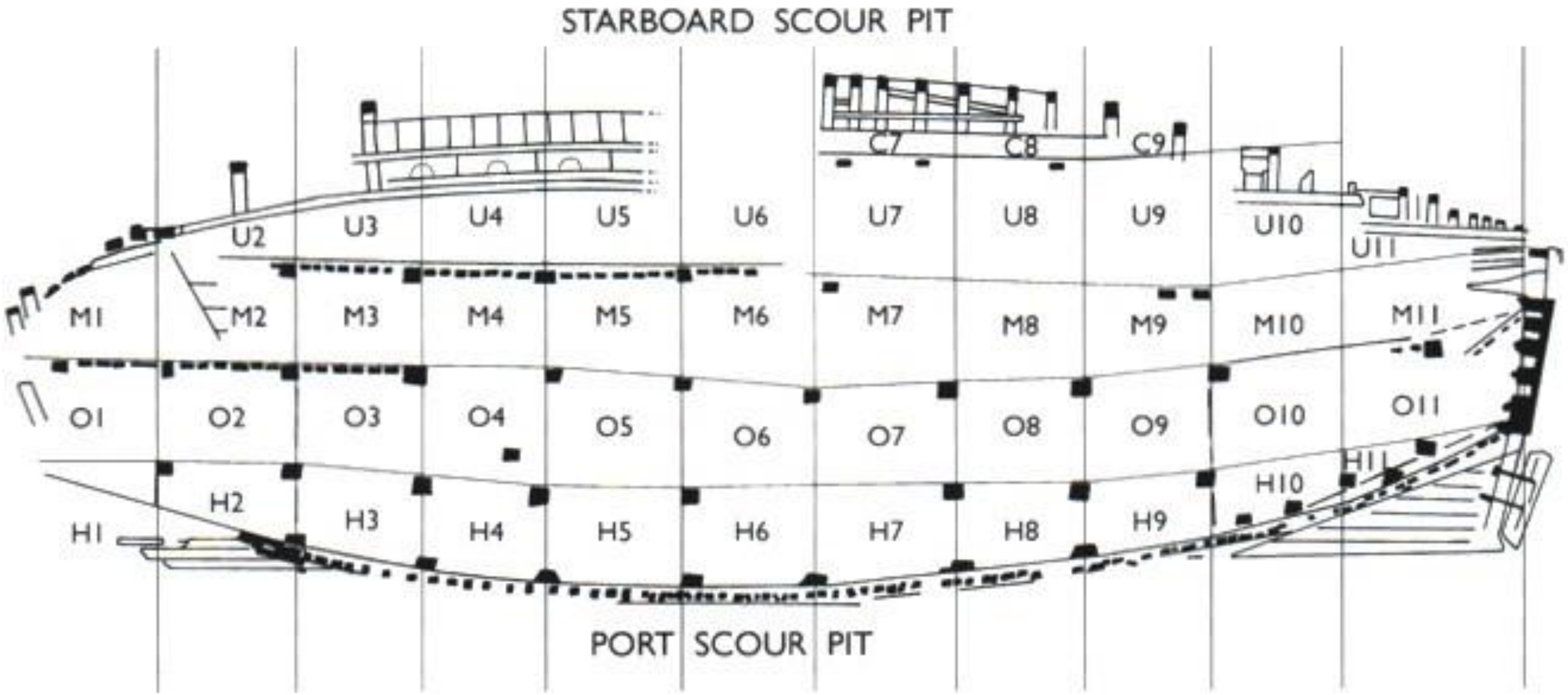


Fig 1.1: The sectors of the *Mary Rose* used during excavation

U – Upper Deck   O – Orlop Deck

M – Main Deck   H – Hold

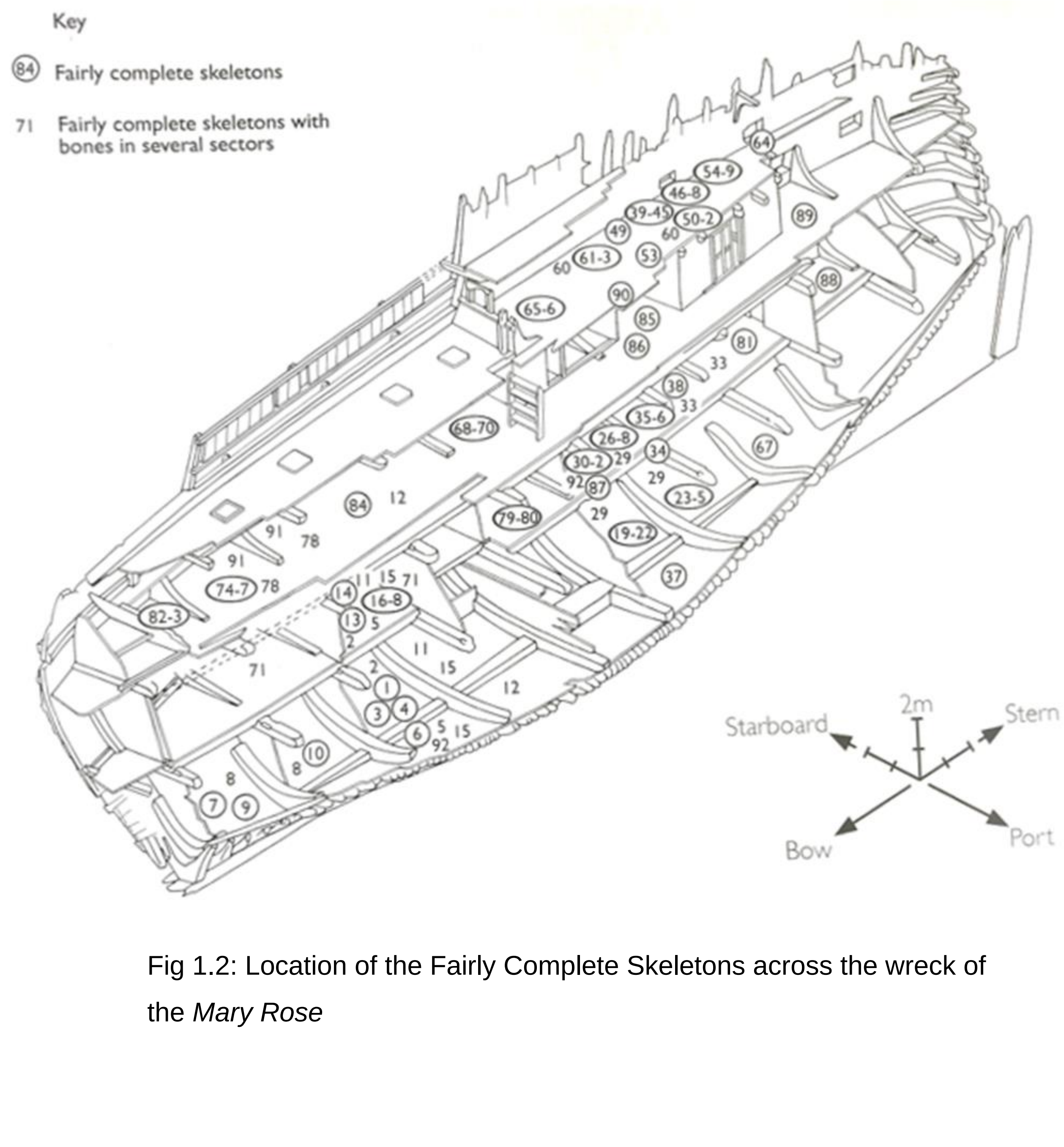


Fig 1.2: Location of the Fairly Complete Skeletons across the wreck of the *Mary Rose*

For all those unknown men of the *Mary Rose*
who did not die a dry death.

A. J. Stirland, 2013

1. Introduction

The concept of war throughout history, particularly the medieval era, is not new; likewise, the history of medicine is extremely well documented from Ancient and Classical times through to the more modern advancements. As Emily Mayhew states in the opening line of her book, A Heavy Reckoning; 'The constant of all warfare, whatever the century, is the wounding of soldiers' (Mayhew 2017: 1). While Mayhew's book focuses on the many medical advancements that came about during the modern war in Afghanistan, the link between medicine and war throughout history should not be overlooked. Warfare, as a cause of injury, is therefore also an environment in which medicine and surgery are essential for the health and survival of those involved.

The *Mary Rose* differs drastically from battlefield sites on land, such as those at Towton and Visby. While Towton, one of the bloodiest battles from the War of the Roses, provides the largest mass grave of casualties from an English battlefield (Fiorato et al 2007: 13; Curry and Foard 2016: 63), the remains differ from those from the *Mary Rose*. The soldiers uncovered from Towton represent individuals killed in battle, with clear evidence of weapons trauma, particularly severe cranial and facial wounds (Novak 2007: 90). Additionally, the remains comprise some 37 or 38 separate individuals, a small sample of the thousands recorded as perishing at the battle in the contemporary chronicles (Boylston et al 2007: 45). The battle-dead of Towton would likely have been stripped of their armour before being interred at or near the site of the battle (Burgess 2007: 34). The individuals on board the *Mary Rose*, however, would have fought and subsequently drowned in the environment in which they lived. The sinking of the ship would not have allowed the crew to be stripped of personal or valuable possessions and interred in a separate grave site;

the ship itself became the tomb for the crew. When the ship was rediscovered over 400 hundred years later, the decks of the remaining starboard side were still distinguishable and subsequently divided into sectors for excavation (see fig. 1). This revealed both the contents and the remains of the crew still situated within the *Mary Rose*.

The remains of at least 179 crew members have been identified from over 11,000 human bones brought up from the wreck site of the *Mary Rose* (Stirland 2013: 77; *Mary Rose* Dive Logs). Of the original crew, only around 2 dozen survived the sinking of the ship, likely due to the anti-boarding netting covering the waist of the ship (Marsden 2003: 134). A low survival rate of the crew can also be seen in the sinking of the Swedish warship *Kronan* in 1676, in which only 42 men survived from the 850 originally on board (Kjellström and Hamilton 2014: 34). As the *Kronan* keeled over, the munitions and powder magazines on board exploded, resulting in the bow being destroyed and the subsequent rapid sinking (Kjellström and Hamilton 2014: 35, 36). During osteological examination of the remains found during the excavation of the ship, numerous ‘cut marks, blows and stripes’ were found on the bones (During 1997: 592). The lack of healing of such marks has led to the conclusion they were possibly a result of the explosion during the sinking, as contemporary sources report the crew had not been engaged in hand-to-hand combat (During 1997: 593). Both the *Mary Rose* and the *Kronan* sank rapidly, likely a cause of the high death rates amongst the crews. Another Swedish warship, *Vasa*, sank in Stockholm harbour on her maiden voyage in 1628 (Kvaal and During 1999: 170). The *Vasa* was designed to carry 133 crew members, with a further 300 soldiers to board when the ship departed for active service (*Vasa*museet.se, Life on Board). As it was the maiden voyage, the crew were allowed to bring their families on board, and it is likely there were also additional invited guests (Kvaal and During 1999: 170). Unlike the *Mary Rose* and the *Kronan* where so few crew members survived, the majority of those on the *Vasa* did survive, with only 30 reported to have died (Kvaal and During 1999: 170). Despite being a warship, however, the *Vasa* sank in very different circumstances to both the *Mary Rose* and the *Kronan*; within a harbour, in sight of many spectators and with other craft in the water capable of coming to aid (*Vasa*museet.se, History). Unlike the *Mary Rose* and the *Kronan*, the remains uncovered from the *Vasa* also include those of women and a child

(*Vasa*museet.se, Skeletons). Due to the known presence of guests on the ship, it cannot be determined which of the remains are definitively crew members, or part of an active fighting force.

With the *Mary Rose* there is less ambiguity as to the remains; being on board a flagship of Henry VIII during an active battle demonstrates membership of the fighting crew. Unlike the crew of the *Kronan*, there is no evidence of extensive, perimortem, cut marks to the bones. This suggests that the cause of the deaths of the crew of the *Mary Rose* is almost certainly universal for all those on board, drowning during the sinking. Due to the certainty of drowning for the crew, any antemortem injuries and trauma to the skeletal remains would have been survived to the extent that the sufferer was able to be an active member of a warship at sea. Therefore, any pre-existing serious trauma is likely to have been treated medically, and successfully.

The correlation between warfare and the advancement of medical knowledge can be seen as far back as Classical Greece when Hippocrates stated, ‘He who wished to be a surgeon, should go to war’ (Porter 2003: 109). By its very nature, war will invariably produce wounds and injuries on a far greater scale than would be suffered by the general population at any given time. Hippocrates’ statement about the importance of war in the training of a surgeon is a concept that has appeared throughout the history of medicine. Thomas Gale (1507-1587), practicing at the time of the sinking of the *Mary Rose*, gained his own surgical experience through treating soldiers on campaign; he wrote of his experiences on the conditions faced by the surgeons during the campaign in Boulogne in 1544. Such experiences enabled Gale to become a successful surgical writer and teacher on his return to London after the war (Beck 1974: 182). In 1560 he was also appointed sergeant-surgeon to Queen Elizabeth I, a title that historically denotes a surgeon who would have followed their monarch into battle (Beck 1974: 183; Thompson 1960: 2). The role of sergeant-surgeon is a long and distinguished one, stretching back to at least the reign of Henry III, when Henry de Saxby was appointed to the post in 1251, followed by Thomas de Weseham in 1260 (Thompson 1960: 5). Many of the eminent surgeons writing during the sixteenth century, around the time of the *Mary Rose*, held the position of sergeant-surgeon, including Thomas Vicary who would produce the first anatomical text in English (Thompson 1960: 6 & 7). The prominent role that some sergeant-surgeons held amongst the Barber-Surgeons and Surgeons of the sixteenth century is beneficial to the study of the surgery available to the crew of the *Mary Rose*, as the surviving medical texts are often compiled by men who would have served in a medical-military capacity. As a result, they are likely to have been writing treatise similar in nature to those used by the Surgeon on board the *Mary Rose*.

The benefit of warfare to the advancement in medicine and surgery can perhaps be most clearly seen in the twentieth century, during the outbreak of the First World War, in the work of Sir Harold Delf Gillies. His pioneering work at the Queen's Hospital, Sidcup, revolutionised the treatment of severe and disfiguring facial injuries for soldiers returning from the front line. It is likely that such advancements were only made due to the large number of patients admitted to the hospital - with thousands being admitted both during the First World War and in the years succeeding it (Bamji 2006: 144). Assessing the medical care of those treated during the First World War is, understandably, far easier than assessing medical care available to fighting men during the reign of Henry VIII - there are over 2500 case files surviving from Gillies' work in Sidcup alone, providing details on the patients, their injuries, and subsequent treatments (gilliesarchives.org.uk).

This thesis uses the archaeological evidence available from the *Mary Rose* as a case study to gain a greater comprehension of the medical care available to a Tudor naval force. Compared with other military sites, whether land-based or maritime, the *Mary Rose* site has the advantage of having the medical chest associated directly with the human remains. This allows for a greater comprehension of what tools and instruments would have been at the disposal of the surgeon, thus enabling the level and range of treatments to be better understood. Similarly, it reveals the extent of treatments available, over what can be revealed through analysis of the human remains alone. This study focuses on the Fairly Complete Skeletons (FCSs) that were uncovered from the wreck, comprising of 92 individuals found throughout the decks of the *Mary Rose* (see fig. 1.2). These 92 individuals were established through the work of Ann Stirland (Stirland 2013: 76). By focusing on the FCSs, as opposed to the disarticulated remains, it will enable a better understanding of the crew as individuals in terms of evidence of trauma and degenerative changes to the bone, potentially as a result of life onboard a warship.

Similarly, it will also allow for more accurate assessment of the age, stature, and sex of the crew, something that would not be possible if singular bones were assessed.

1.1 Aims of the Thesis

Focusing on the *Mary Rose* and the medical care available to her crew during the Tudor era, this study seeks to provide a more comprehensive view of medicine in the past. It assesses the types of injury sustained, the medical equipment available to the Surgeon on board, and evaluates whether or not the care available would have been suitable for the trauma sustained. The *Mary Rose* itself provides a moment frozen in time - when she sank on the 19th July 1545, only about two dozen members of her 415+ strong crew survived, the rest sharing a common cause of death, that of drowning. Many of those who died did so close to the locations on which they had lived and fought, and while the currents of the Solent have had an effect over the intervening centuries, the mass grave of the *Mary Rose* still provides the resting place for nearly half the crew (Stirland 2013: 76).

The *Mary Rose* provides an archaeological site connected to warfare that can be dated with unwavering accuracy - almost to the hour - to a specific point in time. This accuracy enables the site to be placed precisely within its historical context in relation to the medical practices and treatise of the day. Likewise, the presence of the medical chest found on board also provides a conclusive link between the practice of medicine and the crew themselves. These factors coincide to create a unique site for the study and understanding of medicine and surgery in a military environment during the sixteenth century, which has hitherto been unexplored within the archaeological context.

These factors will be addressed in the following study, focusing on three main questions:

1. What trauma (or healed trauma) can be identified skeletally from the human remains found on board the *Mary Rose*? To answer this, the skeletal remains uncovered from the wreck are examined to assess any evidence of trauma or healed trauma in order to demonstrate what types of injuries were sustained by the crew of the *Mary Rose*.

2. What is the state of medical knowledge at the time of the sinking of the *Mary Rose*? The medical knowledge of the time is important for the understanding of how any injuries present within the skeletal collection may have been treated. For this, the medical and surgical texts from the 16th Century are an invaluable source, providing not only the treatments used, but also the tools, instruments, and ingredients needed by medical practitioners in order to treat a wide range of ailments and injuries.

3. What treatment was available to the sailors on board the *Mary Rose*? Did the Surgeon on board have access to suitable medical treatments? Analysis of the *Mary Rose* medical chest and its contents to the medical treatise of the day provides details regarding the medical care available to the crew while at sea.

This brings the final research aim into focus; whether or not the skeletons of the *Mary Rose* display trauma and whether or not such injuries could have been successfully treated by the Surgeon on board the ship.

1.2 Outline of the Thesis

Chapter 2 considers the history of the *Mary Rose*, both her construction and service history, along with her infamous end at the Battle of the Solent. This helps highlight the importance of the *Mary Rose* as one of Henry VIII's flagships. Additionally, the causes of the sinking are also explored, and why the event resulted in so many of the crew losing their lives. The history of the *Mary Rose* did not finish with the sinking of the ship. Multiple salvage attempts across several centuries, culminated in the uncovering, excavation, and raising of the wreck in the 1980s.

Chapter 3 provides an outline of the methodology for the study. It looks at the various elements required to better understand the medical care of the crew on board. These include the evidence of pathology in the crew through their skeletal remains, the contents of the Surgeon's cabin and the tools and equipment available to them, and the study of contemporary medical and surgical texts. These three elements are necessary to better understand the types of trauma being suffered, and how the surgeon may have been able to treat his patients successfully with the tools he had available on board the ship.

Chapter 4 focuses on the practice of medicine in the 16th Century. The medical care available on board the *Mary Rose* cannot be compared to modern medical practice, thus it is through the examination of the contemporary medical traditions that more can be understood about the skills and knowledge available to a Tudor naval surgeon. It looks at the structure of medical practice in Tudor England, education, guilds, and practice licenses. Additionally, the treatments found in the texts of prominent Tudor surgical practitioners are also examined to provide a basis for understanding how the crew members on board the *Mary Rose* may have been treated for various ailments.

Chapter 5 examines the previous work that has been carried out on the Fairly Complete Skeleton (FCS) Collection, conducted in the 1980s. This includes the excavation process, along with the method of sorting the remains into FCSs. The initial analysis of the collection is considered, in terms of age, sex, and stature of the crew, and the accuracy of the results.

Chapter 6 comprises a detailed examination of the FCS collection uncovered from the wreck of the *Mary Rose*. This expands on previous work carried out on the human remains shortly after their initial excavation. This involves an overall assessment of the skeletal remains in terms of sex, age and stature, providing the basis for further examination of the remains for evidence of pathology.

Chapter 7 examines the evidence of pathology found within the FCS collection. It addresses each type of pathology, providing a description, probable cause as well as potential symptoms that would be felt by the individual, based on modern medical knowledge. For each pathology, an example of its presence within the FCS collection is also given, along with conceivable causes for such changes. Such causes could include direct trauma to the bone through an accident, or due to stresses placed on the bones and joints through the lifestyle of hard manual labour on board an active warship. In addition, the dental pathology of the FCSs is also considered. While comparatively few skulls are assigned to the FCS collection, those that are present provide a range of dental pathology. Such analysis can provide a greater understanding with regards to the overall health of the crew. As with the examination of the post-cranial pathology, the various dental pathologies are listed with descriptions and causes, in accordance with modern medical parlance. For each dental pathology, examples are then provided from within the FCS collection.

Chapter 8 examines the medical equipment found within the surgeon’s cabin. The archaeological evidence for instruments is assessed, using illustrations and descriptions from the contemporary medical texts in order to identify which instruments are present. Additionally, the texts help identify which instruments are missing from the archaeological record, particularly those of an all-metal construction, their prevalence in the texts suggesting they would likely have formed part of the original *Mary Rose* medical chest. This helps establish the standard and the range of medical care that would have been available in 1545.

Chapter 9 combines the three elements of this study; the FCS Collection, the medical chest found on board the *Mary Rose,* and the contemporary medical and surgical texts of the day. By bringing these three components together a greater understanding of how various ailments would have been treated on board can be gained. With the pathology evidence provided by the FCS Collection, treatments for such can be identified within the contemporary texts, and their potential use on board the *Mary Rose* can be assessed through the contents of the surgeon’s chest.

Chapter 10 summarises the final conclusions and results of the study. In addition to this, outlines are given for further potential research that could be undertaken on the FCS, and other human remains uncovered from the *Mary Rose*, in order to increase our understanding of the crew.

2. The History of the *Mary Rose*

The *Mary Rose* is perhaps best known for sinking during the Battle of the Solent in 1545, though this was only the culmination of about 34 years of active service as one of Henry VIII's flagships. To more fully understand the importance of the *Mary Rose*, both as a warship, and an archaeological site, her history must be considered. Understanding of both her construction and outfitting also aids in the analysis of why the sinking of the *Mary Rose* resulted in such a large loss of life.

2.1 The Anthony Roll

One of the main primary sources for the *Mary Rose* is the *Anthony Roll*, a unique document that was compiled by Anthony Anthony and presented to King Henry VIII the year after the sinking of the *Mary Rose* in 1546 (Knighton and Loades 2000: 3). It is currently the only known or surviving contemporary record of the *Mary Rose*. Anthony, the son of a Flemish migrant, started his service to the crown in 1530 as a Groom of the Chamber; from here he progressed to becoming one of the Gunners at the Tower of London in 1533, before being appointed to Clerk of the Ordnance at an unknown date. In his role as Clerk of the Ordnance he was responsible for rapidly providing munitions for the navy during the French invasion of 1545 (Knighton and Loades 2000: 3; Moorhouse 2005: 290). In 1549, the new king and Henry's only legitimate son, Edward VI, raised Anthony to the rank of Master Surveyor for the Ordnance; a rank that he could hold for life, with his authority encompassing the Tower of London, Calais, Boulogne, and beyond (Moorhouse 2005: 290). At the time in which Anthony was compiling his Roll for presentation to Henry VIII in 1546, the *Mary Rose* had already been lost but is possible that the hope of salvaging the ship is the reason why it remained as part of the Anthony Roll (Knighton and Loades 2000: 4).

While often referred to in the singular '*the Anthony Roll',* the document did, in fact, consist of three separate Rolls, comprising of a total of 17 membranes of vellum containing both text and illustrations (Moorhouse 2005: 290). The first and third rolls have since been converted into a Codex and are held in the Pepys Library at Magdalene College in Cambridge, with the second roll, still in its original roll form, being held in the British Library (Knighton and Loades 2000: 5). Despite the size of the document covering the 58 ships owned by Henry VIII at the time, the hand it is written in remains constant throughout, suggesting that it was Anthony himself who wrote the document. This is further corroborated by the framed signature of Anthony that is present at the bottom of each roll, which has been favourably compared to the known signature of Anthony in some state papers (Knighton and Loades 2000: 5). The 58 ships that comprised Henry VIII's navy are each depicted within the Roll, and all are illustrated as moving from left to right (see fig 2.1); ostensibly to display the stern where the heaviest armaments would be shown to the greatest effect; in accordance with marine art of the time (Moorhouse 2005: 290).

Fig 2.1: Depiction of the *Mary Rose* in the Anthony Roll (maryrose.org)

Each of the illustrations were initially drafted in lead pencil before a multitude of colours were added with paint and gold to add further details, in particular with the array of banners, flags and pennants adorning the ships. The detail was to the extent that on the depiction of Row Barges and Galleys, it is possible to count the individual oars, and with other ships; the number of guns (Moorhouse 2005; 290, 291).

Though in particular the number of guns is sometimes regarded with scepticism in terms of accuracy, likewise the heraldry adorning the ships is considered to be ‘a bit overdone’ (Moorhouse 2005: 291). Despite the potential inaccuracies of the illustrations of the Anthony Roll, the textual element detailing the tunnage, ordnance, and munitions are recorded in careful detail. The ‘Habillementes for warre’ for example includes records for everything from coils of rope to the number of nails on board the ships, with even individual nails being carefully counted (Moorhouse 2005; 290).

2.1.1 Anthony Roll Crew Numbers

Some of the most informative material to be found within the Anthony Roll is the list of crew members on board. With so many men perishing in the sinking of the *Mary Rose*, the numbers listed on the Anthony Roll help provide a reference point when establishing what percentage of the crew have been uncovered during the excavation of the site. The listing of the crew also divides the men into the categories under which they would have served: be it mariner, soldier, or gunner. The Anthony Roll lists the men on board as follows (from Rule 1982: 26, 27):

Men	Number
Soldiers	185
Mariners	200
Gunners	30
Total	**415**

Table 2.1: Crew numbers on board the *Mary Rose*, according to the Anthony Roll

While this total number gives a good indication of the active fighting men on board it does not take into account the others who would be serving alongside them; individuals such as the officers, cook, purser, Surgeon, and carpenter. As such the estimations for the number of individuals on board the *Mary Rose* at the time of the sinking is usually placed around the 450 mark, though some estimations take this number up to around 700, by claiming an extra 300 archers were on board (Stirland 2013: 79). The figure of 700 however does seem excessively large for both the size of the vessel and the number of human remains uncovered from the wreck. Stirland points out that if this were indeed the case and that the *Mary Rose* sank with over 700 crew members, then the uncovered remains, representing at least 179 individuals is only a quarter of the original crew, despite just under half the ship surviving. The current dimensions of the wreck are 31.1m long and 8.1m wide, weighing approximately 200 tonnes, compared to the complete ship in 1545 which measured 40.9m long and 11.9m wide weighing up to 700 tonnes (maryrose.org, About the *Mary Rose*). Therefore, it seems more likely that the number on board was closer to the Anthony Roll figure of 415, resulting in 43% of the crew being represented by the excavated human remains (Stirland 2013: 79).

2.2 Construction and Service History

2.2.1 Commission and Construction 1510-1511

Throughout his 38-year reign Henry VIII had nearly 30 warships built, each weighing over 100 tons. The *Mary Rose* was one of these ships (Loades 2009: 1). While her size and construction do not necessarily separate her from any of the other warships commissioned by Henry VIII, her continued existence as preserved wreck distinguishes her from other contemporary warships (Loades 2009:1). The *Mary Rose* and the Peter Pomegranate were two new flagships, commissioned by Henry VIII at the start of his reign, between the years 1510 and 1512 (Loades 2009: 4; Marsden 2003: 1). Due to their construction being completed and ready for fitting just 27 months after Henry VIII took the throne, there has been some debate as to whether it was Henry VIII, or his father Henry VII who had initially commissioned the ships (Marsden 2003: 1, 2). However, a warrant for the building of two new ships dating to January 1510, initialled by Henry VIII, almost certainly refers to the *Mary Rose* and the Peter Pomegranate (Marsden 2003: 2; Marsden 2019: 21). While no names are provided on the warrant, either of the ships themselves or the location of their construction, no other warships are thought to date from this time, thus they are thought to be the *Mary Rose* and the Peter Pomegranate (Marsden 2003: 2). Despite this, the exact identity of these two ships cannot be definitively established.

One particular reason is that the weights of these two ships is given as 400 and 300 tonnes; the *Mary Rose* and the Peter Pomegranate would ultimately weigh 500 and 450 tonnes respectively (Marsden 2003: 2). While the difference of 100-150 tonnes may seem significant in today's ship-building parlance, documents dating to the 16th Century can often vary greatly in terms of the tonnage of the King's ships, and as such the disparity is not considered significant (Marsden 2003: 2). Such variations indicate that there was no set formula for the calculation of the tonnage of a ship. Increases in tonnage of the same ship over time have also been attributed to changes in the calculation method by different individuals, as opposed to a simple increase in the weight of the ship (Marsden 2003: 3).

The first mention of the *Mary Rose* by name occurs on the 9th June 1511, where she is listed as the *Marye Rose* (Marsden 2003: 2). While little is known of the construction process, or where construction occurred (Loades 2009: 4, 5; Marsden 2003: 3), documents suggest she was most likely constructed at Portsmouth. This is due to a payment being made for the conveyance of the *Mary Rose* from Portsmouth to the Thames in order to be fitted out (Marsden 2003: 3). In addition to this, Portsmouth was also the location of a dry dock and storehouses that had been built for ship construction during the reign of Henry VII (Marsden 2019: 21).

2.2.2 Original Appearance

While no images of the *Mary Rose* date to the time of her construction, it is known that she was constructed as a *carrack,* the largest type of ship in Northern Europe (Marsden 2003: 5; Marsden 2019: 20). Although the *Mary Rose* is not depicted at this time, other ships of a carrack construction provide an insight into how the *Mary Rose* would have looked at the time of her construction. Such depictions are likely more accurate than the later illustration provided by the Anthony Roll in 1546, after the *Mary Rose* had been refitted with new and increased ordnance. Carracks were built with a narrow 'waist', with high castles both fore and aft (Marsden 2003: 5; Marsden 2019: 20). Lighter guns were positioned in the castle sections, with a few heavier guns on the main deck and in the stern of the ship (Taylor 1950: 145). According to the fighting instructions of Sir Thomas Audley, written in 1530, the key armament for the carracks built at the beginning of Henry

VIII's reign were the bowmen and billmen who would be positioned in the over-hanging castle sections (Taylor 1950: 145). Within the waist of the ship the archers and gunners were provided with *pavesses,* a type of rectangular wooden shield that offered protection from the enemy, but could also be manoeuvred or removed entirely to assist the ship's own crew (Marsden 2019: 25). The lighter guns were used to damage the enemy castle sections that protected their crew from incoming arrows; the larger guns would be used to help prepare a means for boarding the enemy ship (Taylor 1950: 145; Marsden 2019: 20).

It is unclear whether the gunports found on the *Mary Rose* during excavation were part of the original design of the ship, or if they came from a later re-fit. Gunports were part of the latest naval technology in the early 16th century, and lidded gunports are thought to have originated in France in c.1505 (McElvogue 2015: 18). Marsden (2003: 5) suggests that the inventory of the *Mary Rose* dating to 1514, lists enough guns to warrant such gunports as a necessity at the time of building. A painting of Henry VIII's naval ships departing Dover in 1520 in order to attend the Field of the Cloth of Gold in France, also depicts all the ships with various lidded gunports. Unfortunately, the painting itself was created around 20 years after the event, thus may not be an accurate representation of the style of ship being constructed during the first decade of Henry VIII's reign (Marsden 2003: 5). Due to the uncertainty of when the gunports were included in the *Mary Rose*, attempts were made to date the gunports with dendrochronology. However, due to the size of the gunports the samples taken did not produce large enough sequences for a date to be assigned (Dobbs and Bridge 2009: 365). The *Mary Rose* was originally fitted with 78 guns (Marsden 2003: 9); though of these only 5 were designated anti-ship guns. Another 7 could be used as either anti-ship or anti-personnel guns, and the remaining 66 were for anti-personnel use (Marsden 2019: 63). The prevalence of lighter anti-personnel guns, as opposed to the heavier anti-ship guns could link to the question of when the gunports appeared on the *Mary Rose*. The stability of the ship could be compromised by the carrying of heavy-calibre weaponry on the higher levels of the ship (Rule 1982: 150). The original fitting out in 1512 resulted in fewer and lighter guns than those listed in the Anthony Roll of 1546, suggesting there was less of a need for gunports in the early years of the *Mary Rose*'s service.

Studies of the timber frame from the excavated section uncovered from the bed of the Solent can help provide an insight into which elements of the ship were original to her initial construction. Dendrochronology has been used to establish that many of the timbers in the hull of the *Mary Rose* are original from when she was first built, along with a pump well, and slots for swivel guns (Marsden 2019: 23). Dating of timbers suggests that the original ship had an Orlop, Main, and Upper Deck, each with a clearance of about 2 metres (Marsden 2019: 23). It is also possible that the main mast at the time of the construction of the *Mary Rose* was very different to the size of the mast during the sinking in 1545. While the main mast itself no longer exists, a rectangular slot that would have once held the foot of the mast is still visible, cut into the keelson. This slot suggests the mast at the time of sinking, would have had a diameter of between 70 and 80 cm (Marsden 2009: 107; Rule 1982: 110). However, a series of wooden chocks were placed around the keelson, suggesting that the original mast could have been up to 1.5m in diameter at the base (Marsden 2019: 26). While this seems a large diameter measurement, even for a main mast, it would not have been unusual in the early 16th century. The warship *Sovereign,* initially built by Henry VII, underwent refitting around the same time as the *Mary Rose* was under construction. The main mast for the Sovereign consisted of several timbers bound together, creating a single structure that measured 1.3m in diameter (Marsden 2019: 26). This suggests that it is entirely possible that the *Mary Rose* originally had a far thicker and more substantial mast than is suggested through the modern excavation, and the depiction on the Anthony Roll. Such a change to the mast highlights how drastic some alterations could be during a re-fit of a ship. Even with the reduced width of the mast, the canons found in M6 (81A3003 and 79A1276) are of a shorter length than others found throughout the main deck, to allow for the obstruction of the main mast passing through the deck (Hildred 2009: 331).

2.2.3 The Fitting Out 1512

While the *Mary Rose* was likely constructed in Portsmouth, she was taken to London and moored near the Tower of London for the fitting of the finishing elements such as decking, rigging, and weaponry (Marsden 2003: 3). The fitting out period lasted from September 1511 until April 1512 as denoted by payments made to those responsible for the equipment (Marsden 2003: 3). The fitting out not only included vital elements for a warship; such as the sails and the guns, but also more decorative elements. One of the last payments for the fitting out included a payment to the painter, John Browne for 'stuff delivered', most likely referring to the flags, banners, and streamers that would adorn the ship, as well as the painting of the ship itself (Marsden 2003: 5). An inventory taken in 1514 makes mention of the *Mary Rose* possessing 3 streamers for the top masts, 18 gilded flags, and 28 small flags (Marsden 2003: 5). The fitting out period was important, not only to supply the *Mary Rose* with the ordnance necessary for sea battles, but also to provide the splendour required for a flagship of the new King Henry VIII.

2.2.4 The Re-Fit c. 1530

In 1524, a few years after the Second French War of 1522, the *Mary Rose* was held in reserve and docked at Portsmouth Harbour along with 10 other warships and a skeleton crew of just 17 men (Marsden 2003: 15). A review of the naval fleet was made in October 1526, by which time the *Mary Rose* had been docked in Deptford. Whereas some ships, such as the Sovereign, were to be 'new made' from the keel upwards, the *Mary Rose* was determined to be suitable for war but her Orlop, Castles, and decks were to be re-caulked. These repairs took place in June and July 1527 (Marsden 2003: 15). The movements of the *Mary Rose* and the small repairs made to her at this time are known through naval records that state that the *Mary Rose* must be caulked before entering back into service (Marsden 2003: 15, 175; Calendars of Letters and Papers 1526: 1167). Additionally, the subsequent record of payment to labourers responsible for building the dry dock in 1527 to enable such work to be completed, and for those who carried out the caulking of the ship confirms the work was undertaken over the following years (Marsden 2003: 15, 176; Loades 1992: 89; Calendar of Letters and Papers 1530: 2738). However, for over a decade between 1528 and 1539, the movements and changes made to her are far less defined. Suggestions about this time include the *Mary Rose* being re-built in 1536 (Rule 1982: 21; McKee 1982: 23). Bradford (1982: 23, 29) provides two dates for this possible rebuild; one in 1536, and the other in 1539/1540. There is no contemporary source that can confirm the potential re-build of the *Mary Rose*; the date of 1536 is the result of a mention made by Thomas Cromwell in a document dated to the same year. This document records that the *Mary Rose*, along with six other ships, was 'new made' (Marsden 2003: 16; Marsden 2019: 55). Dendrochronology shows that some repairs did occur around 1535-1536 (Marsden

2003: 16). Analysis of 108 timber samples yielded results for 41 timbers from various structural elements of the ship (Dobbs and Bridge 2009: 363). Marsden (2019: 57) states that these results suggest that the bow and stern ends were re-built, and the keel lengthened. Such changes would have enabled the overall ship to be enlarged and the tonnage increased from around 500 tonnes, to the 700 tonnes recorded in the Anthony Roll (Marsden 2019: 57).

Despite the confusion around when lidded gunports were added to the *Mary Rose*, what is clear is that they were a definitive feature by the time of the sinking in 1545. The Anthony Roll, while an artistic depiction of the ship, shows multiple guns run out through multiple lidded gunports on different levels of the ship (see fig 2.2). These gunports would have been necessary due to the increase in heavy guns being carried by the *Mary Rose* in the last years of her service. The number of guns onboard increased from 78, to 96 in 1541, dropping slightly to 91 at the time of the sinking four years later (Marsden 2003: 9). Excavations of the *Mary Rose* have revealed that she did not appear to be carrying as many guns when she sank as are listed in the Anthony Roll. However, this could be due to salvages made of some of the guns shortly after the sinking (Rule 1982: 152).

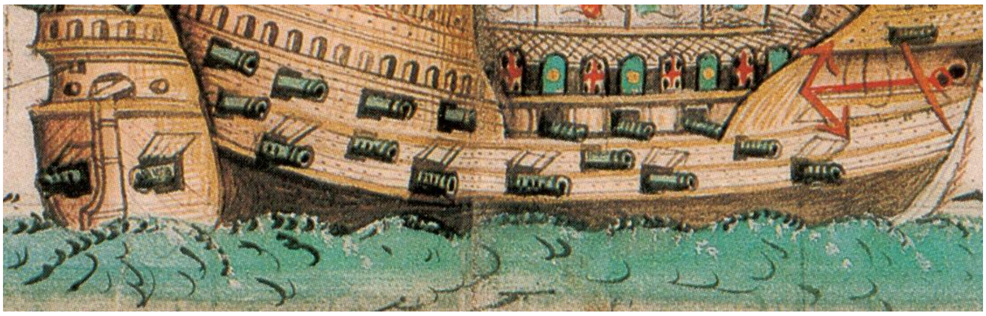


Fig 2.2: The lower gun decks with the lidded gun ports, as depicted in the Anthony Roll (Knighton and Loades 2000: 42)

The later armaments consist of more large anti-ship guns than previously included in her ordnance. As opposed to 5 anti-ship guns, the number increased to 26. Similarly, the number of guns that could be used as both anti-ship and anti-personnel increased from 7 to 12. Despite the increases in the number of large guns, the number of smaller anti-personnel guns decreased from 66 to 53 by 1545 (Marsden 2019: 63). The dates on some of the guns uncovered from the wreck also show that they were a later addition to the ship. The date of 1535 was found on three guns, 1537 was found on one, 1542 was found on another three guns, and one further gun held the date of 1543 (Marsden 2019: 63). This suggests that even if a large re-fit or even a re-build took place in 1536, additions continued to be made to the weaponry of the ship with reasonable frequency until the time of the sinking. The increase in the number and the weight of the guns on board, in addition to the appearance of the gunports in a re-fit during the 1530s is of particular import due to their association with the fate on the *Mary Rose* in 1545.

2.3 The Sinking of the *Mary Rose*

The sinking of the *Mary Rose* is arguably the most well know aspect of the ship; as such there are various contemporary accounts from survivors of the sinking, and eyewitnesses who were present on the day. The events of that day are further immortalised through the Cowdray Engraving depicting the Battle of the Solent (see Fig. 2.3), held by the Society of Antiquities of London. Though the engraving dates to 1778, it is based on an original painting commissioned by Sir Anthony Browne between 1545 and 1548 that was destroyed by fire in 1793 (Nurse 2012: 371; Fontana 2013: 266).

Fig 2.3: The Cowdray Engraving depicting the Battle of the Solent, with the sinking of the *Mary Rose* in the centre (www.sal.org.uk)

With various accounts of the sinking, each one must be considered in order to find the most likely cause, be it human error or a freak accident, that resulted in such a large loss of life.

2.3.1 The Battle of the Solent 1545

Henry VIII had arrived in Portsmouth on the 15th July, several days before the battle would take place, due to reports that threatened a French invasion (Rule 1982: 32). With his forces gathered in Portsmouth, Henry's army boasted a fleet of 100 ships, along with 12,000 men. Yet these numbers were greatly outmatched by the superior French force of 225 ships and 30,000 soldiers (Rule 1982: 33). With such unevenly matched sides, the English took a defensive stance, hoping to draw the French fleet close enough into land to get the enemy ships within range of the gun batteries of Southsea Castle, the Square Tower, and the Round Tower (Rule 1982: 32, 33). The *Mary Rose* formed part of this English fleet and was moored off Portsmouth on the 18th July 1545. This was the same date that Sir George Carew was appointed Vice Admiral of the Fleet and given command of the *Mary Rose* (Marsden 2003: 19). Despite the numbers involved on both sides, the predicted bloody battle and invasion of the French force never came to pass; the loss of the *Mary Rose* became perhaps the greatest consequence of a battle that became little more than a skirmish in the Solent. The battle itself was somewhat inconclusive; with the French fleet withdrawing to the Isle of Wight. Yet even here they were unable to successfully land their fleet; due to the Isle of Wight militia and the Hampshire militia being able to defend themselves sufficiently. As a consequence, the French fleet returned across the channel, leaving only a few small raids in their wake (Rule 1982: 38).

2.3.2 The Cause of the Sinking

The *Mary Rose* ultimately met her fate on 19th July 1545 (Marsden 2009: 12; Marsden 2003: 18). She sank in the Solent, just off the coast of Portsmouth, within view of Southsea Castle, where Henry VIII was able to witness the end of his flagship (Rule 1982: 32). The sinking occurred rapidly and with the addition of the anti-boarding netting covering the Upper Decks, only a small percentage of the entire crew survived. Contemporary accounts provide an indication of the number of survivors; French eyewitness Martin du Bellay stated there were 35 survivors, whereas Van der Delft, who had his account from a survivor of the *Mary Rose*, gives the number as between 25 and 30 men (Marsden 2003: 19). There is no one definitive theory as to why the *Mary Rose* sank. Due to the location of the sinking and the size of the armies involved in the battle there were several eyewitnesses to the event, both English and French. Just before the sinking occurred, the *Mary Rose* is reported to have been heading towards the *Henry Grace à Dieu*, to offer assistance to the larger ship, that was facing a challenge from the French fleet (Rule 1982: 38). From this point there are several different theories, based on both these contemporary eyewitness accounts and the archaeological excavation of the remnants of the wreck.

2.3.2.1 Lack of Discipline amongst the Crew

An element of 'indiscipline and mishandling' was put forward in letters written by two eyewitnesses; Lord Russell and Sir Peter Carew (Rule 1982; 39). These statements corroborated a similar account made Sir Gawain Carew, who had had opportunity to engage in a brief exchange with Vice Admiral Sir George Carew on board the *Mary Rose*, while the former was stationed on a passing vessel. According to Sir Gawain, Sir George had called out that the crew he had under his command were 'the type of knaves, whom he could not rule' (Bell et al 2009; 167). This was also the first Naval Command Sir George had been granted, presenting the query as to whether it was the behaviour of the crew, or the inexperience of the commander that could have resulted in the mishandling of the ship during a battle (maryrose.org, Why did the *Mary Rose* sink). Though it must be remembered that the accounts of indiscipline and mishandling only come from observing eyewitness accounts, rather than any individual who was on board the ship at the time.

2.3.2.2 Attack from the French

With so many ships, both English and French, swarming the Solent, it is expected that the *Mary Rose* herself would have been engaged in an encounter with an enemy at some point during the battle. During the archaeological excavation, it was found that many of the starboard-side guns on board the *Mary Rose* were loaded at the time of the sinking. One gun however, a port-side piece located on the Upper Deck in Section U6, appears to have been in the process of being loaded when the ship sank. The shot for the gun was in place in the barrel, but the cartridge chamber that contained the gunpowder necessary to fire the gun was not in place (Marsden 2009: 391). It is difficult to determine, with the vast majority of guns coming from the starboard side, how they would compare to their port-side counterparts in terms of readiness for battle. A loaded starboard-side, but only partially loaded portside may indicate a ship in the midst of an engagement, having just fired a broadside bombardment at the enemy. It is perhaps expected that an account of the *Mary Rose* suffering from an enemy attack comes from a French eyewitness. The eyewitness, Martin du Bellay, reported that it was after damage sustained to the *Mary Rose* from being fired upon by French ships, that caused her fate (Marsden 2003: 130). This French claim does not stand up to the archaeological evidence presented by the wreck of the *Mary Rose*. The starboard side uncovered from the seabed shows no evidence of damage that would have been sustained from a barrage of French artillery fire. As such it seems unlikely that such cause was the basis for the sinking of the ship (Marsden 2003: 130),

2.3.2.3 Excessive Ordnance

Between 1530 and 1545 there appears to be no record of the *Mary Rose* engaging in any battles at sea, thus it is not clear whether the new armaments that had been added to the ship since the 1530s, had yet seen action on the open water (Marsden 2009: 392). As a result, the handling and stability of the ship may have been less certain than when she was newly built and 200 tonnes lighter at the beginning of Henry VIII's reign. The presence of a large amount of ordnance having an effect on the ship is mentioned in a few accounts dating to several years after the events of the Solent took place. Hall's Chronicles, written in 1548, comment on the *Mary Rose* being *'laden with much ordinaunce'.* This, in combination with gunports being open and close to the water level, supposedly led to the *Mary Rose* taking on water when trying to execute a turn (Marsden 2003: 130). A second account that formed part of the Holinshed Chronicle, written several decades after the fact in 1577, again makes mention of the amount of ordnance on board the *Mary Rose*. Here it is stated that the *Mary Rose* was *'overladen with ordinaunce'*, and again, the open gunports, low to the water level are listed as the cause for the water entering the lower decks (Marsden 2003: 130). While there is thought to be some discrepancy in the accuracy of the tonnage of the *Mary Rose*; particularly with variations being expected during the 16th century, the *Mary Rose* was clearly carrying more guns and of a heavier calibre than when she was first built. While it cannot be known for certain whether this had an effect on the stability of the ship, it must be remembered that the *Mary Rose* had successfully managed to navigate round the southern coast of England in order to get from the Thames, to the port at

Portsmouth. The weight of the armaments may have played a part once the ship began to sink, but it seems unlikely that the weight alone caused the *Mary Rose* to tilt in the water enough to cause the fatal sequence of events.

2.3.2.4 A Turn in the Weather

Of the several dozen men who were able to escape, there was only one survivor who provides a contemporary account of the sinking from the stance of someone who was on the ship as it happened. Unfortunately, the name of this individual is not known, but his account was given to the German Ambassador, Van der Delft (Marsden 2009: 392). This account describes the catalyst for the event as a simple gust of wind. This wind caught the unfurled sails, resulting in the ship heeling sharply in the water, crucially causing the open gunports on the lower decks to dip below the water line (Marsden 2003: 131). As the gunports on the main deck were unable to be closed at the time, the water was able to enter the *Mary Rose* at a rapid rate (Marsden 2009: 392). This was likely too fast for the immediately surrounding crew on the gun deck to react in any way that could have affected the outcome. Of all the eyewitness accounts of the sinking of the *Mary Rose*, this account of a freak gust of wind is the only one to come from an individual who was on board the ship at the time of the event. While somewhat less dramatic than an unruly crew, or a bombardment from the French, by its very nature as an *act* of nature, it was perhaps one of the few events that could not be actively planned for or overcome, no matter the experience of the crew onboard.

2.3.3 Clues from the Position of the Wreck

With various theories and multiple accounts relating to how the *Mary Rose* sank, it can be difficult to determine the accuracy of the narratives, particularly as some date to several years, or even decades, after the actual event. As such it is the preservation of the wreck at the bottom of the Solent that can perhaps help align facts to the accounts. One consistent element of the eyewitness accounts, be it French or English, or written several years after the fact, is that the water was able to enter the ship through the lowest gunports which were left open (Marsden 2003: 19). During the excavation of the ship it was found that the gunports on the starboard side of the ship were open, indicating their position at the time of the sinking. This certainly corroborates the eyewitness reports. The position of the starboard hull, at a 60-degree angle, could also indicate that it was the open starboard gunports through which water entered the ship. It has also been suggested that the ship was left at such an angle after the aborted early attempts to raise her during the following years (Marsden 2003: 132). However, due to the contents of the ship having shifted to the starboard side, it seems likely the angle was due to the action of the sinking, rather than salvage (Marsden 2003: 132). Eyewitness statements also put forward the theory that the *Mary Rose* was in the process of turning in order to present a broadside to the enemy French. Again, this eyewitness account fails to correlate with the evidence provided by the archaeology. Many of the guns found on the starboard side appeared to still be loaded during the excavation, if this was the case there would have been no need for the *Mary Rose* to execute a turn to present her loaded guns, as they would already have been in position (Marsden 2003: 132).

It is not only the bulk of the wreck herself that can provide clues to the sinking, but also the position of crew members and equipment on board the ship at the crucial moment. The locations and clusters of crew members and equipment suggest a ship very much at ‘action stations’ when disaster struck (Marsden 2009: 391). Many sets of remains of the crew, along with weaponry, were found clustered on the Upper Deck, beneath the Sterncastle (Marsden 2009: 391). While some of the crew members found on the Upper Deck were undoubtedly trying to escape, rather than being previously positioned there, the presence of equipment suggests that some were already stationed on the Upper Deck at the time. Open chests containing longbows and arrows, uncovered on the Orlop Deck, further suggest that the crew of the *Mary Rose* were in a state of readiness for action (Marsden 2009: 391). Similarly, clusters of remains on the Main Deck are also indicative of gun crews, in position to operate their weapons. For example, in M3, the remains of six individuals were found, along with a large bronze culverin (Stirland 2013: 140). While some allowance must be made for crew members being moved around by the currents after the sinking, it is apparent that the crew were not sitting idle during their last moments

The most likely cause of the sinking of the *Mary Rose* would be a gust of wind, causing the ship to tilt and subsequently submerging the lowest gunports below the waterline. With the crew at action stations it would be necessary for the gunports to be open and in use. If the crew were unruly or undisciplined earlier in the day on the 19th July 1545, it is hard to imagine that a trained crew on board Henry VIII's flagship would have continued to be so under threat from a French enemy ship. With regards to a French attack, the speed at which the *Mary Rose* sank is also indicative of a dramatic influx of water; through multiple gunports as opposed to comparatively minor damage that may have been caused by French cannon fire. Shifting ordnance and the added weight from additional weapons may in turn have increased the rate at which the *Mary Rose* sank, but having successfully sailed to Portsmouth before the Battle of the Solent, it does not seem likely that such armaments were the root cause of the disaster.

2.3.4 The Loss of Life

Traces of anti-boarding netting were found during the excavation and it is also depicted in the contemporary Anthony Roll illustration (Marsden 2009: 392). Ostensibly, this netting was in place in order to protect the crew of the *Mary Rose* from being boarded by their enemy French counterparts. The fragments of the netting that were uncovered during the excavation of the *Mary Rose*, from U3 to U6 (see fig 2.4) (Marsden 2003: 120), suggest that much of the rope was 12mm thick. Some thicker fragments of 22mm have been interpreted as potentially representing the edge of the netting (Marsden 2009: 203).

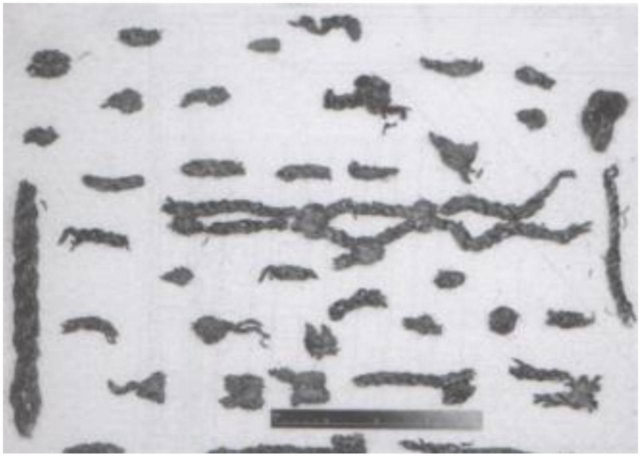


Fig 2.4: The remains of the anti-boarding netting found during the excavation (Marsden 2009: 206)

However, it is not only the thickness of the rope that the crew beneath would have had to contend with as the ship started sinking, but also the spacing of the netting. Of all the netting fragments found, only one piece (79A1253) represents the distance between the knots that formed the mesh structure of the net. Measurement taken from the centre of each knot on this piece give a length of just 115mm

(Marsden 2009: 203). The small dimension of each square of netting would result in multiple ropes having to be cut in order for a crew member to be able to escape through the netting. Additionally, in the circumstance in which the crew found themselves- a listing ship that was sinking at a rapid rate, human elements such as fear, panic, and crowding with lower-deck crews making their way up, may have hindered any ability to systematically cut through enough ropes to allow an escape route. This netting is likely the cause of why, out of a crew of well over 400 individuals, only a few dozen survived (Marsden 2003: 134). With the netting trapping the fighters positioned in the waist of the ship, as well as those stationed on the lower decks, it seems probable that the survivors were those located above and outside the netting (Marsden 2003: 134).

2.4 Salvage Attempts

2.4.1 The 1545 Salvage

Directly after the sinking in July and August 1545 it was initially thought that salvage of the ship was possible. Plans were immediately put in place to recover the hull of the ship, and particularly the valuable ordnance still on board. Lord Admiral Viscount Lisle and the Duke of Suffolk, Charles Brandon, were given the task of overseeing and arranging the recovery (Rule 1982: 39). In order to achieve this, two Venetian salvors, Piero de Andreasi and Simone de Marini were assigned the task. These two men, along with 30 Venetian mariners, 60 British mariners and one Venetian carpenter, set about to recover as much of the ship and her ordnance as they could, using methods that had been successful in the past (Rule 1982: 40; Marsden 2009: 12, 13). The sails and sail-yards had been successfully recovered on the 5th August; only a couple of weeks after the sinking (Marsden 2009: 13). With the *Mary Rose* lying on her starboard side it would have been necessary for the ship to be hauled upright before being lifted from the water. In order to achieve this, two empty ships, the *Jesus of Lubeck* and the *Samson*, were brought in to facilitate the task. Heavy cables were run from these ships and attached to the main mast of the *Mary Rose*; the intention being that at low tide the cables could be winched tight on the capstans on the rescue vessels. Then as the *Jesus of Lubeck* and *Samson* rose with the high tide, the tightened cables would lift the *Mary Rose* with it (Marsden

2009: 13; Rule 1982: 40). The location of the *Mary Rose* (see fig 2.5) was thought to be ideal for such a procedure to be carried out; with a tidal range of 14 foot and relatively weak currents (Rule 1982: 40). Yet despite these conditions, and using a previously successful method, trouble arose when the foremast broke and the Venetian salvors reported they could not continue to lift her as planned (Marsden 2009: 13). By the 9th August the Venetian salvors asked permission for an extra six days in order to attempt to drag her into shallower waters, having failed to raise her in the manner as originally planned (Rule 1982: 40). These extra days were granted due to the 'goodly ordnance' that was on board, particularly the guns (Marsden 2009: 13). It is possible that it was during these manoeuvres that the main mast was pulled from the mast-step, as stratified sediments from the hull show that the mast was removed soon after sinking, rather than at the time of sinking (Rule 1982: 41). Regardless of the issues during the initial salvage attempt, records suggest that the salvors themselves had not lost hope of recovering the ship. Even by the end of August 1545 a letter to Henry VIII from the Lord Chancellor, Baron Wriothesley, made mention of a new mast to be made for the *Mary Rose* (Marsden 2009: 13). Despite this letter, there were no further reports of attempts to lift the ship from the seabed, and attention was instead turned to rescuing as much of her equipment as possible (Marsden 2009: 13).

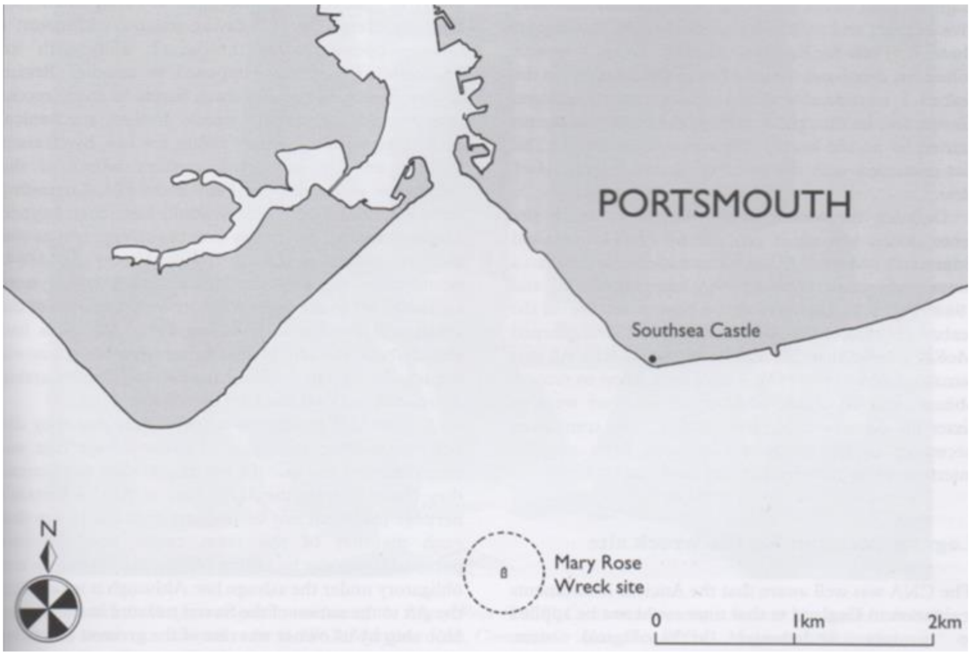


Fig 2.5: The location of the *Mary Rose* wreck site off the coast of Portsmouth (Marsden 2003: 31)

While attempts to raise the whole ship were abandoned, the guns on board were still deemed important enough for their salvage to continue. However, as with the raising of the ship, the salvage of the guns proved trickier than expected. Regardless of the ship itself being only couple of metres below low water surface, specialist equipment was required to be constructed to undertake the salvage (Marsden 2009: 14). Indeed the depth was such that even after a few decades the Elizabethan Admiral, Sir William Monson, was able to report seeing the wreck- most likely the upper portside that had not yet had a chance to fully deteriorate as it would throughout the future centuries (Rule 1982: 41). After 4 years of retrieving as much as possible from the wreck of the *Mary Rose*, any attempts to salvage either the ship or her contents were abandoned in 1549 (Rule 1982: 42).

2.4.2 The 19th Century Salvage

Over the next few centuries, the exposed part of the wreck that had been visible to Admiral William Monson collapsed and the site was largely forgotten (Rule 1982: 42). Layers of silt, gravel, and shells would also be deposited over the site of the wreck, creating a hard and compact shelly seabed that protected much of the starboard side of the wreck, with the exposed portside having eroded away (Marsden 2009: 14). Despite much of the wreck being covered in this way, the movements of the currents beneath the Solent resulted in a few timbers being periodically exposed on the seabed (Rule 1982: 42). It was one of these brief exposures that led to the rediscovery of the site in the nineteenth century when the nets and lines of local fishermen snagged on the timbers protruding from the seabed (Rule 1982: 42, 45). Initially Henry Abbinett was engaged by the fishermen to dive and untangle their nets on 10th June 1836, but only a few kilometres away, further help would be found in the form of the Deane brothers (Marsden 2009: 14). Since 1832 the Deane brothers had been in business as ‘submarine engineers’ in the Portsmouth area and in 1836 were investigating the wreck of the Royal George that had sunk at Spithead 54 years prior (Rule 1982: 45). The Deane brothers were invited to investigate the area in which the fishermen’s nets were snagging, and on 16th June 1836 they dived on the site and discovered the exposed timbers, as well as an eleven foot bronze cannon, for which they received £220.19s as a scrap metal price (Rule 1982: 46). Two months later in August of that same year, three further cannons were discovered, two bronze and one iron, as well as fragment of another, found resting on ‘some wreck completely buried in sand’ (Rule 1982: 45; Marsden 2009: 14). The discovered weapons were passed over to the Board of Ordnance and a Committee was set up under the chairmanship of Major General Sir William Miller in order to determine the identity of the wreck; coming to the conclusion that they had found the *Mary Rose* (Rule 1982: 45). The salvage of items from the wreck however led to tensions between the Deane brothers and the fishermen, with the Board of Admiralty being petitioned and Admiral Sir Frederick Maitland prohibiting further salvage until an agreement was in accord between the two opposing factions. It was ultimately decided that it would be the Deane brothers who would have the rights over the salvage from the wreck (Marsden 2009: 14). Despite the cannons that the Deane brothers had already taken from the wreck and the money they had received, they expended little effort in continuing their search for such salvage (Rule 1982: 46). In addition to the cannons, other items pulled from the wreck included, longbows, pottery, rope and human bone (Marsden 2009: 14; Rule 1982: 46). The site was all but abandoned until the year 1840, when John Deane returned with explosives in order to attempt to break through the hard seabed to uncover the rest of the wreck (Marsden 2009: 14). In total six 13 inch shells filled with gunpowder, which were deemed unusable in their intended function, were detonated at the site- the remaining fragments of which were uncovered over a century later when modern salvage began on the site. Unfortunately for the Deane brothers the hard seabed they had intended to break through remained very much undamaged by their explosives, and the items collected subsequently were likely portside materials that had simply been broken up and redistributed by the explosion (Marsden 2009: 15; Rule 1982: 47).

2.4.3 The 20th Century Salvage

It would not be until over a hundred years later that the next phase of salvage and discovery would begin on the wreck of the *Mary Rose*. It began in 1965, with the commencement of the ‘Project Solent Ships’ by amateur diver and journalist, Alexander McKee (Rule 1982: 47). Initially there was no plan to excavate, or even survey the wrecks they found. Despite the team comprising of experienced and well-trained divers, there was a lack of the archaeological expertise that would have enabled a more detailed study to take place (Rule 1982: 47, 48). At the time of the project it was widely believed that the currents and tidal waters that surrounded the British Isles were not conducive to the preservation of historical wrecks, though this was something both Rule and McKee disputed (Rule 1982: 48). Using historic charts dated to 1841 from the Hydrographic Department of the Navy that depicted the position of several historic wrecks, the actual site of the *Mary Rose* was provisionally located in 1967. However, the exact site of the wreck itself was not firmly located at this time (Marsden 2009: 15). One particular chart compiled by a Commander Sheringham in 1841, depicted a red cross clearly marking the location in which the Deane brothers had discovered the *Mary Rose* five years prior in 1836 (Rule 1982: 50). Over the next several years the site was investigated with increasing intensity; firstly using a sub-bottom profiler from 1967-1968 that was able to detect a buried feature that McKee believed could be the *Mary Rose*, and then through excavations on the seabed between 1969 and 1971 (Marsden 2009: 15). Early exploration of the site proved something of a challenge; McKee and Diving Officer John Towse found during their initial dive investigations that their compasses would behave erratically and the constant traffic of passing ships and ferries also caused further issues when divers had to arrange dives around the ferry schedules. What became apparent during these early forays to the seabed that a more advanced method would be required to survey the site (Rule 1982: 51). The solution came via Professor Harold Edgerton from MIT, who was in the UK in 1967 demonstrating his company EG&G International's new sonar systems. After an invitation from McKee, Egerton spent 2 years surveying the area with his dual channel side scan sonar that provided an acoustic map of the seabed, and a sub-bottom profiler capable of recording anomalies buried within the muddy silts at the bottom of the Solent (Rule 1982: 52). An anomaly was found, buried twenty foot beneath a 5ft mound, measuring in total 75ft wide and 200ft long (McKee 1982: 64). The location of this anomaly was found to be in the right area and on the right alignment for the suspected *Mary Rose* wreck. The size of this anomaly closely matched the overall size of the wreck that was later uncovered at the site, measuring 65ft wide and 135ft long (Rule 1982: 53).

As a result of the sonar anomalies that were picked up on the seabed, the *Mary Rose* (1967) Committee was formed (Rule 1982; 54), partially in response to the risk that finding the site presented- in 1967 the was no legal protection for historic shipwrecks the same way there would be over historic sites on land. To counteract this the *Mary Rose* (1967) Committee applied to the Crown Estate Commissioners for a lease on the area of seabed, measuring a total of 334m^2, where they believed the remains of the *Mary Rose* lay (Marsden 2009: 16). This was granted to the Committee on 1st April 1968 at a cost of £1 per annum (Rule 1982: 54, 55). It would not be until several years later, in 1973, when the Protection of Wrecks Act was passed in Parliament that granted protection to wrecks discovered in British waters that are designated as of historical, archaeological, or artistic importance (Rule 1982: 55; Protection of Wrecks Act 1973). Up until this Act of Parliament was passed, the team working on the *Mary Rose* relied heavily on secrecy as their main form of protection for the area, and they took care never to mark the site they were investigating with a buoy, or any other form of indicator, until after 1973. With only the Crown Estate Commissioners Lease offering protection prior to this, it was also important to avoid any litigation issues which, with limited funds, the *Mary Rose* (1967) Committee could ill-afford if they were to remain solvent (Rule 1982: 55). Such measures were seen as adequate while only the area had been identified; it was not until 1st May 1971 that the specific location of the wreck itself was found (Rule 1982: 55, 56).

2.4.4 Legal Implications of the Salvage

The protection and secrecy of the site was deemed as vital for the preservation of the wreck as an archaeological site. With so little legal protection there was a very real danger that should the site be located by others, there was nothing that could legally be done to stop the selling of any antiquities uncovered, should they decide to do so. This concept of diving historic wrecks for such financial gains was not unheard of at the time (Marsden 2009: 15). Another threat was the presence of the Merchant Shipping Act of 1894, which stipulated that any items lifted from wrecks must be declared to the Receiver of the Wreck. After a year, if the owner of said item could not be identified or came forward to claim their belongings the item must be sold. This had the potential to cause immediate and obvious issues for the salvage team of the *Mary Rose*; mainly that with a wreck that was over 400 years old, the identification of the owner of any items uncovered would be difficult, if not impossible, to prove (Marsden 2009: 16). This Act was already being challenged by a committee comprised of archaeologists, divers, and museum representatives amongst others, formed in 1964 known as the Committee for Nautical Archaeology, as this Act was affecting other historic wrecks, not only the *Mary Rose* (Marsden 2009: 16). Ultimately, the *Mary Rose* was one of the first shipwrecks to benefit from the implementation of the Historic Wreck Act and has enabled further excavations of other historic shipwrecks to be undertaken with greater ease (Marsden 2009: 16).

2.5 The Excavation

2.5.1 Overview of the Site

Though some smaller items were brought up in 1970 including a loose plank from the ship and in August of that year, a sixteenth century cannon, the *Mary Rose* herself would not be uncovered until the 5th May 1971 by Percy Ackland (Marsden 2009: 15). Despite the visibility on the seabed being only about a metre, Ackland was able to uncover a row of timbers during an exploratory dive. These timbers stretched into the gloom of the Solent for about twenty metres and would later be revealed to be the ends of port side frame timbers of the *Mary Rose* (Marsden 2009: 15). With the exact site of the *Mary Rose* finally being located, the excavations and surveying of the wreck could begin in earnest, though the presence of the hard, shelly layer of sediment at the bottom of the Solent caused a bit of confusion for the team. Some argued that no ship, no matter how fast it sank, would have been able to break through such a layer, and if this layer formed the Tudor seabed then there was little chance of uncovering much more of the *Mary Rose* (Rule 1982: 62). The removal of lighter silts, usually between 2'6" and 3'0" thick, from the surface of this hard layer also revealed a number of nineteenth and twentieth century items- but a lack of items dating to the Tudor era which suggested this visible layer was not the Tudor seabed at all (Rule 1982: 62). The softer layers of silts and muds that allowed for such good preservation were revealed with the removal of the hard, shelly layer, but investigation hit another obstacle in the form of the British winter- with the water temperature dropping to 10°C and visibility being reduced to nothing in November; causing the team to abandon the excavations without reaching any firm conclusions (Rule 1982: 65)

The outline of the hull, while still mostly buried at this point, was able to be mapped between 1971 and 1978, to a standard that was far higher than previously achieved in British underwater archaeology at that point (Marsden 2009: 16). This enabled the divers and the boat-based experts to see that the ship had come to rest heeled over on her starboard side. The uncovering of a 108-foot run of timbers revealed that along with lying on the starboard side, the ship's Bow was also pointed north- towards the entrance to Portsmouth Harbour (Rule 1982: 66). Excavations in 1973 were again hindered by the inclement British weather; including the loss of the diving platform due to a gale in August, and a general lack of funds- with only 12 days of excavations being completed during the whole season. Despite the issues on site (or more accurately, above site), during September of that year the Lord Mayor of Portsmouth was able to establish a Support Committee in order to instil new initiative into the large-scale project. The Committee was also able to register as a charity with aided in the raising of money in order to continue to fund the excavation, and with the previously mentioned 1973 Act that gave legal protection to the site, the wreck was able to be marked with permanent buoys for the first time (Rule 1982: 67).

The 1975 season confirmed the orientation and 60° angle of the hull where it had come to rest on the seabed (Rule 1982: 68; McKee 1982: 112). A trench excavated at the stern, to the depth of the keel, revealed the stratified layers of silts, muds, and artefacts in the scour-pit (Rule 1982: 68; Jon Adams, pers. comm. 2020). The following year, in 1976, the budget for the excavation increased- and while it was still less than £5000 per annum, it was a dramatic improvement over preceding years (Rule 1982: 68). In comparison to the 12 days of excavation in 1973, a total of 55 days were managed in 1976 in the few months between June and September, during which time the stern trench begun in 1975 was extended. At the time, this was the world's deepest below sea-level archaeological excavation (Rule 1982: 68, 69). These further excavations also revealed the sequence of events that led to the disintegration of the Port side of the ship. Lying on the Starboard side meant that significant currents had passed beneath the overhang of the bow-castle, the weight of which would eventually become too much for the eroded and weakened support planks, causing the structure to collapse forwards and downwards into the scour pit.

With this projecting part of the ship collapsing inwards and filling the scour pit, the seabed was finally able to level and stabilise (Rule 1982: 71, 72).

The first of the many personal possessions of the crew members were found during the excavations in 1978 when a major trench was excavated across the Bow of the ship, from port to starboard, revealing both the Orlop and Main Decks (Dobbs 1995: 29; Rule 1982: 72; Marsden 2009: 15). This trench would also ultimately reveal that the starboard side of the Hull was a coherent structure; one that it may be possible to salvage in one piece from the seabed (Dobbs 1995: 29; Rule 1982: 72). With such an unprecedented site, the structure and items recovered during the excavation were recorded in great detail (see fig 2.6) (Marsden 2009: 16).

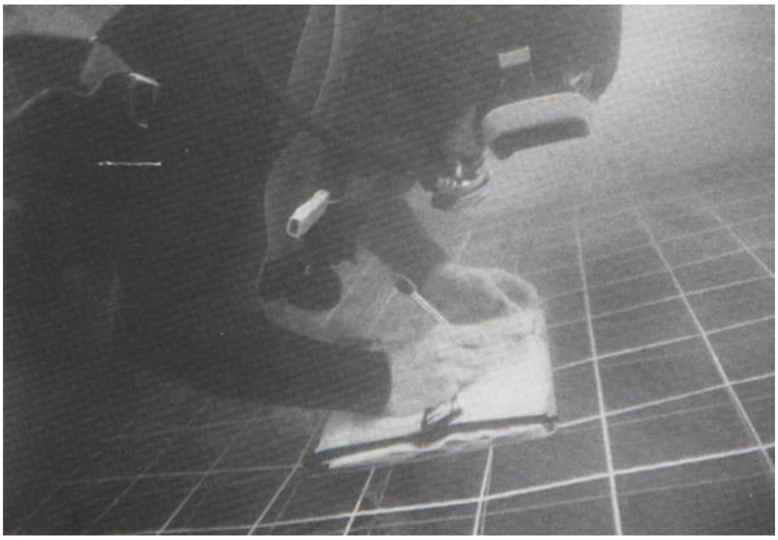


Fig 2.6: Items being recorded *in situ* before being lifted from the seabed, 1979 (Rule 1982: 80)

Despite this original plan, the final decision relating to the raising of the Hull would not be taken until January 1982, and even then the plans could still be halted and then a process of survey and backfill undertaken instead if necessary (Dobbs 1995: 30). Due to these major discoveries, two meetings were convened by the *Mary Rose* Trust, as the removal of the protective silts that had preserved the delicate items for centuries would mean that the sudden exposure could cause the artefacts to decay- as such, if excavation were to be successful it had to be done quickly (Rule 1982: 72). The second of these two meetings would include salvage consultants, salvage contractors, structural engineers, as well as Naval architects in order to establish the most effective way of surveying and excavating the site

(Dobbs 1995: 30). In order for the excavation to be undertaken in the best possible way, a large full-time team of divers and archaeologists were needed, as well as an onshore team who could process the finds as they came up from the wreck. Suitable conservation facilities were also vital due to the delicate nature of objects that had been submerged in seawater for several centuries (Rule 1982: 72).

2.5.2 The Decision to Excavate

With the decision to excavate the wreck made, it was imperative that the work began quickly and that certain conditions were fulfilled, as Margaret Rule stated in two seminars in Portsmouth in 1978; if excavation were to be undertaken it should be complete within two to three years (Rule 1982: 73; Marsden 2009:16). This was due to the consideration that the timbers of the *Mary Rose* would deteriorate too much if left open to the currents of the Solent for too long. Achieving this would involve the formation of a charitable trust with a Board of Trustees that could represent all the interested parties involved in the excavation and survey. Due to the *Mary Rose* being such a large and unprecedented site, there was also the ever-present need for funding, and lots of it (Rule 1982: 73). Due to the time constraints of a handful of years to excavate a site on the scale of the *Mary Rose*, one of the first undertakings was the purchase of a diving vessel, so the dive teams could continue their work on the seabed during any and all of the daylight hours between spring and late autumn. Due to the long season various cut off points were established so that the site could be temporarily backfilled with sand and fine shingle in order to protect the archaeology, should the excavation experience a lack of funding to continue (Rule 1982: 73). Ultimately the excavation process broke down into four distinct phases. First, to remove the secondary silts that currently lay over the Tudor seabed and surrounding the ship. Though the presence of these silts was fortunate as they had prevented the discovery of the wreck during previous century. Second, they planned to remove the contents that lay between the decks, including any collapsed timbers that no longer formed part of the hull structure; including those found in the scour pits. Third, the reinforcing of the hull would have to take place if the team were to have any hope of successfully raising the *Mary Rose* from the seabed, including replacing any lost iron fastenings. Finally, and ultimately the plan was to successfully lift the *Mary Rose* from the seabed to enable her to be brought ashore where she could be conserved and put on display to the public (Rule 1982: 73, 74).

2.5.3 The Process of Excavation

The *Mary Rose* Trust was formerly established on 19th January 1979. Due to the time constraints of the two to three year excavation time frame a full-time team were required; including diving archaeologists, field assistants, conservators, and illustrators, as well as those not directly involved with the site- the administration, secretarial, and fund raising staff. The recruitment and directing of this specialised team was left for Margaret Rule to organise (Rule 1982: 74, 75). With the site being located offshore in the busy shipping lane of the Solent, a key piece of equipment would be a large diving vessel that could not only be stationed above the wreck for most of the year (March through to November) but was also sturdy enough to withstand any tides and weather the normally peaceful Solent may throw at it (Rule 1982: 75). There appeared to be only one suitable vessel available to the *Mary Rose* team in March 1979: the salvage vessel *Sleipner.* Originally built as a salvage vessel for the Royal Navy in 1943, with a length of 43 metres and 8 buoyancy tanks along the hull (Rule 1982: 75), this vessel came with a distinguished history in the salvage of historical ships. Nearly two decades previously it had been instrumental in the raising of the Swedish warship, *Vasa*, on 24th April 1961; 333 years after the *Vasa* had sunk on its maiden voyage (vasamuseet.se, Salvage). The *Sleipner* was purchased from the Neptune Salvage Company who had conducted the raising of the *Vasa*. *Sleipner* arrived in British waters in February 1979 to be fitted with a diving platform at Husband's Shipyard in Marchwood, Southampton (Rule 1982: 76). After the necessary fitting and changes were made to the *Sleipner*, she eventually arrived on the site of the *Mary Rose* on Saturday 14th April 1979. That first season with the *Sleipner* in position saw 149 days of diving, culminating on a total of 6858 dives, with approximately 600 cubic metres of silt being removed from the site; a far cry from the 1973 and 1976 seasons which saw a total of 12 and 55 days of excavation respectively (Rule 1982: 68, 69, 77). 180 volunteers aided with the dives and excavation that season alongside the full-time members of staff, and while the majority were British, some came from as far afield as Australia, the USA, and Canada. The volunteers were divided up into teams, with each team being led by an experienced archaeological supervisor (Rule 1982: 83). Due to the poor visibility conditions in the Solent, no one was permitted to free-dive from the surface to the wreck site and instead a line was used that linked the *Sleipner* and the excavation grid (Rule 1982: 81).

2.5.4 Excavation of Human Remains

Any object brought up from the wreck itself would be immediately passed over to the finds supervisor on board the *Sleipner*, and each individual item would be allocated its own unique number (Rule 1982: 85, 89). This included human remains, which were allocated 'H' numbers to clearly differentiate them from any other type of find when noted in the Diving Logs. Groups of human bones that were found together were assigned the same number (Stirland 2013: 67). Where possible, the objects brought up would be cleaned immediately, and general details such as context and association would also be noted in the Log. A separate finds card would then accompany the item to shore (Rule 1982: 89). In terms of the human remains, each record card for the dives that contained bones also included a diagram of a skeleton on the reverse which could be roughly shaded in to show, at a glance, which bones had been uncovered. Due to the mixing of human remains that had taken place over the centuries after the sinking, it was virtually impossible to excavate the remains of the crew as individuals and so the human remains were excavated by sector, as were the other items recovered from the wreck (Stirland 2013: 67).

2.5.5 The Raising of the *Mary Rose*

By 1982 the excavation of the wreck of the *Mary Rose* had been completed, leaving the empty wooden structure resting on the bed of the Solent. A seven-step process was initially implemented in order to bring what was left of the *Mary Rose* to the surface as part of the final stage of excavation, with the plan being laid out as follows (as taken from Rule 1982: 215, 216):

Phase	Action
1	Removal of backfilled silts, and the sandbags and sheeting that had been protecting the exposed wood during the previous 3 years of excavation. In addition; 4 pits had to be dug to enable the underwater lifting frame to be safely set in position.
2	A final archaeological survey had to be taken of the layout of the decks.
3	The lifting frame had to be positioned above the wreck, using the pits dug as part of Phase 1.
4	Tunnelling under the wreck was to take place in nine places to enable strops to be passed underneath and attached to the lifting frame.
5	Attachment of internal steel bracers to secure the shape of the wreck when lifted from the stabilising silts of the Solent.
6	Using the strops positioned underneath the wreck, lift the *Mary Rose* from the seabed and gently lower into an underwater lifting frame, using water bags to provide adequate support for the wreck.
7	The final phase that would see the *Mary Rose* being brought to the surface, supported by the cradle. Once on a pontoon the ship could then be towed ashore to the Royal Naval Base at Portsmouth Harbour.

Table 2.2: The 7-step process initially implemented to raise the *Mary Rose* in 1982

However, the ultimate raising of the *Mary Rose* differed to this original plan. Rather than use strops beneath the wreck, it was decided to use steel wires attached to steel bolts at more than fifty points spread out across the wreck. This enabled the weight of the ship to be distributed more evenly when in the lifting cradle, reducing the risk of the ship breaking under its own weight during the process (Rule 1982: 216).

2.6 Summary

The *Mary Rose* had a 34-year service history at the time of her sinking on the 19th July 1545. During her years of service, she had undergone many changes, both in terms of her construction and in the ordnance she carried on board. While the cause of the sinking cannot be determined with absolute certainty, a gust of wind causing her to heel unexpectedly seems the most probable cause. Various attempts to raise and salvage the *Mary Rose* were made over the centuries, culminating in her complete excavation and raising in 1982. Part of the excavation involved the recovery of thousands of human remains from throughout all levels of the ship. The nature of the sinking during a battle and in such a rapid timeframe meant the excavation revealed the final moments of the crew on board, some still at their battle stations. This provides a clear correlation between warfare and the human remains, resulting in any pathology found being a potential result of living and fighting on board an active warship.

3. Methodology

3.1 Considerations of the Study

When considering the medical treatment on board the *Mary Rose* at the time of her sinking, there are three distinct elements that must be taken into account to provide a comprehensive overview of the types of wounds and injuries sustained and the manner in which they were treated. Initially, a study of the human remains uncovered from the *Mary Rose* must be undertaken to provide information on the crew themselves and any pathology present on the skeletal remains. Secondly, in order to understand the types of treatment that would have been available in the mid-sixteenth century, contemporary medical texts must also be studied, particularly those with military connections, such as Thomas Gale (1507-1587) who served his Barber-Surgeon apprenticeship in the army of Henry VIII (Copeman 1963: 14). These texts are necessary to understand the level of medical knowledge available to the Tudor Surgeons and how they would contend with the range of injuries they may face while serving on-board a warship. Finally, the third element needed to provide insight into the medical care of the crew of the *Mary Rose* is the contents of the Surgeon's chest that was excavated in an intact state from Sector M7 on the main deck, the location of the Surgeon's cabin (Rule 1982: 189).

It is not possible to conduct a study into the medical treatment of the crew of the *Mary Rose* without all three elements being taken into consideration. Without the examination of the human remains from the wreck, the types of injuries and conditions affecting the crew could not be accurately assessed. As such it could not be determined whether the Surgeon on board would have had the necessary equipment at his disposal. It may be possible to compare the contents of the Surgeon's chest to the medical texts of the day, yet, without the skeletal element, it could not be established whether the Surgeon was fully equipped to treat the crew of the *Mary Rose* with whom he served. Similarly, if the study of the contemporary medical texts were not taken into account, it would be impossible to say whether the contents of the Surgeon's chest was sufficient to deal with, and treat, the pathology present in the skeletal remains. With the modern practice and knowledge of medicine and surgery being so vastly different to that of the Tudor age, the modern interpretation of the equipment and ointments present may differ greatly to that of the past, and thus without the contemporary texts the extent to which the Surgeon was equipped would be difficult to determine. Lastly without the presence of the medical chest itself, it would be impossible to predict whether the Surgeon had access to the equipment, ointments and salves stated in the medical texts necessary for the treatment of the injuries present in the skeletal record. Treatments may be found for the injuries present in the crew members in the medical literature of the day, but without the chest it would be impossible to say whether any of the treatments could be implemented and implemented successfully while on board the *Mary Rose*.

The importance of each element can be portrayed in the diagram below:

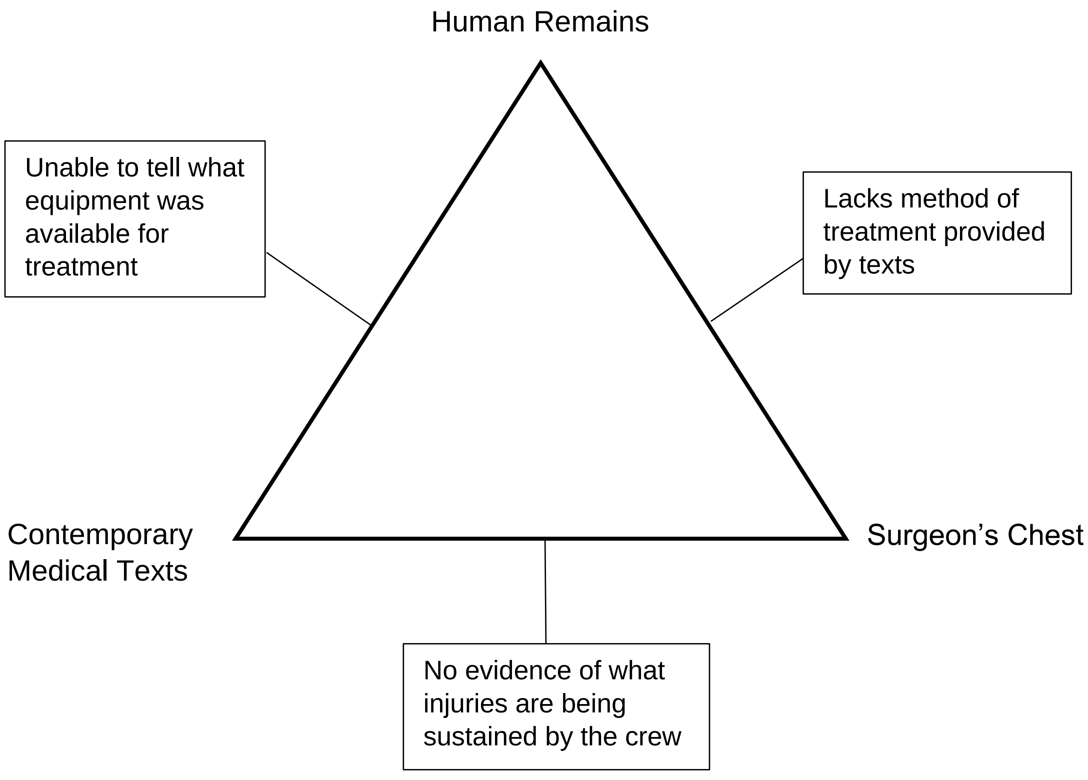


Fig 3.1: The three elements of the current study and why they are necessary to better understand the medical care on board the *Mary Rose*.

3.2 Materials

3.2.1 The Human Remains

The initial focus of this study is the examination of the skeletal remains uncovered from the *Mary Rose*. Limited work has been conducted on the remains since the excavation in the early 1980s, and the bulk of the literature on the remains of the crew is provided by Ann Stirland whose preliminary work established the concept of there being 92 'Fairly Complete Skeletons' (FCSs) from amongst the 11,004 individual bones lifted from the wreck. The figure of 92 FCSs is now taken as the definitive number in terms of relatively complete individuals, with the total number of individuals represented within the entire skeletal assemblage as 179 (maryrose.org, Life of Board). Stirland's work on the assemblage was published in 'Men of the *Mary Rose*: Raising the Dead' (1st edition 2000) which covered the basic data provided through her study of the skeletal material as well as some of the general pathology she encountered. However, as Stirland was principally providing an overview of the human remains, she did not explore in great detail the evidence of injury and trauma and the causation of such, nor did she touch on the relationship between the medical equipment available on board and the treatment of such injuries. A new study of the so-called FCSs from the *Mary Rose*, focusing on signs of pathology is therefore necessary to establish what types of injury and trauma were being sustained, or any evidence of long-term conditions, such as osteoarthritis, are present within the skeletal remains and thus would require treatment from the Surgeon, while serving on board the ship.

3.2.2 Data Collection of the FCSs

Macroscopic analysis of the bones was undertaken, and each individual FCS is recorded separately using skeletal recording sheets designed specifically for the examination of the crew of the *Mary Rose* (*see* Appendix A). Each sheet records in detail which bones are present for each FCS, including the individual bones that comprise the skull, and specific carpals and tarsals, with the requisite siding, in order to provide a comprehensive record of the FCS collection. In addition to this, notes are made as to their location on the wreck, the year in which they were excavated, and the dive numbers associated with the recovery of the bones. In addition to the recording of individual bones, the age, sex, and height of the individual is also assessed, with the references and workings shown to create a clear and transparent record for any future research.

3.2.3 Ageing

The age of the individual is assessed depending on which bones are present within the FCS, due to the lack of completeness within some individuals. The methods used for the ageing of the FCS Collection are as follows:

Ageing Method	After
Dental Wear	Brothwell (1981)
Pubic symphysis	Todd (1920) Suchey Brooks (1990)
Auricular surface	Lovejoy *et al* (1985)
Long bones	Scheuer and Black (2004)
Cranial Sutures	Meindl and Lovejoy (1985)

Table 3.1: Methods for Ageing the FCSs

The concept of cranial suture closing as an indicator of age has been used since the 1500s and was used widely in the early 20th century (White and Folkens 2005: 369; Meindl and Lovejoy 1985: 57). However, despite initial widespread use it was rejected in several studies conducted in the 1950s by Singer (1953), Brooks (1955), and McKern and Stewart (1957). Since then, further studies have been conducted to assess the accuracy of methods of cranial suture closure in terms of ageing (Galera *et al* 1998; Key *et al* 1994). It has been found that methods devised by Masset (1982), and Acsádi and Nemeskéri (1970) do not provide accurate results for younger individuals (Galera *et al* 1998: 938). Meindl and Lovejoy (1985) was found to have greater accuracy for younger individuals, based on the analysis of ectocranial sutures (Galera *et al* 1998: 938). Studies conducted by Perizonius (1983) suggest different methods are required for those >50, and those <50 (Key *et al* 1994: 193), However, there can be great variation in the closing of ectocranial sutures, with individuals of all ages showing evidence of open sutures; thus, open sutures cannot be used as an indicator of young age (Key *et al* 1994: 206). Buikstra and Ubelaker (1994: 36) state that when estimating age, more emphasis should be placed on the dental wear and the post cranial skeleton, over the closing of cranial sutures. With the likely young age of an active fighting force on board the *Mary Rose*, it is likely that assessment of cranial sutures will not provide great accuracy with regards to ageing. As such, the closing of cranial sutures based on Meindl and Lovejoy (1985) will only be used if no other methods are available.

3.2.4 Sexing

3.2.4.1 Sexual Dimorphism in Skeletal Remains

The sexual dimorphism of humans is perhaps more apparent through soft tissue elements than it is the skeletal remains, but there are specific aspects of the mature adult skeleton that can be utilised in order to provide a determination of sex (White and Folkens 2005: 385). The degree of sexual dimorphism between male and female individuals is most pronounced in the pelvis and the skull, with these two elements being the most consistent in sexing the skeleton (Gómez-Valdés *et al* 2012: 156e1). The determination of sex is usually established through visual assessment of the skull and the pelvis (Walker 2008: 39). Of these two elements, it is the pelvis that is the most reliable component of the skeleton in which to determine sex (Mays 2010: 40). However, with both the pelvis and the skull, it is necessary for the individual being studied to have reached sexual maturity by the time of their death, as it is only subsequent to puberty that the required changes occur in the skeleton to allow for accurate sex determination (White and Folkens 2005: 385). The element used can also determine the accuracy of the overall sexing of the skeleton. Meindl *et al* (1985: 79) conducted a study based on 100 adult skeletons of unknown sex (to the investigators) from the Hamann-Todd Collection that included both the pelvis and the skull. From this study it was determined that the most accurate method for sexing, at 97% is with both the pelvis and the skull present, having only the pelvis present still provides an accuracy of 96%, while the least accurate is the skull alone with 92% (Meindl *et al* 1985: 80; Mays 2010: 46).

3.2.4.2 Pelvis

The pelvis provides some of the most distinct differences between male and female individuals, due to the necessary adaptations to allow childbirth in the female population (Cox and Mays 2000: 118; Mays 2010: 40). As such, the female pelvis in general is broader due to the birth canal (Mays 2010: 40). One of the key features of the pelvis used in sexing individuals is the appearance of the Greater Sciatic Notch; being both wider and shallower in females than it is in males (Mays 2010: 43). Ubelaker (1989) states that the angle of the notch is around 60° in females, compared to 30° in males (Gómez-Valdés 2012: 156e2). The notch is particularly useful in archaeological assemblages as it often survives well in the archaeological record, even with poorly preserved remains (Walker 2005: 385). The angle of the sciatic notch can be graded on a scale of 1-5 (see fig 6.5) with ‘1’ showing typical female morphology, and ‘5’ showing more male morphology (Buikstra and Ubelaker 1994: 18). Walker (2005) provides a method for comparing skeletal samples to the diagrams in Buikstra and Ubelaker (1994), by holding the bones above the image and comparing the morphology of the sciatic notch. This enables a consistent method of comparison when assessing the remains of the FCSs. However, it has been noted that females suffering from osteomalacia may present a narrowing of the sciatic notch, making it appear more male, than female (Buikstra and Ubelaker 1994: 18).

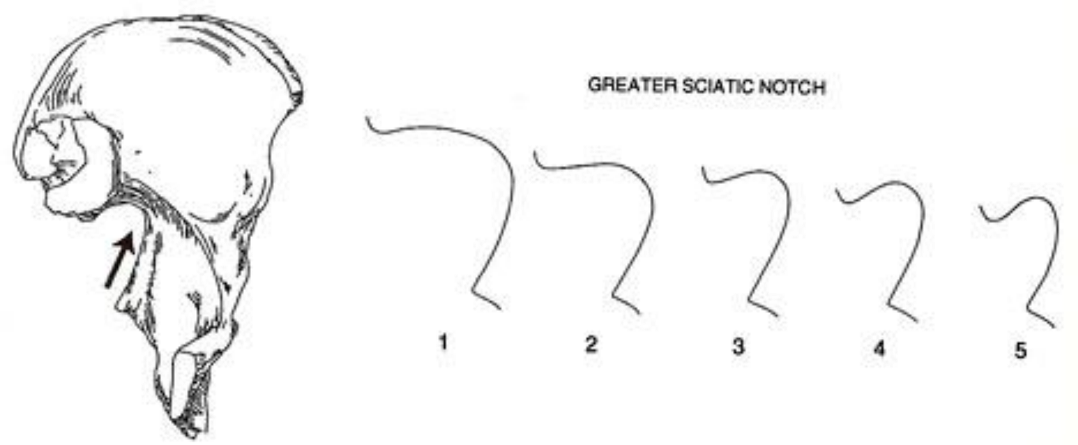


Fig 3.2: Sexual dimorphism in the sciatic notch, from 1 (female) to 5 (male) (Walker 1994: 18)

Three other features of the pelvis that can be integral to accurate sexing are; the Sub-Pubic Concavity (females display a concavity on the ischiopubic ramus), the medial aspect of the Ischiopubic Ramus (narrow in females, broad and flattened in males), and the Ventral Arc (a ridge of bone on the ventral surface of the pubis, found only in females) (Phenice 1969: 298, 300). Further work by Klales *et al* (2012) also provides an in-depth description and clear photographic examples of the features highlighted by Phenice, as well as including 5 grades of expression for each element (see fig 6.6), similar to the grading of the sciatic notch (Klales *et al* 2012:

4). Having multiple sections of the pelvis that can be used in sexing is particularly beneficial in the study of archaeological collections due to the fragmentary nature remains are often in; sexing may still be possible with only a small portion of the necessary bone (Phenice 1969: 297). Despite the accuracy of pelvic sexing within adult collections using the features put forward by Phenice; >96% (Phenice 1969: 298), it must be noted that the same methods cannot be used for those who have not yet reached adulthood (White and Folkens 2005: 398). While the majority of the remains uncovered from the *Mary Rose* are very well preserved and intact, there are instances where erosion and post-mortem breakage has occurred, such as FCS #52. The use of multiple sexing landmarks enables such remains to also be included, as even though the anterior pubis section has been lost and the bone is badly eroded, the Greater Sciatic Notch is still able to be used to determine the individual as 'male'.

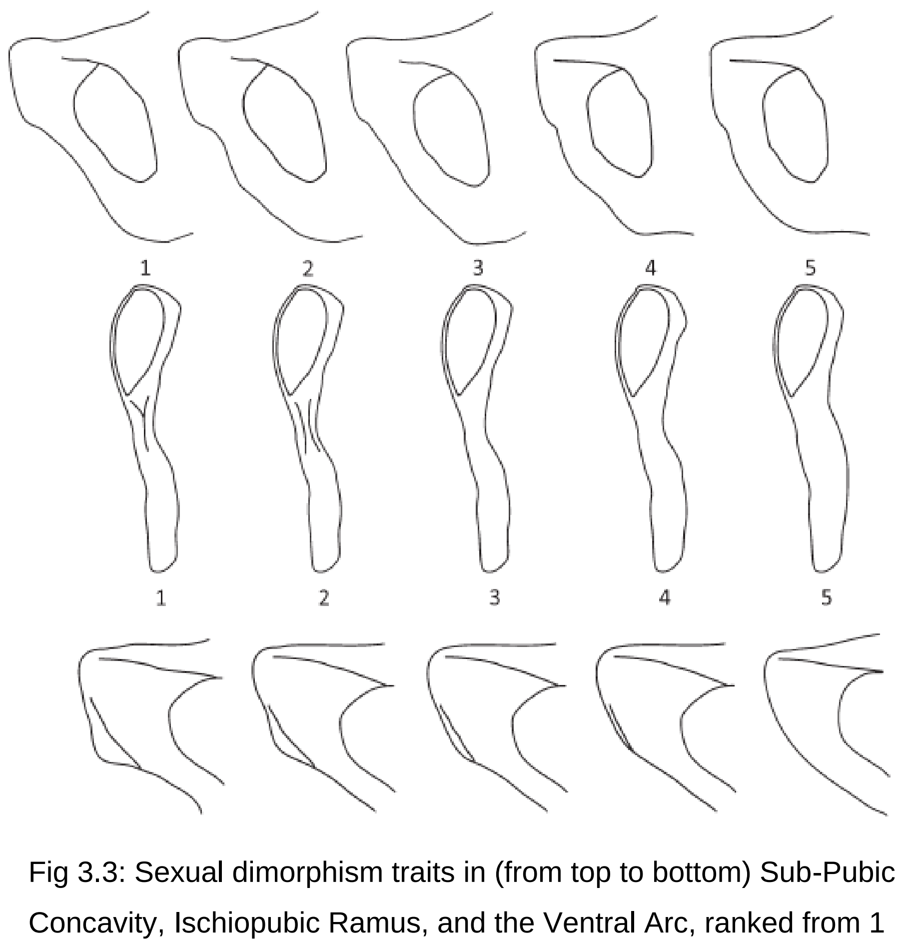


Fig 3.3: Sexual dimorphism traits in (from top to bottom) Sub-Pubic Concavity, Ischiopubic Ramus, and the Ventral Arc, ranked from 1 (female) to 5 (male) (Klales *et al* 2012: 4)

3.2.4.3 Skull

As with the pelvis, there are several components of the skull that can be used in order to ascertain the sex of an individual. While the vast majority of the FCSs that have a skull also have a pelvis, some will need to be sexed using only the skull. For male individuals there are certain features of the skull that tend to be larger and more robust than that of females. This sexual dimorphism of the face and skull is due to male individuals reaching puberty, on average, two years after female individuals. These two years of growth result in an increase in muscle mass, affecting the sites of muscle attachment to bone, resulting in more robust skulls (Cox and Mays 2000: 119). The number of morphological traits associated with sex determination can vary in different studies. Williams and Rogers (2006) included 21 different traits in their study of the accuracy and precision of cranial traits, and Rogers (1991) included 17 traits. Despite the number of traits available for assessment, ordinarily only a small number are included for analysis (Williams and Rogers 2006: 729). Buikstra and Ubelaker (1994: 20) present 5 morphological traits to be assessed for sex (see fig 6.7); the nuchal crest, mastoid process, supra-orbital ridge, supra-orbital margin, and the mental eminence. As with the pelvic sexing elements, these traits of the skull are also assigned a rating of 1-5, with 1 being distinctly female, and 5 being distinctly male (Buikstra and Ubelaker 1994: 20). This method was developed in order to standardise the assessment of dimorphic features that are otherwise difficult to quantify (Walker 2008: 40; Stevenson *et al* 2009: 434).

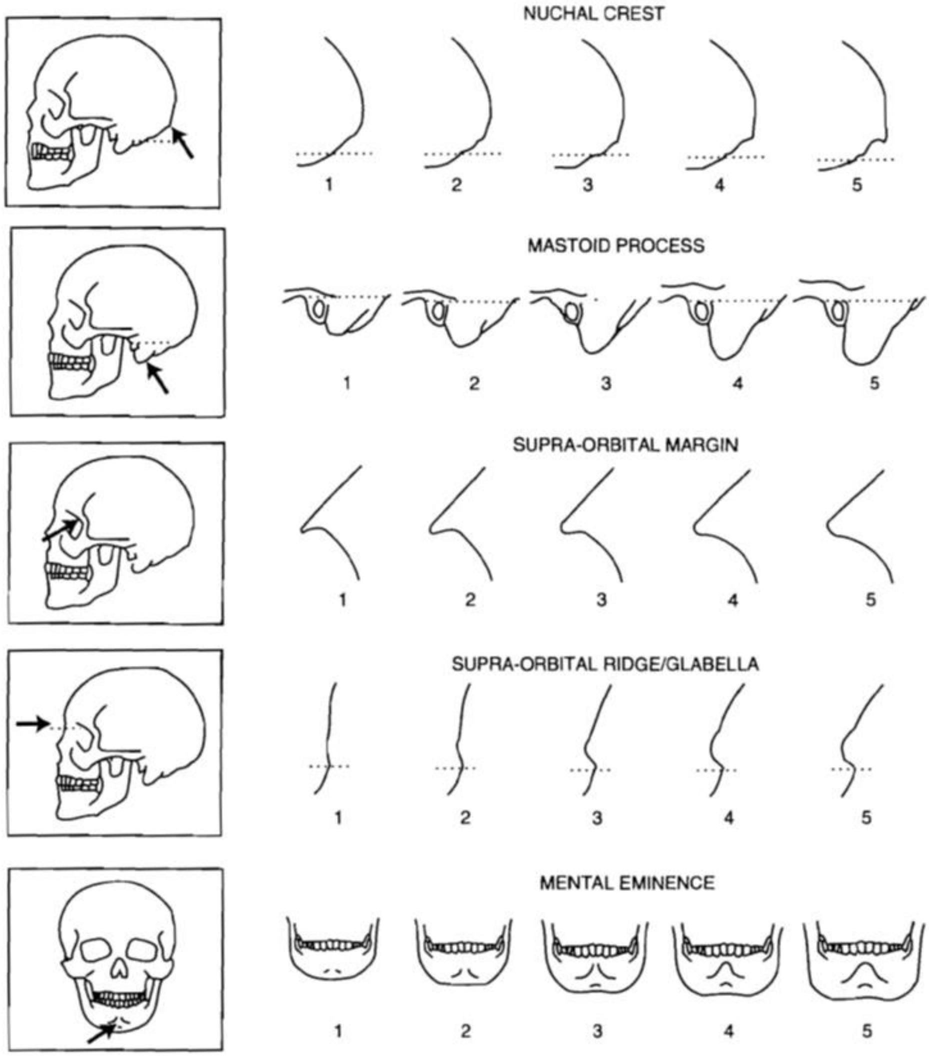


Fig 3.4: Morphological traits of the skull used to determine sex (Buikstra and Ubelaker 1994: 20)

In male individuals these traits present in the skull as larger mastoid processes and supra-orbital ridges. The orbits themselves become more square and develop thicker and blunter edges. The mandible also undergoes a range of changes, with the mental eminence becoming more accentuated, and changes to the gonial angle (Cox and Mays 2000: 119). However, the use of the mandible alone has been shown to be a less reliable indicator of sex than when both the cranium and mandible are assessed together (Williams and Rogers 2006: 733; Maat *et al* 1997: 579; Giles 1964: 129). In addition to this, the general size and architecture of the skull has proven to be a reliable indicator of sex (Williams and Rogers 2006:

734). Of the 5 traits outlined by Buikstra and Ubelaker, the mastoid process was found to be the most reliable indicator of sex from the skull in the study conducted by Williams and Rogers on the 21 morphological traits, with an accuracy of 92%, followed by the supra-orbital ridge at 86% (Williams and Rogers 2006: 734). Assessing the overall size and shape of the skull had an accuracy of 88%, but coupled with a higher intraobserver error score, it was deemed less reliable than the mastoid process and supra-orbital ridge (Williams and Rogers 2006: 734).

3.2.4.4 Sexing the FCSs

The sexing of the individual is based primarily on the pelvis where possible, as it provides the clearest delineation between the sexes with the sciatic notch, providing accuracy of between 90-95% (Brothwell 1981: 62). However, in some cases the pelvis is not present and in such instances the skull may be used in order to give an indication of the sex. The methods used to determine the sex of the FCS Collection are as follows:

Sexing Method	After
Pelvis	Phenice (1969) Bruzek (2002) Walker (2005) Klales *et al* (2012)
Skull	Krogman and İşcan (1986)

Table 3.2: Methods for Sexing the FCSs

For each individual the sex will be determined on a scale of 'Male' to 'Female' as follows:

Sex	Key
Male	M
Probably Male	PM
Undetermined	U
Probably Female	PF
Female	F

Table 3.3: Determination of sexing elements

The final sex determination is also given as one of the categories. While it may be assumed that all crew members on board a warship would have been male, the sex is assessed for each FCS. By using both the pelvis and the skull, the vast majority of the FCSs can be included. However, there are a few individuals, such as

FCS #54 and FCS #90, that are comprised of only long bones with no clear way to determine sex. In such instances, the general robusticity of the individual may be taken into account (Mays 2010: 43), but as vital elements such as the pelvis and skull are missing, the sex is listed as 'Undetermined'. Likewise, with some of the younger members of the crew who have not yet reached full maturity, the sexing elements of the skeleton may not be as clearly defined as an adult, as a 'male' pelvis in an adolescent skeleton may represent a female whose pelvis has not yet undergone the changes associated with adult females (Buikstra and Ubelaker 1994: 16). In such instances the FCS in question will be given the distinction of 'Probably Male' or 'Undetermined' based on the analysis of all markers.

3.2.5 Stature

All complete long bones, both left and right, are measured using an osteometric board, following Buikstra and Ubelaker (1994). In younger individuals where the bone has not fused, if the epiphysis is present and is able to be closely matched with the shaft, it is included, however if the epiphysis is missing, the shaft alone is not measured. Similarly, any incomplete bones where the full length is not represented (due to breakage, for example) are also discarded from the measurements. All measurements represent the total length of the bone with the exception of the tibia where the measurement is taken from the proximal articular surface to the tip of the medial malleolus. The intercondylar eminence is not included in the measurement of the tibia as it sits proud of the articulating surface and thus would not accurately represent the length of the bone in a living person. With all possible measurements taken from the FCSs, calculations can be made to determine the height of the crew members. Due to prior research suggesting a population of black individuals amongst the crew members (Bell *et al* 2009; Scorrer *et al* 2021) it is important that calculations to estimate height are inclusive of both white and black individuals, to encompass all body shapes.

3.2.6 Pathology

As this study is focusing on the pathology represented within the skeletal record, the recording of any evidence of trauma or injury must also be recorded accurately. Due to the many different forms of trauma that can occur to the skeleton, consistency is important in the recording process to ensure accuracy and reliability across the entire FCS collection. In order to provide this consistency and differentiate between various types of trauma, be it blunt force, sharp force, fracture, etc. a system is required to clearly denote the type and provide transparency for any future research purposes (see fig 3.2).

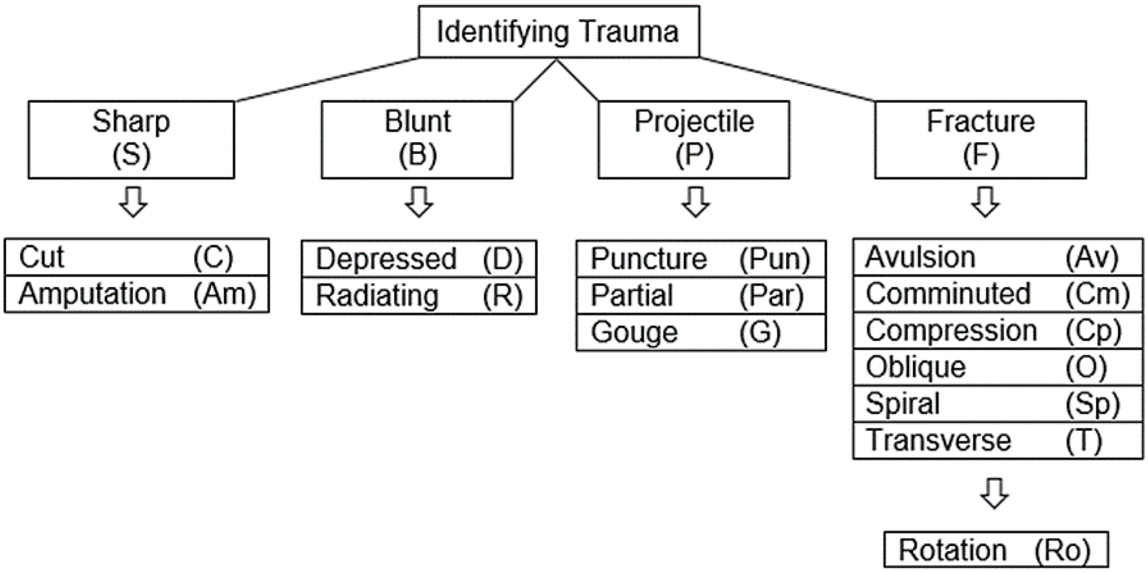


Fig 3.5: Flow Diagram of Trauma in order to provide a clear method of classifying different categories of trauma, including abbreviations that can be added to the skeletal recording sheets where necessary.

While degenerative changes to the bone is the most common cause of changes to the skeleton, trauma through accident, injury, or external influence is the secondary cause (White et al. 2012: 433). Trauma itself is described as an injury to living tissue, be it flesh or bone, due to an external force that can be intended or incidental- fractures and dislocations are often seen as the result of accident, whereas injuries caused by weapons or surgical interventions are seen as the result of intent (Lovell 2008: 341, 342). However, in the case of archaeology the vast majority of individuals exhibiting trauma lack the soft tissue and thus it is lesions on the remaining bone that form the basis for trauma analysis (Redfern 2017: 5). As such various classification have been put in place in order to provide consistency when examining skeletal remains, though the task of exploring the full range of trauma on the skeleton is, according to Ortner (2003), likely to fill ‘a substantial book’ (Ortner 2003: 177), as such no one method of recording trauma is likely to be suitable for all instances within the archaeological record (Lovell 2008: 342). Despite this, Roberts and Redfern (2019: 211) state four ways that various traumas can affect the skeleton, including:

1) Fracture
2) Dislocation
3) Post-traumatic deformity
4) Miscellaneous traumatic conditions (including those that do not affect the skeleton directly)

In addition to this, other physiological factors, such as osteoporosis, may also have an effect on trauma, due to increased vulnerability of the bone (Roberts and Redfern 2019: 211).

Analysis of trauma relies heavily on detailed descriptions of any lesions found, including photographs in order to classify it into one of the main groups of traumas. Lovell (2008) provides a list of key questions to follow when describing evidence of trauma within the skeletal record. The list covers the specific location of the lesion and the age and sex of the individual, in addition to a more in-depth analysis of the type of lesion, its appearance, and possible causation, including any subsequent conditions caused from the initial injury. By following the list of questions when examining the FCSs from the *Mary Rose*, a detailed account can be made of any evidence of trauma. By using the same parameters for each individual any similarities or correlations in trauma present will be more apparent. The list set out by Lovell is as follows (Lovell 2008: 347, 348):

1. What bone is it? If a paired element, what side? Adult or juvenile? Male or female?
2. Where on the bone is the lesion located? Is a joint involved? Is an identifiable anatomical feature involved? Where are the fracture lines located (e.g., proximal end or proximal third of the shaft)?
3. What does the lesion look like? Is there evidence for shortening? Lengthening? Angular deformity? (Comparison with the contralateral element for paired bones is a help here). How big is the lesion? (Provide length and breadth or diameter measurements, taken with callipers, if appropriate.)
4. Can you venture an opinion as to the type of injury (e.g., transverse or oblique)?
5. Can you venture an interpretation as to the biomechanics of injury (e.g., compression or torsion)?
6. Is there any evidence for a predisposing (i.e., pre-existing) condition?
7. Is there any evidence for complications resulting from the injury (e.g., arthritis or infection)?
8. Is the fracture callus represented by immature, woven bone or by mature, well-remodelled bone? Can you hazard a guess as to the minimum length of time that has elapsed since the injury?
9. Are there any other similar lesions in the skeleton that may indicate multiple injuries from one traumatic incident?

Table 3.4: List of questions to describe skeletal trauma (Lovell 2008: 347, 348)

The flow chart tracking trauma designed for use with the *Mary Rose* deals primarily with injuries caused by an external force or implement that results in the loss or gain of bone tissue (through damage and healing), or fracture with abbreviations that can be added into the skeletal recording sheet. In addition to the flow chart classifications, degenerative bone changes were also noted within the Recording Sheet, and photographs taken. Each lesion was also described in accordance to the questions laid out by Lovell to ensure consistency in the recording of any injury or trauma.

3.3 The Medical Texts

In order to fully understand the treatment of any of the injuries and conditions found within the skeletal remains, the medical knowledge and skills available to the surgeon on-board the *Mary Rose* must be understood. The most comprehensive source of information outlining medical and surgical knowledge within the sixteenth century are the various medical texts produced both in that century and the centuries preceding it.

3.3.1 Surgeons and Their Texts

There are some particularly notable texts from both the sixteenth and seventeenth centuries written by eminent surgeons of the day that can be used to better understand the skills that would likely be possessed by the Surgeon on-board the *Mary Rose*. They are principally of importance due to the type of surgery they detail; such as those focusing on naval surgery, or due to the experiences and training of the author; such as those who served their Surgeon apprenticeships in the military, treating battle trauma. The surgeons and their texts are explored in more detail in chapter 4. Those that were studied, and their texts are as follows:

-Hieronymus Brunschwig (c.1440/1450-1512/1533) *The Noble Experyence of the Vertuous handy Warke of Surgeri* (1527)

-Thomas Vicary (1490-1561), *The Anatomie of the Bodie of Man* (1548/1577)

-Thomas Gale (1507-1568), *Certaine Workes of Chirurgie* (1563)

- Ambroise Paré (1510-1590) *The Workes of the Famous Chirurgion, Ambroise Parey* (1634)

-John Banester (1533-1610), *The Workes of that Famous Chyrurgian, Mr. John Banester,* (Collected works published 1633)

-William Clowes (1543-1604), *Prooved Practise for all young Chirurgians,* (1591)

-John Woodall (1570-1643), *The Surgeon's Mate* (1617)

3.3.2 Analysis of the Medical Texts

Using the information on trauma and injury gathered from the examination of the FCSs, the contemporary medical treatises were then studied in order to assess what potential treatments and remedies could be offered by the Surgeon. This provided evidence of what medical treatments would be necessary to specifically treat the crew on board the *Mary Rose*. Without the prior examination of the human remains from the *Mary Rose* it would not be possible to determine what types of injury would need to be treated, thus an overview of the medical treatment could be given but not in direct relation to the crew. Likewise, the contemporary medical texts are required in order to provide an insight into the capabilities of practicing Surgeons during the Tudor era. Using the data collected from the skeletal remains of the crew that relate to injury, the medical texts and treatise can then be used to identify the types of treatment available.

3.4 The Medical Chest

One of the more unusual finds from the wreck of the *Mary Rose* was an intact medical chest located in the Surgeon's cabin on the Main Deck and provides the final element in the research on surgery on-board the *Mary Rose*. While it can sometimes be difficult to determine whether tools are intended for medical and surgical reasons, the location of the chest and the contents of various objects including; tools, ointments and salves concluded that the chest was indeed intended for medical treatment on board the ship (Rule 1982: 189). Despite the fact that the chest had seemingly sat undisturbed at the bottom of the Solent for over 400 years, many items such as the 9 wooden canisters inside were remarkably well preserved, including the ointments contained within them (Rule 1982: 189). Some objects however fared less well; as with other small fragments of metal from elsewhere on the ship, for example, the iron arrow heads, the metal elements of the more delicate surgeons' tools, such as the blades, had completely corroded away leaving just the wooden handles behind (Hildred 2010: 578; Rule 1982: 193). As with modern surgeons the tools available would have been vitally important to the Surgeon on board the *Mary Rose* if he were to be able to carry out his duties effectively towards the crew on board. Despite the tools having lost part of their form through the corrosion of metal, examples of tools similar to those excavated can be found depicted in the contemporary medical texts and treatise of the day. These detailed illustrations of instruments used by Surgeons during the sixteenth century have been used to reconstruct the equipment found on the *Mary Rose*. The tools on display in the *Mary Rose* museum show the original wood handles, with translucent Perspex used to recreate the missing metal elements (see fig. 3.3). This form of displaying the items makes it clear which elements are original while still giving an overall impression of what the tool would have looked like in its entirety.

Fig 3.6: Perspex reconstructions of the corroded metal elements of the surgeon's tools, on display in the *Mary Rose* Museum, Portsmouth

Throughout the history of medicine there have been relatively frequent depictions of medical and surgical instruments dating as far back as Ancient Egyptian and Classical times. A notable example of the depiction of surgical tools is the relief carving on the walls of Kom Ombo temple in Egypt (David 2008: 181). It could be argued that this early example of medical instruments being displayed on the walls of a temple reinforces the importance that was placed on such items within the practice of medicine. During the Medieval era, rather than appear inscribed on the walls of temples, illustrations of surgical instruments appear within the medical texts and treatise that would have been used by the medieval surgical practitioner. Perhaps one of the most renowned illustrations of a medical instrument is that of an arrow extractor (see fig 3.4) constructed by John Bradmore for the specific purpose of removing an arrow head that had become embedded in the face of Prince Hal, later Henry V after the Battle of Shrewsbury in 1403 (Beck 1974: 55).

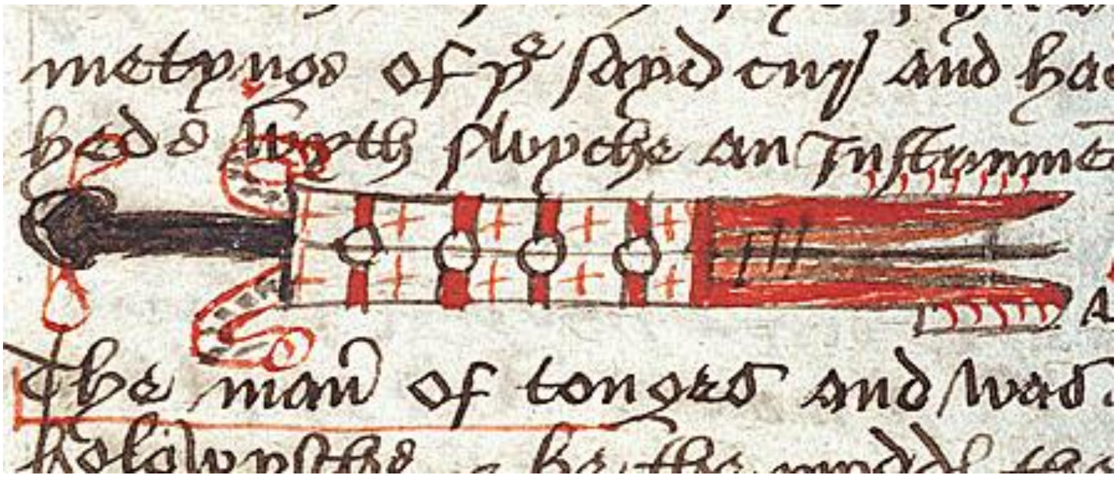


Fig 3.7: Arrow extractor designed by Bradmore to treat Henry V, MS Harley 1736, f. 48 v (British Library)

Despite the relative simplicity of the illustration, due to it being accompanied by the description of the procedure and the function of the tool itself, it has been possible to successfully reconstruct the instrument and confirm its viability (Cole and Lang 2003: 97, 99). Later medieval texts would continue to portray various medical instruments, both in a clear diagrammatic form (see fig 3.5), and as in use during various medical procedures (see fig 3.6). These later illustrations show the instruments in far greater detail than the early sketch of Bradmore's arrow extractor, and as such can be used to gain a more accurate idea of what medical instruments of the day would have been constructed.

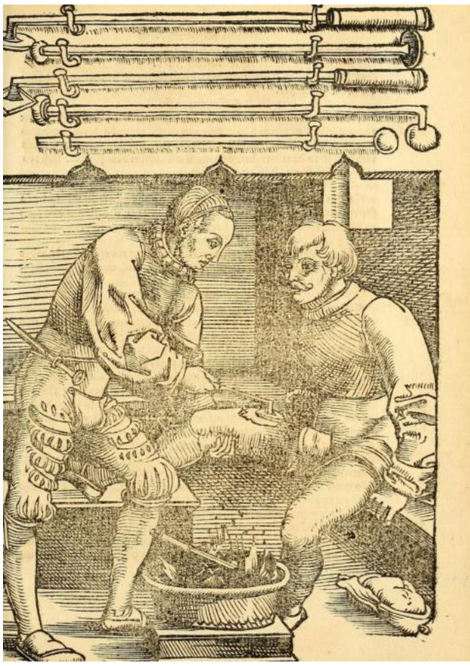


Fig 3.8 (above): Illustration of dental tools (Paré 1634: 660)

Fig 3.9 (right): Depiction of cautery irons, as well as an illustration of their use (Gersdorff 158: xxxvi)

3.4.1 Analysis of the Medical Chest

It is vital that the function of the medical tools is known in order to fully understand their use within the medical equipment available on board. Many of the medical texts from the 16th and 17th centuries also include detailed diagrams of the equipment used by the Surgeon, along with a description of their function. One such example is a series of implements (see fig 3.7) depicted in William Clowes' *Book of Observations*, published in 1597, under the heading of *'curing Gunſhot'*, now preserved in the Wellcome Collection (Copeman 1962: 15). The illustration shows a variety of tools to be used in the treatment of gunshot wounds, including items such as forceps, saws, and a trepanation drill. By using such depictions and descriptions of surgical tools found in the texts, it can be determined what use the medical instruments on board the *Mary Rose* would have been for the Surgeon, and what ailments could have been successfully treated with such equipment.

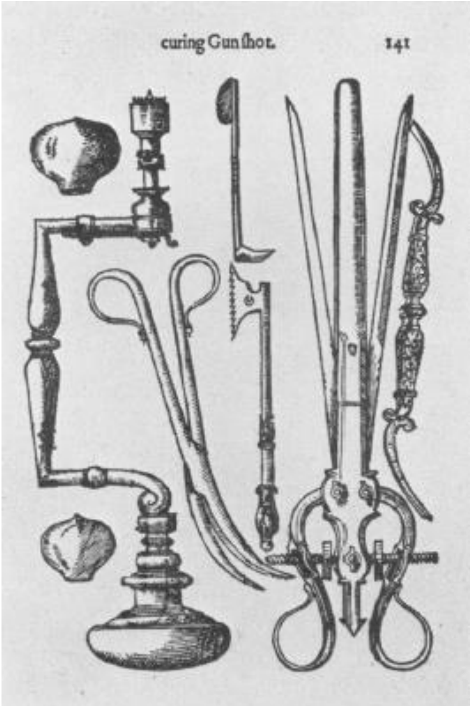


Fig 3.10: Depiction of tools used in the treatment of gunshot wounds as laid out by William Clowes in 1597 (Copeman 1962: 15).

Despite the numerous illustrations of surgical instruments in medical texts during the medieval era, the physical remains of such instruments are far rarer. The medical chest from the *Mary Rose* is the foremost example of surgical instruments from that era, and hence some of the tools have been previously reconstructed. As such, the illustrated examples of medical tools are important in terms of accurately identifying their usage in the treatment of various ailments. It is only through being able to identify the use of the medical tools on board the *Mary Rose* that it can be determined whether or not the Surgeon would have been adequately equipped in order to treat the conditions presented by the crew.

3.5 Analytical Structure and Organisation of Research

Each skeleton was individually examined and recorded both photographically and using the Skeletal sheets designed for this purpose. Once the assessment of any injuries was made, the contemporary medical treatise from the 16th century were evaluated to determine how the conditions present in the bones of the crew may have been treated by the Surgeons of the day. Finally, the contents of the Surgeon's chest were compared to the treatments laid out in the medical texts to ascertain whether or not the Surgeon on the *Mary Rose* would have been equipped to treat the crew. Combining the three elements; the remains of the crew in the form of

FCSs, the contemporary medical texts, and the contents of the Surgeon's chest uncovered from the wreck of the *Mary Rose*, provides a new look into the injuries sustained by the crew and how effectively such injuries could have been treated on board the sixteenth century warship.

4. Tudor Medicine

When considering the practice of medicine on board the *Mary Rose* in 1545, it is important to acknowledge medical and surgical practice of the Tudor age. Comparing the standards of Tudor medicine to that of modern-day medical practice would be ineffective due to the overwhelming advances in science, medicine, and knowledge of anatomy and healing processes. Thus, the skill of the practitioner on board the *Mary Rose* at the time of her sinking must be viewed in the context of the time, rather than medical advancements over the succeeding centuries. By looking at the practice of medicine through the institutions and texts published during the 16th century it can provide a basis for the level of understanding available to the medical practitioner on board the *Mary Rose* in 1545.

4.1 Medical Institutions and Practices in the 16th Century

4.1.1 Education

The level of education and training for any practitioner within the wider medical field depended on the role they occupied; be it Physician, Surgeon, Barber-Surgeon, or Apothecary (see table 4.1). The most highly educated would have been the physicians, whom would have held university degrees, and as such were the most prestigious of all medical practitioners (Watt 1983: 3). The practice of surgery was not included as part of a university medical education (Poynter 1961: 6) During the early Tudor period, the average surgeon was viewed as a craftsman, as opposed to a professional, and their remit was to treat external injuries such as wounds, fractures, and dislocations (Copeman 1963: 11). Rather than a university education, a Barber-Surgeon may spend 7-9 years as an apprentice before undertaking a qualifying examination (Watt 1983: 3). This shows that the suggestion of surgeons being ignorant, comparative to physicians is not true (Castle 2005: 171, 172), they would have undertaken extensive training, though perhaps not in a formal institution. However, some individuals such as John Banester, were qualified as both a physician and as a surgeon, meaning they had graduated from either Oxford or Cambridge, and had undertaken additional surgical training (Mello 2011: 55).

Role	Description
Apothecary	Lowest status. Would sell medicines, ointments, and herbs etc. from a shop. They could not charge for medical advice but could offer free advice to the public.
Barber-Surgeon	7-9 year apprenticeship to a Master Surgeon, with a qualifying examination. Member of the Barber-Surgeon Company.
Surgeon	Member of the Fellowship of Surgeons, more formal education in surgery, possibly at a Continental institution- often dual qualification to practice surgery and physic.
Physician	Seen as the highest status medical practitioner. Formal university education often conducted in Latin, in England this would be a degree from the university of Oxford or Cambridge.

Table 4.1: The ranks of medical practitioners in the mid-16th century (Watt 1983: 3)

A major change within the study of medicine, particularly surgery, occurred during the 16th century with the re-emergence of human anatomical dissection. While dissection of human cadavers had taken place as early as the 3rd Century BC in Alexandria (Nutton 2004: 128), it was Galen's dissection of apes in the 2nd Century AD that provided the basis for anatomical teaching for millennia (Porter 2003: 32; Siraisi 1997: 7). Anatomy formed part of medical education, particularly within Italy, from the early 14th Century. However, emphasis was placed mainly on anatomical texts that were read by the lecturer; with a body used for more illustrative purposes (Wootton 2006: 71). Within other countries, such as England and

Germany, anatomical teaching through dissection would not become common until the 16th Century (Porter 2003: 55). One of the major changes to the study of anatomy came through the publication of *'De Humani Coporis Fabrica'* by Vesalius in 1543, bringing the study of anatomy into sharper focus as a necessary preliminary for the practice of surgery (Copeman 1963: 1). The English universities of Oxford and Cambridge were slower than their continental contemporaries in the adoption of anatomical teaching and dissection. In 1549 it was declared that students at Oxford must view two dissections during the course of their studies, but a specific reader in anatomy was not put in place until 1624 (Russell 1973: 1110). The teaching of anatomy at Cambridge commenced in 1557, and a grant for two bodies of criminals for the purpose of dissection was received in 1565. Despite this, a formal chair for anatomy was not established at the university until 1707 (Russell 1973: 1110).

4.1.2 Guilds, Practice, and Licensing

In 1363 a law was enacted stating that every man who practiced a craft must be a member of a guild, the purpose of which were to set ethical standards for the profession and protect the privileges of members. If there was no guild for a specific craft, then another must be joined in its stead (Talbot 1967: 123). This law meant that the Barbers' Guild, that had been formed as early as 1308, suddenly had not only barbers as its members, but also Surgeons, Physicians, and Apothecaries (barberscompany.org; Talbot 1967: 123). It was shortly after this law was enacted that the separate Fellowship of Surgeons was established in London, around 1368/1369, with a Company of Barbers following in 1376 (Porter 2003: 34). Despite the guilds, the practice of medicine and surgery would continue to evolve with very little external guidance and supervision of the individual practitioners. In 1421 certain dangers were recognised by Parliament about allowing unskilled and untrained persons to practice any medical craft (Poynter 1961: 5). Although while such dangers were identified, no statute or law was put in place in order to control it; instead parliament gave power to the Privy Council to create and implement the necessary changes. The idea was that the Privy Council would be able to restrict practice to those who were adequately trained and protect members of the public from the more unscrupulous and dishonest 'practitioners'. However, the concept of such control was possibly too premature as no action was taken, and the idea of a ‘profession of medicine’ was virtually non-existent (Poynter 1961: 5). With no action thus taken, physicians and surgeons alike, whether qualified or not-so-qualified were free to continue their practices with abandon. Indeed, the concept of introducing a system of licencing at this stage was met with negativity- if only those with an Oxford or Cambridge education could practice medicine it would severely lower the number of practitioners and would deprive poorer and more isolated communities of medical care (Poynter 1961: 6).

Wider control over the practice of medicine came under the Medical Act of 1511 (1512 in the Gregorian calendar) which stated that those practicing medicine, be it a surgeon or a physician, must have a licence from the Bishop of their diocese. Failure to possess a licence meant a fine of £5 per month (Poynter 1961: 6). The only individuals who were exempt from the new licencing laws were those who held a degree in medicine from either Oxford or Cambridge University (Poynter 1961: 6, 7). The regulation that licencing brought to medicine meant that for the first time those who were not formally educated or trained at universities, would now be under the authority of a higher governing body. After the Medical Act was brought in, thousands of licences were issued to practitioners who had been duly examined within the new regulations. The Medical Act of 1511 was just the first step in in the development of a respectable body of ‘general practitioners’ which would establish itself over the next 250 years. This would aid in moving medicine away from the religious and into the more secular world (Poynter 1961: 7). Exactly how stringent the examinations were for licences is, however, questionable. On one single day; the 28th March 1514, a total of 72 surgeons were examined and received licences from the Bishop of London (Poynter 1961: 7; Poynter and Keele 1961: 140). While the Medical Act of 1511 had sought to punish those who practiced without a licence through the use of fines, the Act of 1542 provided an amendment to this. Rather than fining any individual practicing without a licence, it allowed exemption of those individuals helping their own friends and family without taking a fee (Poynter 1961: 9).

Fig 4.1: *King Henry VIII and the Company of Barber-Surgeons* (The Worshipful Company of Barbers) Painting commemorating the union of the Fellowship of Surgeons, and the Barbers Company in 1540, still held by the Worshipful Company of Barbers

In 1540 the united Company of Barbers and Surgeons of London was formed under an Act of Parliament, bringing both Surgeons and Barbers together and clearly defining the roles of each, marking the beginning of surgery as a profession (Copeman 1963: 19). The event was commemorated in a painting by Holbein in 1542 (see fig. 4.1). This meant that a surgeon could not perform the role of a barber, and a barber could not perform the role of a surgeon; yet both were still allowed to pull teeth where necessary (Copeman 1963: 19; Smith 1940: 68). In order to instil further professionalism into the Company, this Act of Parliament also permitted the company to access four bodies a year for dissection and teaching purposes; the bodies themselves being provided from the executed individuals at Tyburn (barberscompany.org; Poynter 1961: 9). Under this Act it was required that all surgeons were to have a public sign outside their place of work to allow members of the public to easily identify them when in need of their services (Poynter 1961: 9).

4.1.3 Colleges

The College of Physicians was formed in London on the 23rd September 1518, during the reign of Henry VIII (also known as the King's College of Physicians) when a group of physicians, led by Thomas Linacre petitioned the king. This was an attempt to try and control those practicing medicine by granting licences and punishing those who practiced unlawfully. In 1523 the powers granted to the College were expanded to cover all of England and a stricter examination for granting licences was implemented; rather than an examination from a qualified medical man and a Bishop to grant the licence, it suggested an examining board consisting of the President and three elects from the College of Physicians. This however proved too difficult to put into action and so the granting of licences still relied heavily on the church; though fellows from the College would occasionally act as examiners for the Bishops' licences (Poynter 1961: 8). The College would later become the Royal College of Physicians after the reformation in the 1660s, a name which is still bears to this day (rcplondon.ac.uk; Porter 2003: 34). This College however would differ from the earlier Guilds and Companies that regulated the practice of surgeons and apothecaries. Linacre wanted to establish an academic body that would require members to prove formal education through oral examinations displaying a classical knowledge of the subject. Furthermore, to gain a full fellowship in the College which would allow voting privileges, the individual would also have to possess a degree in medicine from either Oxford or Cambridge University (rcplondon.ac.uk). These strict regulations enforced by the College meant that the role of physician would still very much be occupied by those of a higher status within the community, as it had in centuries past, where distinguished positions were held by the educated clergy. Once it was established the College of Physicians would also attempt to exert its control over what they considered to be the lower factions of medical practice- the surgeons and the apothecaries. The year of 1540 not only saw the unification of Barbers and Surgeons into one company (Dobson 1974: 86) but also saw new powers granted to the College of Physicians; such as the power to inspect the drugs, herbs and wears of the apothecaries. If such items were considered to be of inferior quality that were potentially harmful to patients, the College had the right to destroy such items. Physicians were also granted the powers to perform surgery themselves, though few took advantage of this change (Poynter 1961: 9), perhaps due to the fact that physicians and surgeons were viewed as occupying very different social statuses.

4.2 Medicine in the Tudor Navy

Procedures for providing a land army with surgical practitioners were in place since the Agincourt campaign under Henry V in 1415 (Castle 2005: 171). However, it took around 100 years for a similar service to be made available for an army at sea. An organised Naval medical service was present within England by at least 1512/1513 (Watt 1983: 5; Underwood 1946: 121), around the time the *Mary Rose* was constructed. There was a hierarchy of naval surgery, each with its own level of pay (Watt 1983: 5; Underwood 1946: 121). The highest rank was held by a Chief Surgeon, followed by 8 chief assistant surgeons who were chosen by the Admiral, with the third rank comprising of other surgeons grouped together (Underwood 1946: 121). It was not only during active service at sea that medical care was provided to the crews of warships; Henry VIII established the Navy Board in 1546 that would take over the health care of the men in peace time (Nelson 2001: 50; Underwood 1946: 121). A surgeon assigned to a specific ship would not solely serve on that one vessel; but would be assigned a position only for the duration of the campaign in question (Watt 1983: 5). This suggests that it is likely the surgeon on board the *Mary Rose* during the Battle of the Solent in 1545 would have only been on board for the duration of the battle, rather than having a long-standing service to the *Mary Rose*. The size of the ship also affected the rank of the surgeon on board, with the higher-ranking surgeons serving on the largest ships. With the *Mary Rose* being one of Henry VIII's flagships it is probable that the surgeon on board would have been of a high rank (Watt 1983: 6). Despite the Naval medical service being in place by 1512/1513, the first text devoted to the practice of medicine at sea, written by the surgeon William Clowes, was not published until many decades later. While the work of Clowes was not published until the last quarter of the 16th century, the publication of such a text suggests naval surgery being increasingly viewed as a discipline in its own right. The increase of heavy artillery in naval warfare raised the importance of the surgeon on board ships, to the equivalent of the army surgeons on land. However, the process of selecting a naval surgeon was more exacting than an army surgeon (Castle 2005: 172; Watt 1983: 5), resulting in the naval surgeons being superior to those of the army (Childs 2009: 263). This is possibly due to the isolated nature of serving on board a ship, where no external help can be rendered if necessary, the same way it could be on land.

4.3 Medical Practitioners and Their Texts

In terms of medical texts relating specifically to naval warfare, there are unfortunately no surviving examples that date to the early 16th century that may have been available to the surgeon serving on board the *Mary Rose* in 1545 (Castle and Kirkup 2005: 182). Beck (1974: 200) puts forward the theory that the lack of surgical texts being produced during the early half of the 16th century is due to the role of Thomas Vicary as Master of the Barber-Surgeon Company. Vicary published his own first text in 1548, but it would not be until after his death in 1562 that other surgeons would publish texts on both surgery and anatomy. Beck (1974: 200) suggests that as Master of the Company, Vicary may have had powers to hinder the publication of potential 'rival' texts and intended his own be used as the standard text of the Company as a whole.

Due to the nature of the *Mary Rose* being a warship, texts written by authors with military or naval connections are preferable to those written by surgeons without such experience. It has been shown that not all those on board the *Mary Rose* at the time of the sinking were English, and that there is evidence of both European and African crew members (Mary Rose Trust 2019, Scorrer *et al* 2021). The influence of Europe in particular, can also be seen in some of the English medical texts of the mid-16th century. Even though the *Mary Rose* was an English ship, in English waters, does not mean foreign influenced texts can be dismissed out of hand. One of the most notable practicing surgeons of the day was Ambroise Paré, a French surgeon born in 1510, seen as a pioneer of both surgery and surgical techniques (Axioti *et al* 2014: 145). Paré served in 17 military campaigns during his lifetime, the first taking place in Turin in 1537 (Ellis 2001: 130; Baskett 2004: 134). He was eventually appointed the head of the French College of Surgeons in 1567 (Goyal and Williams 2010: 2108). A close English contemporary of Paré was Thomas Gale (1507- 1587), who is sometimes known as the 'English Paré'.

Similarly, Gale also started his work as a military surgeon, before becoming Master of the Company of Barber-Surgeons in London (Ellis 2001: 130). Prior to the seminal works produced by these two authors, or other English surgeons, in the later 16th Century, the first major English surgical text came as a translation of a European work. The surgical text of Hieronymus Brunschwig was first published in Strasbourg in 1497, and translated English copies were available by 1525 (Clark 1937: 55; Castle 2005: 172).

Unlike the texts produced by the university-educated physicians that were often written in Latin, texts produced by surgeons tended to favour the vernacular. This meant that the contents of the texts became far more accessible to a wider audience who lacked the classical education required for an understanding of Latin. The use of vernacular language was seen in both a positive and negative light. Some surgeons, such as William Clowes, saw that by publishing in English he made his texts and manuals more accessible which in turn enabled the standards of surgical care to be improved, as their reach was not limited to a smaller number of highly educated practitioners (Chamberland 2010: 73). Others, on the other hand, felt that by making a text more widely available, it would enable any individual to take up the practice of surgery, perhaps without the benefit of any regulations. This again was commented on by Clowes; and also mentioned by Paré. Both practitioners made it clear that while the surgical texts were beneficial, it was not enough to become a competent surgeon. That in addition to simply reading, knowledge also had to be gained through both the experience of apprenticeships and the attending of lectures; the texts were seen as a compliment to the more practical training necessary for a surgeon (Chamberland 2010: 73). Despite the use of the English in the texts, occasional sections of Latin do also appear in many works produced by 16th Century surgeons. The Latin elements predominantly take the form of the ingredients listed for various poultices and unguents required by the treatments. A potential reason for the use of Latin could, again, be linked to the fear of English texts being 'too available' to any, and all, who wished to read them. One English surgeon, George Baker (1540-1600), claimed the use of Latin was a method with which to prevent any 'ignorant asse' from becoming a practicing surgeon (Smith 1940: 66).

4.3.1 English Practitioners

Thomas Vicary (1490-1562)

The holding of an annual 'Thomas Vicary Lecture' by the Royal College of Surgeons perhaps best demonstrates the enduring quality of the work of Thomas Vicary. Though despite his modern accolades, his contemporary achievements are considered less than other surgeons of the day, with his contributions to surgery being decried as 'negative and retrogressive' (Beck 1974: 192; Copeman 1963: 12). It is likely that Vicary's close connection to King Henry VIII aided his fortunes; after successfully treating the King's leg in 1525, records show he received a fee the following year as the King's surgeon. By the year 1530 he had progressed further by becoming the Chief Surgeon to the king, along with being appointed Serjeant of the King's Surgeons (Beck 1974: 192, Thomas 2006: 235). His first instalment as Master of the Barber-Surgeons Company also occurred in 1530; a position he would hold on five separate occasions, including 1530, in the years 1541, 1546, 1548, and 1557 (Beck 1974: 192). A text was published by Vicary in English in 1548, but it was discovered later, by Dr. Frank Payne, that rather than being a collection of Vicary's own work, the text is in fact an abridged version of a text dating as far back as 1392. As this early text was written by a London surgeon, Beck is of the opinion the original author could have been Bradmore or Bradewardyn. While Vicary adapted some of the spelling in his version of the text, the nomenclature used has a far earlier character than would be expected in a 16th century surgical work (Beck 1974: 192, 193). The second section of Vicary's text is titled '*Remedies for all Captaines and Souldiers that Trauell either by Water or by Land',* however there is little coherency in the arrangement of the text in terms of ailments being listed by type or by location. As such it makes for a relatively poor reference text in comparison to the later texts by other authors, which have distinct sections to deal with specific ailments. Although this text can be helpful in providing insight into the medical practices of earlier centuries, it does not provide such detailed descriptions of the healing of traumatic wounds, such as fractures and dislocations, that can be found in later texts. It does however provide a range of remedies for the treatment of various secondary ailments that may have affected the crew of the *Mary Rose*; such as treatments for tooth ache, tooth loss and bad breath.

Thomas Gale (1507-1587)

During his career, Gale served with two different militaries under two different Kings; Philip II of Spain, and Henry VIII of England (Copeman 1963: 14). In 1546 he served as the Junior Warden of the Barber-Surgeon Company, under Vicary who himself was in his second instalment as Master of the Company. After Vicary's death, Gale would go on to serve as Master of the Company in 1561 (Copeman 1963: 14). Gale published a large volume of his work *'Institution of a Chirurgian'* in 1563. This work covered many different aspects of treatment; from fractures, and gunshot wounds, to the first English mention of syphilis (Copeman 1963: 15). In his work on fractures, he distinguished between different types, such as simple or compound fractures. Various subdivisions of fractures were also described using comparisons to the broken stalks of herbs or vegetables (Clark 1937: 59). However, his definition of compound fractures does differ to that of modern medicine; rather than just referring to a fracture that breaks the skin, Gale describes any fracture with a secondary condition such an gangrene, inflammation, or severe contusion as a 'compound' fracture (Clark 1937: 59).

John Banester 1533-1610

Banester was unusual in that he was both a surgeon as well as a qualified physician, after gaining his *Medicinae Baccalaureus* (MB) from Oxford University in 1573 (Mello 2011: 55). This meant that he was able to practice in both disciplines; something that was rigidly controlled by the different Companies at the time, particularly with regards to the Barber-Surgeons (Smith 1940: 68). He was admitted into the Company of Barber-Surgeons in 1572 and was made the Chair of Anatomy in 1579 (Buckland-Wright 1985: 809; Mello 2011: 55). The work undertaken by Banester on anatomy was heavily influenced by the 'new anatomy' of Andreas Vesalius and provided a landmark for English anatomy to move away from the obsolete Galenic anatomical model based on animal dissection (O'Malley 1964: 6). Banester's text, *'The historie of Man Sucked from the Sappe of the most Approved Anathomistes'*, published in 1578 was seen to be the most advanced anatomical work in English to date in England, based not only on the work of leading anatomists, but with the personal comments of Banester himself (Copeman 1963: 8-9). Despite his later work on anatomy, Banester began his career as a military surgeon when he was sent to Northern France, under the Earl of Warwick in 1563 (Buckland-Wright 1985: 809). During his lifetime he also gained some experience in the practice of surgery at sea, when accompanying the Earl of Leicester's expedition to the Low Countries in 1585 (Buckland-Wright 1985: 809). Banester published several texts throughout his life, the earliest being in 1575, with his '*A needefull, new, and necessarie treatise of chyrurgerie',* that focused greatly on the treatment of ulcers. However, it was 23 years after his death when a collection of his surgical teachings was compiled and published in a series of five books in 1633 (Mello 2011: 63-64).

William Clowes (1540-1604)

Watt (1985: 753) claims that Clowes was the *'most cultured, informed, perceptive and innovative of the Tudor surgeons'*. He began his career in Northern France during a military campaign led by the Earl of Warwick in 1563, and about a year later joined the Navy in 1564 (Chamberland 2010: 70; Watt 1985: 753). Clowes joined the Barber-Surgeon's Company in 1569, and eventually became one of the Company's most successful and renowned practitioners, as well as a surgeon to Queen Elizabeth I, and later, James I (Chamberland 2010:70). During his career, Clowes implemented some significant changes to the practice of surgery, particularly on-board ships engaged in military conflict. These include the reduction of pain during amputation by the application of a tourniquet, the debridement of wounds and the avoidance of using sepsis-inducing materials and distinguishing between superficial and deep burns (Watt 1985: 753-754). Clowes published three treatises during his lifetime, between 1579 and 1602, which were not only designed to educate his fellow practitioners, but also highlight the flaws and dangers of what Clowes considered 'ignorant chirugions' (Chamberland 2010: 71; Clowes 1588: 43). He is particularly outspoken with regards to the fate of soldiers, whom he considered to be at greater risk from poor surgical treatment, than the initial wound received in the heat of battle (Chamberland 2010: 71). While Clowes was writing several decades after the sinking of the *Mary Rose*, these discoveries can still be beneficial in determining what the surgeon on board the *Mary Rose* may not have had access to in terms of surgical knowledge. It also highlights the care that must be taken when using texts of a later date than the sinking- that knowledge that is common-place in the latter part of the 16th Century may not have been so in the preceding decades. Clowes produced several detailed case studies during his lifetime and advocated for the use of external ointments and powders; one particular ointment being made of 44 different ingredients (Clark 1937: 59).

John Woodall (c.1556-1643)

Although Woodall was born around 10 years after the sinking of the *Mary Rose*, he travelled extensively during his life, and in 1617 produced his text 'the Surgeon's Mate' which focused primarily on surgery at sea (Longfield-Jones 1995: 11). Previous texts had been produced by surgeons such as Clowes and Gale, which had provided focus to military surgeons on land, but Woodall's text helped to shift this focus to military surgery at sea (Power 1928: 1). As with many of the authors of surgical texts in the 16th century, early in his career Woodall himself served in military campaigns (Keynes 1967: 15). In 1612, Woodall was appointed as the first Surgeon General of the East India Company. As part of this role he compiled lists of instruments and medicines that should be included in the medical chests on board ships (Appleby 1981: 254). Such a list is included in his text 'The Surgeon's Mate' and as such provides a clear indication into the types of tools and medical ingredients required, as well as their functions and uses. Other texts, such as that produced by Gale, do include some instruments, as well as an *antidotarie* of various medicines, but they lack the comprehensive nature of the list compiled by Woodall. Though the work is later in date, many tools listed are recognisable from earlier texts, such as knives, forceps, and spatulas. Comparing the list provided by Woodall, with other treatments from other surgeons can help provide an indication of the likely equipment that would have been required by the surgeon on board the *Mary Rose*. Due to the conditions at the bottom of the Solent, many metal elements have eroded away, leaving no trace. The appearance of certain instruments in earlier texts, and their inclusion in Woodall's list may suggest the continual use and importance of such instruments. As such, even if they do not appear on board the *Mary Rose*, it implies a strong likelihood that these instruments would originally have been present, enabling the surgeon to carry out certain procedures.

4.3.2 Continental Practitioners

Ambroise Paré (1510-1590)

One of the most widely known surgeons of the 16th Century, Paré was born in Bourg-Hersent village, on the outskirts of Laval, France in 1510, and is today considered one of the fathers of surgery and modern forensic pathology (Axioti et al 2014: 145; Baskett 2004: 134; Milburn 1901: 1532). The military career of Paré is well documented; he served continuously between 1537 and 1541 but would frequently be recalled to the army over the next 32 years (Baskett 2004: 134). In addition to this he also served as surgeon to four consecutive Kings of France (Baskett 2004: 134). His years of active service suggest the possibility that he would have been a European contemporary of the surgeon on board the *Mary Rose* at the time of the sinking. Some of the most pivotal work produced by Paré centres around his pioneering treatment of gunshot wounds; such injuries had for many years been regarded as poisonous, due to the presence of gunpowder (Domingues and Pina 2012: 80). Some 15th and 16th Century surgeons, such as the Italian Giovanni de Vigo, suggested the only treatment for such poison was the cauterisation of the wound using boiling oil (Domingues and Pina 2012: 80-81). It was through his own personal experiences as a battlefield surgeon that Paré came to question the treatment of gunshot wounds. In the midst of battle, he found that his supply of oil was used up and so improvised a treatment involving egg yolks, oil of roses, and turpentine (Drucker 2008: 200, Baskett 2004: 134). The prognosis of those treated with the improvised concoction was far superior to those treated with the traditional oil. Paré found that the following day, those treated with his method were in less pain, and their wounds less inflamed. Those treated with oil, however, were in great pain and feverish. From this he concluded that he would cease to treat such injuries with boiling oil and 'burn poor men', as on the field of battle his own treatment method had been proved far superior (Baskett 2004: 134). Paré is one of the most influential figures of 16th century battlefield surgery and provides an example of how military surgery can directly benefit the practice of surgery overall, through the innovation of new techniques. As such he also represents one of the more forward-thinking surgeons of the age; one of his biographers, Geoffrey Keynes, described him as '*the emancipator of surgery from the hand of dogma'* (Baskett 2004: 135). He published several volumes on both surgery and anatomy, but his largest contribution to the discipline came in 1585 when his seminal text '*Apologie and Treatise'* was published, consisting of his work from the previous 50 years of surgical practice (Baskett 2004: 134).

Hieronymus Brunschwig (c.1440/1450-1512/1533)

Brunschwig was a Germanic surgeon who practiced during the late 15th and early 16th centuries. The exact dates and events of Brunschwig's life are often disputed; Henry Sigerist (1946) claims that Brunschwig was born in Strasbourg in c.1440 and died in 1512/1513. AJ Brown (1924), however, claims the slightly later date of birth, c.1450 in the Alsace region, and the date of death as 1533 (Tubbs *et al* 2012: 631). In addition to the differing dates provided, both Sigerist and Brown also assert differing roles for Brunschwig, with Sigerist stating he was not an army surgeon, but Brown claiming he had served in a military capacity, under the name 'Jerome of Brunswick' (Tubbs *et al* 2012: 631). The argument for military service comes from notes in his German text '*Buch der Cirurgia',* that suggest as well as study at Bologna, Padua, and Paris, he also participated in the Burgundian Wars of 1474-1477 (Hernigou 2015: 2082). Billroth (1895/1931) states that Brunschwig did not graduate from university as a Physician, but rather became a 'wound surgeon' (Billroth 1859/1931: 23). Regardless of a lack of certainty surrounding the life of Brunschwig, what can be determined is a translation of his surgical text was published in English in London, on March 26th, 1525 (Tubbs et al 2012: 631; Castle 2005: 172). This text was not only the first surgical text to be published in English, but also one of the first to deal with the treatment of gunshot wounds (Hernigou 2015: 2082). Brunschwig was also the first surgical author to include printed illustrations of tools and procedures within his text (Kirkup 2006: 26). A couple of years after the English translation of his surgical text, a second work a Brunschwig, titled 'The vertuose boke of distyllacyon…' [The virtuous book of distillation…] was published in London by Laurens Andrewe (Brunschwig 1525). Unlike his first text which dealt with practical aspects of surgery and treatment of injury, this second work focuses on 'waters and all manners of herbs' to be used in the treatments of various ailments (Brunschwig 1525). The translation and availability of his texts, 20 years before the sinking of the *Mary Rose*, suggests that not only would it likely have been available during the study of the *Mary Rose* surgeon, but also that there was a European influence in the surgical texts available to those practicing in England.

Brunschwig refers to the teachings of both earlier and Classical practitioners, such as Albucasis, who practised in the 10th and early 11th centuries (Al-Benna 2012: 379), and the ubiquitous Galen, who practiced in the 2nd century AD (Nutton 1973: 159). While other 16th century authors do mention previous practitioners, it is often in the context of how they initially described a wound or injury. For example, Paré mentions the description of a fracture in accordance to Galen (Paré 1634: 561), but when he goes on to describe the treatment of such injuries, no mention of any other practitioners is made. Brunschwig, on the other hand, makes more continuous mention of previous works, stating that various treatments or methods are as described by such authors as Galen, Avicenna, or Hippocrates.

4.4 Summary

The 16th century saw a major change to the practice of medicine and surgery in terms of licencing and regulations. In regard to military medical care, a designated Naval medical service was introduced, resulting in fighting forces at sea having access to surgical care that at least rivalled, if not superseded that available to the armies on land. Practicing in the mid-16th Century, the surgeon on board the *Mary Rose* likely had access to many surgical and medical texts produced both within England, and on the continent. With surgical texts being predominantly written in English, the texts were far more accessible to a wide range of practitioners who lacked the formal university education required for the reading of earlier Latin texts. A university education was not a prerequisite for the practice of surgery, however the introduction of licencing laws, along with the unification of the surgeons and barbers into one company resulted in surgery being far more regulated in the 16th century than it had been previously. This combined with the more accessible English texts, and the re-emergence of the study of anatomy, resulted in surgery being seen more as a profession alongside physicians, as opposed to a craft. The links between surgery and military service can be seen through the number of surgeons who began their careers through serving as surgeons during various military campaigns, both in England and on the continent. Texts written by such surgeons provide a direct link between the type of surgical care being practiced on the battlefield and the treatments recorded in such texts. As a result, these works provide an invaluable source as to what methods and techniques may have been used by the surgeon on board the *Mary Rose* in the middle of the 16th century.

5. The Human Remains from the *Mary Rose*

5.1 The Excavation of the Human Remains

The extensive mixing of the human remains on board the *Mary Rose* was apparent even at the excavation stage. Despite this, every effort was made to excavate the bones by sector, just as they had been discovered by the initial dive teams (Stirland 2013; 67). However, within marine archaeology where there is an extensive mixing of remains, it is important when an articulated skeleton is encountered that the remains are lifted as an individual as far as possible (Mays 2008; 124). Due to the nature of the site of the *Mary Rose*, such instances were rare; due to the currents of the Solent, combined with the activity of marine life, many of the remains had become mixed, sometimes across different levels of the ship (Stirland 2013: 76). Likewise the location of an individual on the ship when it sank would also influence the extent of mixing; those on the exposed Upper Deck, trapped beneath the anti-boarding netting would be far more vulnerable to the effects of the currents and marine life than those within the enclosed Hold. Despite this there are occasional examples where distinct individuals were found within the wreck, usually due to the individual becoming trapped under a heavy object, such as a bronze gun (Stirland 2013: 76), likely caused by the tilting of the ship that would have occurred during the sinking. With the co-mingled remains of the *Mary Rose* where no individuals were immediately present, the remains in the sector were raised and taken to shore where they could be recorded. Dive logs noted how many and which specific bones were brought to the surface from each individual dive (*Mary Rose* Dive Logs, *Mary Rose Trust,* 1980-1982). While skulls and mandibles were kept separate during post-excavation work, other groups of bones uncovered from the same sector were bagged in netting and assigned the same excavation number, to aid with further study (Stirland 2013: 67). Once the bones had been successfully excavated, numbered, and bagged, they had to be placed in a fresh water cascade system in a four-week long process wherein the bones would spend at least a week in the four tier system; starting from the bottom tier and moving to the top. After this process the bones could then be safely dried and individually numbered (Stirland 2013: 71).

5.1.2 Sorting the Human Remains

After being appropriately treated in a cascade system, the bones were then taken for more in-depth study, though the first obstacle to overcome in the study of the human remains was the level of co-mingling. Ann Stirland was in charge of the post-excavation work. One of the first tasks she assigned herself was to attempt to sort the bones into separate individuals; a task that she herself describes as 'intimidating' (Stirland 2013: 71, 72). Such a claim can be seen as understandable, considering the total number of bones listed as being excavated from the *Mary Rose* amounts to the huge number of 11,004 (*Mary Rose* Trust). Though over half this total is comprised of Vertebrae (2368), Ribs (2420), and Foot bones (2179) (*Mary Rose* Trust). The overall excellent preservation of the bones meant that Stirland could attempt to match the long bones from the legs and arms; though the smaller bones from the hands and feet would prove to be more difficult (Stirland 2013: 72). Along with the assistance of two students, Stirland would spend a year assessing the bone assemblage. Initially the bones were studied by the sector in which they had been excavated, to see if any of the long bones could be matched within these smaller groupings. To begin with the focus was on the femur, followed by the tibia and fibula pairings, before attempting to articulate the legs at the knee by matching femora to the tibiae. The next bones to be looked at were pelvis. As with the long bones, the left and right sides were paired together and, if possible, the acetabulae articulated with the matching femora. From this point the obvious next step was to try and assemble the spine, something that proved simpler than Stirland first anticipated, due to the close articulation of the vertebrae (Stirland 2013: 72). If the lumbar vertebrae and the sacrum could be matched, it was also then possible to articulate the spinal column with the pelvis; likewise the cervical vertebrae, in particular the Atlas and Axis, could then be used to match a skull to a vertebral column (Stirland 2013: 72). While it is possible to articulate the skull, spine, hips and legs and assign them with relative certainty to single individuals, it is harder to do the same with the arm bones, scapulae, clavicles and the hand and feet bones due to the nature of their articulation (Stirland 2013: 73). This is due to the joints being primarily supported by the surrounding soft tissue of muscles, ligaments, and tendons, unlike the close-fitting ball and socket of the femur and pelvis joint (Stirland 2013: 73). Likewise articulating the bones of the hands and feet in dry bone is difficult, and it is not possible to join sternal rib ends to the sternum in individuals. Some bones on the other hand are 'free floating', in that they do not articulate directly with any other bone, such as the patella. In order to contend with bones that are free floating or do not articulate closely, it was decided that such bones would only be included as part of an individual skeleton if there had been a clear relation between the bones when they had first been uncovered on the seabed (Stirland 2013: 73). The result of Stirland's work led to a total of 92 'Fairly Complete Skeletons', or 'FCSs', being formed from the co-mingled remains of the *Mary Rose*. Though, as mentioned previously, some of the FCSs were more complete than others. Perhaps unsurprisingly, the most complete individuals came from the Hull of the ship where there had been relatively little movement post-sinking compared to the upper decks. In addition to these individuals, there were also a very few who had been trapped close to or even underneath a larger item such as a cannon or chest. These subsequently provided some level of protection to the bones until they were eventually excavated in the 1980s (Stirland 2013: 76). For the many thousands of bones that were not able to be assigned to a specific individual, they were simply recorded by type and by sector (Stirland 2013: 76), to allow for future study to take place.

5.2 Preservation

The overall preservation of the human remains uncovered from the wreck of the *Mary Rose* is exceedingly good and as an assemblage of Tudor human remains it is unparalleled; particularly in terms of a battlefield assemblage (Stirland 2005: 515, 516). The reason for the excellent level of preservation is most likely due to the conditions on the seabed, closely following the sinking of the ship. There were then, as now, four tides a day in the Solent where the *Mary Rose* had come to rest; the stronger going from East to West and the slightly weaker going from North-East to

South-West (Stirland 2013: 66; Stirland and Waldron 1997: 330). The *Mary Rose* came to rest at an angle that meant these currents hit her broadside-on, wherein fine silts and sediments were able to cover the ship and her contents, including the crew members who had perished inside. This layer of silt allowed for anaerobic conditions (a lack of free oxygen) to form, meaning the rate of decomposition was greatly slowed, leading to the excellent preservation of organic material, including the human remains (Stirland 2013: 71; Stirland 2005: 517). However, while the overall preservation is excellent, the nature of marine assemblages and their being subjected to water currents, as well as predation from marine organisms, means they often become mixed and co-mingled over time, leading to the remains of certain individuals to be incomplete (Mays 2008: 127; Stirland 2013: 67). Owing to the rapid speed at which the *Mary Rose* sunk, human remains were found throughout the different decks of the ship, from the Hold to the Upper Deck. Despite this there was, understandably, a density of remains around the areas of the ship forming the companion ways, obviously where the crew members had perished while making an attempt to escape the ship (Stirland 2013: 67).

Despite the overall good preservation of the human bones from the wreck, there are of course variations within the level of the preservation. Those that had some exposure on the seabed showed evidence of erosion; something that was particularly apparent in the remains uncovered from the Upper Deck. Similarly, certain bones also showed staining and oxidisation where they had lain in contact with iron and other metals within the wreck. During examination of the 92 FCSs, those that were uncovered from the lower levels in the ship- such as from the Hold or Main Gun Deck show a much better and more consistent level of preservation than those uncovered from the Upper Deck. In addition to this there is very little post-mortem trauma in the form of damaged or broken bones; aside from erosion damage from remains uncovered closer to the surface. As with any archaeological site where human remains are uncovered, the bones have undergone certain taphonomic processes that also lead to changes in the surface of some of the bones- again predominantly from those found in the Upper levels of the wreck (Stirland 2013: 67). The term ‘Fairly Complete Skeleton’ itself is somewhat flexible; while some of the individuals designated as FCSs are indeed ‘fairly complete’ with a spine, ribs, pelvis, four limbs and possibly even remnants of hands and feet, such as FCS #8 (fig. 5.1), others are very far from complete. Sometimes the FCSs comprise of only a handful of bones, such as FCS #34 (fig. 5.2) which consists of twelve bones; a right scapula, 4 vertebrae, left and right pelvis with sacrum, both tibiae and the right fibula.

Fig 5.1: The fairly complete remains of FCS #8

Fig 5.2: The more incomplete remains of FCS #34

FCSs such as #34 also present another problem- that of consigning the remains to one individual with a high level of certainty when all the bones do not articulate with each other. Often bones brought up within the same dive are more likely to be attributed to the same individual; but this is not always the case. One particularly noticeable example is that of #32, in which the remains were uncovered over the three-year period the *Mary Rose* excavation took place; 1980, 1981, and 1982. Compounding this is the fact that aside from a limited number of vertebrae; 6 mid-thoracic and 2 lumbar, none of the bones articulate with each other. While all the remains were uncovered from Sector O7, so were multiple other individuals. This makes it difficult to determine why the bones were assigned specifically to FCS #32.

5.3 The Number of Individuals

While the total of FCSs came to 92, this is however not indicative of the number of individuals present on the ship either at the time of sinking, or at the time of excavation. In order to get an idea of the number of crew members present in the excavated bone assemblage, a slightly different approach to the compilation of the FCSs was required, with less emphasis on the articulation of various bones. This involved a focus on distinct pairs of certain bones, as well as the presence of single bones; most notably the skull. Separate to the work carried out by Stirland and her student assistants, the skulls and mandibles that had been kept separate during the excavation phase (aside from 3 that were initially sent to Bristol University for CT Scanning) had been sorted, with the mandibles being assigned to skulls by a team from Birmingham Dental School (Stirland 2013: 71, 72). The work done by this team further emphasised the extent of mixing that the human remains had undergone while on the seabed- a particularly notable case involved a skull being matched with a mandible that had been found three decks below. This showed that mandibles and skulls should not necessarily be matched on a sector-only basis as the initial study of long bones had been, but rather they should be matched from across the whole ship (Stirland 2013: 76). The matched skulls and mandibles provided an obvious and relatively simple way of estimating the number of individuals present within the extensive collection of human remains excavated from the *Mary Rose*, as there is no chance of confusing a skull as belonging to more or less than one individual in the same way that a potential matched pair of long bones could be. The minimum number of individuals garnered from the totals of skulls and mandibles is 179; with the breakdown as follows (Stirland 2013: 77):

Total Number of Skulls and Mandibles Excavated from the *Mary Rose*	
Matched Skulls and Mandibles	68
Unmatched Skulls	58
Unmatched Mandibles	48
Matched Maxillae and Mandibles	2
Skulls from Bristol (CT Scanning)	3
TOTAL	179

Table 5.1: Minimum number of individuals uncovered from the wreck of the *Mary Rose* (Stirland 2013: 77)

The minimum number of individuals calculated from the number of skulls is higher than that which can be determined from the pairs of long bones. The highest prevalence of an individual bone being that of the left humerus which gave a total of 119. Using the number of skulls as a baseline for the number of individuals, it can be tentatively calculated that the wreck of the *Mary Rose* has revealed the remains of at least 179 members of her crew- totalling about 43% of the estimated 415 crew members on board at the time of sinking, according to the Anthony Roll. With just under half of the ship surviving, this number of crew members seems to correlate closely with just under half the crew being accounted for (Stirland 2013: 76). As for the remaining 57% of the crew who would have perished back in 1545, it is possible they are either still buried in the silts of the Solent, or else, drifted away from the wreck (Stirland 2013: 79); particularly after the deterioration and collapse of the portside of the ship which would lead to any remains present to be exposed to the currents and marine life of the Solent.

With the excavated bones having been sorted and assigned to FCSs where possible, their distribution throughout the ship could be plotted with more accuracy (fig. 5.3). This showed that while they were dispersed throughout the different levels of the ship, in certain areas two or more individuals would be clustered together in small groups. This was found to be of particular interest on the Main Deck where various gun crews would have been in operation at the time of the sinking (Stirland 2013: 140). During the analysis of the FCS distribution it was found that in Sector M4 there were the remains of 6 FCSs; #74, #75, #76, #77, #78, and #91. Also present in this same sector was an 11 foot long Culverin Gun; with which the human remains seem to be closely associated, giving rise to the possibility of them being a Gun Crew, as six men would have been needed to operate the 2.1 ton weapon with efficiency (Stirland 2013: 140).

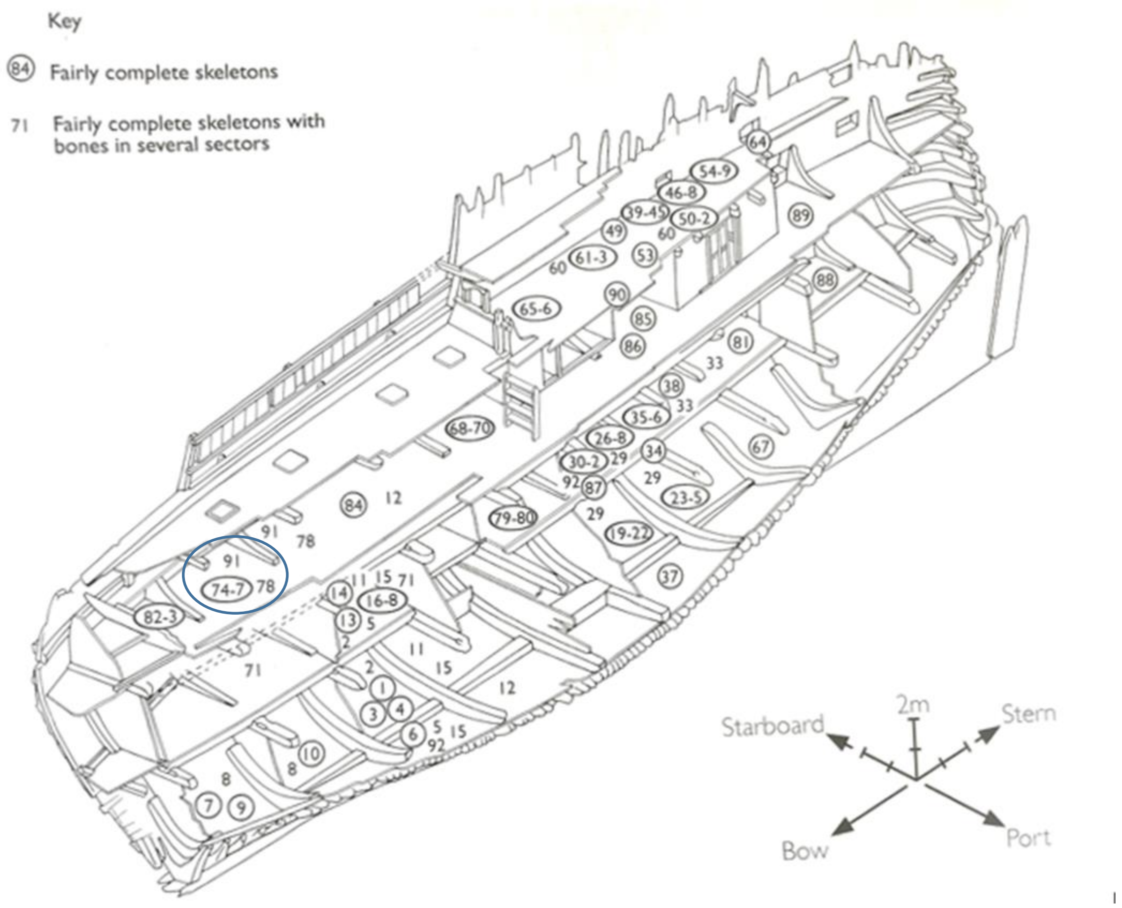


Fig 5.3: The distribution of the FCS throughout the wreck of the *Mary Rose*, the cluster of individuals potentially representing a Gun Crew on the Main Deck is circled (Stirland 2005: 539).

All six men were around the same age- between their mid-twenties and mid-thirties and ranged in height from 5’3” to 5’9”. Stirland found most of the individuals to have robust bones with clear signs of muscle attachments and stress within the spine. The one anomaly of the group is the shortest individual, FCS #78, whose bones lack the marked muscle attachments present in the others and overall has a less robust appearance, though there was evidence of slight stress markers within the spine. Despite the physical differences between the sizes of the bones of FCS #78 and the other individuals found in M4, the bones of FCS #78 also displayed the same staining and discolouration, suggesting that it had lain in M4 for an extended period of time- possibly since the sinking of the *Mary Rose*. Whether this individual made up part of the Gun Crew, and if so, what role he played, however, is harder to determine (Stirland 2013: 142, 143).

5.4 Stature Estimation by Stirland

Stirland's initial assessment of the *Mary Rose* FCSs included estimation of stature. However, a comprehensive list of her results is not published as part of her (2013) book 'Raising the Dead', though they do appear in the appendix of the 2019 publication, 'Who sank the *Mary Rose*' by Peter Marsden. Despite this, she does state that the method used for the estimations was Trotter 1970 White Male, specifically looking at the femur (Stirland 2013: 82). Her reasons for deciding to only use the femur are twofold; that the leg bones give a greater degree of accuracy for stature estimation than the arm bones, and that the greatest accuracy seems to be given by the femur specifically over that of other leg bones (Stirland 2013: 82; Waldron 1998: 76). However, Waldron states that while the use of any bone rather than the femur may produce an underestimate of stature in male individuals, the same cannot be said with female individuals, which, in contrast show no great difference between estimates involving any long bone or involving the femur (Waldron 1998: 76). It may be inferred from Stirland only using Trotter's male equation and her constant reference to the 'men' of the *Mary Rose* (including in the title of her book) that she assumed that all individuals on board the boat at the time of sinking were male. While this is perhaps not an unreasonable assumption due to the situation of the sinking- in the midst of a battle- it is clear that not all the FCSs can be definitively sexed. This is a result of the lack of sexing elements in some of the remains, such as FCS #54 which is comprised solely of long bones. Similarly, some off the younger members of the crew are pubescent, meaning their bodies had yet to develop the secondary skeletal changes necessary to determine their sex before they died. The minimum number of individuals represented by the human remains uncovered from the wreck only totals 179, approximately 36-43% of the total crew that would have once been on board. Though it is probable that the crew would have been male, with over half the crew unaccounted for in the skeletal material, it is difficult to agree scientifically with Stirland's claims of the crew being definitively 'men' as the sex of every individual on board cannot be determined.

5.4.1 Trotter and Gleser Stature Estimation

As Stirland only used the Trotter 1970 set of stature calculations, it is important to acknowledge the source of the data used in the formulae compiled by Trotter and Gleser in the 1950s and 1970s, and how comparable it is to the crew of the *Mary Rose*. Prior to the work on stature estimation undertaken by Trotter and Gleser in the 1950s, the main source of information on such calculations was by Rollet in 1888, based on the cadavers of 50 male and 50 female individuals, ranging in age from 24 to 99 years (Trotter and Gleser 1952: 463). The raw data produced by Rollet's measurements of the cadavers formed the basis for subsequent investigations into stature estimates. However, Rollet's data, along with much of that compiled by anthropologists in the early 20th Century, was based solely on cadaveric measurements, with no comparison to the living heights of the individuals in question. In 1899, Pearson applied stature regression formulae to the data gleaned by Rollet, using only the right-hand side, unless unavailable in which case the left side was utilised. He also stated that care must be taken when considering stature estimates of differing racial types to the source data, as he considered stature to be a racial characteristic (Pearson 1899: 175-177). This was further emphasised by work conducted by Stevenson in 1929 who, using data from 48 male Chinese cadavers, produced formulae comparable to Pearson's based on the Rollet data. He found that the equations produced for each set of data- French and Chinese- produced unsatisfactory results in the other, with a difference of about 4 cm too short or too tall (Stevenson 1929: 310). The work conducted by Trotter and Gleser (1952: 473) introduced three refinements to the previous work conducted on estimation of stature:

1) The combination of both living stature and the length of the dry bone from the same individual
2) Recognition of the effect that ageing can have on the stature of an individual, including the necessary adjustments

3) Testing the validity of formulae on another sample collection of reasonable size

The work conducted by Trotter and Gleser in the 1950s allowed for both the living height and the skeletal measurements of the same individuals to be considered. This was made possible due to the United States of America's program of bringing back the remains of WWII soldiers who had died abroad (Trotter and Gleser 1952: 466). The repatriated remains had been temporarily buried prior to this, and thus naturally skeletonised, resulting in dry bone that was available to be measured when returned to the United States (Trotter and Gleser 1952: 468). For the first time, this enabled the investigators access to both the living height, that had been recorded for each soldier when they first enlisted, and the length of the bones after death (Trotter and Gleser 1952: 467). This provided data from what Trotter and Gleser classed as American 'White' and 'Negro' individuals, all of whom were male American citizens. In addition to this WWII data that consisted only of male individuals, the Terry Skeletal Collection was also used. The Terry Collection comprised of cadavers that had been assigned to medical schools for study, and as with the WWII data, comprised of both black and white individuals. While height was not taken for these individuals during life, a specially adapted vertical measuring board was used to measure the height of the cadavers in a standing position when they arrived at the medical school. Such a method of cadaveric measurement was concluded by Dupertuis and Hadden (1951) to be equivalent to that of living height (Trotter and Gleser 1952: 467, 472). Unlike the military data, however, the Terry Collection also included female individuals of varying ages (Trotter and Gleser 1952: 468). The ages for the military personnel were given as the age in which the individual enlisted, whereas for the Terry Collection, the age was that of age at death (Trotter and Gleser 1952: 468). This likely results in the ages for the Terry Collection being more accurate. As in terms of the military personnel, even though on average only about 2 years elapsed between enlistment and death, the age was still determined by that of enlistment (Trotter and Gleser 1952: 471). This results in the ages for the military being generally lower than those of the Terry Collection. The military comprise of an age range of 17-49 years (though only 2 individuals fall within the last bracket of 40-49 years), whereas the Terry Collection ranges from 19-99 years (Trotter and Gleser 1952: 469). It was decided that only those individuals older than 18 years of age would be included in the data, as it was determined that any increase in stature after the age of 18 was insignificant, therefore those over that age could be considered full grown (Trotter and Gleser 1952: 469). All the individuals that comprised the Terry Collection met this requirement, but 49 individuals were excluded from the military collection due to their age of 17 at enlistment (Trotter and Gleser 1952: 470-471).

A similar study was conducted by Trotter and Gleser in 1958, involving the analysis of stature of those killed during the Korean War; as with the WWII set, the living height was available through enlistment records, with the dry bone being subsequently measured. This vastly increased the number of individuals involved in the study, particularly American black and white males, with white males increasing by 4672, and black males by 577. In addition to this, there were also small numbers of Mexicans (112), Puerto Ricans (64) and ‘Mongoloids’ (92) (Trotter and Gleser 1958: 81,121). This second study demonstrated that unlike the WWII data, where there was no significant increase in stature after the age of 18 in white males, the was evidence of continued growth until the age of 21, possibly even until the age of 23 (Trotter and Gleser 1958: 122). Both the 1952 and the 1958 study comprise of modern populations, and such a difference in growth between one generation and another within a short time frame raises the question which growth pattern, if either, would best represent the growth of an individual in the Tudor navy. It is not only the historical period that separates such studies from the crew of the *Mary Rose*, they are also very distinct geographically. Thus, an issue arises as to how comparable a relatively modern American population can be with a late Medieval European one.

5.4.2 Ancestry

In addition to only using Trotter’s Male equation, the estimation is further narrowed by using only the White Male equation. This again may be an assumption on Stirland’s part that the fighting force of the Tudor navy would all be white. This has been demonstrated to be incorrect through recent scientific analysis of isotopes that featured in a documentary ‘*Skeletons of the Mary Rose: The New Evidence’* that aired on Channel 4 in March 2019. While the results of the documentary have yet to be academically published, it revealed that, of the 8 individuals studied, two originated from mainland Europe, specifically the Mediterranean, and two from North Africa- one of whom is FCS #70 who has been dubbed ‘the Archer Royal’

(*Mary Rose* Trust 2019: 16, 17). While this is not the first time such claims have been made regarding the ethnicity of the *Mary Rose* crew, it is perhaps more conclusive than previous studies. An earlier study of isotopic values for 18 members of the crew concluded that a sizable proportion; up to 60%, of the crew were foreign (Bell *et al.* 2009: 172). This claim was later disputed to some extent by Millard and Schroeder (2010), stating that Bell's work was based on an earlier 2006 study, also conducted by Bell. This earlier work which used a data set of 9 humans and 16 horses, was deemed too small to give an accurate representation of $\delta^{18}O_{carb}$ values in Britain (Millard and Schroeder 2010: 680). Despite this it was accepted that while such a large proportion were not foreign, as stated by Bell, at least one of the 18 individuals did derive from outside Britain (Millard and Schroeder 2010: 682). While these studies have been conducted subsequently to Stirland's work, and each comprise of only a small fraction of the crew, they do suggest that such a narrow set of stature equations- those specifically produced to focus on white individuals- are perhaps not adequate enough to encompass the geographically varied crew we now know were on board the *Mary Rose* in 1545.

5.4.3 Inclusion of Individuals

Stirland's stature data is not only based on the length of the femur, but also only for those individuals who were mature adults, that is to say, adults who had reached their final height (Stirland 2013: 83). It is not stated specifically why the decision to omit the younger members of the crew was made, but it seems as though in order to make comparisons with the average height of European males over the last 200 years, only final adult heights were required, and not those of individuals who may yet have grown further (Stirland 2013: 83). The omission of various individuals by only including those whose FCS contained the femur, and those who were fully mature, has resulted in 27 of the 92 FCSs (29%) being excluded from the stature calculations. Stirland (2013: 159) states that all femurs found throughout the wreck were measured, and provides the following summary of the results in the appendix:

Femurs			
	Left	Right	Combined FCS
Number	82	92	104
Mean (cm)	170.9	171.2	170.6
S.D (cm)	4.5	5.0	4.6
(Imperial)	5’7” ± 1.8”	5’7.5” ± 2”	5’6” ± 1.8”

Table 5.2: Stirland’s summary of stature based on the measurement of all femurs found within the wreck (Stirland 2013: 159)

While both the left and right femora, as well as the combined pairs of femora found in the FCS collection are listed as part of the overall stature estimation for the crew, in the text she goes on to explain how only the left femora were used in order to avoid measuring the same individual twice. In addition to this, circumventing any issues that may have arisen with regards to all the other individuals represented through the co-mingled remains- ensuring that no other crew members, as with the FCSs, were accidentally measured twice (Stirland 2013: 82). Unfortunately, neither the raw data, nor a comprehensive table of results has been published by Stirland, so while the mean statures are available, the range, and heights of the tallest and shortest individuals are not included. The FCSs only encompasses roughly a quarter of the individuals who would have initially made up the crew of the *Mary Rose*. The omission of more than a quarter of this number due to certain bones being absent, further depletes the number of individuals that can be included in stature estimates that help provide an overall impression of the crew.

5.5 Age Estimation by Stirland

The age estimations produced by Stirland found that the majority of the crew onboard the *Mary Rose* would have been ‘Young Adults’, aged between 18 and 30 years (Stirland 2013: 81). This is perhaps not unexpected, as it would be reasonable to assume a warship would be crewed with young and fit individuals in order to carry out all the necessary tasks on board. While the commonality of this age group is apparent in both her published work and in her original notes at the *Mary Rose* Trust, there are some discrepancies in the data with regards to the representation of other age brackets. In the published work the age data according to Stirland's distinctions is described as follows:

Age Category	No. of individuals
Juvenile	1
Adolescent	17
Young Adult	54
Middle-Age Adult	15
Old Adult	1
Adult	4
Total	92

Table 5.3: Age brackets of the FCSs according to Stirland's published work (Stirland 2013:81)

Stirland specifies that Young Adults are aged between 18 and 30 years, Middle Adults are from about 30 to 40 years and Old Adults are those individuals aged 40 years or older (Stirland 2013: 82). The Juvenile age bracket is classed as the one individual who is 'about 12-13 years of age' (Stirland 2013: 81) while the group of 17 Adolescents does not have an age range specifically stated, but based on the 'Young Adult' range being classed as 18-30, it must be assumed that 'Adolescent' covers the ages between 13 and 18 years. These results are different to those produced by the raw data contained within her notes, and the data published by Marsden (2019), supposedly taken from said notes. There are also differences between the information stated in the notes and that published by Marsden, despite the work of Marsden being based on Stirland's work, rather than any further osteological investigation (Marsden 2019: 278-291). The categories used by Marsden differ from those of Stirland in the fact that he uses number brackets (18-30, 30-40 etc.) as opposed to those used by Stirland which are classed as 'Young Adult' or 'Middle Adult'. In order to compare the two data sets, the one contained within Stirland's notes, and those published by Marsden, the age categories used by Stirland in her work are applied to both:

Age Category	No. of Individuals
Juvenile	0
Adolescent	11
Young Adult	61
Middle Adult	15
Old Adult	1
Adult	3
Unknown	1
Total	92

Table 5.4: Age ranges according to published work by Marsden (Marsden 2019: 278-291)

Age Category	No. of Individuals
Juvenile	0
Adolescent	12
Young Adult	62
Middle Adult	14
Old Adult	1
Adult	3
Total	92

Table 5.5: Age ranges according to original notes made by Stirland (*Mary Rose* Trust)

The two data sets are very similar; but differences do occur. FCS #9 is stated as unknown in Marsden's text (Marsden 2019: 278) but listed as 'Adolescent' in the original notes, this accounts for the 11:12 difference in the Adolescent grouping. The other discrepancy comes with the number of individuals classed as 'Young Adult' and 'Middle Adult'. This is due to FCS #26 being classed as a 'Young Adult' in Stirland's notes, but a 'Middle Adult' in the work published by Marsden (Marsden 2019: 283). Both the height (175.00 cm) and the sex (male) are consistent in both sources, but there is no clear indication as to why the age has changed.

5.5.1 Issues with Age Estimation

The youngest individual from the FCSs appears to be FCS #55, based on the lack of epiphyseal fusion- so much so that no long bones could be classed as 'complete' for stature estimation as all were missing at least one epiphysis. Stirland (2013: 81) references one individual as being a juvenile, but does not specify as to which exact FCS she is referring, and, as the classification of 'Juvenile' does not occur in the original notes, the possibility of FCS #55 being the juvenile individual cannot be confirmed. Unfortunately, while the majority of the long bones are present in FCS #55, there is no dentition available to be aged alongside the bone. This is due to the fact that while there is a skull associated with FCS #55, only the neurocranium exists, with the facial bones, maxilla and mandible being lost. As a result, any tooth eruption information for this individual, that could have assisted in producing a more accurate age bracket, is not available. Similarly, the cranial sutures are all open, as the individual has yet to reach adulthood, hence the post-cranial elements of the skeleton must be used instead to produce an age estimate (Meindl and Lovejoy 1985: 62). Using the available information provided by the fusing stages of the long bone an estimation can be made, if not as accurately as if the dentition were also available. As previously mentioned, all the bones present are incomplete due to the lack of fusion, this includes the humerus of which the medial epiphysis is unfused and absent. Due to the young age of the individual it cannot be determined definitively whether they were male or female; and the rate of fusion differs for each sex; thus, the sex of the individual may influence the age estimate. In female individuals, the medial epiphysis fuses between the ages of 10 and 15, whereas in male individuals it is slightly later- between 11 and 16 years of age (Buikstra and Ubelaker 1994). Based on the standards set in Buikstra and Ubelaker (1994: 43) the fusion of the distal and medial humeral epiphyses occurs first out of all the epiphyseal joins in the various long bones; between 9 and 13 years for female individuals, and 11 and 17 years for males. The distal humeral epiphysis in the present right humerus of FCS #55 (the left humerus is absent) has fused to the shaft, with only a small line of union still present on the lateral side. The medial epiphysis on the other hand is completely unfused and is absent.

The age estimation of FCS #4 presents a possible dilemma with regards to the evidence provided by the bones, and whether the bones represent a single, or multiple individuals. The FCS is not comprised of many bones; 2 humeri, 2 femora, 2 fibulae, a left clavicle, a left rib, the manubrium and the sacrum; none of which articulate with each other. In the upper body, the clavicle has an unfused sternal end (the epiphysis of which is missing), and both humeri show a clear line of union around the humeral head, suggesting that fusing had occurred but had not been completed at the time of death. The lower body, comprising of the femora and fibulae, however, does not display any lines suggesting recent union, instead appearing completely fused. Three elements must fuse in the femur for it to become a complete long bone; the distal end (14-21 years), the head/lesser trochanter (15-19 years) and the greater trochanter (17-19 years) (Buikstra and Ubelaker 1994: 43). In addition to this, both the distal and proximal ends of the fibula will also fuse before 21 years of age (Buikstra and Ubelaker 1994: 43). Based on the analysis of the lower body of FCS #4, with the complete fusion and total lack of visible line denoting it, suggests that the individual is aged at least 21 years or older. In the upper body the humerus head fuses between the ages of about 14 and 22 years, and the clavicle between 18 and 30 years (Buikstra and Ubelaker 1994: 43). While these ranges are not necessarily at odds with those of the femur and fibula, the stage of fusing is very different in the humeri and clavicle. This is not to say that the bones definitively represent two individuals, as despite the very marked difference in the rate of fusion, it could simply be the natural growth pattern of that individual, and that their death occurred on the cusp of reaching full maturity.

5.6 Sexing by Stirland

Stirland states that every individual sexed from the wreck site was determined as ether 'Male' or 'Probable Male'. While the sex of the individual is stated in her original notes, the method or bone used to determine the sex is not mentioned. For those adult FCS that have both a pelvis and a skull present, determination of sex is relatively straightforward, but for those who possess neither element, nor fully mature, the method of sexing is more difficult to establish. For example, there are a number of FCSs that are comprised predominantly of long bones (though not all long bones are necessarily present), with the occasional addition of ribs, clavicles, and sternums etc. Three such individuals are FCSs #25, #29, and #76; none of which has a pelvis, or a skull present. Yet all three have been determined as definitively 'Male' individuals. FCS #29 in particular is also aged as being an adolescent, according to Stirland, and so potentially their bones are not yet fully mature; though with the absence of the pelvis and skull, the sex related changes that occur with age are perhaps not as apparent. FCS #17 on the other hand, while also lacking a pelvis and skull, is perhaps more complete than either #25, 29, or 76, yet the sex is only stated a 'Probable Male'. In 'Men of the *Mary Rose*', Stirland refers to the pelvis and skull as being the major sources of information regarding sexing, but also that men can display longer and more robust bones than women. She states that all the FCSs were sexed using all the data provided by the bones for each individual (Stirland 2013: 79). However, the sexing methods used for specific individuals is not addressed in the text, nor do the notes offer any particulars as to which bone was used and why the sex determination was made.

5.7 Work Conducted since Stirland

Since the initial sorting of the human remains from the *Mary Rose* into FCSs and total number of individuals, Stirland published her work in ‘Raising the Dead’ initially in the year 2000, with subsequent revisions under the title ‘Men of the *Mary Rose*: Raising the Dead’ in 2005 and 2013. Stirland’s work also comprises the bulk of existing literature on the human remains from the wreck site, including chapters in other publications such as *‘Before the Mast: Life and Death on Board the Mary Rose’* (Gardiner Ed. 2005). While this chapter does not necessarily provide any new insights into the men and their remains that cannot be found in her stand-alone text, additional segments by R. I. W. Evans on the dentition of the men, and by E. Hagelberg, and I. Frame on the DNA of the crew, provide insights into other sources of information provided by the skeletal remains. However, since the completion of the main excavation of the wreck in 1982, Stirland’s work has provided the primary source of information on the human skeletal remains. Despite this, some work to further the knowledge on the men has been undertaken at the *Mary Rose* Trust, conducted by Mary Rose Drew, usually published under Rose Drew. While her work at the Trust went mostly unpublished, her notes taken on the collection do remain as part of the records of the *Mary Rose* Trust. Amongst these notes some fairly sweeping statements are made by Drew, including declaring the position of the individual amongst the crew, be it ‘archer, ‘gunner’, or ‘cabin boy’, based solely on the skeletal evidence as interpreted by Drew. For example, the individual declared as being a ‘Cabin boy’ (FCS #55) is one of the younger crew members represented in the FCSs, if not the youngest based on the fusing of the long bones, though aside from this there is seemingly no evidence in Drew’s notes as to why this position is assigned over any other that may be occupied by younger or smaller crew members, such as a Powder Monkey. Due to the unpublished nature of Drew’s work and some of the seemingly unsubstantiated claims made as to the occupation or illnesses suffered by the crew members, many of her findings will be discounted in the present study unless there is clear evidence within the skeletal record or through associated finds to validate such claims.

5.7.1 Issues with Previous Work

Aside from the work undertaken by Stirland, there has been no further in-depth study of the human remains from the *Mary Rose* in its entirety as a collection. While Stirland's work provides an excellent starting point and a general overview of the crew from the *Mary Rose*, there is enough scope to build on this previous work through new investigations into the skeletal collection. However, when re-examining the crew of the *Mary Rose*, it became clear that the classification of 'Fairly Complete Skeleton' can be somewhat nebulous, and certainly inconsistent. The use of the term means that those skeletons that consist of skull, spine, ribs, pelvis and all four limbs, possibly also including some hand and feet bones, are categorised in the same way as those that may consist of little more than a spine and a pelvis, such as in the case of FCS #58 (fig. 5.4). The percentage of completeness of the FCS collection can be seen in table 5.6. Conversely, while there is less of FCS #58 remaining than some other FCSs, the vertebrae, sacrum, and pelvis do all articulate closely with each other, implying that the bones do all belong to the same individual. Unfortunately, this is not always the case, as shown in some of the other less complete FCSs. For example, FCS #29 (fig 5.5) contains only a small assortment of bones, but unlike FCS #58, these bones do not articulate closely, if at all. Two fibulas are present in FCS #29, as well as 2 tibiae which at the time of writing, are on display in the *Mary Rose* Museum; these lower leg bones may potentially form a matched pair with each other but without the presence of femurs, pelvis, and spine, with the necessary articulation, there is no way to definitively link the fibulae and tibiae to any of the other bones that comprise FCS #29.

%	Number of FCSs
≥ 75%	11
≥ 50%	17
≥ 25%	39
≤ 25%	23

Table 5.6: the % of completeness of the FCS collection

Fig 5.4: The limited, but articulated, vertebrae, sacrum and pelvis of FCS #58

Fig 5.5: The remains of FCS #29, showing the lack of articulation

In some cases, the bones of less complete FCSs are assigned to the same individual due to the association on the seabed- that if all the bones are found in the same sector, within proximity of each other, and there are limited individuals within that sector, then it may be assumed there is a possibility that they comprise of one individual. This however cannot be the case with FCS #29, as the bones were ultimately recovered from 3 different sectors within the ship. While the box lists the location as O7, by referring to Stirland's diagram of the distribution of the FCSs it can be seen that this is not the only location in which the bones were found; they were also recovered from H7 and H8. Unfortunately, while Stirland explained her process of assigning bones to FCSs, she did not go into detail as to how those such as FCS #29 were compiled, where there is no articulation between some of the bones and they have been recovered from different sectors. Further compounding this issue is the fact that the remains of FCS #29 were not only lifted from different sectors, but also different excavation years. All the boxes for the human remains also state which year they were excavated; usually 1980, 1981, or 1982. FCS #29 shows that the bones were lifted mainly during the 1981 season, but a few were also lifted one year later during the 1982 season. One of the bones lifted the following year is the right fibula- with the left having been lifted in 1981.

Unfortunately, with the tibiae on display within the museum, it was not possible to examine the slight articulation between the tibiae and fibulae and assess whether they could belong to the same individual.

FCS #29 is not the only skeleton in which such issues arise, though at times it is more apparent that a FCS is comprised of more than one individual, based on the bones that are present. The FCSs #57 and #59 are the only two individuals who were not placed in their own box, but rather both individuals are in the same box, without any separation between the two sets of remains, which were somewhat limited. When examining the remains, it was found that one sacrum articulated closely with one pelvis, to the extent that their belonging to the same individual can be assumed with some certainty. However, the other pelvis and sacrum present do not show such close articulation. When trying to articulate the pelvis and sacrum of the second individual, it was found that they lacked the close articulation required to definitively say that they both came from the same individual. As such it can be presumed that the box containing the FCSs #57 and #59 contain the remains of at least three individuals, rather than two. Due to the confusion over the remains and the uncertainly of just how many individuals were represented, the decision was made to exclude the two FCSs from the present study. Both FCS #57 and #59 were found in the same location on the Upper Deck, an area where there was a high concentration of co-mingled human remains, likely due to the fact that as the *Mary Rose* began to sink, men from the lower decks would make their way to the upper decks in order to try and escape. In addition to this, the *Mary Rose* would have been involved in combat at the time and so men would have also been at battle stations along the upper decks. Preservation on the upper decks is also less good than can be found amongst the lower decks as they would have been more exposed to the currents and marine life of the Solent than the more enclosed lower decks. As such the remains from the upper deck show far more erosion than those elsewhere on the ship.

Occasionally during the re-examination of the human remains uncovered from the *Mary Rose*, extra bones would appear within the FCS. These usually took the form of extra vertebrae; their presence immediately obvious by the repetition of certain vertebrae, such as in the case of FCS #42. In this FCS it was found that there were 5 vertebrae that seemed to have doubles; C7, T1, T9, T10, and T11. The lower thoracic spine, T9-T11 were less clear, but C7 and T1 are very distinctive within the vertebral column and it was quickly apparent that some had been incorrectly assigned, as both C7s articulated with the requisite T1s. However due to the lack of the rest of the vertebrae either side of C7 and T1 (C1-6 and T2-8) it cannot be said with any confidence which pairing of C7 and T1 can be assigned to FCS #42.

Stirland's primary focus when working on the skeletal remains from the *Mary Rose* was to assess the general condition of the bones and to establish an estimation of how many individuals the remains represent. While some mention of pathology is made in her text *Men of the Mary Rose;* it is a general overview as opposed to an in-depth study that carefully analyses the causation or treatment of such injuries.

5.8 Summary

Stirland faced a huge task sorting the human remains uncovered from the excavation of the *Mary Rose*. Thousands of human bones were brought up from the seabed over a three-year period, the vast majority of which were extensively co-mingled on each deck of the ship, including some that were found across different decks. Some of the FCSs were excavated over multiple years, and with a lack of articulation of the bones it is difficult to determine why some have been assigned as 'Fairly Complete Skeletons', when thousands of other excavated bones have not been allocated to a specific individual. During her analysis of the human remains, Stirland did provide sex, stature, and age estimations. However, the categorising of all crew members as 'male' seems improbable through Stirland's statement that the individuals were sexed using the skull and pelvis, yet some FCSs lacking these elements are still classified as definitively male. Stature estimations were based solely on the length of the femur, resulting in many individuals not being included as they lacked this particular bone. Additionally, only the Trotter and Gleser 1970 White Male formula was used to estimate the stature of the crew, based on the assumption that the crew would have comprised of white individuals. However, as little work has been conducted on the human remains since the work of Stirland, such discrepancies prove there is ample scope for further investigation into the crew of the *Mary Rose*.

6. Current Analysis of Human Remains

With the re-examination of the human remains uncovered from the wreck of the *Mary Rose*, it is necessary to establish the basic data, such as stature, sex, and age of the individuals. While such analysis was undertaken by Stirland shortly after excavation, more recent evidence has come to light regarding the crew, along with new methods for the examination of human remains. A recent study (Scorrer *et al* 2021) on the isotopic values of eight crew members have shown that not all crew members originated from England, as previously supposed by Stirland. Similarly, recent studies into stature conducted by Mays (2016) have provided formulae for stature estimation partly based on a medieval English population. Such insights into the ancestry of the crew, along with advancements in the estimation of stature were not available to Stirland during her initial investigation, and hence it is important to re-analyse the basic data of the FCS collection to provide the most comprehensive understanding of the crew of the *Mary Rose*.

6.1 Stature Estimation of the Fairly Complete Skeletons

The estimation of stature has a long history within the study of human remains, but the level of accuracy it is possible to achieve in such calculations can vary due to the imperfect correlation of long bone length and height found within even living populations (White and Folkens 2005: 398). This is further compounded by the fact that the height of an individual is subject to change over their lifetime; with it increasing until adulthood but then decreasing as they age further (Brothwell 1981: 100). There are three different methods of estimating stature from skeletal remains (Mays 2010: 128):

1) Measurement of the skeleton in the grave
2) The anatomical technique
3) Mathematical stature estimation

The first method of measuring the remains in the grave is inappropriate for the individuals uncovered from the *Mary Rose*. Due to the comingling of the remains associated with the movement of the water currents at the bottom of the Solent, and that the remains have long since been excavated from their archaeological position. The second method, the anatomical technique, relies on the measuring of the skeleton with the necessary articulation, as found in the Fully Method (1956). This method also involves the estimation of the sizes of the soft tissues and cartilage that are present in the living body. This in turn can lead to significant errors on the overall stature estimate due to the difficulty in assessing how thick the cartilages and other tissues would be in a living individual (Harrison 1953), as well as issues associated with the natural curvature of the spine (Mays 2010: 129). Despite this, when used correctly, the anatomical method can produce some of the most accurate results for stature estimation- a recent study found statures calculated using Fully's anatomical method produced estimations very closely related to living stature estimations (Raxter *et al* 2006: 378). However, the Fully method necessitates the measurement of specific elements of the body, including the entire spinal column in order to produce a stature estimate (Fully 1956). As with grave measurement, the fragmentary nature of the skeletons uncovered from the *Mary Rose* results in the lack of the required bones to successfully employ the anatomical method (Mays 2010: 130).

The final method; Mathematical Stature Estimation, involves the measurement of the various long bones of the body and employing a mathematical formula to generate an estimate based on the long bones. Due to the length of the long bones they provide the closest correlation between the bones and height of an individual (Mays 2010: 130). The formulae put forward by Gleser and Trotter (1958) and Trotter (1970) are amongst the most widely used when estimating the stature of adults from skeletal remains (Mays 2010: 130). Due to the issues with the incompleteness of the FCS uncovered from the *Mary Rose*, mathematical stature estimation provides the most consistent means of calculating the heights for the remains of the crew.

6.1.1 Data Collection

During analysis of the FCS collection all suitable long bones were measured using an osteometric board; those bones that were either broken post-mortem or had missing epiphyses were not included as they were not representative of the full length of the bone. Due to the partial completeness of many of the FCSs, wherein not all long bones are present, both the left and right sides were measured, even if a particular long bone was available for both sidings. This enabled a comprehensive dataset for all the complete long bones contained within the FCS collection. As laid out in the methodology, there is no one set of stature estimation equations that fits the crew of the *Mary Rose*, and previous work by Stirland only focused on the Trotter 1970 White Male equation. In contrast, the current study encompasses a range of stature calculation formulas in order to produce the most accurate stature estimations for the crew of the *Mary Rose*. All long bones were measured to two decimal places using an osteometric board. All subsequent stature estimation was also calculated to two decimal places, in accordance with stature calculation formulae written at two decimal places.

6.1.1.1 Issues with Data Collection and Calculations

Measuring both sides of the FCSs enabled any discrepancies in long bone length to be noted. One particular issue was highlighted with #38, wherein there was a 2.35 cm discrepancy between the two tibial lengths; the right measuring 35.00 cm, and the left 37.35 cm. While the difference in the raw data was less than two and a half centimetres, the corresponding stature estimations showed a more marked difference, with the right side giving an estimation of 165.40 cm, and the left of 173.44 cm, using Mays 2016 OLS Female equation set. Female equations were used as part of the stature assessment as the formulae relate to the body shape of the individual, rather than a specific sex or 'race'. The use of the terms 'white' and 'negro' in early stature estimation calculations can be misleading and are a product of the time in which the equations were written. The idea of 'race' as a social, religious, or political term is now somewhat outdated in the field of osteoarchaeology (O'Connell 2004: 26). Biological ancestry is not defined in terms of 'black' and 'white', but rather is seen as physical variation and body type differences between geographical populations (O'Connell 2018: 35; Barker *et al* 2008: 322). Many anthropologists disagree with the concept of ‘race’, or find it counter-productive, in terms of the human population (Sauer, Wankmiller and Hefner 2016: 254, 255; O’Connell 2018: 35, White *et al* 2012: 422). Therefore, if a certain equation proves to be the most accurate for a particular FCS, the ‘race’ or sex of that equation does not denote the ancestry or sex of that individual, but rather the closest body type.

In addition to the contradictory lengths of the two tibiae of #38, the shaft thickness is also different for each, with the right being noticeably thicker than the left. It is almost certain that these tibiae do not comprise a matching pair- while both are marked with #137 (the former FCS number for #38) only the left tibia has the dive number H57- the right appears to have no associated dive number marked. Without the dive number being marked on the bone there is a possibility that both were brought up on separate dives yet have somehow found themselves as being designated a matched pair. The dive logs relating to FCS #38 show that only one tibia (the right) was brought up from the seabed in that particular location, suggesting that the left tibia was assigned to the FCS during the post excavation work on shore. As only the right tibia is recorded as being brought to the surface with the rest of the remains of FCS #38, the measurement taken, and subsequent stature estimation are based on the right tibia, rather than the left. FCS #38 also highlights some of the issues surrounding the human remains uncovered from the *Mary Rose* in terms of the comingling that has occurred over the centuries, in particular when bones are assigned to FCSs during post excavation work.

FCS #38 was discovered on the O8, along with a further 4 FCSs (#33, #34, #35, and #36). All of these sets of remains also include 2 tibiae, no pair of which display the size discrepancy present in those of FCS #38. However, O7, 8, and 9 do contain a large number of human remains; the presence of a ladder found loose in Sector 8 (Marsden 2009: 146) is suggestive of the location of a companionway providing access into the main storage area of the Hold (Marsden 2009: 117). The large number of individuals found across these three sectors, 14 in total, is also indicative of an access point where people would amalgamate during the sinking, in order to attempt to escape. A similar situation is also present in O4, where another companionway is present linking the Orlop deck to the Galley in the Hold (Marsden 2009: 117). In this instance 8 individuals were found in the sector, with three of them (#2, #5, and #24) having their remains uncovered from both the Orlop deck, and the

Hold. The mixing of remains between different levels of the ship highlights the issues faced when many individuals are uncovered within the same area- that of the extent of mixing that can take place, particularly when subjected to the degradation of the exposed half of the ship and the effects of the current and marine life over the course of several centuries. With #38 being found alongside so many other individuals it is entirely possible, if not probable, that one of the tibiae associated with the FCS belongs to another member of the crew. From the other FCSs found within O7, 8, and 9, the only individual who has one tibia (as opposed to both or neither) is #31, found in O7, which only has the right tibia present. The length of the right tibia for #31 is 33.5 cm, and clearly not a match to the left tibia of #38 which measures 37.35 cm. The majority of the bones that comprise of FCS #38 do not articulate with each other at all- a sacrum is present, but the pelvis, femurs, and fibulae are all absent. The only close articulation within the FCS is between that of the C4 and C5 vertebrae. In such an instance it is difficult to see why the bones have been associated with one another, especially when found in a crowded companionway area, and how such differing tibia could have been initially matched as a pair.

6.1.2 Calculations

The height of FCS #38 is not included in the stature estimations conducted by Stirland, so it is possible that the mis-matched tibiae were not initially noted. This is due to Stirland only using the femur on which to base her stature estimations: as such, the lack of femoral bones in #38 would have excluded it from the calculations. The use of all the present long bones in the current estimation of stature resulted in a far bigger data set for each of the FCSs (up to 172 separate results), especially as both left and right measurements were also represented separately for each set of equations. With such a large amount of data being produced and the variation between each of the different equation sets, it is clearly necessary to narrow down the results to a single figure so as to give the stature estimation for that individual. In order to achieve this, the spread difference for each method table is calculated by subtracting the lowest result from the highest result, for example:

Trotter and Gleser (1958) Male Black			
	Left	Right	SEE
Humerus	174.98	175.13	± 4.23
Radius	173.41	172.08	± 4.57
Ulna	173.49	173.49	± 4.74
Femur	173.23	173.97	± 3.91
Tibia	173.51	173.18	± 3.96
Fibula	172.27	173.20	± 4.02
Hum + Rad	174.42	173.84	± 4.18
Hum + Ulna	174.46	174.54	± 4.23
Fem + Tib	173.35	173.58	± 3.68
Fem + Fib	172.77	173.67	± 3.63
Average	173.59	173.67	**173.63**

Table 6.1: Results for the Trotter and Gleser 1958 Black Male Equation for FCS #80

For the left-hand side, the highest estimation in 174.98 cm (highlighted in blue), and the lowest is 172.27 cm (highlighted in green), providing a spread difference of 2.71 cm.

MALE	Left	Right
T+G 1958 W	5.03	4.22
T+G 1958 B	**2.71**	3.05
T 1970 W	4.16	2.95
T 1970 B	3.02	4.08
M 2016 OLS	7.61	7.02
M 2016 RMA	6.96	6.27
Smallest	**TG 58 B**	T 70 W

FEMALE	Left	Right
T+G 1958 W	7.63	5.04
T+G 1958 B	3.15	4.37
T 1970 W	7.63	5.04
T 1970 B	3.87	5.10
M 2016 OLS	9.62	9.28
M 2016 RMA	7.67	6.89
Smallest	T 70 B	T 70 B

Table 6.2: The spread difference for the male (top) and female (bottom) equation sets for FCS #80

When compared to the other spread difference results, it is clear that the equations for Trotter and Gleser 1958 Black Male produces the smallest difference (highlighted in blue), specifically on the left-hand side, compared to that of the right.

This suggests that the most appropriate body shape for #80 is represented by the Trotter and Gleser 1958 Black Male equation. While this has succeeded in narrowing the results field from 172 to 10, further clarification is required in order to produce a single height estimate for FCS #80. For this it is necessary to refer to the SEE (standard error of the estimate) numbers for each of the long bones included in the table; with the lowest SEE score indicating which bone is likely to produce the most accurate stature estimation.

Trotter and Gleser (1958) Male Black			
	Left	Right	SEE
Humerus	174.98	175.13	± 4.23
Radius	173.41	172.08	± 4.57
Ulna	173.49	173.49	± 4.74
Femur	173.23	173.97	± 3.91
Tibia	173.51	173.18	± 3.96
Fibula	172.27	173.20	± 4.02
Hum + Rad	174.42	173.84	± 4.18
Hum + Ulna	174.46	174.54	± 4.23
Fem + Tib	173.35	173.58	± 3.68
Fem + Fib	172.77	173.67	± 3.63
Average	173.59	173.67	**173.63**

Table 6.3: Results table for Trotter and Gleser 1958 Black Male showing the ultimate stature calculation for FCS #80

For the Trotter and Gleser 1958 Black Male equation, the lowest SEE score is assigned to the femur + fibula, with ± 3.63 (highlighted in blue). As the initial low spread difference of 2.71 cm related to the calculations for the left-hand side, the result of the left femur + fibula is then taken as the stature estimate for FCS #80, providing an overall stature estimate for the individual of 172.77 cm (highlighted in green). Of the 85 individuals who were able to have a stature estimation calculated, 11 were based on Trotter and Gleser Black Male equations, around 13% of the stature estimations. While the stature of FCS #80 is based on the combined femur and fibula calculation, the femur is the most frequent bone used in the stature calculations. The femur is used in 48 of the final calculations (accounting for about 56% of the estimations). The prevalence of the femur in the final estimations is not unexpected as for each set of formulas, it is the femur, as the longest bone, that consistently provides the lowest SEE score. The number of individuals assigned to each stature calculation can been seen in Table 6.4.

Method	Number of Individuals
Trotter & Gleser 1958 White Male	10
Trotter & Gleser 1958 Black Male	18
Trotter & Gleser 1958 White Female	0
Trotter & Gleser 1958 Black Female	0
Trotter 1970 White Male	10
Trotter 1970 Black Male	4
Trotter 1970 White Female	0
Trotter 1970 Black Female	0
Mays 2016 OLS Male	27
Mays 2016 OLS Female	4
Mays 2016 RMA Male	9
Mays 2016 RMA Female	1
Trotter & Gleser 1958/70 White Female	2

Table 6.4: Number of individuals assigned to each stature calculation method

6.1.2.1 Calculation of Stature without a Complete set of Remains

While FCS #80 has all long bones available for the estimation, it is one of only 2 that do, the other being FCS #8. The majority of the FCSs do consist of multiple long bones, and as such the stature calculations can be conducted in much the same way as demonstrated with FCS #80. The spread difference between the bones present is used to ascertain the most accurate set of formulae, and the lowest SEE used for the final stature estimation. However, there are some individuals whose remains only contain one long bone overall that is suitable for measurement, or one long bone on the left and one on the right. Five of the FCSs had only one available bone for measurement, either because there was only a single long bone associated with the individual, as in the case of FCS #32, and #58, or unfused epiphyses resulted in incomplete bones suitable for measurement, such as with FCS #28 and #71. Another reason for only one bone being available is because part of the remains are currently on display in the *Mary Rose* Museum, and so are unable to be accessed and measured at this time. This is the case for FCS # 75; the right femur is available, but the arms are on display in the injury case of the museum (as of 2021). The presence of only one bone resulted in there being no spread difference to be calculated, as with an individual with multiple long bone measurements. As such there was no clear indication as to which set of formulae would be best suited to the body type of that individual. In such instances the SEE scores are used to ascertain which calculation would have the smallest margin of error, compared across all formulas, rather than those within the same table. While such a method may not provide as accurate a result as those calculated using a spread difference, the lowest SEE score will provide a stature estimation with the lowest margin of error for that particular bone. A further 7 individuals (FCSs #5, #15, #19, #21, #22, #38, and #41), had two long bones present. However, each came from the left or the right, resulting in one bone per side of the individual. Consequently, when measurement results were assessed, there was no spread difference that could be calculated for either side. As with the calculation of stature for individuals with only one long bone, the SEE scores were used to establish which bone had the lowest margin of error. For those individuals that were determined to be male, only the male equations were considered. For others such as #38, there was no pelvis or skull to allow accurate sex determination, thus both male and female equations were considered. However it is more likely the individuals would be male rather than female, as they were on an active warship at the time of death.

6.1.3 Results

The full list of results can be found in Appendix B in table B1.

The most frequently used equation relating to the FCS is Mays 2016 OLS Male, with 27 individuals. This is likely due to the low SEE scores, particularly that of the femur which is ±1.96 cm- the lowest SEE score from any of the male equations used, regardless of the bone. Additionally, all the other bones included in Mays 2016 OLS Male table consistently have a lower SEE score than any of their male counterparts in the other equation sets. If one of the FCSs only included one particular bone that was suitable to be measured and had been determined to be male, Mays 2016 OLS Male would consistently prove to be the most accurate estimation because of these low SEE scores. As a result, 27 out of the 85 FCSs, around 32%, have their stature estimation calculated using this particular set of equations. The next highest represented sets of equations is Trotter and Gleser 1958 Black Male with 18 individuals. Four equation sets that performed most poorly were the Trotter and Gleser 1958 White and Black Female, and Trotter 1970 White and Black Female with no individuals assigned to these calculations. Some individuals such as FCS #25 had few long bones available to be measured, but there is also a right tibia and fibula assigned to the individual. However, they are currently on display in the museum and so are unable to be measured at this current time. The inclusion of these lower leg bones may have an impact of the overall height estimate.

Nearly all the FCSs can be assigned to one particular method of stature estimation, with the exception of 2 individuals- FCSs #30 and #70. Both individuals were calculated using Trotter and Gleser 1958, and Trotter 1970 White Female equations, and are assigned as ‘Mixed’ on the graph depicting stature equations used (see fig 6.1). This is because the equations used for both sets are the same, and the SEE scores are also the same. As a consequence, there is nothing to differentiate the results, and as such the individual can be assigned to either category for their stature estimation. For FCS #30 it is the left Radius, and for FCS #70 it is the left fibula.. For the remaining six methods, the number of individuals for each varies between 1 and 10 (see table 6.4).

The wide spread of methods used, and the variation of the numbers of individuals assigned to each, show that there is not one method that definitively out-performs any of the others when it comes to estimating the height of the crew of the *Mary Rose*. Such a variety also suggests that the narrow use of formulas employed by Stirland in her initial assessment; Trotter 1970 White Male using only the femur, it by no means broad enough to fully encompass the range of individuals on board. It is hoped that this current study and employment of various methods and bones used for stature estimation will provide the most comprehensive dataset for the crew of the *Mary Rose*.

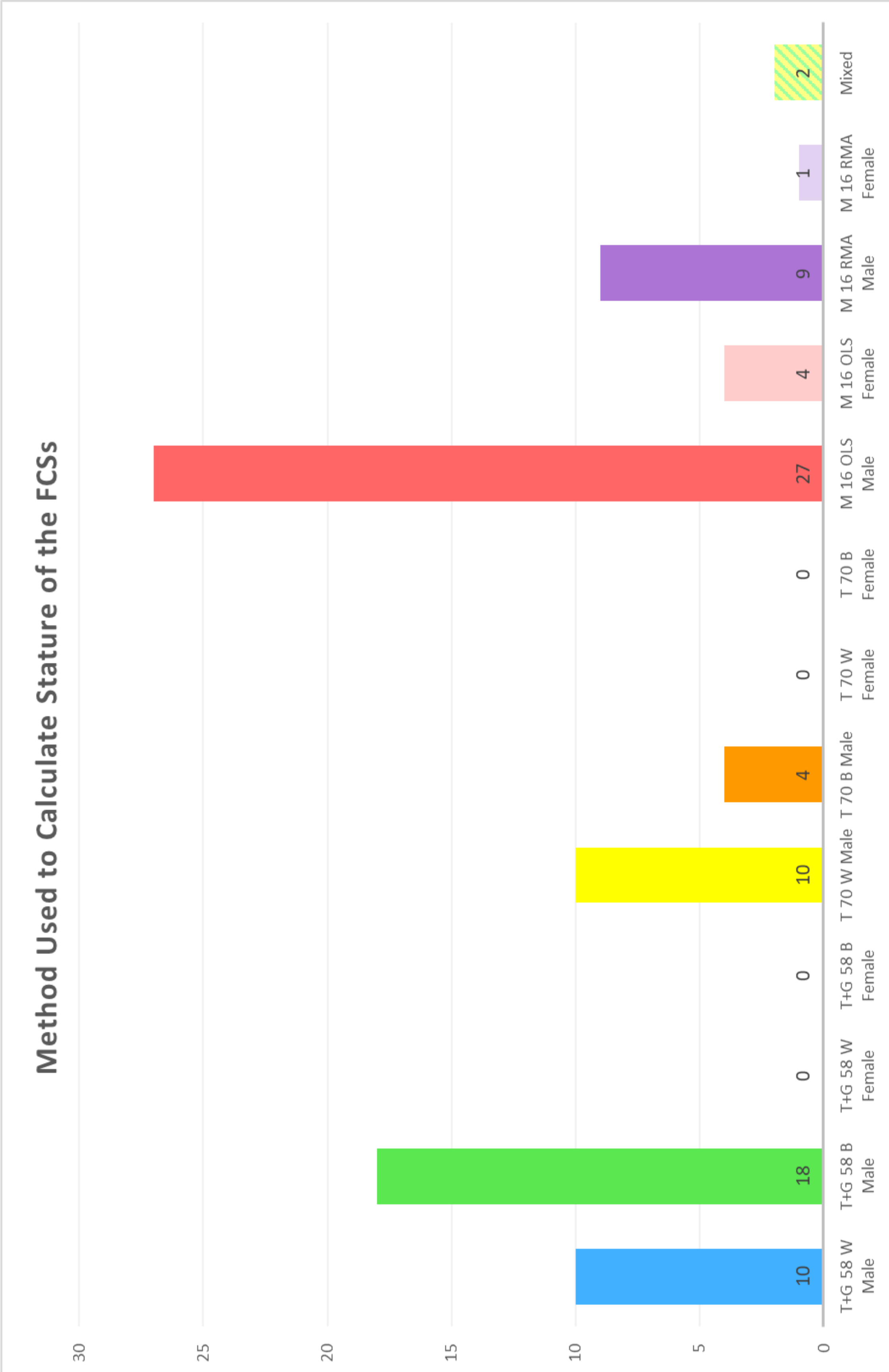


Fig 6.1: Graph showing how many of the FCSs were assigned to each method of stature estimation.

6.1.4 Comparison to Stirland's Results

While the number of individuals included in this study differs to that of Stirland (65 in the previous study compared to 85 in the current study) there are some correlations between the two sets of results. The mean height for the crew represented by the FCSs, based on Stirland's calculations is 170.60 cm, only a 2cm difference to the current FCS study, which provides a mean stature of 168.88 cm. While the tallest estimation of any of the individual statures comes from Stirland at 182.00 cm (#83), as opposed to 180.71 cm (#83) in the current study. The current study provides a wider range of statures, with the smallest being 156.99 cm and the tallest at 180.71 cm. The shortest individuals according to Stirland are FCSs #10, #78, and #86, all of whom are given a stature estimation of 161.00 cm, a difference of around 4cm from the current estimation of FCS #78 at 156.99 cm. As Stirland does not provide any decimal places in her stature calculations, it is impossible to differentiate between various individuals who share the same basic estimation. While there is a difference of several centimetres between the two statures assigned to FCS #78, those of FCSs #10 and #86 are more similar with #10 being 159.23 cm and #86 being 158.28 cm.

The height range that encompasses the greatest number of individuals within Stirland's estimations is for the range 165.01 cm to 170.00 cm, which comprises 27 members of the crew. This is similar to the most recent estimations, in which the same range bracket includes 36 members of the crew. This results in 42% of individuals from Stirland's calculations falling within this height bracket, compared to 40% of individuals from the current study. Though the overall range of stature estimations based on Stirland's work is smaller than that of the current study, the trend shown in the graph (see fig 6.2) relating to stature range show a similarity in distribution across the shared stature groupings. A breakdown of the results shown in the graph can be seen below (see table 6.5). Due to the difference in the number of FCSs included in each of stature estimations, a percentage is also included to make comparisons clearer.

Stature Range	Stirland	%	Current	%
155.01-160.00	0	-	5	6
160.01-165.00	7	11	12	13
165.01-170.00	27	42	33	36
170.01-175.00	18	28	25	28
175.01-180.00	12	18	8	9
180.01-185.00	1	1	2	2

Table 6.5: Stature estimate ranges, comparing Stirland and the current study

This shows that there are some similarities between the two data sets, particularly for the stature ranges 165.01-170.00 cm and 170.01-175.00 cm. The greatest difference appears in the lower ranges, where no crew members fall within the 155.01-160.00 cm bracket, according to Stirland’s calculations.

While it is difficult to provide exact figures for the stature estimations of past populations, it is hoped that by utilising various methods encompassing multiple bones of the body, a more accurate picture can be formed of the crew of the *Mary Rose*. Stirland’s work focused on the femur, and while this can provide an accurate calculation, due to the fragmentary nature of many of the FCSs, a large proportion lacked the necessary bones to be included in her stature estimations. By incorporating those individuals who had previously been omitted, the current study will hopefully provide the most comprehensive stature analysis of the crew to date, thus providing further information on the physicality of a Tudor fighting force.

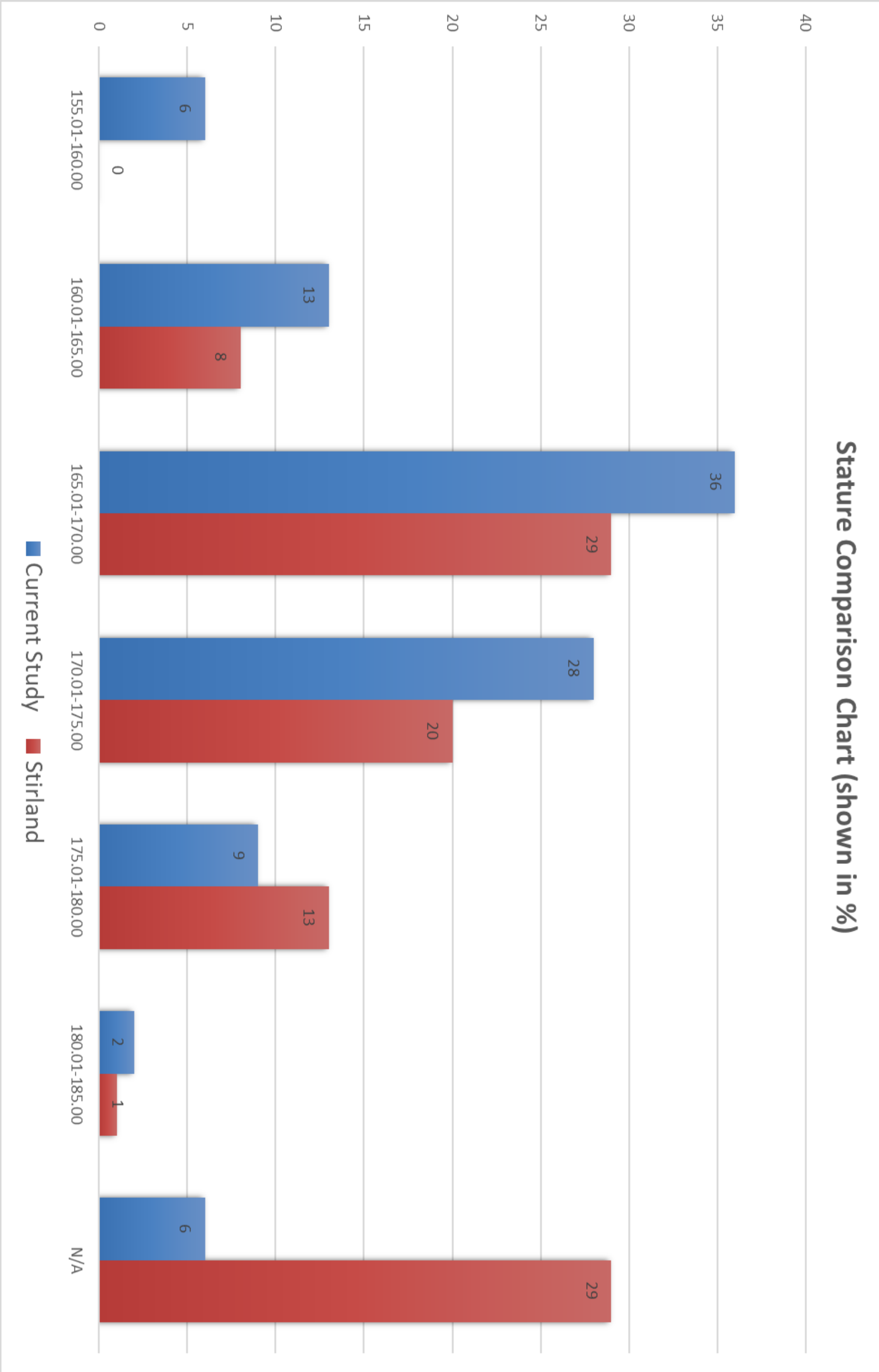


Fig 6.2: Graph comparing stature calculations of Stirland and the current study

6.2 Stature Estimation Anomalies

While calculating the stature estimates for the FCSs, there were a few instances were such calculations were not possible. A total of 7 FCSs were unable to be included in the calculations for various reasons; ranging from lack of long bones present (FCS #69) to being on full display in the museum (FCS #7). The reasons for the lack of inclusion for each of these FCSs are shown in the following table (6.6):

FCS #	Reason for lack of inclusion in Stature Estimation
7	One of the more complete FCS is currently (as of 2021) on display in the *Mary Rose* Museum in a gallery focusing on the crew. Stirland provides an estimate of 176 cm (± 3.27) based on the Trotter 1970 White Male femur calculation.
24	There are few long bones present in this FCS and all the long bones present are missing at least one epiphysis. As a result, all the long bones preserved are incomplete and hence accurate measurement of the bones for stature estimation is not possible.
55	Similar to FCS #24, the young age of the individual has resulted in missing epiphyses, meaning it was not possible to take complete long bone length measurements.
56	As with FCS #55 and #24, the long bones are present but due to missing epiphyses, measurements to enable stature estimation are not possible.
57 & 59	Unlike the other FCSs, measurements were not taken from the long bones associated with FCS #57 and FCS #59 as, during initial analysis, it was determined that while the two FCS share a box, the only two to do so, the remains of at least 3 individuals were present. Due to the lack of articulation between any of the bones present, these FCSs were removed from the current study as it is impossible to say with any certainty which of the bones present represent the two stated individuals.
69	While the other FCSs included in this list have long bones present (if incomplete), FCS #69 does not have any long bones associated with it for measurements to be taken.

Table 6.6: FCSs not included in the stature estimations

6.3 Age Estimation of the Fairly Complete Skeletons

Unlike the determination of sex in which the basic distinctions are ‘male’ or ‘female’, or the estimation of stature based on tangible data gleaned from the measuring of long bones, the estimation of age involves studying a range of gradual changes that occur to the skeleton over the course of an individuals’ lifetime. Even those who are of the same living age may show differences in the rate of skeletal development (White *et al* 2012: 384), meaning that assessment of skeletal remains may produce discrepancies. It is difficult to specify a specific age, such as 20 years old, to a set of skeletal remains and as such age ranges, or age classes, are often used.

The accuracy of estimation of age varies depending on whether the individual in question was a juvenile or a mature adult at time of death. For juvenile skeletons who had not yet finished growing, the growth plates and fusing of the long bones can be compared to more recent data relating to the growth patterns of children of known ages (Mays 2010: 51). However, the differences in modern populations, as compared to archaeological populations, may also have an effect on the fusing of bone epiphyses. Dreizen *et al* (1957) state that poorer nutrition in childhood results in later epiphysial fusion, meaning that individuals who suffered periods of malnourishment may be under-aged on the basis of their skeletal development (Mays 2010: 58-59). Furthermore, in the 19th Century, those of the poorer social classes could have their growth prolonged by up to 10 years (Mays 2010: 59) resulting in inaccuracies when determining age at death. Despite this, epiphyseal fusion of bones in the immature skeleton still provide an approximation of age, and potentially provides a more accurate method than any available for mature skeletons.

There are three main approaches to determining age at death for mature adult skeletons, each relying on different elements of the skeleton (Mays 2010). The first looks at morphological changes in the joints of some bones, such as cranial suture closure, and the morphology of the pubic symphysis, auricular surface, and sternal rib ends. The second looks at the structure of the bone itself, but unlike the other methods, can be destructive to the remains by requiring samples to be taken and examined microscopically. Finally, the third method uses the dental remains of the individual, including dental wear- the only method for ageing that is taken from archaeological specimens and does not rely on data generated from a modern population (Mays 2010: 59-61). Estimation of age is generally more accurate in individuals who have yet to reach full maturity, or else are in the early stages of adulthood. As a person becomes more mature, it is harder to determine whether changes associated with age occurred at the same rate amongst different individuals (Brothwell 1981: 64).

6.3.1 Issues with Data Collection

The teeth are often considered the most vital and reliable element of the skeleton when it comes to the estimation of age; whether it is through the eruption of dentition in younger individuals, or through the tooth wear seen in older individuals (Brothwell 1981: 65). As such, the teeth have been used extensively in the estimation of age for human skeletons (White *et al* 2012: 385). However, when it comes to the study of the FCSs from the *Mary Rose*, the skull is not as well represented in the assemblage as other elements also used for age assessment, such as the pelvis. In addition, post-mortem tooth loss is an issue in an assemblage that has been subjected to tidal movements and marine life effects. While loss of molar teeth is less common than of incisors, canines, and premolars, due to the multiple roots anchoring the teeth into the maxilla and mandible, such losses still occur. For example, FCS #75 has no maxillary teeth in situ, though the evidence of tooth sockets within the jaw are indicative of the fact that teeth were present during life and have subsequently been lost over the intervening years. In addition to this, poor dental health amongst the crew members has also resulted in ante-mortem tooth loss, even in seemingly younger individuals. FCS #79 shows a loss of premolars and molars in the maxilla, but the healed bone shows that the teeth were lost during life. Despite this, five molars are present in the mandibular jaw (the sixth being unerupted), which show various levels of tooth wear. Yet, with so many molars absent in the upper jaw, it could be supposed that the dental wear occurring to the mandibular molars is less severe than might have been the normal condition, due to the lack of opposite occlusal surface in the maxilla, potentially resulting in an under-ageing of the individual. Similar to ante mortem tooth loss, the extent of decay present in some molars also renders them unsuitable for ageing through tooth wear, as in some instances only the roots are present. FCS #5 (see fig 6.3) has very poor dental health, with evidence of ante mortem tooth loss, and extensive decay present, particularly in the maxilla. In addition to the decay, the expansion of the bone around the maxillary molars is also indicative of a long-standing infection and the presence of abscesses that have perforated the external maxillary bone on both the left and right sides.

Fig 6.3: The poor dental health present in the maxilla of FCS #5

As a result of the poor condition the teeth would have been in during an individual's life, the evidence of tooth wear is difficult to determine. This is a result of the necessary occlusal surfaces having been either eaten away through decay, or else lost entirely through ante mortem tooth loss. The only molar present in-situ in FCS #5 is the second molar on the right-hand side of the mandible. While most of the occlusal surface is visible in this instance, caries is present on the buccal surface, encroaching slightly on the occlusal surface.

It is also highly likely that individuals who did suffer from very poor dental health, such as large caries and abscesses, would have found chewing, particularly foods which were tough or hard, extremely painful. As a result, such foods may have been avoided and/or measures taken to relive the pressure of eating in the usual way. Depending on the severity of the pain and how long the individual suffered dental issues, the wear on the teeth may have been affected. The previously mentioned FCS #79, who suffered extensive tooth loss in the maxilla, shows an uneven level of wear in those molars present in the mandibular jaw (see fig 6.4).

Fig 6.4: Mandible of FCS #79 showing a greater level of wear on the left molars, as opposed to the right.

The molars on the left side of the mandible show more wear than those on the right, suggesting they favoured the left side when they ate. The presence of the M2 molar, along with the first and second premolars on the left side of the maxilla may also indicate why they favoured their left side, as opposed to the right, where only the M3 molar and first premolar would have been present. In this case, each side of the mandible has the potential to provide a different age bracket based on the tooth wear; the right-hand side with less tooth wear is indicative of a younger individual than the more worn left-hand side. If the level of wear represented in this one individual were present in two- one with greater overall wear and one with less, it is likely that those two individuals would be given differing age estimations, with one older and one younger.

It has previously been mentioned that there have been some discrepancies as to the sorting of the human remains into FCSs, and whether certain FCSs contain one or more individuals. In the case of FCS #64, the ageing of the skull produced a result that did not appear to correspond to the age of the post cranial skeleton. The skull of FCS #64 suggests the individual is a young adult, either late teens or early 20s, as indicated by the limited tooth wear (Brothwell 1981), with the left maxillary M3 molar showing no evidence of wear. Additionally, the skull is very gracile, the sexing elements of which are not distinct enough to determine with certainty whether the individual is male or female, suggesting that the individual had not yet reached full maturity at the time of their death. While the skull represents a young, not yet fully mature individual, the post-cranial skeleton is indicative of a person who has reached full maturity. While the post cranial skeleton consists of only a right arm, both scapulae and clavicles, ribs, and some vertebrae, the bones that are present are fully fused and robust. Indeed, the stature calculation of FCS #64, based on the length of the humerus, provides the tallest stature calculation of any of the FCSs at 180.36cm.

6.3.2 Results

The full list of results can be found in Appendix B in table B3.

Of the 90 individuals in the current study, only 2 were unable to be reasonably accurately aged as the skull and the post-cranial remains provided differing results. The other 88 individuals ages ranged from Adolescent to Mature Adult (see table 6.7). The ageing of the FCSs in the current study do not differ drastically from the ages of Stirland, in that the majority of the individuals are aged in their 20s and 30s. This is not necessarily unexpected due to the nature of the *Mary Rose* being an active warship, requiring an active crew. However, due to different ageing brackets, it is difficult to directly compare the age estimates of Stirland with the current study. Stirland classed an individual in the age bracket of 18-30 as a 'young adult', whereas in the current study this bracket is divided into 'young adult' and 'adult' (a table of age comparison with Stirland's study can be found in Appendix B in table B2). This results in a total of 60 individuals being classed as 'YA' by Stirland, compared to the 14 in the current study. However, if YA, YA/A, and A categories from the current study are combined to fit with Stirland's bracket of 18-30, it provides a total of 61.

Age	No. of FCSs
Ad	4
Ad/YA	11
YA	14
YA/A	12
A	35
A/MA	7
MA	4
OA	0
U	2
U/YA?	1

Key	Age
Ad	<18
YA	18-25
A	25-35
MA	33-45
OA	45+
U	Undetermined

Table 6.7: Age ranges based on analysis of the FCS Collection, in the current study

Two individuals could not be assigned a specific age bracket due to the contrasting results obtained from the skeletal remains. One of the individuals is FCS #64, discussed above, where the skull and post cranial remains appear to be of different ages, with the skull being adolescent/young adult, and the post cranial skeleton being a fully mature adult. The other individual is FCS #82, the dentition suggests an adolescent/young adult, likely in their late teens, with three of the four M3 molars not having erupted, and there being very little wear on the present molars. The pelvis however, as well as the post cranial skeleton suggest an older, mature adult individual. Interestingly, FCS #82 was found alongside FCS #83 in the Pilot's Cabin and were the only two individuals located in that particular sector. #83 has an overall age bracket of YA/A, with the skull of an adult individual, but the pelvis appearing from a YA/A. The left humerus of #83 also displays a line of epiphyseal fusion on the humeral head. It is possible that the skulls and post cranial skeletons have been mixed in the assigning of the FCSs. Rather than one YA/A and one undetermined individual, there is a fully grown adult, and an Adolescent/young adult individual present, and the skulls are not assigned to the correct individual.

While the accurate ageing of younger individuals can be difficult, due to the lack of archaeological samples of juveniles of a known skeletal age (Schaefer *et al* 2018: 46), FCS #55 shows the lowest rate of bone fusion of any other crew member. Stirland (2013: 81) states there is one juvenile individual within the FCS Collection, the number of that individual is not specified but it is likely #55 is the individual in question. This unspecified FCS is given an age range of 12-13 (Stirland 2013: 81). For FCS #55, both humeri have the distal epiphyses attached, however the medial epiphyses are absent (see fig 6.5). Aside from this all other epiphyses for the long bones are also absent; because of this, no long bone lengths could be taken for #55. In addition to the lack of complete long bones, the metatarsals and phalange of the left foot (see fig 6.6) and the metatarsals of the right foot, and the metacarpal bones of the left and right hand also have unfused epiphyses.

Fig 6.5: FCS #55 right distal humerus showing unfused medial epiphysis.

Fig 6.6: FCS #55 bones of the left foot showing the unfused epiphyses of the metatarsals and phalanx.

According to Buikstra and Ubelaker (1994: 43), the fusing of the distal and medial epiphyses of the humerus begin around 11 years of age in male individuals. The next bones to fuse, at the age of 14-15, are the proximal radius and fibula, distal fibula, tibia, and femur, the humeral head, the acromion of the scapula, and the iliac crest. None of these bones have begun to fuse in FCS #55, suggesting that while they are likely above the age of 11, they are unlikely to be older than 15. However, external conditions such as poor nutrition are known to have an effect on the growth and development of an individual (Schaefer and Black 2005: 782). While FCS #55 is young, the death does not denote that the individual would have been in poor health at the time of death, due to the cause of death being drowning during the sinking of the *Mary Rose*, rather than any underlying health issues they may have suffered from during life. Unfortunately, only the cranium of #55 survives, with no dentition which may have provided additional information, not only on the health of the individual, but also the age through the eruption of teeth (Cunningham *et al* 2016: 13; Brothwell 1981: 64). If FCS #55 had suffered through period of malnutrition during childhood, it is possible they would have been older than their bones suggest at the time of death.

In some instances, age could not be determined with any accuracy, beyond ‘adult’. The reasons for such are shown in the following table (6.8):

FCS #	Reason for 'Adult' Age Bracket
2	No skull or pelvis present, all long bones fully fused.
7	Currently on full display.
17	No skull or pelvis present, all long bones fully fused.
25	No skull or pelvis present, all long bones fully fused.
30	Fragments of skull and no pelvis present, all long bones fully fused.
38	No skull or pelvis present, all long bones fully fused.
45	Only left pelvis present, post-mortem damage results in no pubic symphysis. All long bones fully fused.
46	Both sides of the pelvis are present, however erosion and post-mortem damage have affected both the pubic symphysis and auricular surfaces, likely due to its location on the Upper Deck. Long bones are fully fused.
49	No skull or pelvis present, all long bones fully fused.
52	Only right pelvis present, badly eroded with extensive post-mortem damage. All long bones fully fused.
70	Skull on display, no pelvis, all long bones fully fused.
76	No skull or pelvis present, all long bones fully fused.
85	No skull, post-mortem damage and metal staining affecting the pelvis. All long bones fully fused.
88	No skull or pelvis present, all long bones fully fused.
90	No skull or pelvis present, all long bones fully fused.

Table 6.8: Individuals aged as 'adult'

In four instances, FCSs #4, #29, #54, and #60, there was no skull or pelvis associated with the individual, however the long bones still showed lines of epiphyseal fusion, suggesting that the individuals were young adults, likely in their early 20s at the time of death.

6.4 Sexing of the Fairly Complete Skeletons

6.4.1 Issues with Data Collection

As with other aspects relating to the assessment of the FCSs from the *Mary Rose*, the level of completeness of the remains provides some issues when it comes to the sexing of the individuals. While previous studies have determined the most accurate method of sexing involves using both the pelvis and the skull, only 23 individuals include both these bones within the sets of remains. However, in some instances the skull of the FCS is currently on display in the *Mary Rose* Museum, thus unavailable for a detailed assessment. A total of 6 FCS skulls are on display; those belonging to FCS #7, #12, #16, #23, #70, and #84.

Of the five morphological traits relating to the skull outlined by Buikstra and Ubelaker (1994: 20), only one, the mental eminence, involves the mandible, as opposed to the cranium. As such, only having the mandible present as part of an FCS will result in a less-accurate assessment of sex based on the features of the skull. Three individuals; FCS #24, #32, and #92, only have the mandible present, with no cranium having been assigned during the initial sorting of the remains conducted by Stirland. FCS #24 and #32 also have no pelvis present, further increasing the difficulty of producing an accurate sex estimation. According to Stirland's notes on the FCSs, there were also mandibles associated with FCSs #19, and #38, however, in the current study these elements did not appear as part of the FCSs. Yet, FCS #19 does include the pelvis, thus enabling sex assessment to take place. As with only having the mandible present, not having a complete cranium will also impact the accuracy of the sex assessment. Certain features will not be present, and others potentially obscured by the fragmented nature of the bone, such as the overall shape or robusticity. During the examination of the FCS Collection, there were three individuals in which only fragments of the skull survived. For both FCS #30 and #56, only the fragmented calvarium is present, with no viscerocranium. For FCS #58 only a single fragment, the right parietal, is present. The prevalence of the pelvis is far higher amongst the FCSs than the skull, with 71 individuals having one or both sides of the pelvis present (78%), compared to 29 individuals (32%) with a skull (not including those with just a mandible or fragments of the cranium). A breakdown of the number of crew members with the bones necessary for sexing and which type of bone can be seen in the table (6.9) below:

Sexing Element	No. of FCS
Skull and Pelvis	24
Just Pelvis	44
Just Skull	5
Just Mandible	3
Skull Fragments	3
Neither	11

Table 6.9: Sexing elements present in the FCS collection

Of the four FCSs with just a skull present for sexing; FCSs #27, #64, #69, and #72, one individual, FCS #64, only has the cranium present, with no mandible assigned to the remains.

With the 11 individuals that do not include either the pelvis or the skull, along with the 4 with just fragments of the cranium, the determination of sex is difficult. It can be argued that females generally possess smaller and lighter skeletons than their male counterparts (White and Folkens 2005: 386). However, this does not take into account natural variations within populations and individuals; males may be smaller and gracile, and females taller and more robust (White 2012: 411). All the FCSs that included the skull and/or pelvis were sexed using the standards set out by Buikstra and Ubelaker (1994).

For these 15 individuals mentioned previously, and those few who had not yet reached maturity before their deaths, sexing their remains may not be possible. It could be inferred from the *Mary Rose*'s role as a functioning warship that it was crewed with all men; but based on analysis of the crew members that are available and the fact that not all are able to be sexed definitively, it cannot be said with absolute certainty that every person on board was indeed male. Previous published work has assumed that all on board were male and as such the crew are invariably referred to as ‘men’ in the available literature.

6.4.2 Results

The full list of results can be found in Appendix B in table B5.

The results of the assessment of sex show that, aside from the 11 lacking either element, all the FCSs were determined to be either ‘Male’, ‘Probable Male’, or ‘Undetermined’, with none showing any distinct female morphology to be classed as ‘Female’ or ‘Probable Female’. The results of the assessment are shown in the following table (6.10):

Sex	No. of FCSs
Male	51
PM/M	2
Probably Male	17
U/PM	5
Undetermined	2
N/A	11

Table 6.10: Results of sex assessment for the FCSs

From the FCS Collection there were 2 individuals, FCS #30 and #64, whose sex could not be determined, and thus are classed as ‘U’. Both these individuals had no associated pelvis. FCS #30 had only skull fragments available, and so no morphological traits could be determined. FCS #64 had a very gracile skull that could not be accurately sexed with any certainty. Many of the individuals classed as ‘Probable Male’ were assessed using the pelvis. While they displayed male morphological traits, many had yet to reach full maturity, with the ischium and iliac crest yet to fuse. Due to this they were classed as ‘Probable Male’, as opposed to definitively ‘Male’.

While these results do not contradict earlier work that stated all individuals were male, it must be remembered that the FCS Collection only represents less than a quarter of the original crew numbers. However, while it cannot be scientifically concluded that every individual was male, it is highly likely that an active warship in battle was crewed by an all-male contingent.

6.5 Blue Bones

Of the FCS Collection, two individuals were particularly noticeable due to the odd colouration that had affected the bone, leaving sections a bright blue colour (see fig 6.7). Both individuals, FCS #82 and #83 had been uncovered from the same location, M2, which is thought to have been the Pilot's Cabin (see fig. 6.8). These two individuals were the only crew members found within this sector, and are the only individuals to show the blue colouration to the bone. Stirland (2013) makes a brief mention of vivianite being present on the remains of FCS #82 and #83 in a footnote, but does not cover it in any detail within the main body of her text (Stirland 2013: 146). With vivianite only being briefly mentioned by Stirland with no further references, verification was required. Confirmation that the blue coloration did represent the presence of vivianite was given by Dr. Dave Errickson after a visual examination of the images (pers. comm. 2019).

Fig 6.7: FCS #83 distal right humerus showing the light blue colouration of the bone due to the presence of vivianite.

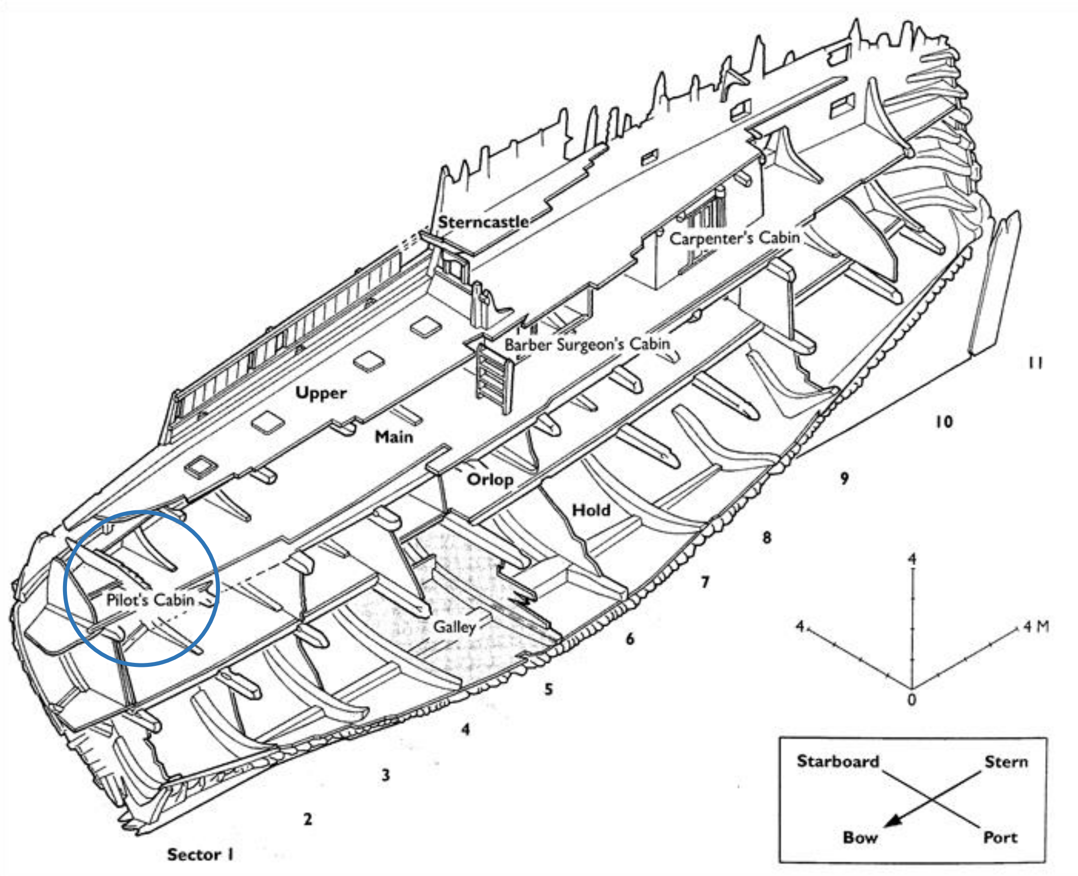


Fig 6.8: The wreck of the *Mary Rose*, showing the location of the Pilot's Cabin (circled) on the Main Deck

Despite the confirmation of vivianite, the cause of the blue colour, and why only two individuals from the crew were affected by it is less clear. While the wreck of the *Mary Rose* provided limited evidence of vivianite, it has been more apparent in other archaeological sites. Vindolanda, a Roman site just south of Hadrian's Wall in Northumberland, revealed a constant presence of a distinctive 'blue substance', thought to be vivianite (Taylor *et al* 2019: 582). The geographical position of Vindolanda; bordered on the North, East, and South sides by streams, with ground water appearing as springs on the West, results in a waterlogged site (Taylor *et al* 2019: 583). Despite the presence of water at the site, layers of impervious clay provided anoxic conditions resulting in excellent preservation of both organic and metallic objects. Within these deeper layers, the blue coloured substance was found (Taylor *et al* 2019: 583).

Vivianite is a hydrated iron (II) phosphate mineral, that when exposed to air, oxidises the iron (II), resulting in a colour change that can get progressively darker as the oxidation continues (McGowan and Prangnell 2006: 96, 97; Rothe *et al* 2016: 53; Taylor *et al* 2019: 583). As such, when first excavated, vivianite is a colourless or white mineral; it is only through exposure to air that the distinctive blue colour appears (Rothe *et al* 2016: 53; Taylor *et al* 2019: 583). However, the occurrence of a blue colouration, particularly to bone in an archaeological setting, cannot only be caused by the presence of vivianite. Arsenic used in an embalming process may also result in a blue or green crystal formation (McGowan and Prangnell 2006: 96). Similarly, copper artefacts may also result in staining if in close contact with bone within the burial environment (Morris 1981: 42).

Vivianite typically occurs in archaeological samples that are associated with human remains, human and animal waste deposits, industrial waste deposits, and areas rich in iron (McGowan and Prangnell 2006: 97). The Pilot's Cabin on board the *Mary Rose* certainly encompasses one of these factors; the human remains. Despite being located on the Main Gun Deck where there were many iron guns and iron shot, there was limited iron within the cabin itself. This may be due to the use of the navigation equipment within the cabin. An account from 1627 talks of wooden pins being used in a chest in a Pilot's Cabin, as iron nails would affect the accuracy of the compass (Barbour 1986: 11). In addition to these physical factors, a waterlogged or submerged environment with poor oxygenation is a vital factor necessary for the formation of the mineral (McGowan and Prangnell 2006: 102). The submerged and silt-filled wreck of the *Mary Rose* could have easily provided such an oxygen-deprived environment. However, other individuals found on the Main Deck of the ship would also have been in a similar environment to those in the Pilot's Cabin, and in close contact with large amounts of iron, due to the iron guns found on board. Yet it is only in the Pilot's Cabin that vivianite is found. M3, adjacent to where the Pilot's Cabin is located, contained the remains of several crew members showing evidence of iron staining on the bones (see fig. 6.9).

Fig 6.9: The posterior skull of FCS #75 (top), and the thoracic spine of FCS #76 (bottom), both showing the rust-coloured staining associated with iron

It is not clear why vivianite is present on the remains found within the Pilot's Cabin, and not those found in the adjacent sector, as the burial conditions are likely to have been very similar. The most significant difference between the two sectors is perhaps the presence of other instruments within the Pilot's Cabin made of various metals including brass, lead, and copper alloy; but only in small amounts (Stimson 2005: 167, 273, 279). Despite this, with vivianite being derived from iron, it is unclear why additional metals should have had an effect when they occur in other areas of the ship without the presence of vivianite. With the conditions necessary for the formation of vivianite present in many areas of the ship, it is perhaps unusual that the only occurrence should be in one specific location, affecting only two individuals from all the FCSs uncovered from the wreck.

6.6 Summary

Initial analysis of the FCS Collection from the *Mary Rose* reveals a relatively young crew, who would have likely been all-male. This is understandable in the context of an active fighting force on board one of Henry VIII's flagships during a naval battle. Comparisons with the previous work conducted by Stirland has shown similarities in the basic data of stature, ageing, and sexing. However, it has revealed further inconsistencies with regards to the concept of a 'fairly complete skeleton' and whether they do actually represent one individual in all cases, particularly as 62 of the 90 individuals are less than 50% complete. While this is something to consider with regards to any future research into the collection, the subsequent analysis of trauma and pathology (Chapter 7) does not necessarily rely on every FCS being confirmed as one individual. Even if a FCS is later confirmed to be two individuals, any pathology that is present in the remains would still have been present in at least one crew member. With the initial data on the crew confirming it was comprised of young male individuals, any serious degenerative changes that occur frequently, or in multiple individuals may also be seen as a result of the environment in which they lived and worked. Injuries sustained on a warship may not simply be the result of combat, but also the daily tasks completed in constricting environments, manoeuvring cannons and heavy weaponry, or climbing masts and rigging.

7. Pathology

To be able to understand the medical care available to the crew on board the *Mary Rose*, evidence of pathology within the skeletal remains must be assessed. A study of the pathology present within the FCS Collection provides an insight into the types of injuries or ailments that may have required medical intervention while on board the ship. The medical care that would have been available on board the *Mary Rose* is explored in greater detail in Chapter 8. Stirland provides an overall look at pathology in chapter 7 of *Raising the Dead,* though when discussing the various pathology within the collection, the specific FCSs affected are rarely mentioned. During the current study of the FCS collection the pathology present was assessed during the examination of the remains. Following this assessment, the aetiology and potential causes of the pathology could be considered, along with how many of the FCSs were affected by certain conditions.

Changes in the structure or shape of a bone can help provide information on the antemortem condition of an individual in terms of disease and injury. Ortner (2003: 45) states that variation from the normal bone anatomy can occur in several ways:

1) Abnormal bone formation

2) Abnormal bone loss

3) Abnormal bone density

4) Abnormal bone size

5) Abnormal bone shape

Pseudopathologies appear as a result of changes occurring to the bone post-mortem, through factors such as environmental conditions or the excavation process (Ortner 2003: 45). It is important to distinguish between pathology (a result of a living condition) and pseudopathology (the potential result of the seabed environment over the centuries) (Redfern and Roberts 2019: 211). Trauma to the skeleton can be a result of intentional or accidental injury, and existing pathological condition may increase the chances of the bone being affected by such external forces (Redfern and Roberts 2019: 211). Redfern and Roberts (2019: 211) state that various types of traumas can affect the skeleton including:

1) Fracture
2) Dislocation
3) Post-traumatic deformity
4) Miscellaneous traumatic conditions

The examination of the FCSs revealed various examples of pathology within the skeletal collection. Some of the pathology, such as fractures and dislocations are suggestive of external force, such as a fall, being the causative agent for the osteologically visible trauma. Other examples show degenerative changes, particularly to the spine, thereby suggesting stress being placed on the bone for a sufficiently extended period of time to cause such changes to it. Both types of pathology could be a result of the life led by the crew members; the hard, physical labour that was required of those serving on board a warship laden with heavy armaments, and the risks that such a lifestyle brought both in terms of the day to day running of such a ship and in battle contexts.

7.1 Fractures

A fracture refers to the partial or complete discontinuity of a bone, with or without damage to the surrounding soft tissue, and is usually caused by an external force that exceeds the natural elasticity of the bone (Ortner 2003: 120; Aufderheide and Rodríguez-Martín 1998: 20). There are 5 different mechanisms of applying pressure to the bone that can ultimately result in differing fractures. These include (after Ortner 2003: 120, Rodríguez-Martín 1998: 20, Redfern and Roberts 2019: 213):

1) Flexion; where force is applied perpendicular to the long axis of the bone. Produces a transverse or oblique fracture.
2) Shearing; similar to flexion, but two opposing forces are applied to the bone causing a horizontal fracture.
3) Compression; can be caused by a fall that applies pressure in the axial direction. Produces a crushing or impaction of the skeletal tissue- particularly in the vertebrae or joint surfaces.
4) Rotation; a twisting force produces a spiral fracture.
5) Traction, or tension; a severe muscle contraction can cause the avulsion of a small piece of bone at its tendon insertion. Can sometimes be accompanied by a joint dislocation.

Along with the type of fracture, the causation of fractures can also vary. ‘Dynamic’ fractures are those caused by a sudden high stress to the bone, such as a traumatic event or accident. ‘Static’ involves low levels of stress initially, which then increases over time and ultimately results in a break in the bone. ‘Fatigue’ or ‘Stress’ fractures are the result of excessive, but intermittent, stress that occurs over an extended period, such as weeks or months. ‘Pathological’ fractures may also occur, but unlike the other types of fracture, the stress needed is much lower due to the bone being weakened by a secondary morbid condition (Ortner 2003: 120). In both the archaeological record and modern medical practice, it is the ‘dynamic’ fracture that occurs most frequently, though the mechanism, or multiple mechanisms, of fracture can vary, and it is not always apparent which type of stress on the bone is the proximate cause (Ortner 2003: 120). Depending on the severity of the trauma, the resultant fracture may be ‘simple’, with only a single line of separation, or else ‘comminuted’ where many broken fragments are present at the fracture site. Despite this, either type of fracture may also result in a ‘closed’ fracture where the surrounding tissue and skin remains intact, or an ‘open’ fracture in which the bone punctures the skin, which, in turn, can greatly increase the risk of infection to the site and thus affect the overall healing of the trauma (Ortner 2003: 124).

The level of healing present within the bone is the clearest indication for ante-mortem or post-mortem fracture within the archaeological record. The rate of healing is dependent on the type of bone, with skull fractures being slower to heal than fractures of the long bones (Ortner 2003: 126). Furthermore, the age of the individual can also play an important role. The bones of children tend to heal faster and can remodel the fracture so completely that all evidence of the fracture can be obliterated. Additionally, as an adult individual ages, the length of time required for healing and remodelling increases as the overall metabolic bone turnover rate decreases (Ortner 2003: 126, Aufderheide and Rodríguez-Martín 1998: 23). Other factors such as the severity of the fracture and any subsequent infection may also influence the overall healing time (Ortner 2003: 126). The healing process of bone fractures can be separated into 6 stages as follows (Mohan-Iyer 2019: 12; Schinz *et al* 1951-1952: 377):

1) Haematoma formation; the clotting of the blood at the fracture site (within 72 hours).
2) Organisation of haematoma; blood clot is permeated with granulation tissue (3-14 days).
3) Formation of fibrous callous by osteoblasts; providing the matrix for the formation of the primary bony callus (end of second week).
4) Ossification of the callus (3 weeks- 6months), this continues until the fracture is fully healed. Cast may be removed, and patient given limited mobility.
5) Consolidation; transformation of primary callus to a secondary bony callus; involves the conversion of fibre bone callus to lamellar bone, providing a much stronger union of the fractured ends.
6) Remodelling of callus; if the positioning of the fracture ends is good, the callus may remodel and appear to disappear entirely (up to a year following injury).

Stages 3 and 4 are often combined into a single stage of ‘Callus Formation’ (Adams and Hamblen 1992; Mays 2010: 240). Within long bones and under optimal conditions, new bone may be produced as little as 5 days post-injury, but the fibrous union of the fracture ends takes about 2 weeks, with full union of the fracture ends by a woven bone callus taking at least 6 weeks (Mays 2010: 241). However, if factors preventing the healing rate are excessive, no union may occur at all (Mays 2010: 241).

7.1.1 Fractures within the FCS Collection

There are relatively few examples of fractured long bones from among the FCSs, and it is conceivable that such a lack is due to the possibility that such injuries resulted in individuals being unable to continue their service on board an active warship (Castle and Kirkup 2005: 176, 178). One of the most distinct traumatic injuries to any FCS is the fractured right femur of FCS #66, on display in the *Mary Rose* Museum at the current time (as of 2021). The fracture is well healed and occurs in the proximal third of the shaft; but is very distinct from the femoral neck, in which fractures can be common in the elderly (Lovell 1997: 162). In modern instances, fractures of the femoral shaft vary depending on the sex and age of an individual; in men the highest incident of shaft fracture occurs in those aged between 15 and 25 as a result of a high energy trauma, such as road traffic collision, falls from heights, or gunshot wounds. For women the highest incidence is in those over the age of 75 and the most likely cause is a fall (Egol *et al* 2010: 408, 410). Such an injury can produce secondary risks to the initial trauma, such as nerve damage, arterial damage, and subsequent changes to the mobility and gait of an individual (Lovell 1997: 162). How FCS #66 sustained such an injury cannot be determined from the skeletal remains, but a fall from a height is a common cause of such fracture in modern society (Egol *et al* 2010: 410) so a fall from the mast or rigging of a ship has the potential to cause such an injury.

Though healed, the fracture has resulted in a slight deviation of the shaft, resulting in the femoral neck and head being bent medially from the original axis of the shaft. This is due to the bone not being fully reduced and aligned prior to healing; this can be achieved easily in modern medicine with the aid of x-ray and anaesthetic (Waldron 2009: 142); but would have been much harder to accomplish in the 16th century. The femur of FCS #66 shows extensive bone remodelling with no apparent sign of infection in the bone, suggesting that the individual had recovered well from the initial trauma. This is further compounded by the location in which they were found- U7, indicating that they were either able-bodied enough to be at an active battle station on the top deck during an engagement, or that they were not impeded in any way by their healed injury during their escape from a lower level of the ship. A secondary consequence to a fracture of a long bone is the associated changes within the articulating joints. The right acetabulum of FCS #66 shows degenerative changes to the superior rim in the form of bone loss, but matching changes are not present on the left acetabulum. No similar changes appear to the left femoral head. The superior location of such degenerative changes is indicative of pressure being placed on the acetabulum through the femoral head as a result of the malunion of the femoral shaft. The changes evident in the right acetabulum, as well as the overall shortening of the right femur due to the angle of the healed fracture suggests that, though healed, the injury would have had a lasting effect on the gait of the individual. However, that is not to say that such an injury was incompatible with life on board an active warship. The presence of such an affected individual, particularly on the top deck, is indicative that any mobility and pain concerns were not insurmountable.

While the femur of FCS #66 provides an extreme example of fracture amongst the FCS Collection, it is not the only individual to show evidence of healed fracture. FCS #1 shows evidence of a transverse fracture on the distal end of the left fibula (see fig. 7.1). Today, ankle fractures are one of the most common injuries for the lower extremities, and account for around 10% of fractures (Tang *et al* 2003: 561; Kheiran and Mangwani 2018: 27). They are most commonly found in either young men, or older women (Kheiran and Mangwani 2018: 27). The mechanism of injury is usually a rotational force to the ankle (Kheiran and Mangwani 2018: 27). Various systems have been developed to classify the different types of ankle fracture, such as Weber and Lauge-Hansen (Kennedy 1998: 577). The fracture of the fibula of FCS # 1 would be classed as ‘Type A1 Isolated’ in the Weber system as it affects the distal fibula below the distal end of the tibia, but the Medial Malleolus of the tibia is unaffected (Heier and Collinge 2008: 353; Zhang and Wang 2018: 506). The Lauge-Hansen system describes both the position of the foot and the force that likely caused the fracture (Heier and Collinge 2008: 354). In the case of FCS #1, the most likely classification under this system is ‘Supination-Adduction Stage I’ in which there is a transverse fracture of the fibula below the tibial plafond (Zhang and Wang 2018: 497; Heier and Collinge 2008: 354)

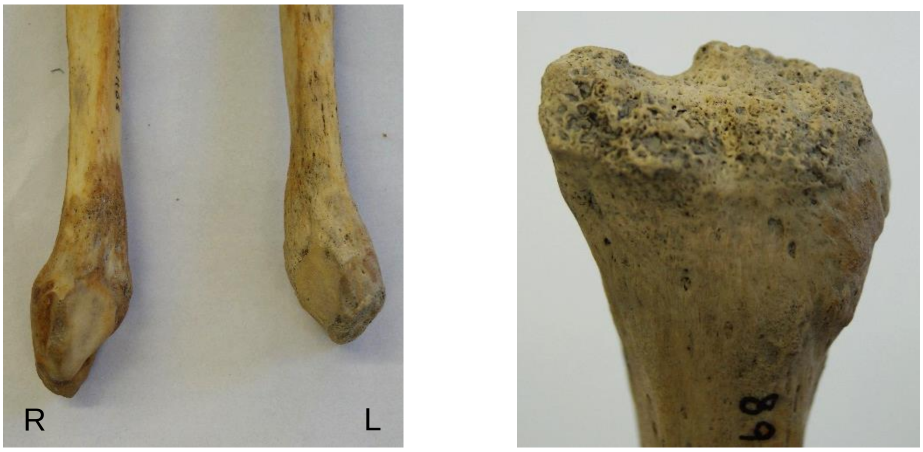


Fig 1: FCS #1 transverse fracture of the left distal fibula compared to the right (left) and lateral view of the fracture (right)

Despite showing early signs of bone remodelling on the surface of the fracture, it is clear that the main shaft of the fibula was not reunited with the distal tip during the process, as there is no evidence of unification. If there is no contact between the fractured ends of the bone, 'gap healing' may occur so long as the gap between the bone is less than 1mm (Borelli Jr. and Norris 2020: 30). The size of the missing piece of bone likely means that it was missed during the excavation process, as is seen with many of the smaller bones. Today, it is unlikely that such a fracture would be treated operatively as many minor ankle fractures are seen as no worse than a sprain of the lateral ankle joint (Heier and Collinge 2008: 354). Despite this however, should the fracture result in a non-union, it can cause stiffness in the joint and affect the gait of the individual (Pugh 2018: 309). FCS #1 was located in the Hold at the time of sinking, suggesting they were not part of the active fighting force located on the higher levels of the ship. The location within the galley of the Hold has led to the suggestion that FCS #1 may have held the position of cook (Marsden 2019: 279).

7.2 Dislocations

A dislocation can be described as the complete loss of contact between two bone surfaces that should ordinarily be in contact with one another, and a subluxation is when the loss of contact is only partial (Waldron 2009: 138, 139). Dislocations tend to affect young and middle-aged adults, as older adults suffering the same trauma are more likely to fracture the bone, and juveniles are more like to suffer the displacement of an (unfused) epiphysis (Lovell 2008: 345). As with fractures, dislocations can be described as 'closed' or 'open' and are often the result of high energy trauma (Egol *et al* 2010: 361; Ortner 2003: 159), and as a consequence, can result in an associated fracture which can be seen in the skeletal remains. Similarly, the ossification of joint membranes, ligaments, and tendons that would sustain damage through a dislocation may also appear in the record (Lovell 1997: 140). For such changes to be skeletally apparent, the dislocation must occur sometime before death. The resultant injury must not have been reduced for some time, in order for the necessary changes to occur in the bone. In modern medicine, it is recommended that hip dislocations are reduced as soon as safely possible and certainly within 12 hours of the injury occurring (Rickman and Büchler 2019: 95). However, even with quick reduction, a long-term complication of hip dislocation is the development of arthritis in the joint as a result of the damage sustained to the joint surface (Rickman and Büchler 2019: 96). If dislocations can be easily reduced soon after occurring and there is no associated fracture, such injuries normally will not be seen in the skeletal record (Lovell 1997: 140). Persistent and repeated dislocations of the same joint can result in more obvious changes to the bone, and can accelerate degenerative bone diseases and disuse atrophy associated with the immobilisation of the joint (Aufderheide and Rodríguez-Martín 1998: 25). As such, the identification of incidents of dislocations within the crew of the *Mary Rose* is harder to establish than that of fractures. For example, smaller dislocations that may occur, such as of the fingers, would be quickly reduced and unlikely to provide any lasting skeletal evidence (Lovell 1997: 140). Despite this, there is evidence of 3 hip dislocations within the skeletal remains of the crew.

7.2.1 Dislocations within the FCS Collection

There are three cases of hip dislocation that occur within the FCS Collection; FCS #9, #39 and #79. FCS #79, was found in O6, next to the main mast where it passed through the various decks. FCS #79 comprise the remains of a young man, aged around the early to mid-twenties (based on tooth wear). In spite of his relatively young age, the skeletal remains show various examples of trauma that would have occurred during life. One such incident is a superior/posterior acetabulum rim fracture, likely the result of a dislocation that forced the femoral head out of the socket causing the fracture (see fig. 7.2). Acetabular fractures are a result of high-energy trauma (Pountos and Giannoudis 2019: 105), suggesting a high-impact injury.

Fig 7.2: Acetabular rim fracture of the right pelvis, from FCS #79, indicative of a posterior hip dislocation .

Some joints are considered more stable than others (Ortner 2003: 159). The hip joint is considered to be a stable joint within the body; as such dislocations are not a common occurrence (Waldron 2009: 155). Dislocations are usually the result of high energy trauma, such as a fall from a height, and are usually caused in one of three ways (as taken from Egol *et al* 2010: 361):

1) Anterior surface of a flexed knee striking a surface
2) Force through the sole of the foot with the leg extended
3) Force through the greater trochanter

Anterior dislocations of the hip only occur in 10-15% of cases, whereas the posterior dislocation is far more common and is caused by trauma to a flexed knee (Egol et al 2010: 363, 364). It is the posterior dislocation that can result in the type of fracture seen in FCS #79. Incidence of fracture in a posterior dislocation depends on whether the hip joint is in an adducted, neutral, or abducted position at the time of the trauma. If the hip is in an adducted or neutral position, there is unlikely to be a resulting fracture. However, if the position is slightly abducted at the time of trauma, a fracture to the acetabular rim usually occurs (Egol *et al* 2010: 364). This suggests that when

FCS #79 suffered the injury shown in the right acetabular rim, it is likely his leg was bent at the knee, with the hip joint in an abducted position, with the impact hitting the knee. The high level of force needed to cause such a dislocation is indicative of a fall from a height. After the initial injury, the individual would have been unable to move their leg and be in severe pain, particularly if the sciatic nerve was impacted by the injury (Egol *et al* 2010: 364). Even after reduction, the resultant fracture and the inability to immobilise the joint would have resulted in continued discomfort for the individual, particularly in regard to weight bearing and movement.

The fracture of the acetabular rim of FCS #79 shows that while fragments of bone have been displaced slightly from their original position, they are still present. Other examples of hip dislocation from the FCS Collection demonstrate a loss of bone from the acetabular rim; in FCS #9 and #39. Of these two individuals FCS #39 shows a greater extent of trauma to the bone (see fig 7.3). The causation of such an injury is likely similar to that of FCS #79; a posterior dislocation with the leg in an abducted position.

Fig 7.3: The right pelvis of FCS #39 showing damage to the posterior rim of the acetabulum

FCS #39 also shows changes to the femoral heads, in terms of angle and shape. However, it is not the right femur that appears to show a pathological change.

Despite the right pelvis showing signs of dislocation, it is the left femoral head that appears to be both broader and flatter than the right (see fig 7.4). The left pelvis also displays a wider, shallower acetabulum than the right, similar in shape to the femoral head. The angle of the left femoral head along with the shortening and broadening of the femoral neck, and the associated changes to the acetabulum could be indicative of a slipped capital femoral epiphysis (Waldron 2009: 212). As FCS #39 was uncovered from the Upper deck there is a strong chance that the intermingling of the remains has led to confusion as to which bones are assigned to which body.

Fig 7.4: The femoral heads of FCS #39, showing the anterior (left) and posterior (right) view. The left femoral head shows distinct difference to the right.

All three individuals who suffered hip dislocations on board the *Mary Rose* were young, with FCS #9 likely in their late teens at the time of death. The level of healing in each of the individuals shows that the bone had not had time to fully remodel. This suggest injuries that were less than a year old at the time of their death. Such trauma to the hip would likely have resulted in pain and a change of gait, in order to compensate for their injury. Each were found on different levels of the ship; FCS #9 was in the Hold, #39 was on the Upper Deck, and #79 was on the Orlop Deck. As with many of the FCSs, it is difficult to determine whether these final locations are indicative of where they were serving during the battle.

Despite being one of the most stable joints and therefore not as prone to dislocation, there were at least 3 hip dislocations on board the *Mary Rose*. There is little evidence to suggest the dislocation of other major joints, such as the shoulder; a joint that is most frequently and easily dislocated (Waldron 2009: 155). The shoulder is a highly mobile joint, however, this mobility is at the cost of the stability of the glenohumeral joint (Waldron 2009: 155). As with the dislocation of the hip, a shoulder dislocation may be the result of direct trauma, such as falling onto an outstretched hand, or from injury due to vigorous exercise. Unlike hip dislocations, an anterior dislocation of the shoulder is far more common, occurring in 95% of cases (Waldron 2009: 155; Hill and Sachs 1940: 692). A shoulder dislocation can be easily reduced, resulting in minimal damage to the scapula and humerus involved. However, two types of lesion can be found on the humeral head or glenoid fossa that are indicative of a dislocation having taken place. A 'Hill-Sachs' lesion refers to a groove in the humeral head caused by an anterior dislocation, by which the humeral head is forced out of the glenoid fossa and against the glenoid rim (Hill and Sachs 1940: 691). Hermodsson (1934) found that such a lesion was likely to be bigger if the dislocation lasted longer, had occurred frequently, and had occurred anteriorly, rather than posteriorly (Calandra *et al* 1989: 254). A Hill-Sachs lesion can be identified in 30-40% of cases involving an anterior dislocation, and 80% of recurrent dislocations (Widjaja *et al* 2006: 436). A Bankart lesion refers to the damage caused to the scapula during a dislocation; specifically, the detachment of the glenoid ligament from the anterior surface of the glenoid cavity, particularly due to repeated dislocations (Bankart 1938: 25). The presence of a Bankart lesion can be found in up to 85% of dislocations in a living individual (Widjaja *et al* 2006: 436). Both the Hill-Sachs and Bankart lesions can be seen in the skeletal remains of an individual, the Hill-Sachs as a depression on the humeral head, and the Bankart as an avulsion of the joint capsule or labrum from the glenoid rim (Widjaja et al 2006: 436). After an initial dislocation, the Bankart lesion may only affect the cartilaginous labrum; repeated dislocations usually involve the bone. If an individual has suffered a shoulder dislocation, often both types of lesion are found (Waldron 2009: 155).

Today, shoulder dislocations are one of the most common pathologies seen by military orthopaedic surgeons, with the male sex and young age being high risk factors for such injuries (Wolfe *et al* 2018: 158). The young age of individuals can also influence the reoccurrence of such injuries; approximately 70% of those under 30 suffer from recurrent dislocation (Wolfe *et al* 2018: 158; Widjaja *et al* 2006: 437). Studies within a modern American Military Academy have found that of those who suffered a traumatic dislocation of the shoulder, 90% would continue to have recurrent anterior instability (Taylor and Arciero 1997: 307). While there are no clear examples of shoulder dislocation within the FCS collection, the age range and sex of the crew would put them in the higher risk category for such injuries; as would the active lifestyle on board a warship in which climbing masts and rigging, along with heavy manual labour was required. The fragmentary nature of some FCS also presents a problem when diagnosing a specific injury such as shoulder dislocation, in that many of the FCS do not have the requisite bones present. The possibility of only the cartilaginous labrum being affected, rather than the bone itself, increases the difficult in diagnosing definitive shoulder dislocations.

7.3 Schmorl's Nodes

First described by Christian Georg Schmorl in 1927, Schmorl's Nodes (SN) present as small depressions that can occur anywhere on the surface of the vertebral body (Waldron 2009: 45). The depressions themselves are caused by the herniation of the nucleus pulposus, the partially liquid central part of the intervertebral disc, into the vertebral body (Mann and Hunt 2012: 87; Renfrew 2003: 237; Schmorl and Junghanns 1971). Within the normal modern adult population, SN are a common occurrence, though the exact aetiology is unknown (Dar *et al* 2010: 670). It is thought that they are caused partially through stresses placed on the spine through activities such as heavy lifting or trauma to the spine, particularly through axial loading (Mann and Hunt 2012: 87; Fahey *et al* 1998: 2274). It has been found that they are more common in male individuals, particularly in the lower thoracic and lumbar vertebrae (Hilton *et al* 1976: 128; Plomp *et al* 2015: 526). Mok *et al* (2010: 1949) states that the sex, height, and weight of the individual can also increase the possibility of SN, with taller and heavier male individuals being most affected. Skeletal remains excavated from two 16th-19th Century sites from Croatia, Sisak and Koprivno, were examined for the presence of SN. The two sites differed in population activity; the Sisak cemetery was the most prestigious in the city and represented an affluent, urban community (Novak and Šlaus 2011: 271, 272). Koprivno in comparison was a small rural community that engaged in hard manual labour through pastoralism (Novak and Šlaus 2011: 271). It was found that while males from both sites exhibited a higher frequency of SN than females, the incidence of Schmorl's Nodes in the rural community of Koprivno was higher than the urban Sisak (Novak and Šlaus 2011: 274). However, neither site showed any correlation in regard to prevalence of Schmorl's Nodes and an increase in age (Novak and Šlaus 2011: 277). Comparisons of these two sites were also made with other archaeological collections, including the crew from the *Mary Rose*. The frequency of SN was highest from Koprivno, at 29.4%, with Sisak at 17.6%. The *Mary Rose* prevalence is lower than Koprivno, but slightly higher than Sisak at 19.5% (Novak and Šlaus 2011: 279). In accordance to the work undertaken by Stirland and Waldron on the *Mary Rose* collection, the higher incidence of SN within the Koprivno sample suggests that Schmorl's Nodes can be an indicator of higher levels of stress on the spine during life (Novak and Šlaus 2011: 279).

SN have been found within both living and past populations, with prevalence rates ranging greatly from 5%-77% (Plomp *et al* 2015: 526). The lower thoracic spine is more commonly affected, possibly due to the biomechanical function of the vertebral column. The intervertebral discs are also thinner in the lower thoracic spine and flexion and extension of the spine is more limited than the cervical (Üstündağ 2009: 707). The presence of multiple SN is associated with lumbar disc disease, as well as lower back pain; though it is thought the node itself does not cause the pain, but rather the damage associated with the surrounding structures (Kyere *et al* 2012: 2115; Fahey *et al* 1998: 2273). A study conducted by Stäbler *et al* (1997: 934) found that individuals with larger SN experienced back pain to a greater degree than those individuals with smaller Nodes.

7.3.1 Schmorl's Nodes Within the FCS Collection

The presence of SN within the FCS collection was something noted by Stirland during her initial assessment of the remains. A study of activity-related markers found that SN were particularly present in the younger members of the crew, indicative of large amounts of stress to the lower thoracic and lumbar sections of the spine (Stirland and Waldron 1997: 331; Stirland 2013: 138, 139). Of the 90 individuals included in this study, 73 had at least one vertebra present, and of these 33 displayed evidence of SN in at least one vertebral body. FCS #70 exhibits SN (see fig 7.5) within both the thoracic and the lumbar spine, starting on the inferior surface of T4, and continuing until L3; the last lumbar vertebrae present in the FCS.

In addition to the SN, L3 also shows the degeneration of the superior/anterior vertebral rim. #70 was found in M6 and in association with the skeletal remains was a leather wrist guard for an archer (item 81A1460), decorated with the coat of arms of Katherine of Aragon. Due to this association, it has been suggested that FCS #70 would have been one of the archers on board the ship. As such, the associated skull of FCS #70 is currently on display in the *Mary Rose* Museum, under the title of 'the Archer Royal'. It is possible that the stresses placed on the torso and spine of an individual, associated with drawing a longbow, could have influenced the formation of the Nodes. FCS #70 does not have a pelvis present as part of the remains, and with the skull currently on display in the *Mary Rose* Museum, determination of age is difficult. They were certainly a fully mature adult, with the long bones displaying no remaining evidence of the lines of epiphyseal fusion.

However, while FCS #70 displays evidence of SN, along with a link to archery through the presence of a wrist guard, there are other individuals with similar pathologies but no archaeological link to the practice of archery. The practice of archery and the stresses placed on the spine through the continuous drawing of heavy longbows may certainly have had an effect on the formation of SN, however, it cannot be the only cause of such degenerative changes. If the presence of the SN is linked to archery, it may be expected that those individuals would be on the higher levels of the ship, where archers would have been stationed during a battle; for example, FCS #70 was found on the Main Deck. Yet, several individuals with SN are also found in the Hold of the ship; in H2, 3, 4, 5, and 7. The cooking galley would have occupied H4 and 5 (Marsden 2019: 245), in which the FCSs #1, #11, and #12 were found, all of whom display evidence of SN (see fig 7.6). At this level of the ship the every-day work would have been very different to the manning and operation of weapons. The area in front of the galley ovens, where #11 and #12 were found only had a clearance height of 1.5m (Marsden 2019: 245). The statue estimations for #11 is 166.68cm, with #12 slightly taller at 167.88cm. Based on the evidence of tooth erosion and the pelvis for FCS #11, his age is likely to be mid-30s, though his overall dental health is fairly poor. Ageing of FCS #12 is based only on the pelvis, as the skull is currently on display, thus access to the skull and the assessment of the teeth is not possible at this time. This individual is likely to be slightly older than FCS #11 and aged in their 40s.

If this was the location in which these two individuals were working, the constant stooping in order to prepare food may have taken its toll on their bones. To compound this limited height working area, the individuals would also be required to fuel the fire for the ovens. A stack of 155 logs were found in the galley, with a further 370 stored on the Orlop Deck, immediately above (Marsden 2019: 246). With each of these logs measuring a metre in length it can be assumed that there was a significant weight to them. This would have resulted in the crew based in the galley having to undertake heavy manual labour, while in an area that would not have allowed them to stand fully upright. Such an environment is likely to have contributed to the degenerative changes seen in the vertebrae.

With modern medical science unable to determine the exact aetiology of SN, their presence amongst the crew of the *Mary Rose* shows that stresses from very different activities on board could have had an effect. FCS #70 shows a correlation to the stresses associated with the practice of the long bow, whereas FCSs #11 and #12 suggest that heavy labour in a restricted height environment may also have had a detrimental effect on the spines on individuals. It seems that SN was not solely an affliction of the fighting force, or those involved in heavy manual labour

Fig 7.5: FCS #70 inferior view of T7-T12 vertebrae showing Schmorl's Nodes

Fig 7.6: FCS #11 inferior view of the T10-L1 vertebrae showing Schmorl's Nodes

7.4 Ossified Ligamentum Flavum

As with Schmorl's Nodes, the exact aetiology of Ossified Ligamentum Flavum (OLF) is still relatively unknown (Ono *et al* 1999: 18; Wang *et al* 2007: 1123). Excessive and repetitive mechanical stress to the ligament is thought to be a factor in the development of OLF (Song 2012: 24), though it has also been suggested that genetic and dietary factors may also have an effect (Li *et al* 2007: 1075). Initially genetic and dietary factors were considered more important, as it was thought that the condition only occurred in certain areas of the world. However, it has since been shown that it can affect individuals all over the world and so an increased focus has been put on the biomechanical cause of OLF (Ahn *et al* 2014: 89, 90). OLF typically affects adult individuals, most commonly middle-aged men (Song *et al* 2012: 24). It is observed most frequently in the thoracic and lumbar spine, with occurrence in the cervical spine at <1% (Rahimizadeh *et al* 2018: 1; Song *et al* 2012: 24). Although rare, cases in which the cervical spine is affected by OLF can result in cervical myelopathy, which has been shown to cause gait disturbances and reduced grip strength in the patient (He and Fang 2020: 1734).

7.4.1 Ossified Ligamentum Flavum Within the FCS Collection

As with Schmorl's Nodes, OLF appears in 18 crew members from the FCS Collection. OLF appeared in the spines of 12 individuals who also exhibit Schmorl's Nodes. FCS #61 exhibits some of the clearest evidence of OLF (see fig 7.7). The individual was found in U8 and shows evidence of OLF and Schmorl's Nodes in the lower thoracic spine, between T8 and T12. While the individual was found on the Upper Deck, an area notorious for the co-mingling of remains, the vertebrae of #61 articulate closely, and so come from the same individual.

Fig 7.7: Lower thoracic vertebrae of FCS #61, showing the bony spurs of Ossified Ligamentum Flavum

The ages of the individuals who displayed OLF ranged from Ad/YA to MA, however it occurs more in older individuals, than younger (see table 7.1).

Age	No. of individuals
MA	2
A	9
A/YA	4
YA	2
Ad/YA	1

Table 7.1: The ages of the crew members displaying OLF showing an increased occurrence in older individuals

7.5 Osteochondritis Dissecans

Osteochondritis Dissecans (OD) is a joint disorder which can affect both the bone and cartilage of the joint in question. Specifically, OD refers to a lesion of primarily the subchondral bone and, secondly, the articular cartilage that disrupts the smooth motion and force transmission of the joint in question. The osteochondral fragment may be *in situ,* completely detached and free within the joint, or partially attached (Clanton and DeLee 1982: 50; Brackett and Hall 1917: 79; Pappas 1981: 59). The exact aetiology is unknown, but the most common theories involve trauma to the joint, repeated microtrauma, abnormal ossification of the epiphysis and ischemia (Clanton and DeLee 1982: 50; Resnick 1995: 2613). In addition, some studies also suggest a genetic disposition seen through various family members from multiple generations displaying OD in the same joints (Stougaard 1964: 542-543), or the percentage of family members affected in comparison to the wider general public (Gornitzky *et al* 2017: 1578). Those who are involved in vigorous physical activity, such as sport, are also found to have a higher than average occurrence of OD, and, like Schmorl's Nodes, it appears to affect male individuals more than female (Waldron 2009: 154). The onset of the condition often occurs in adolescence or young adulthood (Ortner 2003: 351). The development of osteoarthritis as a result of OD is also far more prevalent in those who develop OD in adulthood as opposed to childhood (Linden 1977: 774).

There are usually specific sites within the affected joint that are involved with OD, such as the medial condyle of the knee, and the capitulum of the elbow. OD can occur bilaterally, but it usually only affects one joint (Campbell and Ranawat 1966: 201). The symptoms of OD can be vague, and the sufferer may be unaware of the condition (Clanton and DeLee 1982: 54; Waldron 2009: 154) but factors such as pain and swelling of the affected area, and the locking of the joint can occur (Campbell and Ranawat 1966: 201). A common long-term effect of OD is the development of osteoarthritis in the affected joint (Waldron 2009: 154). Identifying OD within the skeletal record is often very simple as it presents as a small concavity of the sub-chondral bone; the edges of the lesions are often not remodelled, and the surface is irregular (Brothwell 1981: 151; Waldron 2009: 154). However, the subchondral defect may be covered by a thin layer bone providing a smooth surface, but the depression caused by the OD will remain (Ortner 2003: 352).

7.5.1 Osteochondritis Dissecans Within the FCS Collection

FCS #46, found in U9, exhibits an example of OD on the lateral area of the medial condyle of the right femur (see fig 7.8); one of the most frequent areas of any joint to be affected (Ortner 2003: 352). The lesion presents with the irregular surface and concavity expected of OD, the surface of which had not been remodelled at the time of death.

Fig 7.8: Evidence of Osteochondritis Dissecans in FCS #46 on the lateral area of the medial condyle of the right femur.

FCS #61, found in U8, also exhibits evidence of OD, which, as with FCS #46, also appears on the lateral area of the medial condyle, but on the left femur, as opposed to the right. Unlike FCS #46, however, the example of OD in #61 has healed, with smooth bone covering the original depression (see fig 7.9). While the bone has remodelled, creating a smooth surface, the evidence of the depression is still very much apparent.

Fig 7.9: Evidence of healed Osteochondritis Dissecans in FCS #61 on the lateral area of the medial condyle of the left femur.

Neither the sets of remains for FCS #46, nor #61 contained the skull, which, through analysis of tooth wear, would have provided the best age estimate for the individuals. However, both do have the pelvis present, though for #46 only the right pubic symphysis is present due to post-mortem damage to the left. Analysis of age estimates provided by the pelvis produce differing ages for the two individuals. FCS #61 is a young adult, most likely in his early 20s, FCS #46 however, is a more mature adult, aged in his 30s. The healed nature of OD in the younger individual is potentially suggestive of them suffering OD in their childhood. It has been shown that spontaneous healing of OD can occur in children, thus if #61 suffered OD in childhood it could explain the healed nature of the lesion despite his relatively young age at death (Clanton and DeLee 1982: 56; Edelstein 1977: 343; Wall *et al* 2008: 2662)

7.6 Os Acromiale

Os Acromiale (OsA) refers to the failure of union between the acromion epiphysis and the acromial process of the scapula (Hunt and Bullen 2007: 310; Hurst *et al* 2019: 525). At birth, and throughout childhood, the acromion of the scapula is cartilaginous, with ossification taking place around the age of 15; by the age of 17 there are three distinct centres of ossification; the met-acromion, meso-acromion, and the pre-acromion (Hunt and Bullen 2007: 310; Liberson 1937: 684). The complete fusion of the acromial process usually takes place between the ages of 22 and 25 (Hunt and Bullen 2007: 310). The unfused OsA is considered to be a source of shoulder pathology, resulting in degenerative changes, including impingement. This may be associated with work done overhead, and rotator-cuff tears, which can result in a limitation of movement and weakness of the shoulder joint (Sammarco 2000: 394; Edelson *et al* 1993: 551; Mudge *et al* 1984: 427; Hutchinson and Veenstra 1993: 28).

The two main hypotheses for the aetiology of OsA are hereditary influences and/or through activity and stress induced trauma (Hunt and Bullen 2007: 315). The work conducted by Stirland (2013) on the crew of the *Mary Rose* and the prevalence of OsA formed a major part of her research and provides one of the strongest arguments for activity induced OsA (Hunt and Bullen 2007: 315). During her examination of the skeletal remains, she found an unexpectedly high number of OsA in the scapulae. From the entire collection of bones uncovered during the excavation, not just those within the FCS collection, there were 206 scapulae. Of these, 26 had OsA; 12.6% of the total (Stirland 2013: 120). Due to the incomplete nature of many of the FCSs, it is unsurprising that many of the 206 scapulae examined did not comprise a matching pair. There were only 52 matching pairs, leaving nearly half the total, 102, as single bones. Stirland made the decision to assess only the complete pairs of scapulae for OsA, so it could be determined whether the occurrence was bilateral or unilateral. From the complete pairs, it was established that of the 10 pairs that display OsA, 6 are bilateral, while three show it on the left side only, and one on the right side. This means that the frequency of OsA among the matched pairs of scapulae is 19% (Stirland 2013: 120). Stirland's work looked at all the available scapulae uncovered from the *Mary Rose*, whereas the current study is looking primarily at the FCS collection. If OsA is noted only for the 92 FCSs, it is found in 7 individuals (FCSs # 7, 19, 27, 38, 68, 69, and 85), or 7.6% of individuals.

The prevalence in OsA within a more modern population varies, with some citing the findings of Macalister (1893: 249), who found 15% of 100 scapulae selected at random exhibited OsA (Sammarco 2000: 394; Liberson 1937: 684; Hurst *et al* 2019: 526). Though, as Macalister highlights in his paper, many of the specimens used in his study were from museum collections, and as such, he states that the estimation of 15% is possibly too high to be an accurate representation of OsA (Macalister 1893: 249, 250). A study by Hunt and Bullen (2007) based on the Terry Collection involved the examination of 1728 individuals used for anatomical courses from the 1920s to the 1960s. From this, only individuals over the age of 25 and with both scapulae were selected, resulting in a study sample of 1594 individuals; totalling 3188 scapulae (Hunt and Bullen 2007: 311). Not only was this a far larger sample size than that of Macalister, but, due to the connection to the anatomical courses, more information was known about the individuals included, such as their age at death. This study revealed OsA in 133 individuals; 8.34% (Hunt and Bullen 2007: 314). This compares well with the study conducted by Sammarco (2000) on the Hamann-Todd Collection, consisting of 1198 individuals from the early 20th century, with a total of 2367 scapulae. It was found that 96 of the individuals had OsA, or 8.0% of the total number (Sammarco 2000: 395, 396). A study of a modern population was conducted by Rovesta *et al* (2017), based on the MRI scans of 1042 shoulders between 2006 and 2010, with 726 MRIs being suitable for the study of OsA (Rovesta *et al* 2017: 202). The prevalence of OsA from the scans was 3.44%, with the average age of those affected being 58.5 years (Rovesta *et al* 2017: 203).

The studies conducted by Hunt and Bullen (2007) on the Terry Collection, and Sammarco (2000) on the Hamann-Todd collection both provide a prevalence of around 8%. Both these collections comprise individuals who died between the

1920s and 1960s. Both provide large sample sizes and together consist of a total of 2792 individuals, totalling 5555 individual scapulae. The study of a modern population through analysis of MRI scans provides a sample size of 726 with a prevalence of 3.44%. While this study is smaller than either of those conducted by Hunt and Bullen, or Sammarco, it is still far bigger than that conducted by Macalister, which found a prevalence of 15% from only 100 individuals. With such a variation of results from different periods, it could be indicative of OsA being more prevalent in past populations than a modern population. The skeletal remains from the *Mary Rose* show a prevalence of 19%; higher than any of the studies mentioned. However, this percentage only relates to the 52 matched pairs of scapulae; which accounts for just over half the total number of scapulae excavated from the wreck. If all 206 *Mary Rose* scapulae are included, the prevalence drops to 12.4%. This value, while higher than the more recent studies, falls below that of Macalister. However, in order to ascertain whether the frequency of OsA within the *Mary Rose* collection is unusual, comparisons need to be made with collections of a similar date and type. Although skeletal remains that can be definitively linked to battle and warfare can be difficult to determine, an exception is the mass grave from the 1461 Battle of Towton. While the battle took place around 85 years before the sinking of the *Mary Rose*, as with the crew of the *Mary Rose*, the remains represent a fighting force. The Towton collection is smaller. The minimum number of individuals excavated is 38, and the prevalence of OsA is 8.6% (Fiorato *et al* 2007: 46, 115). A further study on the prevalence of OsA within a historical context was conducted by Miles (1994), looking at a Scottish population uncovered from a Christian burial ground on the Isle of Ensay in the Outer Hebrides. The burials from the site were divided into 4 levels; 1500-1600 AD, 1600-1700 AD, 1700-1800 AD, and 1800-recent (Miles 1994: 153). The burial ground produced the remains of around 200 adults and 200 juveniles, and included 110 pairs of adult scapulae. Of this sample, 9 individuals displayed OsA; 8.2% of the total pairs of scapulae (Miles 1994: 152).

7.6.1 Os Acromiale Within the FCS Collection

The seven individuals presenting with OsA uncovered from the wreck of the *Mary Rose* were uncovered from various levels of the ship. FCSs #7 and #19 were found in the Hold, FCSs #27 (see fig 7.10) and #38 were found on the Orlop Deck, and FCSs #68, #69, and #85 were all found on the Main Deck.

Fig 7.10: Os Acromiale present in both the left and right scapulae of FCS #27

OsA has been associated with archery and archers by Stirland, and the most likely location for archers during a battle engagement would have been the Upper Deck, from where arrows could be freely shot at the enemy. However, due to the extensive mixing seen amongst the remains uncovered, this does not exclude any of the seven individuals from serving as an archer during combat. Similarly, the lack of OsA found amongst individuals from the Upper Deck does not imply that all individuals stationed there lacked OsA. The nature of the remains uncovered from this highest level of the ship; very fragmented, eroded and co-mingled also do not lend themselves to the good preservation of thin and fragile bones, such as the scapulae and detached acromia.

7.7 Enthesopathy

Entheses are the sites where tendons, ligaments, and joint capsules attach to the bone (Claudepierre and Voisin 2005: 32); enthesopathy refers to the pathology of such sites. Entheses provide a mechanism for reducing stress at the bony interface and are a common location for partial and micro-damage (Eshed *et al* 2007: 1553; Sudoł-Szopińska *et al* 2015: 73, 74). The type of attachment at entheses can be categorised into two types: fibrous, and fibrocartilaginous, depending on the tissues present at the attachment site. Fibrous refers to an indirect attachment, whereas fibrocartilaginous refers to a direct attachment of the tendon or ligament to the bone (Benjamin *et al* 2006: 472).

The inflammation of the entheses is referred to as Enthesitis (Eshed et al 2007: 1553). Enthesopathy refers to a pathological change or alteration at the enthesis (Benjamin *et al* 2006: 483; Resnick and Niwayama 1983: 1). Enthesopathies are more commonly found in elderly individuals and/or can result from cases of strenuous overuse or trauma. As such, symptoms can often be seen in modern professional athletes (Claudepierre and Voisin 2005: 34; Benjamin *et al* 2006: 471). Conditions such as Diffuse Idiopathic Skeletal Hyperostosis (DISH), and seronegative spondyloarthropathies can also increase the potential for enthesopathies (Villotte *et al* 2010: 224; Claudepierre and Voisin 2005: 35) Degenerative enthesopathy may refer to the bony spurs or osteophytes found at the tendinous and ligamentous attachment sites; so-called due to occurring more frequently with advancing age (Resnick and Niwayama 1983: 4). Despite this, advancing age is not the only cause of such changes. Factors such as muscular activity, trauma, and localised ischemia may also contribute. Degenerative changes can be particularly apparent in the posterior and plantar aspects of the calcaneus, the anterior aspect of the patella, and the olecranon (Resnick and Niwayama 1983: 4). If this degenerative enthesopathy occurs at synovial joints, such as the knee, osteoarthritis may also occur (Resnick and Niwayama 1983: 4). Another cause of enthesopathy can be through the rupturing of ligament and tendon attachment sites due to trauma. Tendons and ligaments distribute the force applied to the skeleton in order to enable movement, and, in doing so, stress is added to the site where they attach to the bone (Benjamin *et al* 2006: 471). The stress at the insertion site may be as much as 4x that in the midsection of the tendon or ligament (McGonagle 2003: 898).

7.7.1 Enthesopathy Within the FCS Collection

In terms of the bones most often affected by degenerative enthesopathy, the patella and calcaneus do not appear often in the *Mary Rose* skeletal collection. Of the 90 FCSs, only 14 FCSs include at least one patella, and 13 FCSs include at least one calcaneus. This is most likely due to their small size resulting in their loss in the silts on the seabed both over time and during the excavation process. In spite of the patella and calcaneus not occurring frequently within the FCSs collection, evidence of degenerative enthesopathy still occurs. For example, FCS #84 has both calcanei present, and both display the spurring on the posterior surface where the Achilles tendon would attach in life. FCS #12 displays the most significant spurs on the anterior surface of the present right patella, where the quadriceps muscle would attach.

7.8 Osteoarthritis and Eburnation

Osteoarthritis is one of the most common conditions to be found in skeletal collections (Weiss and Jurmain 2007: 437). While clinicians can diagnose osteoarthritis in living individuals based on the pain and swelling present in the joint, in archaeological assemblages, evidence is presented through marginal osteophytes and eburnation. Osteoarthritis can be said to be present in an individual if their bones display either eburnation, or any two of the following: marginal osteophytes, new bone formation on the joint surface, pitting on the joint surface, or alteration to the joint contour (Waldron 2009: 33). Often associated with osteoarthritis, eburnation occurs when subchondral bone is exposed after cartilage is destroyed. This results in the exposed bone taking on a polished, ivory-like appearance due to the bone on bone movement (White and Folkens 2005: 327; Brothwell 1981: 148; Mays 2010: 186). The size of the joint affected by eburnation can determine how easily identifiable it is, with evidence of eburnation being more obvious in larger joints (Waldron 2009: 34). The various causes of osteoarthritis includes sex, age, weight, and repetitive mechanical loading, or even as a response to acute injury (Jurmain 1977: 353, 354; Weiss and Jurmain 2007: 438; Plomp *et al* 2013: 515). Injury that may result in Osteoarthritis can include a fracture to the joint surface, a foreign body within the joint, or an unreduced dislocation (Jurmain 1977: 355).

7.8.1 Osteoarthritis and Eburnation Within the FCS Collection

The most severe case of Osteoarthritis within the FCS Collection can be found in the elbows of #75. Despite the arms of FCS #75 being currently on display, formation around the joint surfaces clearly show the presence of osteoarthritis. Though articulated in a display case, the joint surfaces will likely show eburnation. The tendency of osteoarthritis and eburnation to occur in older individuals may also be a factor in a crew where the majority are aged in their 20s and 30s. However, it has been found that Osteoarthritis of the elbow is not as affected by age as some of the other large joints of the body (Jurmain 1977: 360). Another example is that of

FCS #44 (see fig 7.11), which shows the distinctive polished surface on the right anterior capitulum of the humerus.

Fig 7.11: The distal end of the right humerus of FCS #44, showing the distinct polishing of eburnation

The presence of the eburnation and pitting, as well as thickening of bone on the edges of the joint surface, indicate that #44 would have suffered from osteoarthritis in the right elbow. In modern society, the elbow joint is considered to be a relatively uncommon location, with clinical prevalence being reported as 1.3-7% (Plomp *et al* 2013: 515). However, its appearance in archaeological assemblages is far more common, with it being found in 27% of a medieval population excavated from a Medieval necropolis in Provence, France (Debono et al 2004: 398). The prevalence in males increased for those from the 16th and 17th centuries, as opposed to those from the 13th and 14th centuries (Debono *et al* 2004: 398).

7.9 Spina Bifida Occulta

Spina Bifida is a congenital disorder that affects the spine, resulting in the incomplete closure of the spine, and translates literally as ‘split spine’ (Tamas-Csaba *et al* 2019: 95; Fletcher and Brei 2010: 3). Unlike other pathologies found within the FCS collection, Spina Bifida occurs during embryonic development when the spinal neural tube fails to close (Copp *et al* 2015: 1). There are two distinct forms of Spina Bifida; Spina Bifida Aperta (open) and Spina Bifida Occulta (closed), with Occulta being the mildest form (Tamas-Csaba et al 2019: 95; Zemirline 2013: 150). Spina Bifida Occulta (SBO) differs from the Aperta form by having no exposed neural tissue or visible cystic mass; the neural tissue remains beneath the skin (Kumar and Tubbs 2010: 21; Singh 2013: 14). The most obvious sign of SBO within the skeletal record is a defect in the fusion of the spinal arch, that can occur anywhere in the spinal column, affecting one or multiple vertebrae (Kumar and Tubbs 2010: 22). Groza *et al* (2016) examined the prevalence of SBO across Medieval and post-Medieval sites in Romania, based on the examination of 275 adult sacra. Of this, 11 sacra showed evidence of SBO (4%), with only two of the individuals being female (Groza 2016:106, 107). Various studies have found that SBO is more prevalent in male individuals, rather than female (Eubanks and Chervuru 2009; Groza 2016)

The effect of SBO on a person can vary between individuals. SBO that affects the lumbo-sacral region may be asymptomatic and not have any particular impact on the health on the individual that would be noticeable during life (Zemirline 2013: 150; Kumar and Tubbs 2010: 23). However, it has been linked to lower back pain, herniated discs, and functional difficulties of the lower urinary tract (Sign 2013: 14; Kumar and Tubbs: 23; Eubanks and Chervuru 2009: 1539). In addition to this, symptoms can include pain and weakness in the legs, along with leg and foot deformities (spinabifidaassociation.org).

7.9.1 Spina Bifida Occulta Within the FCS Collection

SBO was recorded where there was non-fusion of all sacral vertebrae. Three individuals uncovered form the wreck of the *Mary Rose* provide an indication of SBO, evidenced by a lack of fusion of the dorsal aspect of the sacrum, from S1 to S5 (see fig 7.12). All three individuals came from a different level of the ship, and all three were of differing ages. In addition to the three individuals displaying no fusion across all sacral vertebrae, a further 13 individuals (FCSs #8, 19, 22, 39, 43, 50, 55, 61, 78, 80, 81, 83, and 84) display a partial lack of fusion, affecting only the sacral vertebrae of S3-S5.

Fig 7.12: The sacra of (from left to right) FCSs #11, #28, and #68 showing no fusion from S1 to S5, indicative of Spina Bifida Occulta.

FCS #28 was the youngest of the three, with some long bones epiphyses yet to fuse, and was located in O7. The eldest was FCS #11, in their mid-30s, who was found in H4. The final individual, FCS #68, was in M6 and aged in the early 20s. However, FCS #28 was found in an area of extensive co-mingling where it is thought individuals were trying to access companion ways, in order to escape the sinking vessel. Similarly, FCS #68 was also found in the vicinity of an access route to the Upper Deck. As a result, the location of these individuals at the time of sinking may not be indicative of their position during a battle. FCS #11 also has Schmorl's Nodes present in the spine, increasing the chances of the individual suffering from back pain. FCS #11 is a young individual and shows no other degenerative changes to the spine. However, this individual does also present with slipped capital femoral epiphysis in the right femur, likely affecting their gait.

7.11 Dental Pathology

Due to their highly mineralised construction and resistance to many taphonomic processes, teeth can survive remarkably well within the archaeological record, and occasionally are the sole remaining element of human remains (Ogden 2008: 283). Teeth also have the unique distinction of being the only part of the skeleton that interacts directly with the environment in which the individual is living through mastication, wear, and trauma. Unlike bone, the teeth do not remodel during life and so any changes to the structure or surface remain. These observable changes can help provide information about the individual such as age, health, and diet (Ogden 2008: 283; Hillson 2005: 286). If left untreated, severe dental decay and poor dental health can not only induce pain and discomfort, but also produce serious implications for the individual suffering from it. If left untreated, caries of the maxillary teeth in particular can lead to infections within the cranial cavity, such as meningitis and cavernous sinus thrombosis (Mays 2010: 220). Before the treatment of such infections with antibiotics was available, the incidence of death due to dental infection could be very high. As late as the 1940s, American hospitals could see a 50-90% death rate from meningitis and cavernous sinus thrombosis resulting from such dental infections (Calcagno and Gibson 1988: 510). As a result, in advance of the development and introduction of antibiotics, there is the potential for poor dental health to have major implications on the health of a population, including that of a Tudor crew on board a warship.

Within the FCS Collection there are 18 complete skulls with mandibles, 5 skulls without mandibles, 3 mandibles, and 3 sets of fragments. However, not all the elements present included the dentition. A further 6 skulls from the collection are currently on display and so not able to be studied in detail. From those that were available for study, the three FCSs that had only skull fragments (FCS #30, 56, and 58) had no dentition. All 3 single mandibles show dentition (FCS #24, 32, and 83), however there is only a single tooth, the left 2nd premolar, present in FCS #83. Of the 23 remaining examples, consisting of skulls, with or without the mandible, all apart from FCS #55 contain dentition. The lack of dentition in FCS #55 is due to the skull remains consisting of only the neurocranium, as such neither the maxilla nor mandible is present. Those that did provide an insight into the dental health of the crew as well as providing dentally-derived age estimates. The available dentition reflects the fact that most of the crew are mature adults with fully erupted teeth; there are no deciduous teeth among the FCSs. Some individuals had yet to have their third molars erupt at the time of death, and in the case of FCS #9, the unerupted molar can be seen within the maxillary bone. Many of the skulls show extensive post-mortem tooth loss, particularly of the canines and incisors, most likely due to the single root providing a less secure anchor than the multiple roots found in the molars. Despite this, examination of the teeth has presented a variety of pathological changes that can offer an insight into the overall dental health of the crew on board the *Mary Rose*.

The high prevalence of post-mortem tooth loss amongst the FCS Collection- all individuals who had dentition, also displayed post-mortem tooth loss- also highlights a potential issue with the effect of the burial environment on the skeletal material; especially regarding the fragile bone surrounding the teeth. In a marine environment, skeletonisation of an individual may occur in as little time as three weeks, exposing the bone to other environmental factors (Mays 2008: 125). With initial salvage attempts still being made on the *Mary Rose* until 1549 (Rule 1982: 42), it is apparent that the silts of the Solent had not yet formed a protective layer over the entirety of the wreck until years after the sinking. This suggests that some of the remains may have been subject to the activity of marine life, as well as the currents and other abrasive surfaces such as rocks and sand, before the wreck became encased within the seabed. Such activities can result in the erosion and pitting of bone surfaces and can result in advanced bone degradation (Mays 2008: 125). Erosion of the alveolar bone in both the maxilla and mandible could increase post-mortem tooth loss and, with such fragile bone, affect the appearance of any pathology that may be present. For example, the erosion of the bone around an empty tooth socket may give the appearance of periodontal disease, particularly if the bone has been smoothed by the erosion process. As a result, care must be taken in order to distinguish between evidence of pathology in a living individual, and evidence of erosion that occurred post-mortem to skeletal remains.

7.12 Plaque and Calculus

Plaque is the result of a build-up of bacteria and other micro-organisms in the mouth. The bacteria adhere to the tooth surface and each other through either their cell structure or by the adhesives that many species produce (Hillson 2005: 287). Some bacteria may colonise the soft tissues of the mouth, such as the tongue, cheeks and gums, but, as these tissues continuously shed their surface cells, they provide only a temporary location. The teeth, on the other hand, provide a permanent site where the bacteria can continue to colonise, resulting in the large communities that cause plaque (Hillson 2005: 286). The levels of plaque next to the surface of the tooth often become mineralised, resulting in the formation of calculus (White and Folkens 2005: 330). These mineralised deposits are formed of the dead bacteria that initially formed the plaque, and, in a living mouth, the calculus is covered by a layer of living plaque (Hillson 2005: 289). As calculus requires an alkaline environment, the most common location for it to be found is the lingual surface of the anterior mandibular teeth, as this is the most alkaline area of the mouth (Waldron 2009: 241).

Calculus is often seen in archaeological remains, usually as a thick, uneven texture on the crown, with the lower edge mimicking the shape of the edge of the gums, as they would have been in life (Hillson 2005: 289; Brothwell 1981: 159). While calculus usually affects the crown of the tooth, if the build-up is large, it may also overhang the gums, and, if the gumline has been affected by periodontal disease, calculus may also be found on the roots (Hillson 2005: 289). If it appears on the occlusal surface of the teeth, it may be indicative of a lack of direct occlusion between the upper and lower teeth, or a sign of a long-standing illness that has enabled such a decline in the oral health of that individual (Brothwell 1981: 160). In archaeological remains, care must be taken in the cleaning of areas of calculus. While in life it is closely bound to the surface of the tooth, in death it can be easily broken off from the surface of the tooth (Brothwell 1981: 159; Hillson 2014: 72). Even if no calculus appears on the teeth, it cannot be assumed that there was no calculus during life as such deposits may have been washed away during post-excavation cleaning, or eroded by the burial environment (Brothwell 1981: 159; Waldron 2009: 241).

7.12.1 Plaque and Calculus Withing the FCS Collection

Due to the close correlation between calculus and poor oral hygiene (Waldron 2009: 241), it can perhaps be assumed that the crew of the *Mary Rose* would be similarly afflicted. However, many of the skulls and mandibles present within the FCSs collection are missing the anterior teeth, and this is the location at which calculus usually accumulates (Waldron 2009: 241). FCS #10 is one of only two mandibles that have some of the incisors still in situ, the other being FCS #35. #10 has both the first right, and the first left mandibular incisors present, but the second incisors on both the left and right side have been lost post-mortem. Despite this, the two present incisors display some of the largest calculus deposits of any teeth within the FCS collection, both on the labial and lingual surfaces (see fig 7.13).

Fig 7.13: the mandible of FCS #10, showing the build-up of calculus, particularly on the incisors.

The presence of calculus on the right canine, and to a lesser extent, the left first premolar, also suggests that the calculus would present on the missing second incisors. On the right canine, the calculus deposit is larger on the mesial surface or the tooth than the distal surface, implying that the calculus deposits were more significant on the more mesial teeth. The presence of calculus on the mandibular molars is difficult to ascertain due to the extensive caries on the buccal surface, particularly on the left-hand side. The size and shape of the calculus affecting the incisors also demonstrates that, in life, the deposits would have produced an over-hang on the gums. There is also some calculus present on the mandibular teeth of FCS #35, but to a far lesser extent to #10. The overall dental health of #35 is also far better, with the most dentition in situ relative to all other FCS, and also associated with very little evidence of caries or other dental pathology.

7.13 Caries

Caries are one of the most common causes of tooth loss and oral pain and can affect individuals at any stage in life. In addition, caries can also affect any part of the hard tissues of the tooth from the crown to the root (Selwitz *et al* 2007: 51). The positioning of the carious location on the tooth can be indicative of the diet of the individual. Prior to sugar being widely available, caries tend to appear on the cemento-enamel junction. In a more modern diet, where sugar is more accessible, caries occur on the occlusal and contact surfaces of molars (Waldron 2009: 236; Evans 2005: 553). In a study of dentitions of British populations ranging from the Iron Age period to the beginning of the Tudor period (around 1500), Moore and Corbett (1973: 150) found that the vast majority of caries were located on the cemento-enamel junction. Caries are ultimately caused by acid and are the result of a bacterial film (plaque) reacting with a fermentable carbohydrate, leading to the demineralisation of the tooth tissues (Waldron 2009: 237). Caries initially present as a dark brown spot on the tooth that, left untreated, will eventually develop into a cavity through the destruction of the enamel and underlying dentine. The softer exposed dentine can wear down at a much faster rate compared to the hard enamel (Waldron 2009: 238; Hillson 2014: 72). The ability of exposed pulp to respond to infection is limited and subsequent inflammation (pulpitis) may occur. This results in the individual experiencing either a sharp or dull pain, particularly when eating hot or cold food (Hillson 2005: 307,308). As a consequence of infection, the pulp usually dies, resulting in the pulp chamber and root canal remaining open and the inflammation of the periodontal tissues (periapical periodontitis) (Hillson 2005: 308). The progression of such deterioration of the inner structure of the tooth may also lead to the eventual collapse of the enamel crown through mastication (Shafer *et al* 1983: 432).

7.13.1 Caries Within the FCS Collection

Caries are prevalent within the teeth of the FCSs, particularly along the cemento-enamel junction. This could be indicative of a lack of sugar within the diet of the crew. The caries present vary greatly in their severity. A very mild case is that of FCS #86, where just the dark brown spots, appear on the left mandibular 1st premolar and 1st molar, indicating the start of caries along the cemento-enamel junction. Had the individual lived longer, these would have likely developed into the more severe incidence of caries seen in other members of the crew. One of the most severe cases of caries occurs in the teeth of FCS #10. The three molars in the left mandible all show extensive cavities along the buccal surface that have destroyed not only the enamel surface, but also much of the underlying dentine (see fig 7.14).

Fig 7.14: The occlusal surface of the left mandibular molars of FCS #10, showing the extensive caries on all three molars at the cemento-enamel junction.

Despite such extensive damage to the buccal and medial/distal surfaces of the three molars, there is little evidence of caries on the occlusal surfaces, with only the third molar showing slight occlusal caries. Given the extent of the caries within the teeth, it is possible that, had the individual lived longer, the caries may have resulted in the collapse of the molar crowns, and eventual loss of the teeth themselves. A possible case of crown collapse comes from FCS #5, where only the roots of the maxillary molars, showing extensive signs of decay, are present. The extent of the exposed dentine in FCS #10 may have also had implications while eating, with food being caught in the carious lesions or causing pain through contact with an exposed pulp cavity. The damage would have been irreversible and, like other members of the crew similarly affected by such caries, the individual may have suffered continuous discomfort. There are two examples where the caries present have a reasonably significant impact on the occlusal and contact surface of the tooth; FCS #75 on the distal 3rd mandibular molar on the left-hand side, and FCS #11 on the medial side of 1st maxillary molar on the right.

7.14 Granulomas, Cysts, and Abscesses

The description of dental cavities within dry bone as an ‘abscess’ is often incorrect, as often such spaces are formed by granulomas or cysts, and such conditions would have far fewer health implications for the individual (Dias and Tayles 1997: 553). All such conditions begin with exposure of the dental pulp, usually from caries, which can result in the infection of said pulp, and ultimately result in the formation of a dental cavity. This cavity in the socket of the tooth is caused by the infection extending into the root canal (Mays 2010: 220). An acute dental abscess leaves no mark on the bone and as such cannot be determined from the skeletal record. However, an inflammatory response in the soft tissues around the root apex of the affected tooth may ultimately result in a cavity in the bone forming. However, the presence of a cavity, or the exposure of the root of a tooth is not necessarily evidence of a pathological process. In some instances, the root of the tooth may be exposed due to taphonomic processes; the lack of evidence of pathology around the root is indicative of the absence of infection (Ogden 2008: 294). In order to determine the exact cause of a bone cavity in relation to the dentition and whether it represents an abscess, several factors must be taken into account. Ogden (2008: 297) lays out several characteristics that must be considered when determining a diagnosis:

1) Lesion must extend from, or incorporate, the root apices of one or more teeth. If it does not, it is more likely to be part of a systemic disease, such as multiple myeloma, and there will be other lesions elsewhere.
2) A cavity that is smooth in shape and with a 2-3mm diameter, is liable to be granuloma.
3) Those larger than 3mm are more likely to be developing an internal cyst. If the bone is less porous it could also be indicative of a cyst that had developed a lining membrane.
4) A cavity with a thin, sharp margin indicates a non-infected granuloma or cyst. If the margin is thickened with evidence of bone remodelling, it likely indicates a chronic abscess.

While such changes are easily observable within the skeletal record, other cavities only appear through the use of radiographs (Hillson 2005: 313; Ogden 2008: 297, 298). Cysts, granulomas, and abscesses all result from an infection in the dental pulp of the tooth, but their eventual outcome relies on the severity of the infection and the immune response of the individual suffering (Dias and Tayles 1997: 548; Waldron 2009: 242). The time between infection and death may also affect how the condition is viewed within a skeletal sample. The first response to an infection is the formation of a granuloma, which commonly further develop into cysts, which have similar morphological characteristics but are invariably larger in size. An abscess may be formed if pus develops in the granuloma (Waldron 2009: 242). Depending on the time elapsed between infection and death, the individual may only display the early stages of what could develop into a more severe infection. A small periapical infection may also be difficult to identify in dry bone as the inflammation, demolition and healing of the tissues involved occur concurrently (Dias and Tayles 1997: 549). Despite appearances, granulomata and apical cysts are usually benign and may also be asymptomatic for the most part, as long as the cavity is occupied by a granuloma or cyst. Mild discomfort or pain may be experienced by the individual only when biting into solid foods (Dias and Tayles 1997: 553). While granulomas and cysts may have no serious health implications themselves, the presence of any cavity within the maxilla or mandible has the potential to develop into a more serious dental infection that could ultimately lead to an impairment of the immune system, and death (Dias and Tayles 1997: 554).

7.14.1 Granulomas, Cysts, and Abscesses Within the FCS Collection

The FCSs that include skulls and dentition provide a variety of different lesions and cavities of various sizes and shapes within the maxilla and mandible. Some, such as the exposed root cavities on the anterior maxillary surface of FCS #75 suggest the effects of taphonomic processes that have removed the thin bone that would have initially covered the roots of the incisors and canines. There are no teeth present in the maxilla of #75, most having been lost post-mortem, but with some premolars and molars having been lost ante-mortem. It is not clear whether the loss of the covering bone caused the loss of the anterior maxillary teeth, or if it was the movement of the teeth that resulted in the damage to the thin bone. FCS #5, found in H5, exhibits several small lesions within the maxilla (see fig 7.15).

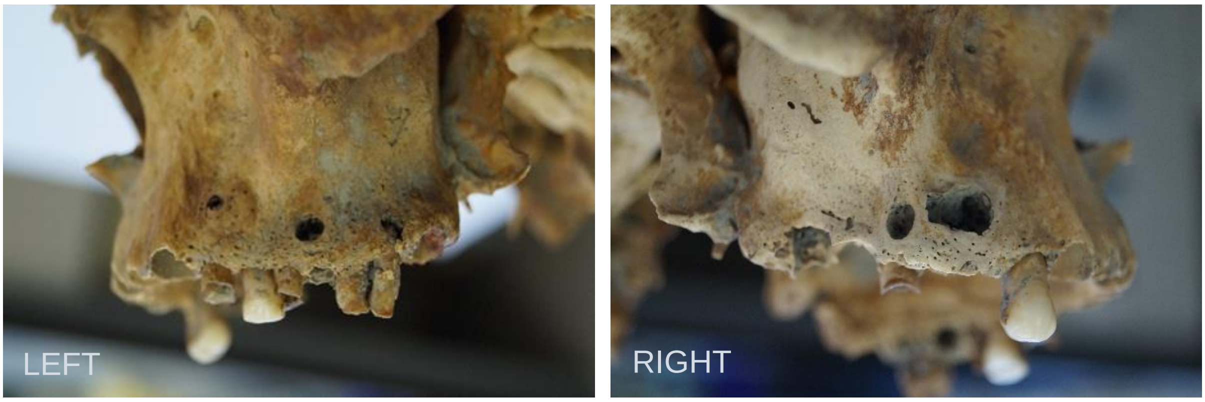


Fig 7.15: The maxilla of FCS #5 showing several lesions of differing sizes

The dental health of the individual is generally poor, with evidence of ante-mortem tooth loss, particularly of the mandibular molars on the left-hand side. There is also extensive post-mortem tooth loss throughout both the mandible and maxilla. Within the maxilla, the molars that are in situ on both the left (1st and 2nd molars) and right (1st molar) sides consist of only the root portion of the teeth. This is due to the extensive decay that had taken place during life. It is likely that the individual initially suffered with caries of the molars that progressed to the point of collapse of the crown, leaving only the roots behind. On the right side there is some evidence of remodelling of the alveolar bone beginning to take place where the 2nd and 3rd molar would have originally been (see fig 7.16). Although there is clear evidence of severe decay when examining the occlusal surface of the teeth, on the external maxilla only a few small lesions are present. The lesions seen superior to the 1st left molar, and in the location of the 3rd right molar are both smooth in shape, and their size is indicative of large granulomas, or small cysts. With the level of decay present in the teeth, however, it is likely that the cavities would have eventually progressed into abscesses. Combined with the exposed roots of the molars, this likely would have made eating particularly painful for this individual. Had this individual survived the sinking of the *Mary Rose* it is likely that such lesions would have ultimately led to ante-mortem tooth loss.

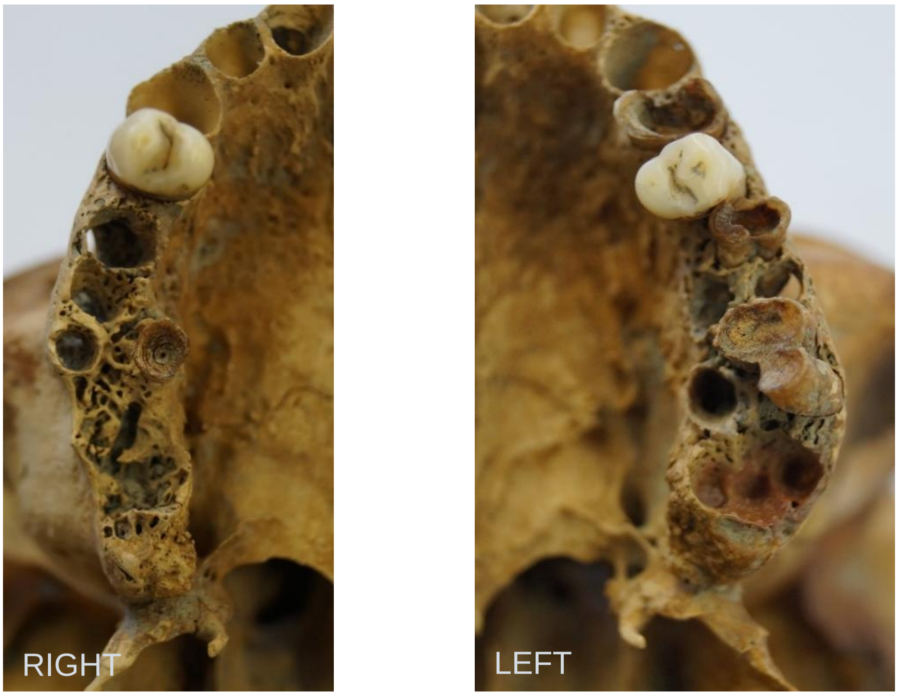


Fig 7.16: The maxilla of FCS #5 showing the carious lesions within the molars and pre-molar on the left-hand side and remodelling of the alveolar process on the right-hand side.

7.15 Tooth Loss

Periodontal disease is one of the main causes of tooth loss in living individuals, with the loosening of the teeth being one of the key diagnostic tools for those suffering the disease in life. The disease itself progresses slowly and while it can be relatively pain-free, it can create issues with regards to chewing and malnutrition (Waldron 2009: 239). Though the incidence of periodontal disease and tooth loss increases with age, tooth loss can also be seen in young adults as a result of rapidly progressive periodontitis and acute necrotising gingivitis/periodontitis. However, it is not apparent how younger individuals come to be affected by this form of periodontal disease. (Hillson 2005: 306). The chronic inflammation of the tissues around the teeth and the subsequent destruction of bone is what leads to the tooth loss. The accumulation of bacteria in plaque initially leads to gingivitis, swollen and bleeding gums, which can then form gingival pockets in which the bacteria can proliferate and produce toxins. This then initiates the reabsorption of the alveolar bone around the tooth. Once enough bone is lost, the tooth will become loose and eventually exfoliate (Dias and Tayles 1997: 552). All the skulls and mandibles uncovered from the wreck of the *Mary Rose* displayed some evidence of periodontal disease, though some displayed it to a far greater extent than others (Evans 2005: 554).

Teeth lost post-mortem can be easily distinguished from those lost during life, as the tooth socket shows no evidence of remodelling if lost after death. In comparison, those lost in life display levels of remodelling in the mandible or maxilla, which can potentially be used to ascertain what order the teeth were lost in (Waldron 2009: 239). In some instances where individuals have lost all their teeth during life, particularly the mandibular teeth, the reabsorption of the bone may result in the jaw looking significantly smaller than had the teeth been present. Although the cause of tooth loss cannot often be determined exactly within the skeletal record, if there is other evidence of extensive periodontal disease it is likely that it was the ultimate cause (Waldron 2009: 239).

7.15.1 Tooth Loss Within the FCS Collection

While there is evidence of post-mortem tooth loss among all 25 of the FCSs that show dentition, as seen by the empty tooth sockets in both the maxillae and mandibles, there is also evidence of ante-mortem tooth loss in 11 of these 25 FCSs. These incidents are distinct from post-mortem loss due to the remodelled bone providing a smoothed surface over the alveolar socket in the mandible or maxilla. One particularly clear case of ante-mortem tooth loss is from FCS #79, found in O6 (see fig 7.17). The wear on the surviving molars suggests the individual was in his early to mid-twenties, implying that he suffered from rapidly progressing periodontitis, rather than the more delayed periodontal disease that usually affects older adults.

Fig 7.17: The maxilla of FCS #79, clearly showing the remodelled bone where molars were lost during life

The tooth loss in FCS #79 only affects the maxillary molars and premolars; on the right side, the second premolar, and the first and second molar have been lost ante-mortem, and on the left side, the first and third molars have been lost. The right third molar has been lost post-mortem, and the left second molar is the only one to remain in situ, though a single root remains of the third molar. In contrast, all three molars on the right of the mandible are present with both premolars being lost post-mortem, and, on the left, both premolars are present, along with the first and second molars, with the third being unerupted. Despite the extensive tooth loss from the maxilla, the remaining teeth appear relatively healthy and show very little in the way of other pathological change, such as caries or excessive wear.

An example of progressing periodontal disease that likely would have ultimately led to loss of a tooth can be found in FCS #24, uncovered from H8 (see fig 7.18). Despite being in the lowest and most sheltered level of the ship, #24 consists of mainly the axial skeleton, but only the mandible is preserved from the skull. The level of tooth wear and the unerupted 3rd molars, along with the unfused epiphyses of the present fibula and radius, suggest this individual was in their teens when they died. Despite the empty sockets in the mandible, the 9 absent teeth would have been lost post-mortem, and there is no evidence of any remodelling associated with ante-mortem tooth loss. However, had the individual not died, it is likely that they would have experienced tooth loss soon. The 1st molar on the right-hand side is absent, but the mandible displays evidence of periodontal disease and the reabsorption of the alveolar bone. The ‘U’ shaped lesion appears on both the buccal and lingual sides of the mandible, which likely would have resulted in a very loosely anchored tooth during life. Despite this, the tooth socket itself, with the insertion points for the roots does not display any signs of remodelling; indicative of the tooth still being present at the time of death. The depth of the lesion, being greater than 3mm, and the steeply angled sides suggests the individual had a more aggressive periodontitis that was in either an acute or quiescent phase at the time of death (Kerr 1991: 348). The rounded edges and symmetrical nature of the lesion is also indicative of long-standing chronic periodontitis, as irregular edges would suggest more recent episodes (Hillson 2002: 266).

Fig 7.18: The mandible of FCS #24 showing the ‘U’ shaped lesion, suggesting progressive periodontal disease

While molars are often the only remaining teeth in the skulls from the *Mary Rose* collection, due to the multiple roots providing a firmer anchor, the loss of this particular molar from #24 is likely due to the effects of periodontal disease on the surrounding bone. As stated earlier, there is a risk of post-mortem erosion due to the marine environment that may affect evidence of periodontal disease. However, in the case of FCS #24, the individual was uncovered from the lowest level of the ship, the Hold. Remains uncovered from the lower decks show a greater level of preservation than those from the more exposed Upper Deck. Had FCS #24 been uncovered from the Upper Deck, there would have been a higher chance that any pathology present was the result of erosion in the marine environment. However, with the excellent preservation apparent for all the remains associated with FCS #24, it seems likely that the defect to the mandible is the result of a pathological condition as opposed to post-mortem erosion, particularly as no other tooth socket within the mandible is affected to the extent of the right 1st molar.

Similar instances, wherein the tooth is still present within the mandible or maxilla, but likely would have been lost during life had the individual survived, can be seen through the presence of carious lesions. Such lesions can be seen in 7 individuals, including the previously mentioned FCS #5. The poor dental health of #5 is particularly apparent and this individual shows the most extreme form of carious lesions from the FCS collection. FCS #37 shows a clear example of a carious lesion on the 1st molar of the left maxilla (see fig 7.19). as with FCS #5, had this individual survived the sinking of the ship they likely would have suffered the ante-mortem loss of the tooth.

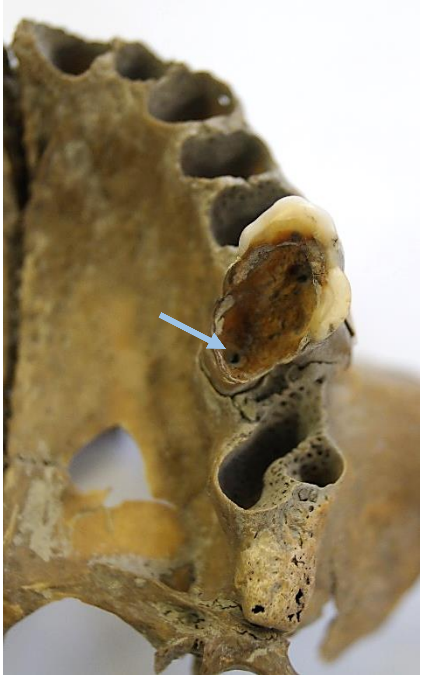


Fig 7.19: The carious lesion present in the 1st maxillary molar of FCS #37 exposing the pulp chamber and the root canal

While evidence of periodontal disease can be seen clearly in such cases as FCS #24 and would likely have resulted in tooth loss had the individual survived the sinking of the ship, more direct causes could also result in ante-mortem tooth loss, such as traumatic injury. With the loss of the tooth ante-mortem and the re-healing of the alveolar bone, assessing traumatic injury can be difficult. However, in the case of FCS #39 there is evidence that suggests one maxillary incisor was broken during life. While it is impossible to ascertain the exact cause of such an injury it is likely an external force impacting on the right maxillary 1st incisor caused the tooth to break but did not result in the loss of the tooth entirely (see fig 7.20).

Fig 7.20: The broken 1st maxillary incisor of FCS #39 showing the remodelled alveolar bone surrounding the fragment of tooth that remains in situ

Due to the post-mortem loss of the other anterior teeth from the maxilla, and with no associated mandible, it cannot be determined whether damage to the crowns also occurred in these teeth. Though there is no evidence of remodelling within or surrounding the present anterior tooth sockets.

7.16 Hypoplasia

Kim Seow (1997: 173) sets out the formation of enamel into 3 distinct phases:

1) Matrix formation: where the proteins involved in amelogenesis are produced
2) Calcification: most of the original proteins are removed and minerals are deposited
3) Maturation: newly mineralised enamel undergoes crystallisation and remaining proteins are removed

Each of these stages can be affected by environmental or genetic factors at any point during the process, resulting in defects of the enamel. Events that affect the earliest stages of enamel formation can result in enamel hypoplasia (Kim Seow 1997: 173). Hypoplasic developmental defects are commonly found within the archaeological skeletal record (Hillson 2005: 169). As enamel is not remodelled during the life of an individual, it can provide a record of the first 10-11 years of life, during which the enamel crown is formed (Ogden 2008: 284; Kim Seow 1997: 173; King 2005: 547, 548). The defects found in enamel hypoplasia can be divided into three forms, first established by Berten in 1895 (Hillson 2005: 170; Hillson 2014: 162), and are as follows:

1) Furrow Form: the most common type, can range from sharp, narrow lines that look as though they have been engraved in the surface enamel, to broader indentations that are less clearly defined (Hillson 2014: 163-164). Furrow form is often referred to as ‘linear enamel hypoplasia’ (Waldron 2009: 244).
2) Plane Form: more extreme than Furrow Form, it presents as a wide brown-coloured stria that continues around the circumference of the crown (Hillson 2005: 174)
3) Pit Form: unlike Furrow and Plane Form that extend continuously around the circumference of the tooth, Pit Form is discontinuous and is made of a series of isolated pits in a band around the crown (Hillson 2014: 170).

These defects seen in the enamel can be the result of a variety of factors, including birth trauma, infections, dietary deficiency, or systemic illness (Waldron 2009: 244; Kim Seow 1997: 176). Other changes to the surface of the tooth, such as caries, or attrition can also hide the signs of hypoplasia (Waldron 2009: 244). While changes to the enamel can provide clues as to the nature and timing of various events, there can be diagnostic difficulties in establishing an exact cause and they can be considered as non-specific indicators of systemic stress (Kim Seow 1997: 173; Saunders and Keenleyside 1999: 513). However, if the defect to the enamel does not occur across multiple teeth within the same jaw, it may be the result of a localised infection or trauma, rather than a developmental disruption (King *et al* 2005: 547). The teeth available for study within an archaeological sample can also influence the study of hypoplasia as there is normally a higher prevalence of defects on the anterior, rather than the posterior dentition. Studies by both Saunders and Keenleyside (1999: 515), and Goodman and Armelagos (1985: 482) found that the anterior first incisors and the mandibular canines had the highest frequency of defects in the dentition. The lowest frequency of enamel defects is found in the molar dentition (Goodman and Armelagos 1985: 480).

7.16.1 Hypoplasia Within the FCS Collection

Due to the prevalence of missing teeth, particularly anterior teeth within the skeletal assemblage uncovered from the *Mary Rose*, the incidence of enamel hypoplasia can be difficult to determine. The majority of the teeth that remain in situ within the maxillae and mandibles of the FCS collection are molars, and due to the high incidence of caries and erosion seen in many individuals, enamel hypoplasia prevalence is difficult to determine. A total of 14 individuals have anterior teeth in situ. Of these, 7 individuals have incisors and canines present, 3 individuals have only canines, and 4 have only one canine present of all the anterior teeth. One of the few skulls from the FCS collection that has both incisors and canines present is FCS #82. This is one of the two individuals, the other being FCS #83, found in the Pilot's cabin on the Main deck. All the bones of both individuals suffered heavy staining, most likely from the various metals in the surrounding areas. The teeth of #82 show signs of this staining, but this staining has also highlighted the lines of linear enamel hypoplasia present in the teeth (see fig 7.19). This is the only skull to display a clear example of enamel hypoplasia within the FCS collection.

Fig 7.21: The maxilla of FCS #82, the staining caused by iron highlights the linear marks of enamel hypoplasia

The maxillary anterior teeth that are present consist of the right 1st incisor and canine, and the left 2nd incisor and canine. The mandibular dentition on the other hand have fared less well, with the only anterior tooth present being the left canine. The anterior maxillary teeth, particularly the right 1st incisor and the left 2nd incisor and canine, show the clearest signs of hypoplasia. With so few examples of skulls with anterior teeth in the FCS collection it is difficult to estimate the prevalence of enamel hypoplasia in the crew of the *Mary Rose*. Had more of the skulls retained their anterior teeth, more examples may have been noted, and thus given a more complete impression of the crew.

7.17 Head Trauma

The main evidence of pathology within the skull comes from the dentition. There are few examples of traumatic cranial trauma within the FCS Collection. This is likely due to the limited number of skulls within the collection that are currently available for study. There are 22 complete crania within the FCSs, with a further 6 on display. There are additionally 4 skulls that have been damaged post-mortem and thus consist of fragments. From these, there is evidence of 2 potential head traumas. One is that of FCS #39 (see fig. 7.20), that presents with a depressed section of the right parietal, measuring 3.8cm at the widest point. Such an injury is consistent with blunt trauma, but it cannot be determined it this is a result of warfare, or a domestic accident. If caused by blunt trauma, the smoothness of the depression suggests it was well healed at the time of the individual’s death. The second possible trauma comes from FCS #30 (see fig. 7.21), located on the left parietal. Unlike #39, this skull is very fragmented due to post-mortem damage. The lesion appears on the edge of one of the left parietal fragments, measuring 1.5cm in length. The loss of the natural skull contour makes the nature of the pathology harder to determine, though it is unlikely to have been blunt force trauma. The linear shape could be indicative of sharp force trauma.

The skulls present in the FCS Collection represent a fraction of the 129 crania found from the wreck of the *Mary Rose*. Examination of the rest of the skulls may result in further evidence of head trauma and possible treatment.

Fig 7.22: Depression on right parietal of FCS #39. Possible blunt force trauma

Fig 7.23: Possible evidence of sharp force trauma to the left parietal of FCS #30

7.18 The Question of Soft Tissue and Disease

While the level of preservation of the skeletal material uncovered from the *Mary Rose* is generally of a very high standard, particularly those uncovered from the lower decks, such remains cannot provide an insight into the soft tissues of a living individual. With accidents or trauma severe enough to affect the underlying bone, there would have been a wide range of soft tissue injury, including contusions, open wounds, and infections. It is not only traumatic injuries that may have had an effect on the crew, but also disease and other illnesses. As most diseases tend to only appear in the soft tissues of an individual (Waldron 2009: 1), their presence amongst the skeletal crew of the *Mary Rose* may go unnoticed. Contemporary written accounts are perhaps the only source that can reveal the health of a ship's crew at the time of the sinking in 1545. John Lisle, commander of the Harry Grace à Dieu, provides an insight into the health of the English naval crews in two letters written in August 1545, immediately following the sinking of the *Mary Rose*. The first letter, written to the Duke of Suffolk on the 1st August, less than two weeks after the loss of the *Mary Rose*, describes a disease that had *'fallen amongst the soldiers and mariners in almost every ship'*. The prognosis for the spread of the disease appears so dire, that Lisle suggests it may be necessary to bring in new men to replace those who have been struck down (Castle and Kirkup 2005: 174). No exact name is given to the illness, but a description is provided by Lisle, stating that those affected suffered from *'swelling in their heads and faces, and in their legs, and divers of them with the bloody flux'.* Conditions such as scurvy could be common even on land, particularly in winter when a diet of salt meat would be prevalent. Similarly, various ailments such as lung infections, typhus, plague, or dysentery could also spread throughout the population (Castle and Kirkup 2005: 174). The effects of disease can be seen in military engagements throughout history; one of the most well-known instances occurring in 1415, when the army of Henry V suffered from wide-spread dysentery during the siege of Harfleur, resulting in a portion of his army having to be invalided home. The combination of disease and casualties caused the loss of around 25% of Henry V's 12,000 men (Curry and Mercer 2015: 15, 92). The cramped conditions of the soldiers and mariners serving on board English navy ships at Portsmouth in 1545 no doubt allowed the rapid spread of disease, especially when combined with a poor diet. Often crew members suffering from a sickness or infection would be taken to land, in order to prevent the spread of disease amongst the rest of the crew (Loades 1992: 100). The disease that Lisle talks of in his letter is thought to have been caused by both the victuals available to the crews, and the conditions of the ships. This is shown in the response by the Duke of Suffolk who writes to Henry VIII of the *'corruption of their victual'* and by *'the straight and warm lying in the ship'.* The solution to the spread of such illness in August 1545 appears to be the re-supply of fresh victuals as far as possible (Castle and Kirkup 2005: 174).

If such illness was so widespread by 1st August 1545 as to bring into question as to whether new recruits would be needed, it is entirely possible that such disease was already present two weeks prior when the *Mary Rose* was still afloat. Certainly, John Lisle does not portray the general condition of naval crew members in a positive light, writing that *'men in this army decay very sore',* and that even those who are described as 'whole', were *'very unsightly, having not a rag to hang on their backs'* (Castle and Kirkup 2005: 174). Such accounts can help provide an insight into what the general health of a crew may have been like, such as aboard the *Mary Rose*; something that is not immediately apparent from the analysis of the skeletal remains. Crew members would have come aboard ship already in a condition of poor health (Castle and Kirkup 2005: 174) before being pressed into service in a labour-intensive role, with limited access to a healthy diet or environment. It is highly likely, if not certain, that the crew on the *Mary Rose* would have suffered from disease and illness not visible in the skeletal remains. Unfortunately, without any evidence in the form of physical remains showing such disease, it is impossible to establish what disease and symptoms individuals presented with, along with any potential treatment that could be provided by the surgeon. Contemporary medical texts reveal a wide range of conditions that would have been treated by practitioners of the day, including disease and conditions that would affect the soft tissues, rather than bone.

While a comprehensive understanding of both the health and fitness of the *Mary Rose* crew cannot be gained without knowledge of any trauma or disease that may affect the soft tissues, analysis of the skeletal remains can help provide an insight into such questions. It can be difficult to speculate what types of disease may have been prevalent, as even with contemporary descriptions, even named conditions may not necessarily correlate to those of the modern day (Castle and Kirkup 2005: 174). As such it is the skeletal remains that provide the most solid evidence regarding the condition of the crew when alive. Indeed, some conditions that are easily recognisable within the bone, may not have been so apparent in a living individual. While some knowledge is lost through lack of soft tissue, the skeletal remains reveal both trauma and evidence of long-standing conditions that likely would have affected crew members as they carried out their labour-intensive duties.

7.19 Summary

Examination of the FCS Collection has revealed a range of different pathology affecting both the bones and the teeth of the crew members. Evidence of direct trauma related injuries such as fractures and dislocations would require a certain immediacy of medical intervention in order for them to be treated effectively. Other pathology, such as the presence of Schmorl's Nodes in multiple members of the crew, may have presented as back pain in some individuals, but is unlikely to have warranted such immediacy of surgical intervention. The surgeon was not only on board to serve during battle, but also to care for the general health of the crew. Some ingredients found preserved within the chest and cabin could have been used to produce poultices and salves to treat the aches and pains that would undoubtedly be suffered by such an active crew.

While the presence of pathology is recognisable within the skeletal remains, what is less evident is the cause of such injury. The degenerative changes to elements such as the joints and the spine are not the result of a single event, the same way a fracture may be, but rather a possible result of the lifestyle on board the ship. Even when not engaged in active battle, there would have been risks to serving onboard warships. Contemporary accounts report crews in poor health with illness spreading rapidly due to the poor conditions and diet of the crew. For example, it is clear from the excavation of the *Mary Rose* that there were some areas of the ship, such as the galley in the Hold, that had a restricted headroom, not allowing crew members to stand fully upright. The pathology shown in the remains of the FCSs suggests a life of hard manual labour and difficult conditions, that could result in severe fractures and dislocations, along with degenerative changes to the joints and spine. The poor dental health suggests that even the process of eating would have been difficult, if not painful, for many crew members suffering from caries and tooth loss. The analysis of the pathology of the FCS collection helps provide a greater understanding of the realities of living and working on board a Tudor warship and any surgical or medical intervention that may have been required.

8. Medicine on Board the *Mary Rose*

8.1 The Location of the Surgeon

One of the many items recovered from the wreck of the *Mary Rose* was a walnut chest, measuring approximately 4' x 1'9", found in one of the Surgeon's two cabins. Both these cabins were located on the Starboard side of the Main Deck; found in M7 (see Fig 8.1) (Watt 1983: 6; Castle 2005: 171).

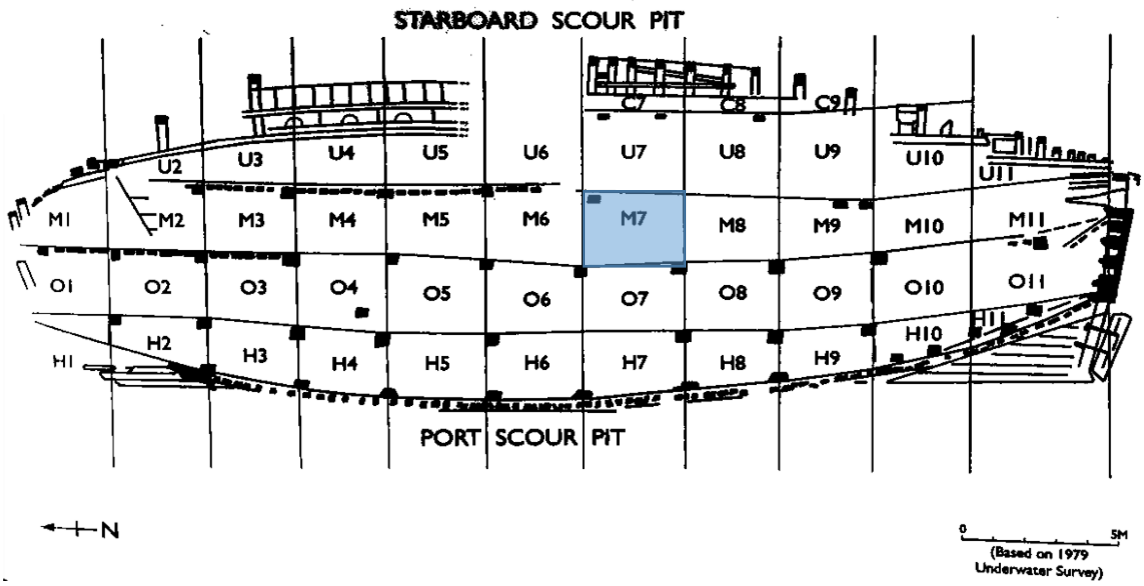


Fig 8.1: the excavation sectors for the *Mary Rose*, with the location of the Surgeon's Cabin highlighted in blue

When opened, it was revealed that the chest contained a complete, and seemingly undisturbed, medical kit. Despite the presence of the chest in the cabin, there were no human remains located within, suggesting that the ship's surgeon may have been elsewhere, possibly treating those wounded in battle, when the ship sank. While the Surgeon's cabin was unoccupied, several sets of human remains were recovered from the Hold level along with mattresses and palliasses, an accepted location for the treating of the wounded (Childs 2007: 86). During a battle situation, the Hold was considered a relatively safe space in terms of dangers posed by cannon bombardment and assaults from enemy vessels (Watt 1983; 6). This would seem to corroborate the description by the Naval Commander John Hawkins (1532-1595) who described placing those wounded during battle on the ballast in the Hold. This meant the cries and images of dead and dying men would be hidden from those still engaged in battle on the Upper Decks, for fear of demoralising those at battle stations (Rule 1982: 184). Over two hundred years later the same reason- that of not demoralising the other men- was also why the Officers on board the Victory at the Battle of Trafalgar covered Nelson’s distinctive uniform and medals before transporting him below to the Orlop Deck, where he would ultimately succumb to his wounds (Rule 1982: 184). It is possible therefore, considering the importance of keeping up morale of the fighting men, that those wounded during the battle were being treated in the Hold of the ship rather than in the smaller Surgeon’s cabin. The location of the cabin, being in a fairly central position on the main gun deck, may also have made it difficult and dangerous to access during the midst of a sea battle. It is also likely that the relatively small size of the cabin could have proved to be a hindrance, as it would have been unable to contain multiple injured crew members at the same time. During a battle the Main Deck would have been an active place, not only with gun crews firing on enemy ships, but with other crew members moving between the fighting stations of the Upper Deck above and the storage areas of the Orlop Deck below. Such movement would be necessary in order to keep those fighting on the upper sections of the ship supplied with provisions to engage the enemy. As such, there would be no place that injured or dying crew could be laid out for treatment or comfort without impeding those still actively involved in the fighting.

However, even if the wounded were being treated in the Hold during the battle, the chest of medical supplies was left, closed, in the cabin two decks above. The chest is not small, and as such, the size and weight may suggest that it was left behind for convenience. Transferring such a cumbersome item, filled with potentially expensive tools, ointments, and potentially volatile liquids, through the companionways that led to the Hold would, no doubt, have been a difficult task. If the surgeon was treating individuals in the Hold at the time of the sinking, it is possible he may have taken some of his equipment with him, but, without the protective casing of the chest which preserved so many items, it is likely that such items would not have survived several centuries at the bottom of the Solent. Perhaps some of the most likely items to have been used would be metal tongs and forceps, to remove splinters of bone and foreign debris from wounds, and simple bandages to staunch blood and protect injuries. If this were the case, such items would be unlikely to survive; even within the cabin itself there is little evidence of metal tools as the materials used to make them have long since corroded away.

While the remains of the Surgeon have not been identified from amongst those recovered from the *Mary Rose*, nor is a name recorded in any muster rolls, the nature of their role on board the ship would have meant that they were a fully trained, and possibly senior member of the Company of Barber-Surgeons (Castle 2005: 171). An indication of this high rank can be seen in the presence of a velvet coif with silk ties found within the cabin (Rule 1982: 193). Such a valuable piece of clothing is unlikely to have been worn on a day-to-day basis while on board the ship; it acts as an important indicator of the Surgeon’s rank, wealth, and profession. Similar coifs can be seen in the famous Holbein painting depicting King Henry VIII, surrounded by high ranking members of the Guild of Barber-Surgeons, painted 5 years before the sinking of the *Mary Rose* (barberscompany.org). This portrait, dating to 1540, represents the major change in the medical profession that occurred during the reign of Henry VIII. The training and expectations of surgeons, particularly those practising at sea, was raised to the highest possible standing (Childs 2007: 85). This means that while the location of the surgeon at the time of the sinking remains unknown, due to their position as surgeon on one of Henry VIII’s flagships, they are likely to have been highly skilled in their profession, and most likely had also received an education in anatomy to assist in the practice of surgery. This education and status would match well with an individual who wore an expensive velvet coif as a mark of their office.

Unfortunately, the name of the surgeon on the *Mary Rose* at the time of sinking is unknown, but there are documents dating from over 30 years prior in 1513, during the first French War of 1512-1513 that do provide some named individuals (Stirland 2013: 60). The accounts of the Treasurer of the Fleet, Sir Thomas Wyndham, show that Robert Symsom was the Master Surgeon at this early point in the history of the *Mary Rose*, and that he was assisted in his duties by a junior surgeon, Henry Yonge. The skills of Robert Symsom as a surgeon must have been apparent as 13 years after he was listed as serving on the *Mary Rose*, he became the Second Warden of the Company of Barber-Surgeons (Rule 1982: 186). Robert Symsom would not have continued on as the Surgeon on board the *Mary Rose*, nor is it likely that Henry Yonge progressed to the role of master surgeon on board the ship, as he is still listed as being alive in 1554 according to the records of the Company of Barber-Surgeons (Stirland 2013: 60, 61). Despite the information available regarding the officers on board during the early years of the *Mary Rose*, there is very little in relation to similar information in the years before the sinking. When Stirland attempted to discover more on the surgeon of the *Mary Rose*, in particular a name, she discovered two issues with the surviving contemporary records. Firstly, that there are very few records relating to Henry VIII's navy still in existence, and secondly, the survival of any records is somewhat erratic and so they fail to provide a continuous narrative pertaining to a specific period of time. She also hoped that the Company of Barber-Surgeons, which had been formed in 1540, would provide records containing some useful information. But upon enquiring with the Company's modern descendant, the Worshipful Company of Barbers, she was informed that despite numerous and continued efforts to reveal the mystery of the Surgeon of the *Mary Rose*, his name and identity have continued to be somewhat elusive (Stirland 2013: 61). One additional clue as to the Surgeon's identity could come from his possessions uncovered from the Surgeon's cabin; in particular two pewter dishes (finds numbers 80A1625 and 80A1635), both found nearby to the medical chest in the cabin. The smaller dish with two trefoil handles, known as a 'porringer' (see Fig 8.2), and a plain larger dish, are both stamped with the initials 'W.E' (Castle and Derham 2005: 200, 202).

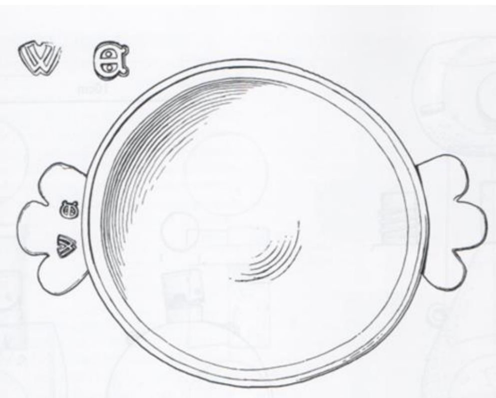


Fig 8.2: The porringer (80A1625) found within the surgeon's cabin with the initials 'W E' (Castle 2005: 202)

The porringer, despite sometimes being referred to as a ‘bleeding’ vessel’ may have also been used for eating and drinking. The presence of the same initials being on two separate dishes from the cabin could suggest that these are the initials of the Surgeon himself, and, while it is still a long way from a definitive identity, it may prove useful at a future juncture.

8.1.1 The Role of the Surgeon

Tending to the wounded during and after battle would have been just one aspect of the Surgeon’s role on board the *Mary Rose*. As well as being both a surgeon and physician, he would also fulfil the roles of barber and apothecary for those on board the ship. As such, the tools and equipment used by the Surgeon would reflect these varied roles (Rule 1982: 188). Despite the possible wealth of the surgeon shown by the existence of a velvet and silk coif, the cabins that would have been occupied by him during his time on the ship were shown to be sparsely furnished, with the only items being the large medical chest, and a wooden bench that may have been used for preparing plasters and dressings when necessary (Rule 1982: 188). The chest was discovered late in the 1980 excavation season and presented the dive team and archaeologists with something of a quandary; whether to excavate the contents of the chest in situ, despite the poor visibility and conditions at the bottom of the Solent, or attempt to bring up the entire chest intact. It was ultimately decided that the best course of action was to excavate in situ, with a dive volunteer sent to open the chest underwater and assess the contents. This enabled any necessary arrangements to be made for bringing the contents of the chest to the surface. As chests of arrows had previously been found within the wreck, it was thought there was a possibility that this chest would also contain something similar (Rule 1982: 189). However, when the chest was opened, it was reported back that the contents seemed to consist of clay pigeon discs. Upon hearing this report, Margaret Rule decided to dive down herself to investigate such a strange claim. Lifting the lid, she too was confronted with a series of discs that did indeed resemble clay pigeons, but after carefully lifting one of the discs, an air or gas bubble was released and the ‘clay pigeon’ was revealed to be the lid of a wooden ointment jar. Closer inspection revealed a row of similar wooden jars, plus a row of ceramic vessels, leading Rule to conclude that they had discovered a medicine chest (Rule 1982: 189).

8.2 The Medical Chest

The tools of the surgeon would be an intrinsic part of the craft, enabling the various procedures to be carried out to the best of the surgeon's ability. Kirkup (2006: 41, 42) states that the original tools available to the surgeon would have been their hands; tools are thus simply an extension of the hand that would allow more demanding procedures to be carried out (Arnold and Söderqvist 2011: 721). For example, the pinching motion of a finger and thumb can be a precursor to the application of forceps or tweezers, and a single finger may be used in much the same way as a probe or hook (Arnold and Söderqvist 2011: 721). Classical Hippocratic writings emphasise the necessity for surgical instruments to be adapted to the hand of the surgeon (Thompson 1942: 9). Thus, numerous different instruments of various shape and form have developed and been used over the centuries, with each one adapted to the specific function required by the surgeon (Thompson 1942: 10). Prior to the uncovering of the medical chest from the *Mary Rose*, some of the best sources for information regarding medical instruments in the 16th century come from the text and illustrations found in the medical and surgical texts of the day. Archaeological and material evidence for tools in the 16th century is scant, with there being limited representation of surgical tools from the Roman Age until the 17th century (Kirkup 2006: 65). This is possibly the result of corrosion and disintegration of the materials used for the construction of instruments, such as iron and low-grade steel (Kirkup 2006: 61). Woodall's text includes a comprehensive list of both surgical tools and ingredients necessary to fulfil the role of surgeon, whereas Paré includes multiple illustrations of instruments, along with descriptions of their use. Such accounts from the 16th century can help provide information not only on what was required for a medical chest, but also how such items were used and their intended purpose.

Despite the silts that had covered the wreck of the *Mary Rose*, the medicine chest (see Fig 8.3) was found to be relatively silt-free when it was excavated (Rule 1982: 189). The good preservation of the contents of the chest was no doubt aided by the thick clay sediments that had surrounded the chest on the seabed (Castle 2005: 189). Aside from one narrow lidded shelf, there were no separate compartments within the chest, but overall, it was found to contain over 60 items (see table 8.1) relating to medicine, including 11 lidded wooden canisters that contained various types of ointments, and one containing peppercorns (Rule 1982: 189, Castle 2005: 190). The chest itself was primarily constructed from walnut wood, with elm handles and beech batons. The use of walnut wood, along with the dovetail construction of the chest, are indicative of continental manufacture (Knell 1997: 64). Dovetail construction was not typical of English carpentry during the 16th Century, but such chests were frequently imported from areas of Germany and Northern Italy (Knell 1997: 64). However, there is no direct evidence to suggest that the medical chest on board the *Mary Rose* was of foreign manufacture (Richards 1997: 91). While the exact source for the medical chest is unknown, the wood used, and the construction method clearly denote an expensive item; this is possibly a reflection of the status of the surgeon who owned such an object (Castle 2005: 189). The importance and expense of the contents of the chest can also be seen in a square section of rebated wood on the front of the chest, that likely once held an iron lock that has since corroded away (Castle 2005: 189).

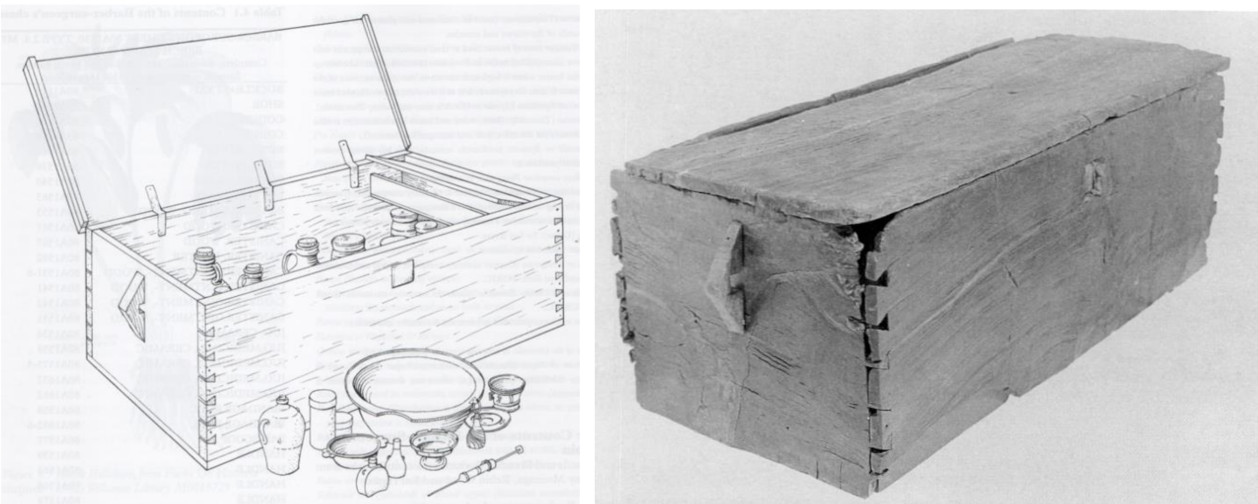


Fig 8.3: Illustration of the medical chest uncovered from the *Mary Rose* (left), showing the small lidded compartment to the right, as well as a selection of items uncovered from the surrounding cabin (Castle 2005: 90). The medical chest (right) after excavation and conservation (Knell 1997: 66)

Item	No. of Item	Finds No.
Buckle & Strap	1	80A1612
Shoe	1	80A1571
Coins	multiple	80A1861, 83A0004
Wood Bowl	2	80A1562, 80A1536
Glass Bottle	2	80A1540, 80A1565
Feeding Bottle	1	80A1555
Wood Canister	2	80A1561, 80A1567
Pewter Canister	1	80A1582
Ointment Canister	9	80A1531-3, 80A1535, 80A1537-8, 80A1541, 80A1542, 80A1551
Ceramic Jug	1	80A1534
Medicine Jug	6	80A1559, 80A573-5, 80A6037, 80A1662
Bandage Roll	6	80A1558, 80A1892-6
Ear Scoop	1	80A1577
Handle	8	80A1539, 80A1563, 80A1566, 80A1579, 80A1580, 80A1917, 80A1919, 80A1920
Saw Handle	1	80A1578
Chisel? Handle	1	80A1581
Probe? Handle	1	80A1918
Trepan	1	80A1585
Syringe	1	80A1560
Spatula	5	80A1557, 80A1587, 80A1915, 80A1927, 80A2063,
Strap	1	80A1608
Whistle	1	80A1586
Wallet	1	80A1564
Purse	1	80A1584
Comb	1	80A1572
Razor	7	80A1570, 80A1576, 80A1921-5
Knife	1	80A1588
Whetstone	1	80A1569

Table 8.1: The contents of the Surgeon's Chest found within the Surgeon's Cabin

8.3 Equipment

8.3.1 The Wooden Bench

Alongside the medical chest, a second large wood item was uncovered from the cabin in the form of a wedge bench (MR80A1503) (see Fig 8.4). The oak plank that forms the top of the bench is 1.4m long, but only 20cm wide, and tapers in thickness with one end being narrower than the other. In addition to this, the legs of the bench, one of which was found in situ, show that, when standing, the bench would have had a pronounced slope, with the longer legs positioned at the thicker end of the top plank (Knell 1997: 70; Chinnery 2005: 377). The size and shape of this bench, with the slope, suggests that it was not used for seating, but rather would have served as a work surface for the surgeon, with the long length enabling the preparation of bandages and dressings (Knell 1997: 70; Castle and Kirkup 2005: 214).

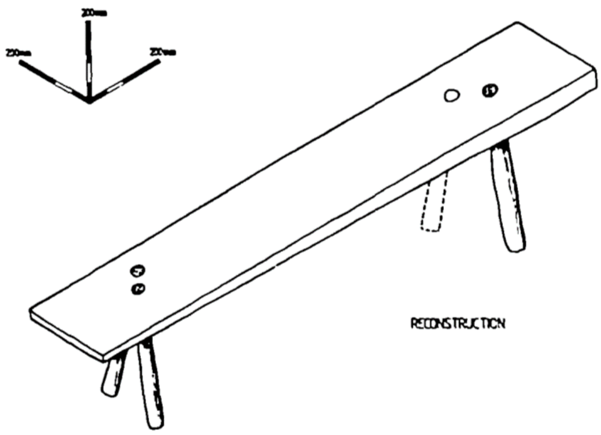


Fig 8.4: Illustration of the wedge bench found in the Surgeon's Cabin on the main deck, showing the tapering shape and slope of the top plank (Knell 1997: 72)

Further insight into how the bench may have been used by the surgeon can be found from contemporary 16th century illustrations in the medical and surgical texts. Illustrations from Brunschwig's text show a similar bench being used during the reduction of a dislocated shoulder. This image appears to show the distinct sloping surface of the bench also present in the one uncovered from the *Mary Rose*.

8.3.2 Jugs, Jars, and Canisters

It is not only the wooden chest that shows evidence of foreign construction, but also some of the contents found inside. The seven salt-glazed jugs found are typical of Raeren pottery, that would have been manufactured in the area around modern-day Belgium (Castle 2005: 190). Other foreign sourced items include a standing costrel (80A1459, Vessel 39) from Portugal, and a tin glazed jug (80A1483, Vessel 26) that was made in the Netherlands, likely at Antwerp (Castle 2005: 192). In addition to these, 3 small glass bottles (80A1540, 80A1565, and 80A1631) were found; two were unbroken in the chest and one was found broken within the cabin (see Fig 8.5). While these items are not necessarily foreign made, the quality and delicacy suggest they would have been relatively expensive objects (Castle 2005:

192, 193). Glass vessels were often used for a visual examination of urine, though the small size of the bottles uncovered implies they could have been intended to hold small amounts of more caustic or volatile substances. Unfortunately, the contents of these glass jars no longer survive, but globules of mercury were found within the chest itself, and so may have formed the contents of one of the glass jars in 1545 (Castle 2005: 193, 214).

Fig 8.5: The broken glass bottle (80A1631) found within the Surgeon's cabin (Gardiner 2005; Plate 28)

The most numerous types of vessel preserved within the medical chest and surrounding cabin are the 19 wooden canisters (see Fig 8.6), of which 11 were found within the chest itself. Most of the wood canisters are made of poplar wood (Castle 2005: 195), and, as with the pottery vessels, have a continental source. They most likely came from the German city-states situated along the Rhine; examples of similar vessels have been found in archaeological contexts, particularly within Germany (Castle 2005: 196). Not all the wooden canisters retained their lids, but many still had their contents present, allowing for chemical analysis to take place (Castle 2005: 193, 220, 221). Such analysis is vital in establishing the types of ingredients the surgeon would have had at their disposal during their time on the ship.

Fig 8.6: Some of the wooden canisters uncovered from within the surgeon's chest. The concentric circle decoration on the lids is likely what lead them to being initially likened to clay pigeon discs (Gardiner 2005: Plate 30, © Robin Wood)

The quality and continental source of many of the items found within the medical chest could provide an insight into the surgeon and his education. Continental universities were considered to be superior to the English universities of Oxford and Cambridge with regard to medical training during the 16th century (O'Malley 1968: 1). The surgeon on the *Mary Rose* may have undertaken his surgical training at a Continental institution, compiling various necessary vessels for his own medical chest, while living and learning on the Continent. It has been previously suggested that the quality of the velvet coif found during the excavation signifies the rank and wealth of the surgeon onboard (Rule 1982: 193). Certainly, the quality and Continental influence seen among the items found within the Surgeon's cabin are also indicative of a practitioner who is of high status, and with the wealth necessary to supply themselves with good quality equipment. In addition to the objects related to his craft, personal items that belonged to the surgeon have also been found within the cabin, suggesting an individual of wealth. Pewter dishes and saucers were uncovered, likely intended for dining (Castle 2005: 200). These pewter dishes also include letters 'W E', as on the previously mentioned porringer (Castle 2005: 201). The presence of pewter items could reinforce the theory that the surgeon spent time on the Continent before their assignment to the *Mary Rose*. An embargo on the importing of pewter at this time makes it likely that if such items were manufactured on the Continent, they would have to be purchased abroad, rather than in England (Castle 2005: 200; Hatcher and Barker 1974: 152). However, regardless of where the pewter items were made or bought, their high quality and expensive cost further reinforce the status of the surgeon as being an individual of means.

8.3.3 Metal Instruments: Blades and Razors

While many wooden items have been well preserved within the Surgeon's cabin, certain metal items have not fared so well having been submerged in seawater over the centuries. In some instances, it is the evidence provided by the surviving wood that helps supply an insight into what instruments would have been present in 1545. One key absence among the surgical equipment is the lack of bladed tools such as knives and saws. It seems improbable that a surgeon would go to war without the tools necessary to perform any procedure that involves cutting into the flesh; from amputations to the removal of debris and necrosing tissue. Yet, while these blades no longer exist, the wooden elements of the instrument do survive. A series of turned wooden handles, and one of bone, were found within the medical chest. Despite the blades having long since corroded away, the size and shape of the handles, along with equipment lists in contemporary medical and surgical texts, provide an impression of their original form. In particular, one large, ornately turned, cherrywood handle (80A1578) is of a size and shape indicative of an amputation saw (see Fig 8.7) (Castle 2005: 212).

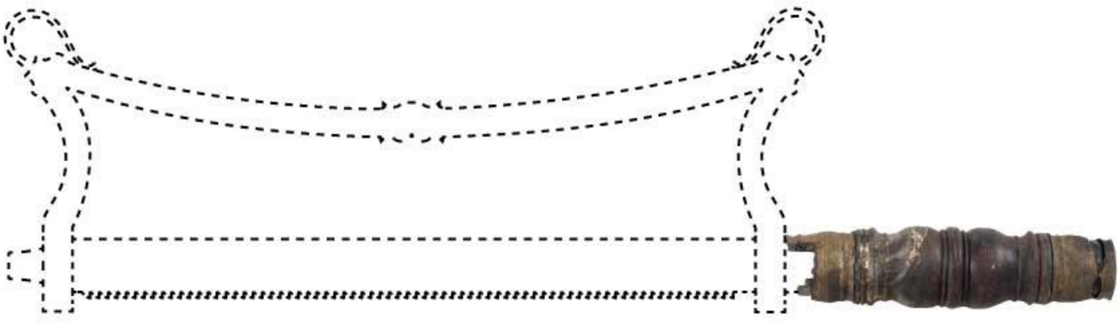


Fig 8.7: Turned wooden handle (80A1578) with the reconstructed outline of the amputation saw (www.maryrose.org/meet-the-surgeon/)

The reconstruction of the metal saw blade is very similar in form to a rare surviving example of an amputation saw dating to the 16th century, currently in the collection of the Science Museum Group (object A241432) (collection.sciencemuseum group.org.uk). As with this example, the *Mary Rose* amputation saw shows two loops built onto the back of the saw blade; this feature was added to allow such an instrument to be hung from a hook when not in use (Thompson 1942: 29). An illustration from Brunschwig's original German text, *Das Buch der Cirurgia,* published in 1497, shows what appears to be an amputation saw hanging on a hook, along with a range of other instruments (see Fig 8.8)

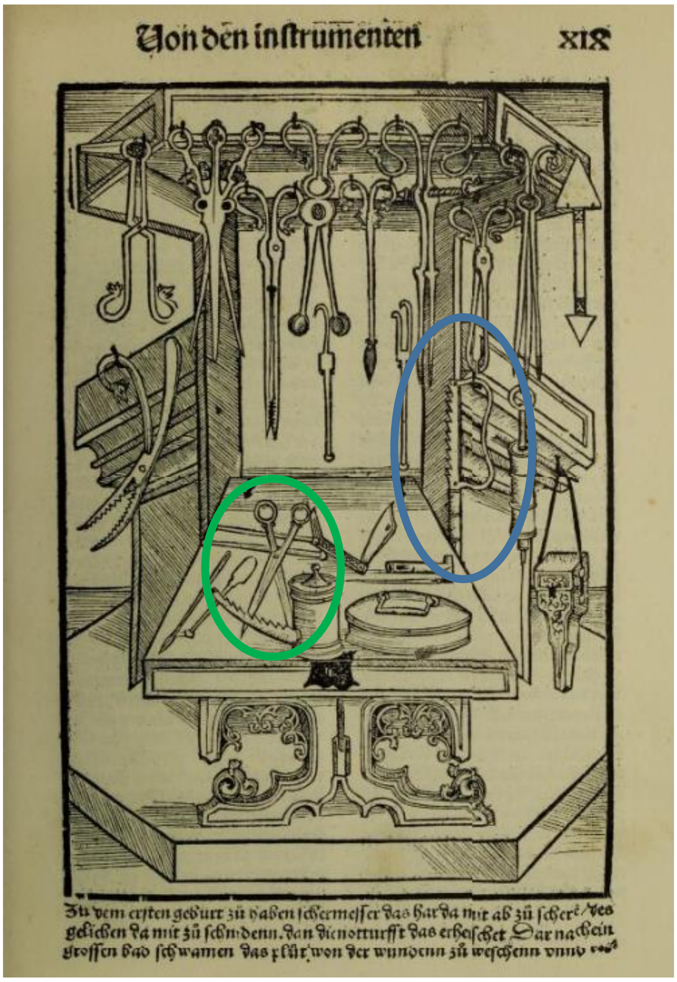


Fig 8.8: Illustration showing a range of surgical equipment, including an amputation saw (circled in blue) hung from hooks, and scissors (circled in green) (Brunschwig 1497: 33)

However, the handle for the *Mary Rose* saw, along with many of the other turned handles was uncovered from the chest, as opposed to the wider cabin. This could have been a result of the cabin's situation on board a ship, as there would be certain drawbacks in hanging sharp implements from a wall that would be constantly moving with the tides and wind. Similarly, if the surgeon was not in the cabin during the battle it seems likely that expensive and valuable equipment, particularly blades that could be commandeered as weaponry, would be locked in the chest, ready for when the surgeon had use of it.

While a saw would have been necessary to get through bone during an amputation, other blades would be required for the cutting of the flesh. Illustrations of simple blades do not appear as frequently in the 16th century texts as other instruments, such as tongs, bullet extractors, and cautery irons. This is possibly due to the blades being simpler in form and more familiar to practitioners, and hence do not warrant illustrations depicting their structure and use. While illustrations are infrequent, the first two items named in Woodall's list of equipment necessary in a surgeon's chest are *'Inciſion Knives'* and *'Diſmembring knives'* (Woodall 1655), showing their importance as integral tools to the surgeon's work. The dismembering knife would have been used during amputation, to cut away flesh or damaged tissue from around the bone. Paré gives a description of the use of such a knife, describing in his text as a 'crooked knife', and providing an illustration with the alternate name of 'dismembering knife' (See fig 8.9) (Paré 1634: 458, 459). A 'crooked knife' also appears in the earlier work of Brunschwig, the accompanying image (see fig 8.9) is attributed to the earlier 10th century practitioner, Albucasis. Brunschwig describes the knife as being sharp on the blade, but not at the point (Brunschwig 1525).

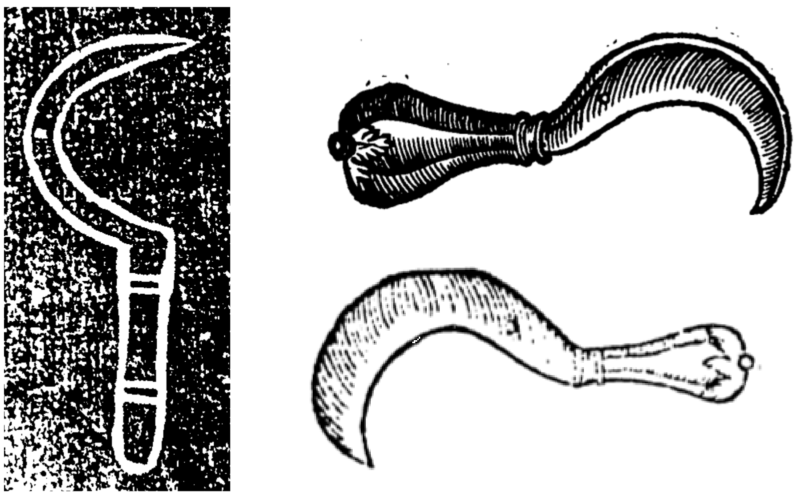


Fig 8.9: 'Crooked knife' that appears in Brunschwig's text, attributed to Albucasis (Brunschwig 1525). 'Dismembering knife' as it appears in Paré's text (top right) (Paré 1634: 459), compared to the dismembering knife found in the work of Clowes (bottom right), likely a copy of the Paré illustration (Clowes 1588).

The crooked or dismembering knife also appears in the work of Clowes (see fig 8.9), however there is no accompanying text to the image. The form of the knife and the handle, including decoration, also bear such a strong resemblance to that of Paré, that it is likely that the knife found in Clowes' work is a copy of that in the work of Paré. Clowes would have been practicing surgery several decades after Paré, so it is possible that he would have studied the other man's work and drawn knowledge from it. The presence of a curved knife in the early text of Brunschwig, Paré's work, and again in Clowes, suggests this form of knife was recognised throughout most of the 16th century. As a result, there is a possibility that one of the handles found in the *Mary Rose* chest would have originally held a similar blade.

Other types of bladed instrument that could have formed part of the *Mary Rose* chest are scissors, also seen in the illustration of surgical tools from Brunschwig (see Fig 8.8). Likely of all-metal construction, the corrosive effects of the marine environment would mean no evidence of such instruments survived. Along with the early depiction of scissors within the work of Brunschwig, Woodall also lists *'inciſion ſheers*' [incision shears] as part of his necessary surgical equipment, and includes an illustration as part of the equipment required for amputation (see Fig 8.10) (Woodall 1655).

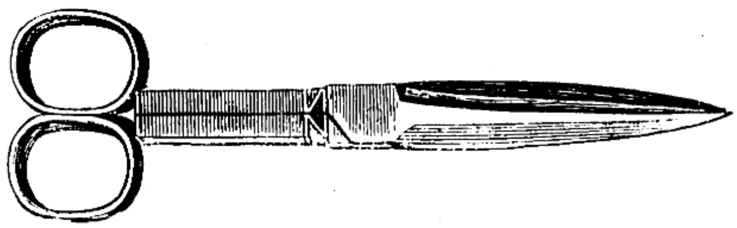


Fig 8.10: A form of scissors that appear in Woodall's illustration of 'Instruments for amputation' (Woodall 1655: 412).

A practical use for such a tool is provided in the work of Gale, who states that if a wound is too small for debris to be successfully removed (be it wood splinters, gun shot, or arrow heads), then a *'paire of ciſers or … ſheres'* [pair of scissors or … shears] may be used to enlarge the wound (Gale 1563). In his text, Banester also mentions the necessity of enlarging wounds in order to successfully extract debris, though he does not specify whether to use scissors or a blade (Banester 1633: 148, 149).

It was not only the wooden handles of large bladed implements that were found within the cabin; but additionally, several small wooden handles for smaller instruments. These handles could have contained razors which would have been used for more mundane every-day tasks, such as the barbering of the crew; they may have also functioned as scalpels for surgical procedures (Castle 2005: 217). As with the larger metal instruments, these thin blades have completely corroded away over time, leaving only their wooden casings, split down the length where the blade would once have been folded away (Castle 2005: 217). The handles themselves vary slightly, both in form and decoration, with it being suggested that some may have belonged to individual crew members who may have preferred being shaved with their own blade, as opposed to a communal one (Castle 2005: 217). One handle in particular (80A1925) is inscribed with a crude 'W' at one end (Castle 2005: 217). Some of the more expensive metal items within the cabin were inscribed with 'W.E', likely denoting initials of the owner. It is possible that this letter also references the owner of the razor. Whether or not it is the same 'W' as the owner of the pewter dishes is, unfortunately, unable to be determined. Examples of surgical knives that fold into the handle also appear in the contemporary texts of the 16th century. One particularly elaborate example comes from the work of Paré. The instrument is described as an 'incision knife' (see Fig 8.11); the handle of which acts as a sheath for the blade when not in use (Paré 1634: 298). Such a design would have the advantage of protecting the blade when not in use, particularly if it was being stored in a chest along with other equipment.

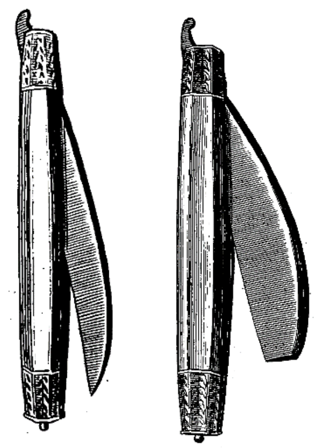


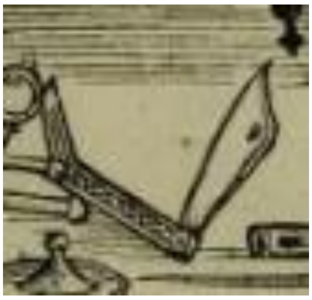
Fig 8.11: The elaborate folding incision knife (left) of Pare (Paré 1634: 298)

Fig 8.12: The simpler folding knives of Woodall (right) (Woodall1655: 30)

The example of Paré's knife is particularly elaborate; there is no evidence that such a decorated instrument was in use on board the *Mary Rose*. More practical examples of such blades can be found in the illustrations of Woodall (see Fig 8.12).

Woodall (1655) lists 4 razors as being necessary specifically for the barbering of the crew. This suggests that the 10 razors present on board the *Mary Rose* are unlikely to have all belonged to the surgeon solely for use in barbery. Some may have belonged to other crew members, or a different function was required of the blades (Castle 2005: 217).

The wooden cases excavated from the *Mary Rose* range in size, with lengths varying between 130mm and 165mm. Nine of the cases are a straight design, with one example (80A1570), showing an angled handle that turns roughly 45° away from the mid-line (see Fig 8.13). It has been suggested that the angled handle may have provided a better grip and greater control when wielding the blade, or that the curved handle allowed a larger blade to be folded into the handle (Castle 2005: 217). A folding blade with an angled handle can be seen in Brunschwig’s depiction of surgical instruments (see Fig 8.13), with the blade partially exposed, revealing its shape. The blade appears to be wider towards the tip compared to the relatively thin-bladed illustrations in Woodall and Paré.



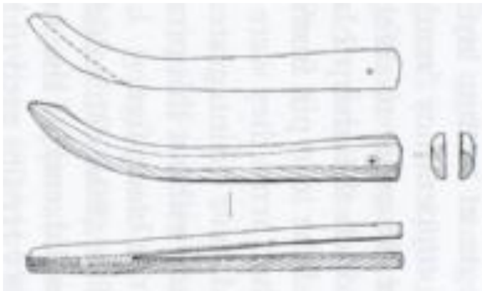


Fig 8.13: Folding blade with an angled handle (left) (Brunschwig 1497: 33), and the angled handle (80A1570) found during the *Mary Rose* excavation (right) (Castle 2005: 218)

It is difficult to determine whether all the bladed razor-like knives found during the excavation of the *Mary Rose* were used solely for barbery, or whether they would have also held a function as small blades for smaller procedures, such as letting blood. An issue with the illustrated examples of folding blades in the contemporary medical texts, is the lack of reliable scale denoting the size of such instruments. Folding blades do appear in an illustration of anatomical dissection tools in *De Humani Corporis Fabrica* (1543) by Vesalius (see Fig 8.14). As the instruments are recommended for dissection, as opposed to the treatment of living patients, it could be argued that such folding blades are intended for more invasive surgery-like uses. However, it is also possible that they were used as razors for removing hair prior to the dissection of the body.

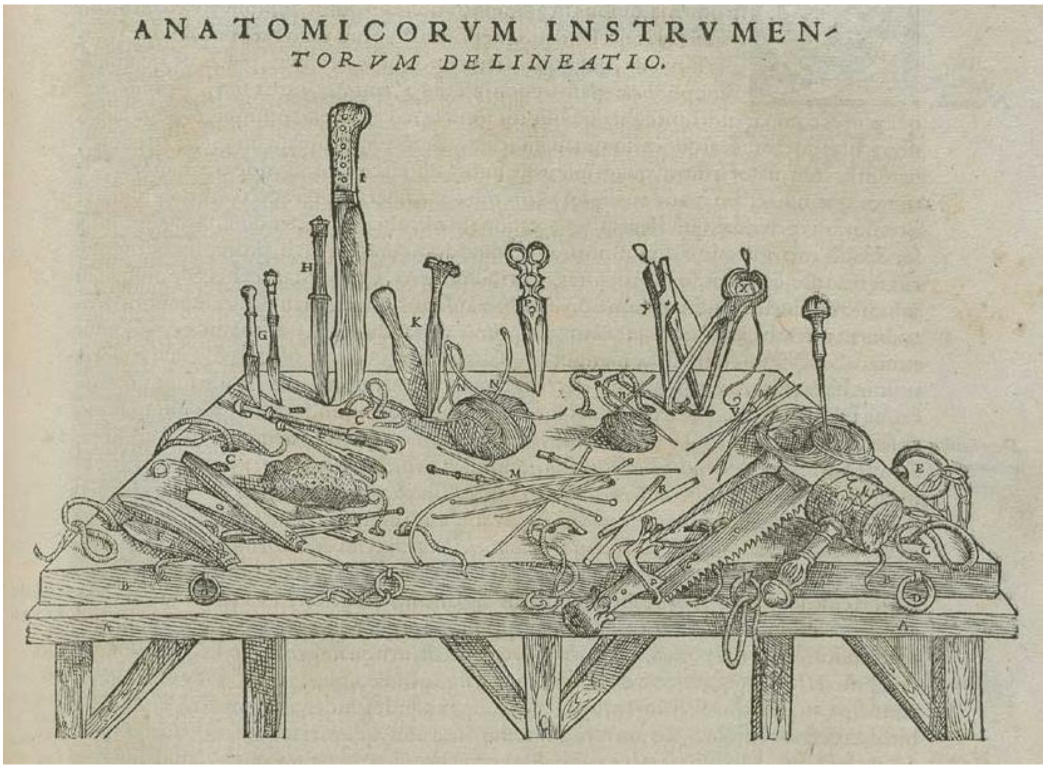


Fig 8.14: Illustration of the dissection tools used by Andreas Vesalius (1543) showing the folding blades in the bottom left corner (Wellcome Library V0010421B00)

The range of bladed instruments from an amputation saw, to smaller blades and razors, clearly show the wide range and serious nature of the injuries that the surgeon may have had to contend with in the performance of their duties to the crew. While there is no direct evidence of major surgical procedures, such as amputation, amongst the skeletal remains uncovered from the *Mary Rose*, it must be remembered that less than half the crew were found. Similarly, had the *Mary Rose* survived the battle of the Solent, there may have been more opportunity for the ship and the crew to engage in closer combat with the enemy, resulting in the presence of more severe wounds requiring immediate surgical intervention. The presence of the closed medical chest, containing various blades, within the surgeon's cabin during the battle may also provide an insight into the actions of the surgeon during combat. It could be that limited medical assistance would be given during the battle, with more serious and traumatic procedures, such as amputation, being delayed until the surgeon was once again able to treat individuals within the cabin. However, this would first require the patient to be taken down into the Hold, before being brought back up to the Main Deck. This still may have been preferable to trying to operate in the midst of a battle. Carrying out more invasive procedures after the battle may also have had the advantage of providing the surgeon with more assistance in the form of other crew members. Descriptions of reducing fractures in the contemporary texts, for example, often state the need for 2 or 3 extra individuals to successfully treat such injuries.

8.3.4 Other Metal Instruments: Cautery Irons and Trepans

While metal tools such as knife and saw blades seem an obvious inclusion in a medical chest, other instruments of a metal construction also hold an important function in the treating of wounded individuals. Cautery irons would have been a vital piece of equipment to treat many open and bleeding wounds. As with the larger bladed implements, the only evidence of such cautery irons come in the form of the wooden handles left behind after the corrosion of the metal element. During the 16th Century, cautery could either be performed using heated metal rods to rapidly seal the blood vessels of an open wound (Alsanad *et al* 2018: 3), or else boiling oil may be used to a similar effect, particularly in the treatment of gunshot wounds. The use of oil cautery in the treatment of gunshot wounds was credited with neutralising the poisonous elements that were widely believed to be contained within the gunpowder (DeVries 1990: 132). The change in opinion over the treatment of gunshot wounds and cautery with oil came less than a decade before the sinking of the *Mary Rose*. In 1537 Paré found that those treated with the oil cautery, fared less well than those who were not (Baskett 2004: 134; DeVries 1990: 132, 133; Axioti *et al* 2014: 146). As with the bladed instruments, illustrations from the contemporary texts provide an invaluable insight into what the cautery irons on board the *Mary Rose* may have looked like. *'Cauterizing irons'* are listed by Woodall as being a necessary part of a surgeons' kit, and an illustration depicting such irons along with other tools required for amputation also appears in his text (see Fig 8.15) (Woodall 1655: 412).

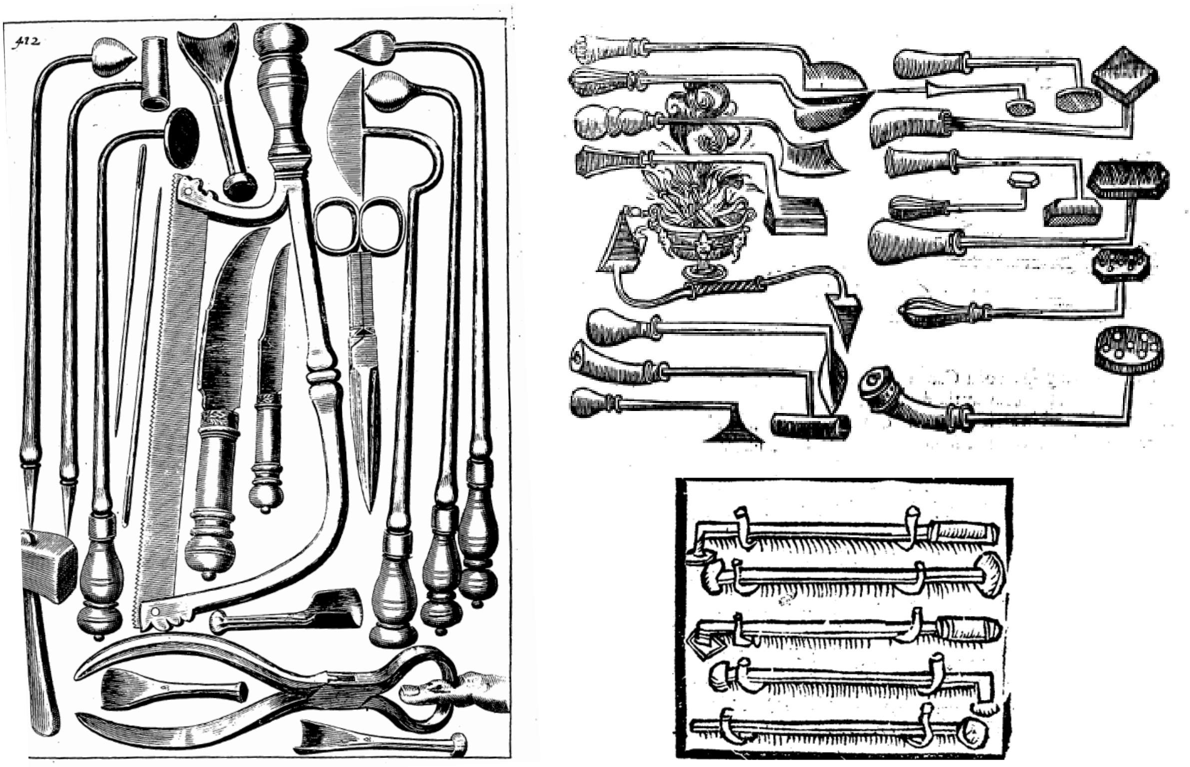


Fig 8.15: Illustration from Woodall's text (left) depicting various tools necessary for amputation, including cautery irons (Woodall 1655: 412). Similar cautery irons from Paré's work (top right), showing the comparable forms of wood handles and variously shaped metal heads. (Paré 1634: 749). Comparisons with the earliest depiction of cautery irons in the texts studied, those of Brunschwig (bottom right), demonstrate the continued variation of form throughout the 16th century (Brunschwig 1525)

While Woodall was practicing at a later date than the mid-16th Century, cautery irons in their various forms also appear in the work of Brunschwig (see Fig 8.15), practicing at the beginning of the 16th Century, and Paré (see Fig 8.15), who was practicing around the time the *Mary Rose* sank. Multiple sizes and shapes of cautery irons are depicted by Paré, the reason for which he explains as being due to the range of severity of wounds that may be treated. The different shapes, be it flat, pointed, or blade-like, similarly have different functions depending on the type of wound (Paré 1634: 749). For example a smaller wound would require a smaller iron; a large iron would simply cause extra and unnecessary trauma to the surrounding tissue. William Clowes states that small cautery irons are required to 'stay the flow of an artery or vein' (Clowes 1588: 92). Further accuracy can also be achieved by using a protective plate with a small hole that can be placed over the affected area and a cautery iron carefully inserted (see Fig 8.16), so that it '*may onely touch that which is to be cauterized'* (Paré 1634: 649). Despite cautery irons appearing in Paré's text, he himself questioned its ability to heal and pushed for the use of ligation instead. However, cauterisation continued to be used as the main method of stopping blood flow by many surgeons (Kirkup 2006: 318). It is not only bleeding wounds that would require cautery; ulcers could be treated in a similar manner. Banester (1633: 383) makes mention of the treatment of a mouth ulcer on the palette with cautery. However, in this instance cautery is seen as a last resort, as Banester warns that cautery in such an area can lead to the patient being unable to speak 'perfectly' as a result.

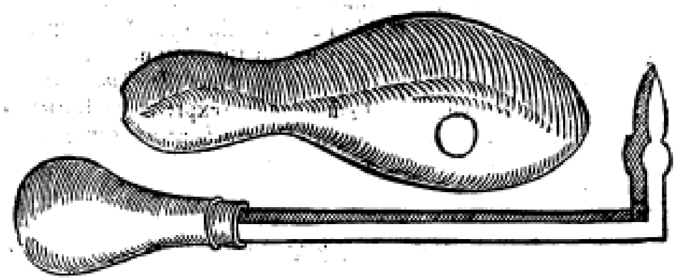


Fig 8.16: Cautery iron with plate for treating what is described as 'a weeping fistula of the eye', the cautery is sharp for better penetration (Paré 1634: 649).

Reconstructions of the cautery irons found within the surgeon's cabin on the *Mary Rose* display a variety of shapes, reflective of the examples found in the contemporary texts. Several wooden handles have been identified as likely belonging to cautery irons; objects 80A1566, 80A1919, and 80A1920, all display a diamond-shaped hole for a tang that could have originally fitted a metal cautery element (Castle 2005: 211). Other smaller handles have been identified as belonging to needles and probes, though their overall shapes are similar to the rounded handles seen in the illustrations of cautery irons, particularly those of Paré. The lack of surviving medical tools from the 16th Century can make it difficult to confirm what may have once been contained in the wooden handles. Comparing a 16th Century object found in the modern era, to a relatively simple 2D sketch from a Tudor manuscript obviously presents difficulties when establishing materials, dimensions, and methods of making such instruments. The appearance of cautery irons within the texts and their variety of shapes suggests they were relied on to treat various ailments, not only open wounds gained in battle. As such their presence as part of the *Mary Rose* medical chest seems certain, even if the distinctive metal elements have not survived. It also seems likely that there would have been multiple versions, with a selection of sizes and shapes, in order for the surgeon to be able to treat any ailment necessary.

Unlike the metal blades and cautery irons, one metal-based item did survive the corrosive effects of the marine environment. Object 80A1585 (see Fig 8.17) was found concreted to the wooden handles that had been uncovered from within the medical chest. Though it is impossible to say which of the metal handles it was associated with originally, some details of the object itself suggest that it could have been part of a trepan drill (Castle 2005: 212).

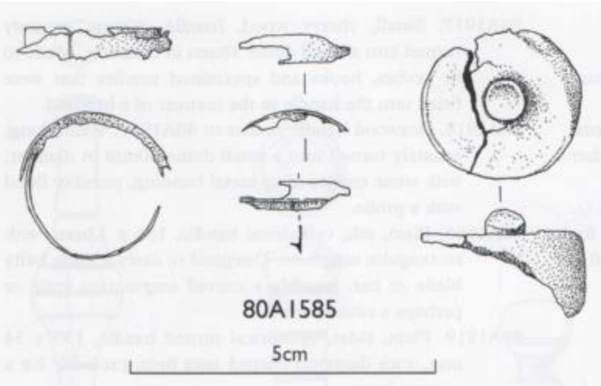


Fig 8.17: Object 80A1585 found with the medical chest, thought to be part of a trepan drill (Castle 2005: 212)

The object itself is circular in shape and would have had ‘teeth’ around the edge, much as you would expect in a saw element (Castle 2005: 212). Illustrations of trepan drills appear in several of the contemporary texts, including Gale, Paré, and Woodall. A depiction of a surgical procedure being carried out on the cranium also appears in the earliest text of Brunschwig, though the form of the instrument is larger and of a different form to trepans found in the later texts. A similar tool to that depicted by Brunschwig also appears in the work of Paré, where it is defined as a ‘*Levatorie’.* This is described as a tool to lift and restore the cranium to its original shape, rather than for principally drilling holes (Paré 1634: 344). With only such a small fragment of the drill head surviving, and no definitive handle, it is impossible to say exactly what form the putative trepan took. However, of the three texts that feature a definite depiction of a trepan drill, only Paré and Gale are surgeons who would have been practicing at the time the *Mary Rose* sank. The two handled drill with interchangeable heads depicted in both texts (see Fig 8.18) seems the most likely to represent the instrument on board the *Mary Rose*.

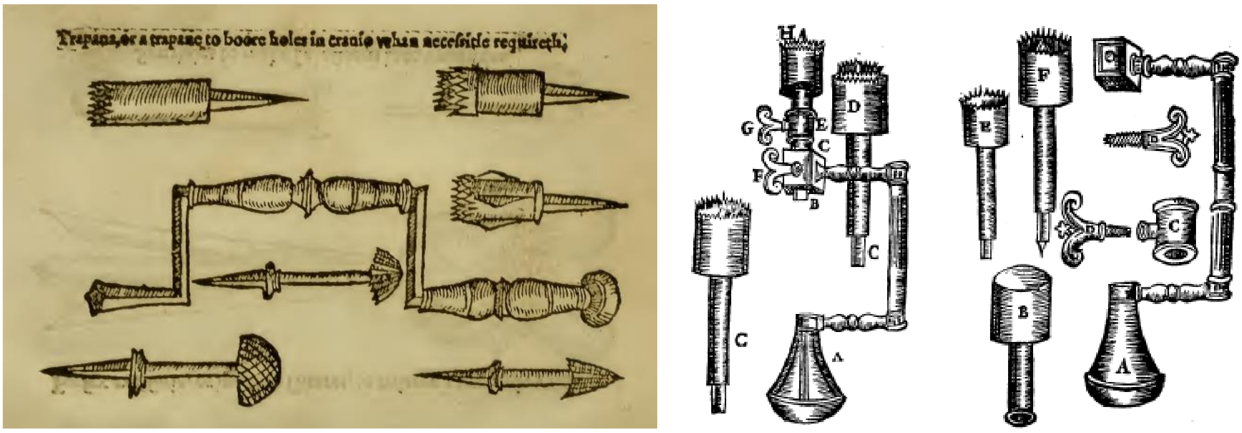


Fig 8.18: Illustrations of trepan drills with interchangeable heads in Gale (left) and Paré (right) (Gale 1563; Paré 1634: 366).

The reconstruction of the trepan drill currently on display in the *Mary Rose* Museum also mirrors the illustrations found in the works of Paré and Gale (see Fig 8.19).

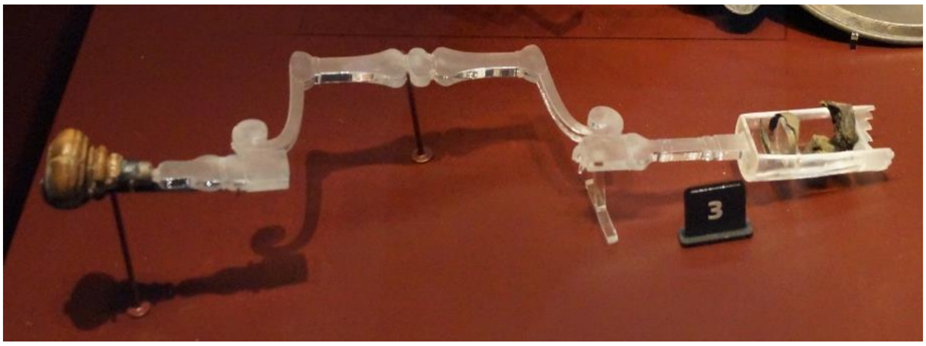


Fig 8.19: The reconstruction of the trepan drill on display (as of 2020) in the *Mary Rose* Museum, showing the excavated drill head on the right-hand side.

The appearance of the same instrument, albeit in slightly different formats, spanning almost a century in the written texts, emphasises the likelihood of a similar tool being on board the *Mary Rose*. There is no skeletal evidence amongst the FCS collection that suggests a trepan had been used, but only 24 skulls were present within the collection; a small number compared to the overall crew size at the time of sinking.

8.3.5 Syringes

In addition to the various blades present within the cabin, there were also more specialised implements in the form of metal syringes. Unlike some of the metal implements, which have long since corroded away, these syringes remain intact due to being made from brass and pewter. One syringe was found within the chest and another found nearby, within the Surgeon’s cabin. Both these syringes (see Fig 8.20), the pewter one (80A1741) measuring 260mm and a plunger of 150mm and the second brass one (80A1560), measuring 232mm with a 138mm plunger, had small, rounded tips and it was initially thought that they would have been used to draw pus from abscesses (Rule 1982: 192).

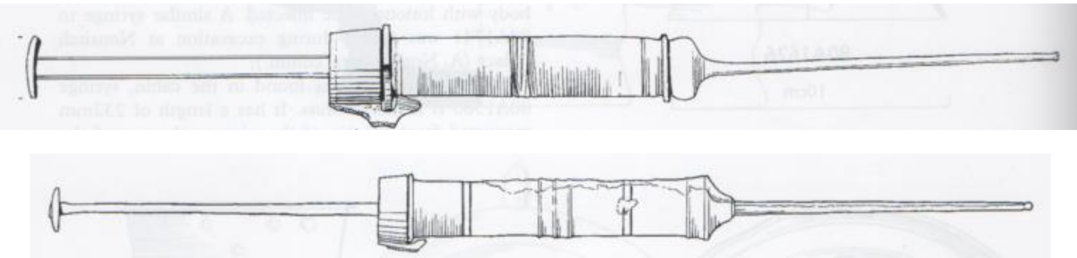


Fig 8.20: The two syringes found within the Surgeon’s cabin, the top one (80A1741) made of pewter, the bottom (80A1560) made of brass (Castle 2005: 206)

Contemporary surgical texts also provide other uses for syringes, including the surgeon Ambroise Paré who describes using a small syringe for urethral injections designed to treat bladder stones and gonorrhoea. The use of syringes in the treatment of gonorrhoea is also discussed by the military surgeon John Woodall, who also lists further possible uses of syringes in the treatment of constipation, ulcers and fistulae (Rule 1982: 192, 193). In addition to these two syringes found in the Surgeon’s cabin, a third syringe was uncovered from O11 which was revealed to be different in size and structure to the examples found in the Surgeon’s cabin. This third syringe was made of a copper-alloy and was smaller in size measuring 80mm with a 136mm plunger. The tip of the needle was also found to be much shorter and sharper than the others. It is difficult to determine whether these differences in the three syringes is due to a different manufacturer being responsible for their construction, or whether it denotes different uses (Castle 2005: 205). John Woodall's book *'chiefly for the benefit of young sea surgeons'* states the importance for surgeons to have at least two or three syringes, each with three tips, prepared and ready at any one time within their chests for use whenever they were needed. The presence of two syringes within the Surgeon's cabin as well as the third discovered on the Orlop deck suggests the surgeon on the *Mary Rose*, whomever they may have been, was fully prepared to treat the men under their care on board the ship (Rule 1982: 193).

8.3.6 Miscellaneous Equipment

Along with the more recognisable surgical tools, such as the blades, saws, and syringes, are a series of other pieces necessary for the surgeon to carry out his duties in the care of the crew. One of the more distinctive items is a turned wooden feeding bottle (80A1555) (see Fig 8.21), of a type that appears to be unique in England from the time (Castle 2005: 212; Wood and Hather 2005: 213).

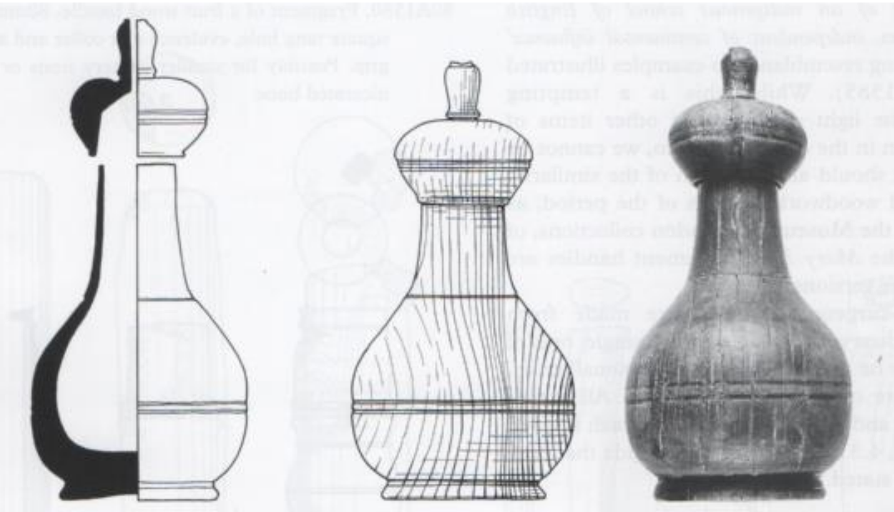


Fig 8.21: Photo of the feeding bottle (far right) with two archaeological illustrations showing the structure of the bottle and the lid (Castle 2005: 212)

The bottle consists of a hollow wooden body, to which a lid can be firmly attached, providing a watertight seal (Wood and Hather 2005: 213), necessary if the bottle is to be upended for the purposes of feeding someone. Its presence within the Surgeon's cabin on board the *Mary Rose* clearly denotes its function as a device for feeding crew members who were sick, suffering facial injuries, or otherwise unable to consume food as they normally would (Castle 2005: 212, 213). The presence of the feeding bottle is not the only example of such care being available; a wooden spoon (80A1675) (see Fig 8.22) has also been suggested as a feeding spoon for invalided crew members (Castle 2005: 214). This is not the only supposed function of the spoon. It has been suggested that it was also intended to be used to measure specific quantities of ingredients. Both functions have been suggested due to the shape of the spoon not being that of a standard eating spoon of an almost circular bowl, as opposed to the 'U' shaped bowl found in this example (Castle 2005: 213, 214).

Fig 8.22: Possible feeding spoon found within the cabin (Castle 2005: 212)

The poor dental health of the crew members could indicate that such feeding implements as the bottle and spoon would have been particularly beneficial when treating such individuals. Some individuals, such as FCS #10, show extensive caries of the molar teeth, likely making mastication a difficult, if not painful, experience. Ante-mortem tooth loss was also seen in several individuals, FCS #5 shows the ante-mortem loss of all but one mandibular molar, along with the ante-mortem loss of all but two maxillary molars; though the remaining molars are represented only by the roots. Eating with such poor dental health would have been difficult for the individual on a day-to-day basis, if they were taken ill through an accident or disease, the ability to provide a limited diet through a bottle and feeding spoon may have been the only way to sustain such a patient.

8.4 Salves, Ointments, and Unguents

The exact contents of the multiple jars and canisters found within the medical chest was not immediately apparent upon excavation, and subsequent chemical analysis was required. Several different analytical techniques were used, with the initial stage of analysis to ascertain the nature of the sample comprising a visual inspection under a microscope and a basic elemental composition analysis. Further study was then carried out using X-ray Fluorescence Spectrometry and Gas Chromatography/Mass Spectrometry to identify mineral elements and organic compounds (Allen 2005: 636). An important factor that had to be considered was any change that may have occurred to the chemical makeup of the substances as a result of an extended period of time submerged in seawater (Derham 2005: 219). Fortunately, the excellent level of preservation found in other areas of the ship, was also apparent in the Surgeon's cabin. Several jars with their stoppers intact were found inside the medical chest, the added protection of the chest around the sealed canisters resulted in some of the best samples for chemical analysis. These help to show what the surgeon may have had at their disposal for the treatment of the crew (Derham 2005: 222).

Such chemical analysis on the samples has enabled a far more comprehensive understanding of the equipment available to the Surgeon on board, and the types of conditions he would have been able to treat as a result. Contemporary medical texts reveal that various pharmaceutical elements and preparations were considered necessary for a surgeon to have access to, in order to successfully treat patients. The samples taken from the *Mary Rose* canisters and jars reveal a wide range of treatments that would have been available to the crew on board. The various preparations were not only found contained within the jars of the medical chest, but also impregnated in a roll of bandages. The bandages were initially considered to be 'unguent rolls', a method of storing raw materials and various compounds in a matrix, ready for use (Derham 2005: 219). Further analysis revealed them to be rolled linen bandages, impregnated with pine oleoresins and coniferous tar (Derham 2005: 222). Due to such additions to the bandages, it is thought that they would have been used for the binding of broken limbs; the resins and tars would have set solid when dry, effectively producing a cast around the affected area (Derham 2005: 223).

Peppercorns were found in various containers throughout the *Mary Rose*, the biggest sample came from the contents of the medicine chest. The value of peppercorns was quite high; thus, it is likely that the various quantities of peppercorns found on the *Mary Rose* were present for medicinal, rather than culinary, purposes (Rule 1982: 189, 192). The presence of peppercorns found within one of the wooden canisters demonstrates the day-to-day care that would have been provided by the surgeon, not just his surgical procedures. Brunschwig (1525) states that peppercorns and mustard seeds, when chewed, provide a remedy for headaches and coughs (Brunschwig 1525; Castle 2005: 221). The contents of other canisters and their uses within Tudor medicine also shed light on how the surgeon may have been able to treat the crew. Various different oils were found; this is an ingredient mentioned frequently in many of the contemporary texts.

However, there are some substances that are mentioned frequently within the contemporary texts, but do not appear in the chemical analysis of the contents of various jars and canisters. Oil of roses appears frequently in the treatment for fractures in the texts of Brunschwig (1525), Banester (1633: 287), Paré (1634: 565) and Clowes (1588), with rose water being used by Gale (1563). Woodall (1655: 48) states that oil of roses is beneficial to wounds of the head and ‘elsewhere’, while also having many diverse uses within surgery. Despite its frequent mentions within the texts, rose oil has not been identified within any of the samples taken from the medical chest of the *Mary Rose*. Similarly, eggs, particularly egg whites, are mentioned with great frequency in various remedies, particularly in the soaking of bandages, often alongside oil of roses, yet do not appear in the Surgeon’s cabin

8.5 Summary

It is unfortunate that no record of the surgeon on board the *Mary Rose* in 1545 has been found, and that their remains cannot be identified from amongst the crew. However, the evidence provided by the preserved medical chest in the surgeon’s cabin can help provide some information as to their status. The velvet coif, along with the well-made chest and other belongings, suggest an individual of standing. The possible foreign construction of the chest, along with the jugs, wooden canisters, and glass jars found within it, could also point to a surgeon who had trained on the continent. Due to the corrosion of metal over the centuries, instruments that would have been entirely constructed from metal have likely completely disappeared from the surgeon’s cabin, leaving no trace. Similarly, the metal elements of tools such as knives, saws, cautery irons, and drills have also corroded away. With this latter group, the wooden handles have often survived, giving an indication as to the number and type of instruments that may have originally been present. The contemporary texts, particularly the illustrations, provide a valuable source for identifying what instruments would be expected for a surgeon at sea. Some, such as Woodall, provide lists of equipment clearly laid out, whereas others, such as Paré, provide numerous detailed illustrations of tools ranging from needles to trepan drills. These texts can help fill the gaps in the archaeological record by providing lists and illustrations of the surgical instruments being used during the 16th Century. In turn, such information can help provide a greater understanding as to what tools would have been necessary for the surgeon on board the *Mary Rose* to carry out their duties successfully. Information provided by the texts is particularly useful for identifying tools of an all-metal construction, such as shears, tongs, and forceps, which do not survive in the archaeological record but appear frequently within the contemporary texts.

While the archaeological excavation of the Surgeon's cabin and chest has revealed the marine environment has had a detrimental effect on certain items, particularly of metal construction, the cabin and chest have provided an overview of the procedures the surgeon would be able to carry out. The presence of smaller, folding blades, in the form of razors shows the more mundane tasks that would be expected to be carried out in the cabin, such as the barbering of the crew. Alongside this is evidence of larger, more specialised blades and instruments, such as the amputation saw and trepan drill. This shows the surgeon would have had the tools necessary to perform more extreme surgical procedures that may be required after a battle. The chemical analysis of the canisters, jars, and bandage rolls also show a range of treatments, from the remedy for headaches and coughs seen in the presence of the peppercorns, to the ability to bind and set broken limbs with resin-impregnated bandages. The medical chest shows the tools needed to be an effective surgeon to the crew in peacetime, and the instruments needed to attempt to save the crew after battle.

9. Discussion

This study is comprised of three main study areas; the human remains, the medical chest uncovered from the wreck of the *Mary Rose*, the contemporary 16th medical and surgical texts. While these three elements were studied individually they need to be combined in order to create an overall understanding of the health and medical care available on board ship. The treatments laid out in the contemporary texts cover a wide range of ailments, such as disease, soft tissue injury, and trauma to bones. The 16th century in particular saw an increased interest in treatments regarding gunshot wounds. While firearms had been around since the early 15th century, the increase in accuracy and power of such weapons during the 16th century (Hernigou 2015: 976) lead to a need for more effective treatment. Surgeons such as Gale, Clowes, Woodall, and particularly Paré, all wrote on the treatment of gunshot wounds. It is clear from the prevalence of such treatments that firearms were a frequent cause of injury in warfare. However, unless such injury affected the bone, it will not be possible to see any evidence within the skeletal collection of the *Mary Rose*. Even if such an injury were sustained to the bone, establishing the exact cause of pathology within dry bone is difficult. As such, it is the treatments relating directly to the bones and teeth that are examined within the contemporary texts and related to the conditions seen within the FCS collection.

It is not only the written treatments laid out in the Tudor texts that provide an insight into how various ailments were dealt with; the addition of illustrations in many of the texts helps to provide a visual aid to the descriptions of treatments, and of the tools necessary for such treatments. The first example of a surgical text containing depictions of instruments is by Albucasis, c.1000 AD (see fig 4.4), although the accuracy of the depictions is hard to determine (Kirkup 2006: 25). By the 16th century, depictions of tools, as well as treatments, are far more detailed; providing both the contemporary and current reader with a clearer comprehension of tools and methods available.

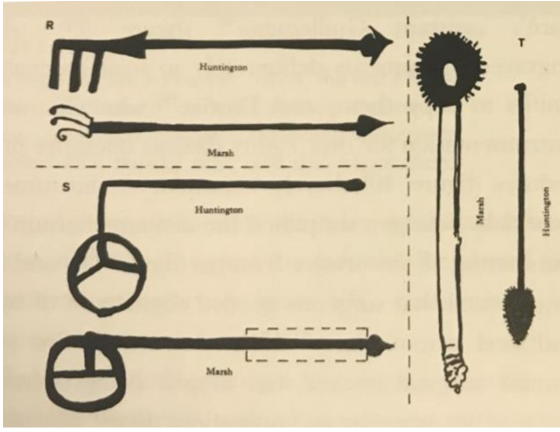


Fig 9.1: Albucasis instruments from the Marsh and Huntington manuscripts (Kirkup 2006: 25)

However, not all the texts studied include such illustrations, and those that so can vary considerably in the number and quality of the depiction. The texts of Vicary and Banester do not include any illustrations, though the reason for Vicary may be due to the text being a reproduction of a 13th century text, as opposed to his own work. Despite being the earliest text, the work of Hieronymus Brunschwig provides some of the most detailed depictions of treatments, providing an invaluable source as to how surgeons operated in the 16th century (Hernigou 2015: 2083). These include full page illustrations showing the use of large pieces of equipment designed for the reduction of fractures or the straightening of limbs. One such example is described as '*An inſtrument to make a croked knee ryght'* (fig. 4.5), showing the leg of a patient strapped into a device with the surgeon operating a pully system to straighten the limb.

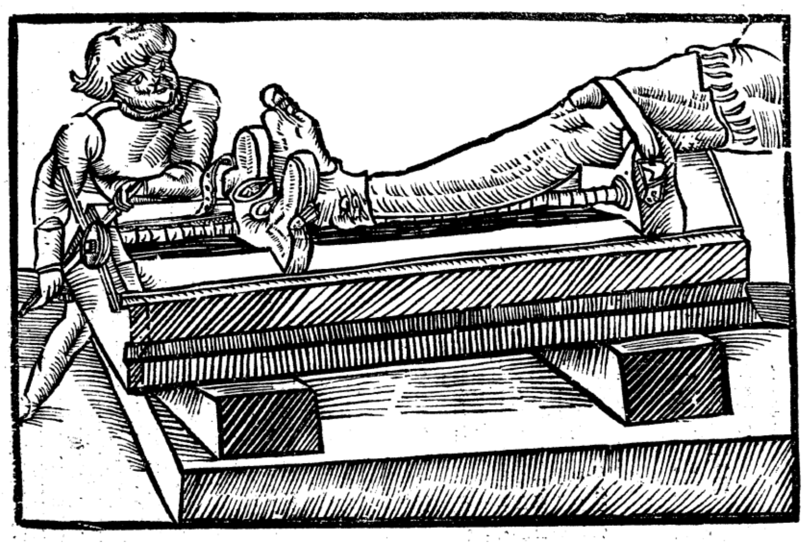


Fig 9.2: Illustration of an instrument to correct a 'crooked' knee (Brunschwig 1525)

Brunschwig has many other similar depictions of a similar device being used in the reduction of dislocations and the splinting of a broken leg. However, other illustrations show less specialist equipment, such as a simple bench, being used to apply salves by the surgeon. Such depictions can help provide a visual guide for the surgeon, as to how a treatment should be carried out. Illustrations in medical texts increased throughout the 16th century, providing a standard image reference for practicing surgeons (Sarton 1955: 167). The illustrations found within works such as Brunschwig, Paré, Gale, and Woodall also provide information as to what tools and equipment may have originally been on board the *Mary Rose*.

9.1 Fractures

One of the most obvious bone-related treatments in the texts are the treatments regarding fractures. Vicary makes little mention of the treatment of fractures in his text, aside from a remedy for *‘Of Wounds in the Head, with fracture of the Bone’* (Vicary 1599: 67). This is unlike the other authors who dedicate specific chapters or books to the treatment of such injuries. There is a consistency of the method of fracture treatment across many of the texts. Both Brunschwig (1525) and Banester (1633: 286) state that a fracture that occurs closer to either the proximal or distal end of a bone are harder to treat, than fractures that occur mid-shaft. Diagnosis of fracture is often done by the surgeon feeling the site of the injury; Brunschwig (1525) notes the site can often feel hot to the touch, while Paré describes the ‘crackling’ of the bone that can be felt (Paré 1634: 562).

For all texts, the initial stage of resolving a fracture is the reduction of the injury in order to unite the two ends. Such a task, particularly when involving large bones such as the arms and legs, is not possible with only one individual. Gale (1563) describes how it is necessary to place the patient on either a chair or bed and for two individuals to be involved in order to reduce a fracture satisfactorily, with one above and one below the fracture site. Should even this method prove ineffective for reducing the fracture, Gale further states that bands are required to extend the affected limb. Using straps tied above and below the fracture site, two men must then stand at the head and feet of the patient in order to pull the bones with more force. This same treatment using straps or towels to provide more force when reducing a limb is also described in the texts of Banester (1633: 287), Paré (1634: 654) and Clowes (1588). Once the limb has been successfully reduced, it must be kept immobile to allow for the healing process to take place. Again, there is consistency in the process of binding and supporting the fractured limb within the texts. According to Gale, soft linen impregnated with egg whites and rose water should be placed over the fracture site and surrounding area. The eventual binding of the limb must not be too tight as it may affect the 'nourishment' that is able to reach the fracture site, and cause a flare of 'humours and inflammation'; but nor must it be too loose, which would cause the bones to become separated again. Gale states that the exact tightness should be determined by the surgeon binding the leg, as well as the comfort of the patient. Two rolls of soft cloth are required to bind the limb, both of which should be soaked in a mixture of wine and water before beginning. The first soft cloth should be wrapped around the fracture site initially between 3 and 5 times before rolling upwards to the sound part of the limb. The second roll must then be, again, wrapped around the fracture site and then downwards to the sound part of the limb, before moving back up to finish at the top part of the limb where the previous roll finished. If a splint is to be used to provide further stability, Gale states that it must be smooth and not crooked, but also thicker in the middle where it will support the fractured point of the limb. Further detail for the binding of a limb is provided by Clowes who writes that a bandage for a fractured leg must be '*two yeards long and foure fingers broade'* (Clowes 1588).

Splints are frequently used when setting a limb; Brunschwig provides various materials that are deemed suitable, such as wood, horn, iron, or stiffened leather. Whichever material is used, the ends of the splints used should not touch or cause pain to any joint near fracture. This particular treatment is attributed to Albucasis, a 10th century Arabic surgeon from Andalusia in Spain (Al-Benna 2012: 379; Amr and Tbakhi 2007: 220). This suggests that such a use of splints at the time of the sinking of the *Mary Rose* would not have been new; it would have been the accepted fracture treatment for centuries. As many splints as needed should be applied to the fracture, and then the whole should be bound in bandages soaked in egg whites. In addition to the written description of treating fractures, Brunschwig also provides an illustration of a patient having their leg splinted and bound (see fig 4.2).

Splints are shown to be of particular use in the work of Woodall (1655: 149, 150). He initially states in the opening page of his text that he does not use rolls of bandage in order to immobilise the leg, as earlier surgeons had done. Rather he uses splints, 'clowts' and tape. His reasoning for doing so is that the continuous movement required to adequately wrap a fractured leg with a roll of bandage being passed under and over the limb repeatedly, results in discomfort for the patient, as well as a risk that the hitherto reduced fracture may become misaligned. The initial setting of the bone and the subsequent immobilisation and rest then required of the patient is the main focus of his treatment; that if these two elements are carried out satisfactorily then a simple fracture would require nothing else to treat it. The previous treatment seen in earlier texts however, with the continual lifting of the limb in order to roll bandages around it, is seen as a hindrance to the process of healing.

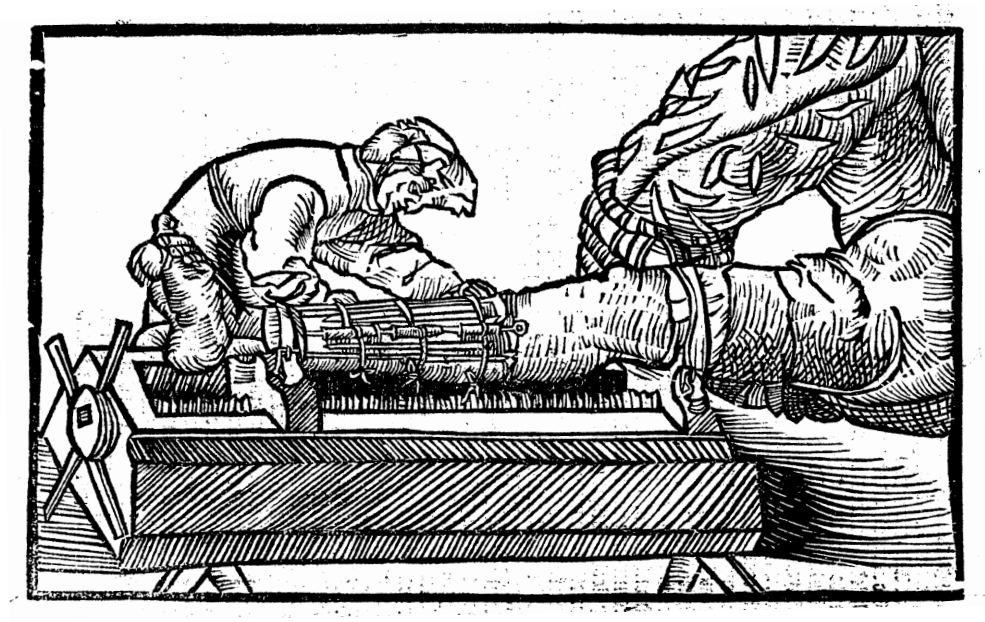


Fig 9.3: Illustration from Brunschwig of a fractured limb being bound with splints (Brunschwig 1525).

Long bone fractures feature prominently in the texts, likely as such fractures pose the greatest risk to the patient, but other, smaller fractures are also mentioned. For nasal fractures, Brunschwig initially describes the placement of fingers and the manipulations necessary to realign such a fracture, requiring no other instruments. However, if the nose is too small for fingers to be inserted, a small piece of wood, covered in linen cloth, and dipped in oil of roses can be used instead. Once the fracture has been realigned, he states a mixture of wax, mastic powder, and

'Dragon's blood'; a deep red plant sap that has been used by many different cultures for millennia (Gupta *et al* 2008: 362), should be mixed with oil of rose and inserted into the nose. Should there also be an open wound on the nose, Brunschwig suggests the use of sutures to close it, the dressing of which should be changed twice a day.

The healing time for fractures varies depending on the bone. Gale (1563) and Banester (1634: 286) both state that the healing of long bones can take up to 40 days, whereas the nose only requires 18 days. The healing of a nasal fracture according to Brunschwig is slightly shorter at 12 days. Brunschwig also provides the healing times for the cranium; 11 days, and the ribs; 20 days. The necessity of keeping fractures immobilised for a period of time would be more difficult on board a ship, than it would be on land. The surgeon would not only have to contend with the constant moving of the ship on the water, but also restricted space in which both his own duties, and other crew members duties, had to be carried out.

9.1.1 Treatment of Fracture on the *Mary Rose*

The initial phase of treating a fracture would be the reduction of the injury, followed by binding with bandages and splints. A common component of such treatment is the use of eggs, particularly egg whites in which many of the bandages are soaked before application to the fracture site (Brunschwig 1525, Gale 1563, Paré 1634, Banester 1633, Clowes 1588). Despite all the preserved elements found within both the Surgeon's cabin and the medical chest on board the *Mary Rose*, there is no evidence of eggs. However, this does not necessitate that eggs would not have been present at the time of the sinking, all trace of which has subsequently been removed by the passage of time, or by marine life. The bandaging and immobilisation of the affected limb is another key element to the treatment of fracture; much as it is in modern medicine, with many of the 16th century surgeons using splints where necessary. There is no direct evidence of splints, wood, metal, or any other material found within the cabin or the chest. As with the eggs, or the metal elements of the surgeon's tools, this could simply be due to a lack of preservation of thin strips of fragile material. However, despite this, there is evidence that the surgeon would have been able to immobilise a limb effectively with bandages. The rolls of bandages found within the cabin were impregnated with pine resins, resulting in bandages that would set firmly and function as a splint (Castle and Kirkup 2005: 176), potentially without the need of additional support. In the case of the ankle fracture of FCS #1, it is possible that no external medical intervention was required.

The fractures found amongst the crew comprising the FCS collection all appear to be healed or in the process of healing. It is possible that the well-healed femur fracture of FCS #66 would not have been treated by the surgeon on board the *Mary Rose*, but the more recently fractured ankle of FCS #1 could well have been under his care. Such evidence of fractures and the resin-soaked bandages present in the cabin suggests that such injuries were likely a concern, and a recognised risk of being stationed on a warship.

9.2 Dislocations

As with fractures, the treatment of dislocations and subluxations feature prominently within the contemporary medical texts. Similarly, there is also consistency across the texts as to how treatment is conducted. Dislocations are diagnosed through the joint ‘slipping’ out from its correct position and the loss of movement in the affected limb (Brunschwig 1525: Banester 1633: 292; Gale 1563; Paré 1634: 595). The term ‘tumour’ is used by both Banester and Paré to describe the displaced joint head creating a bulge under the skin (Banester 1633: 292; Paré 1634: 595). As with fractures, the first stage of treatment for such an injury is the reduction of the dislocation. For larger bones, this requires some force. Gale cautions that the attending surgeon must apply such force carefully, and with as little discomfort and pain as possible to the patient. Again, as with the reduction of fractures, occasionally additional force would be required in the form of an assistant or straps to increase the strength to reduce the dislocation (Gale 1563; Paré 1634: 597). The importance of reducing the dislocation shortly after the occurrence is emphasised, it is stated that such injuries are seldom fully cured, if a callus is allowed to form (Banester 1634: 293). Paré (1634: 596) further emphasises this caution by acknowledging that if a dislocation is left untreated, the bone may form ‘*a new cavitie in the neighbouring bone’,* at which point a full cure is impossible.

Brunschwig and Paré both provide a list of treatments for dislocation, depending on which bone is affected, starting at the jaw and moving down through the body. Both also provide illustrations demonstrating techniques to restore dislocated bones; particularly those of the arms and legs. Paré in particular provides six methods of reducing a shoulder dislocation, a joint he describes as 'easily dislocated' (Paré 1634: 608). Along with manual manipulation, some treatments also use extraneous equipment in the form of doors and ladders (see fig 2.3).

Fig 9.4: Methods of reducing a shoulder dislocation according to Paré (1634: 611, 614)

Dislocations of smaller bones are not seen as particularly challenging to treat. Banester (1634: 293) states fingers *'make no great buſineſſ'.* Additionally, Paré (1633: 623) also notes that such injuries can be quickly and easily reduced as they are short joints with shallow sockets. For larger joints, care must be taken to ensure that the joint does not dislocated again. Gale recommends the wrapping of the joint in bandages soaked in egg white and oil of roses; as with fractures (Gale 1563). The patient must the remain with the limb in a 'natural position' for around 10 days to complete the cure (Gale 1563). According to Banester (1633: 294) Splints may also be used to stabilise the injury, but rather than the wood used for fracture, splints of stiffened leather and pasteboard are used. The time for recovery is matched with Gale at 7-10 days (Banester 1634: 294).

Woodall's text differs slightly in how he presents the information on dislocations. He states that he has known men to perform 'skilfull work' on dislocations, has read a number of texts on the treatment of such, and treated the condition himself (Woodall 1655: 153). Despite this, he cannot describe the treatment adequately to encompass all dealings with dislocations. One of the reasons is that there are so many variants in both the cause and the treatment of such, that he would be unable to cover all in enough detail as part of his text. In order to ensure the limb is correctly reduced, Woodall recommends using the other non-dislocated limb as a guide as to what the correct form should be (Woodall 1655: 154). Some of Woodall's own personal experiences are mentioned, wherein he treated a man for a dislocated shoulder and the patient was able to return to work the same day (Woodall 1655: 154). This is different to the earlier texts of Gale and Banester which prescribe the binding and resting of a limb for 7-10 days after the reduction has occurred.

9.2.1 Treatment of Dislocations on the *Mary Rose*

As with fractures, the first step of treatment for any dislocations suffered by the crew would be the reduction of the injury. Subsequent binding of the injury with bandages soaked in egg white present similar issues to the treatment of fractures on board the *Mary Rose*; that being the lack of evidence for eggs. The hip dislocation present in the FCS Collection would be described as 'outward' in the contemporary texts (Brunschwig 1525; Paré 1634), resulting in the affected limb being shorter than normal. Paré describes placing a patient suffering from such a dislocation on a 'bench or table' (Paré 1634: 627). The wedge bench uncovered in the Surgeon's Cabin could certainly have fulfilled the role of providing a stable surface on which limbs could be manipulated. There is no evidence of any specific instrument associated with the reducing of dislocations. However, some of the texts refer to the use of simple manual manipulation with hands and straps (Banester 1633: 294; Gale 1563). Paré (1634: 611-614) provides illustrations of various methods of reducing shoulder dislocations; some involving manual manipulation, with others requiring the additional use of a board placed under the armpit. Alternatives of this method include the use of rungs of a ladder, or the edge of a door; elements that would have been available on board the *Mary Rose*. Even without specialised tools, the surgeon on board the *Mary Rose*, along with the assistance of other crew members, would likely have been able to treat dislocations successfully.

9.3 Aches and Pains

The treatments for aches and pains with the texts provide more variation than the more universal treatments of fractures and dislocations. Rather than there being a dedicated book or chapter, such remedies are usually spread throughout the texts. Paré (1634: 329) notes the importance of pain management in the curing of wounds. It seems a wide variety of ingredients could be used to relieve pain; Gale provides a long list of medicines, including herbs, figs, lettuce, and various oils. Egg whites and oil of roses also appear (Gale 1563). Though a one-ingredient remedy is provided by Vicary (1599: 257) as *'An excellent Medicine for an Ache or griefe in any Limbe'* which requires raisins to be made into a paste and applied to the affected area. While the ingredients may be wide-ranging, some treatments only require bread, or 'bisket' crumbs. Vicary (1599: 132) combines white breadcrumbs with milk, egg yolk, oil of roses, saffron and turpentine to make a plaster to 'slake pain'. Woodall (1655: 174) simply combines 'bisket' with hot wine or beer in order to 'asswage the pain'

Heat also plays a role in some treatments of pain (Vicary 1599: 271; Banester 1633: 294; Paré 1634: 715; Woodall 1655: 174). Vicary's (1599: 271) remedy for aching joints requires elder bark boiled in urine and applied to the patient *'as hote as you can suffer it'.* Paré (1634: 715) provides his own experience of heat pain management when he fell and hurt his hip. An initial remedy was the application of hot cloths to the area, but he found the skin became blistered from the heat while the joint pain was not relieved. Other remedies such as bags filled with oats and millet, dipped in hot red wine, and an ox bladder filled with hot herbs were found to be far more effective (Paré 1634: 715).

Many of the pain treatments appear throughout the texts, and sometimes as part of the treatment of another injury, such as Banester recommending the limb be bathed in warm water to treat pain during dislocation (Banester 1633: 294). However, Woodall also provides a long list of unguents and waters he deems necessary for a surgeon to have in their chest (Woodall 1655: 31). This is effectively a list of ingredients with which the uses are also noted. For example, *oil of Lumbricarum* [earth worms] is said to help pain in the joints and can be used against convulsions and cramps (Woodall 1655: 48).

9.3.1 Treatment of Pain on Board the *Mary Rose*

It is likely that while conditions such as Schmorl's Nodes, Spina Bifida Occulta, and Osteochondritis Dissecans would have been unknown to the surgeon on board the *Mary Rose*, the effects they may have had on the individual sufferer may have been more known. A likely all-male crew involved in an active lifestyle, combined with the manoeuvring of heavy equipment, no doubt would have suffered from the effects of these conditions in the form of back and joint ache. Unlike the treatment of fractures and dislocations which are clearly defined in the contemporary medical texts and can be linked to the presence of resin-soaked bandages within the Surgeon's Cabin, the treatment of aches and pains is less clear within the archaeological record. This is likely due to treatments regarding pain being less tangible; there is no specialist equipment or instrument to be utilised, but rather ingredients are mixed and applied directly to the affected area as salves and unguents.

Ingredients such as butter, oil and peppercorns were found to be present in the surgeon's chest; components that can also be found in a salve by Vicary (1599: 180) to treat an '*Ache in the backe and legge'.* However, Vicary's salve also includes the addition of ox marrow, egg yolks, and milk, which do not appear in the chest or cabin. One particular sample, taken from one of the wooden canisters within the Surgeon's cabin, revealed traces of a plant oil that was determined to be poppy oil (Derham 2005: 220). Such an oil could be used as a more extreme pain management method, with Gale (1563) describing it as a 'stupefactive'.

9.4 Dentistry

Woodall places great importance on the practice of dentistry at sea. He states that the cleaning of teeth and gums, as well as blood-letting from the gums are normal duties that should be performed in order to maintain the crews' health on board (Woodall 1655: 10). He also highlights the dangers of poor dental care; that if an *apoſtume* [abscess] forms beneath a rotten tooth, resultant swelling in the face and throat could result in suffocation and death (Woodall 1655: 10). Similarly, poor procedures carried out by the surgeon, such as during the pulling of teeth can also result in danger to the patient. Woodall goes as far as to state that no surgeon should go to sea if he is unwilling or incapable of successfully carrying out a tooth extraction on board a ship (Woodall 1655: 10).

Vicary provides several small remedies for the treatment of ailments relating to the teeth and mouth. These range from various treatments regarding pain relief for toothache, to concoctions designed to freshen the breath, or even whiten teeth (Vicary 1599: 73-77). The treatments provided by Vicary for dental conditions are relatively simple, with an emphasis placed on medicinal cure, as opposed to surgical cure, such as through the pulling of teeth. This however could be a result of the age of Vicary's text; with it being based on a 13th century manuscript. For toothache, one of the remedies suggested is as simple as taking a root of the *Acorus* plant, and laying it on the affected area (Vicary 1599: 73). Another treatment involves the boiling of chickweed in water and rinsing out the mouth with the liquid, with the intention of relieving the pain. Similarly, another involves making a decoction of the *hyſope* [hyssop] plant and vinegar; after heating the warm liquid is then used to rinse out the mouth and reduce the pain suffered by the patient (Vicary 1599: 77).

Paré provides a series of medicinal treatments for the teeth in Chapter XXV of the seventeenth book. He begins with addressing toothache, commenting that it is a common ailment (Paré 1634: 656). However, no matter the extent of the pain, Paré does not recommend the immediate removal of the affected tooth; but rather the consultation of a physician, before surgical intervention is required (Paré 1634: 656). The only treatment requiring the removal of teeth in Vicary's text is when bad breath is caused by a rotten tooth (Vicary 1599: 75).

Paré describes toothache as a pain which *'more cruelly tormenteth the patients'* than any other condition (Paré 1634: 656). Other ailments include loose teeth, those that have become 'corrupt and rotten', or 'have worms in them (Paré 1634: 657). The causes of loose teeth are described as either coming from a fall or blow, the defluxion of humours from the brain, or due to a lack of nourishment in elderly patients. The cause of the loose teeth seemingly has an effect on the success of the treatment. If the looseness is caused by 'decaying gums', Paré states that there is nothing to be done, though the patient may want to refrain from speaking too earnestly or chewing hard foods in order to slow the loss of the teeth (Paré 1634: 657). Teeth that have become loose due to a physical cause, such as a blow to the jaw or a fall, Paré cautions not to pull them, but to fasten them to neighbouring teeth that have not been so affected. He claims that in time, the loose teeth will be restored to their original fixed state (Paré 1634: 658). This treatment is substantiated by Paré providing an example of a patient he treated that suffered three loose teeth but was cured by binding the loose teeth with wax thread and feeding him a diet of broth and *gellyes* [jellies] (Paré 1634: 658).

While Paré does not recommend drawing teeth for every ailment, it is necessary in certain instances. According to Paré, risks involved in the removal of teeth include dislocation of the jaw, caused by the surgeon removing the teeth with too much force. It is recommended that the gum is cut and fingers are used to initially loosen the tooth, as he cautions that if a tooth is '*fast in'* then abrupt removal may result in damage to the surrounding bone (Paré 1634: 659). For teeth that are affected by caries, Paré suggests filling the hole with cork, lint, or lead, prior to extraction to enable the forceps to grasp the tooth, without causing it to break. Once the tooth had been successfully removed, the surgeon should allow the blood to flow freely from the wound, before pressing the gum into the space left by the removed tooth. Paré states that allowing the free flow of blood results in the patient being 'freed from pain' (Paré 1634: 652)

Paré mentions some instruments during his description of tooth pulling, along with providing accompanying illustrations. A more comprehensive list of the tools required for the practice of dentistry is provided by Woodall. In his chapter *'On Instruments and their Uses'* he lists seven instruments that he classes as 'needful' in the Surgeons Chest (Woodall 1655: 10). These tools are as follows:

1) Pacis- from the description of use it is a spike used for the removal of multi-root teeth, such as the molars, particularly from the mandible. It is inserted into the gums to aid the removal of the roots. It is stated that care must be taken not to snap the instrument, and that the bigger the tooth being removed, the bigger the pacis should be.
2) Punches or Forcers- similar to the pacis, but better suited for maxillary teeth.
3) Pullicans- a type of forceps best suited for the pulling of single root teeth.

4) Crowes Bills- another type of forceps, suited to the extraction of small fragments of tooth or bone. Can also be used elsewhere on the body to remove similar small fragments of bone.
5) Phlegmes- a small blade similar to a lancet, that can be used to cut into the gum to bleed them, or to aid with the removal of teeth.
6) Gravers- a type of file used ‘to take scales off’; most likely to remove plaque and calculus. Woodall also states graves can be used to ‘scrape and clean’ the bone in other parts of the body.
7) Files- used to smooth and sharp edges of the teeth that may be an irritant to the lips, cheeks, or tongue. As with the graves, files can also be used to smooth fractured bones elsewhere.

As with Paré, Woodall provides a description of tooth extraction. Firstly, the instrument being used, such as the pullicans, must be placed as far down the tooth as possible, in order to ensure the strongest hold or leverage. With one of the surgeon’s hands thus occupied, the other must be used to steady the jaw of the patient. He recommends drawing the tooth in an upwards motion as the best method for ‘saving the jaw’ (Woodall 1655: 10). He cautions the surgeon not to be ‘sudden or rash’ when extracting teeth, particularly with the molars that have multiple roots. The reason for this is that such a violent extraction could cause damage to the gum or cause the roots to break off (Woodall 1655: 11).

9.4.1 Dentistry on the *Mary Rose*

Dentistry does not feature in the medical texts as heavily as other treatments, such as those of fracture and dislocation. However, Woodall does place emphasis on the importance of dental health at sea, with the cleaning of teeth and gums a vital duty to be carried out by the surgeon on board (Woodall 1655: 10). The FCS Collection reveals an array of dental pathology; particularly prevalent are caries and tooth loss. Rather than decaying teeth simply being removed, various authors such as Vicary and Paré put forward suggestion for the treatment of toothache; a condition that Paré views as the most tormenting for the patient (Paré 1634: 656). One such treatment put forward by Paré is the cauterisation of the affected tooth with *Oyle of vitrioll* [sulphuric acid] (Paré 1634: 401). Within the Surgeon’s cabin on board the *Mary Rose*, several small glass vessels were found, it is thought that such containers would have originally held volatile liquids (Castle 2005: 193). The lack of survival of metal tools presents a problem in establishing what dental equipment would have been available at the time of the sinking, but tongs and forceps appear frequently in the texts and accompanying illustrations. Both Paré and Woodall provide a surgical solution for poor teeth; giving descriptions on how to successfully pull teeth, with Woodall stating that a surgeon should not be at sea if he cannot pull teeth (Woodall 1655: 10). Despite this, Paré declares that the pulling of teeth should only be a last resort; based on the evidence of extensive caries amongst the FCS Collection, the surgeon on board the *Mary Rose* may well have followed a similar process.

9.5 Summary

The medical equipment that was found during the excavation of the *Mary Rose* does not represent all the tools listed in the contemporary medical texts. This is likely a result of the burial environment, with metal blades in particular having corroded away in the saltwater environment. The contemporary texts help provide an insight into how various ailments would have been treated and combined with evidence of medical equipment from the chest gives an indication of how treatment was conducted on board the *Mary Rose*. The contemporary texts also provide the opportunity to fill gaps within the archaeological record. For example, the prevalence of eggs used within a range of treatments strongly suggests that such an ingredient would have originally formed part of the surgeon's supplies. It is the combination of contemporary texts that represent the medical knowledge available in the mid-16th century and the presence of the medical chest on board the *Mary Rose* that provide a unique opportunity to provide the analysis of how the surgeon would have been able to treat the crew of the *Mary Rose*.

10. Conclusions

This case study into the medical care on board the *Mary Rose* in the mid-16th century set out to address three factors;

1) What pathology was present within the skeletal material that forms the FCS Collection at the *Mary Rose* Trust.
2) What was the medical knowledge like during the mid-16th Century at the time of the sinking of the *Mary Rose*.
3) What equipment was available to the surgeon to enable him to treat the crew on board the ship.

Each of these factors is necessary to understand whether the medical care on board was sufficient for treating the crew members.

It is clear from the examination of the FCSs, that the crew of the *Mary Rose* suffered from a range of trauma and pathology. Some are a result of more direct trauma from an external force, in the form of fracture and dislocation. Others are a result of degenerative bone changes, likely caused by the hard, physical labour involved in living and working on an active warship. Some of the degenerative bone changes have previously been explored through the work of Ann Stirland (Stirland 1992, Stirland and Waldron 1997, Stirland 2013). However, it is the cause of such changes, rather than the treatment of such, that is addressed in Stirland's work. It as this pathology that formed the basis of the study into the level of medical care available on the *Mary Rose* at the time of sinking in 1545.

The contemporary medical texts of the 16th Century provide a range of treatments that may have been used by a surgeon working as part of a military campaign. They not only define large surgical procedures such as the amputation of limbs, or the reducing of fractures, but also smaller day-to-day elements such as the treatment of pain and dental issues. The texts were originally intended as a guide for surgeons of the day, and in turn provide a modern reader with an insight into how medical and surgical treatments were carried out.

The medical chest uncovered from the wreck of the *Mary Rose* is a rare example of medical instruments from the 16th Century. Despite this, there is not complete preservation of the chest and all the tools contained inside. In particular the marine environment in which the chest sat for several centuries, has resulted in the near-complete corrosion of the metal components of the tools (Castle 2005: 208). Analysis of the contemporary medical texts, along with the illustrations often provided in the same texts, enable a more comprehensive understanding of what equipment may have originally been present in the chest. While there is no archaeological evidence of items such as tongs and forceps (Castle 2005: 208), the varied forms and uses appear frequently in the texts (Brunschwig 1525; Paré 1634; Clowes 1588; Woodall 1655) This suggests the surgeon on board would have had access to such items. The medical texts highlight the range of tools that would have been required for a surgeon to be fully operational while at sea (Woodall 1655: 10).

The combination of the medical chest and the contemporary texts of the 16th Century show that the surgeon on board the *Mary Rose* would have been well-prepared for a range of ailments presented by the crew. The texts demonstrate that treatments for injuries such as fractures and dislocations were well established, with similarities across all treatments (Brunschwig 1525; Gale 1563; Banester 1633; Paré 1634). There is a lack of medicinal ingredients from within the chest and cabin, particularly items such as eggs, vinegar, and oil of roses. However, the frequency and extent that these ingredients appear in the texts strongly suggests that they would have originally been present as part the surgeon’s equipment but have subsequently been lost in the marine environment. Analysis of the FCS Collection showed that many of the crew members presented with pathology, such as Schmorl’s Nodes, Spina Bifida Occulta, and degenerative joint conditions such as osteoarthritis, which would likely have led to pain in the back and joints. The treatment of pain is less clear from the contents of the medical chest. Some ingredients that are mentioned in contemporary pain treatments also appear in the chest, such as the treatment given by Vicary (1599: 180) that includes butter, oil, and peppercorns. Despite this, the evidence provided by the contents of the chest still lack the ox marrow, eggs, and milk.

The dentition across the FCS Collection was generally fairly poor, with some individuals, such as FCS #79, showing extremely poor dental health with multiple teeth lost during life. Dentistry treatments did not feature as prominently in the texts as those regarding either the bones or soft tissues.

The location of the locked chest in the cabin, with tools still inside, also provides potential evidence of how the surgeon functioned when the ship was at active battle-stations. The cabin was located on the Main Gun Deck; an area that would have been both dangerous and demanding during battle. Such an environment would not have been conducive to emergency medical treatment, especially if multiple individuals required attention. The presence of mattresses and palliasses within the Hold (Childs 2007: 86) suggests a system seen in both contemporary and later naval warfare, with the injured crew members being taken to the safer lower levels of the ship (Rule 1982: 184; Watt 1983; 6). It seems likely that basic treatment would take place in the Hold while the battle was in progress, with more drastic surgical intervention happening in the cabin after the conclusion of the battle. If the surgeon was performing surgical procedures in the cabin just prior to the sinking, it seems unlikely that he would take the time to pack items back into the chest before trying to escape the sinking ship. Thus, the packed and closed chest suggests there were no surgical practices taking place in the cabin at the time the *Mary Rose* sank.

There is no record of who the *Mary Rose* surgeon was in 1545, but the chest and contents of the cabin can again provide some clues as to his identity. The velvet coif denotes a member of the Company of Barber-Surgeons and a man of means. Likewise, items within the chest of foreign manufacture, such as the wooden canisters and glazed jugs (Castle 2005: 192, 196), suggest an individual of wealth, who may have trained or practiced surgery on the Continent at some point in their professional life. This would not be completely unexpected, due to the superior education available on the Continent, in regards to surgery (O'Malley 1968: 1).

The contents of the medical chest suggest the surgeon on board was equipped to care for the crew in many different ways. For example, the presence of wooden handles for small blades and razors, could have been used for the barbering of the crew (Castle 2005: 217). However, other items such as the trepan drill, remains of an amputation saw handle, and resin impregnated bandages, show the surgeon was also equipped for more extreme surgical procedures. There is no evidence of procedures such as trepanation or amputation within the FCS Collection. With the *Mary Rose* sinking mid-battle, there may not have been cause for such procedures, or opportunity to perform the surgeries, as the battle was yet to end. Despite this, there is evidence of severe trauma amongst the crew of the *Mary Rose*, such as femur fracture of FCS #66, the fractured ankle of FCS #1, and the hip dislocations and associated fractures of FCSs #9, #39, and #79. While these injuries certainly did not occur around the time of the sinking, the presence of such injuries suggests the very real risk of crew members suffering trauma that would require the immediate intervention of the surgeon.

10.1 Scope for Further Work

The emphasis of the current study was on the pathology displayed by the FCS Collection, and how the surgeon would have treated those on board. However, this study did not incorporate all the human remains that were uncovered during the excavation of the ship. Based on the number of skulls recovered, there are at least 179 crew members represented in the entire collection of human remains. While these individuals may not be represented by a complete, or even near complete, set of remains, an examination of such skeletal material may provide further evidence of pathology amongst the crew. Although it would be preferable to examine any evidence of trauma or pathology in the context of a more complete individual, any evidence of injury or trauma is still representative of at least one member of the crew. By expanding the examination of pathology across the entire collection of human remains, it would also enable a greater percentage of the original crew to be studied. The study of 90 individuals revealed degenerative changes to the spine and joints in multiple individuals, along with leg fractures, and hip dislocations in a handful of others. Including a greater number of remains has the potential to expand on the types of pathology present amongst the crew, and possibly reveal evidence of any surgical intervention. It may also reveal any patterns of injury; for example, much of the traumatic pathology found in the current study, the fractures and dislocations, occurred to the hips and the legs, rather than the upper body.

10.1.1 The ‘FCSs’

During the analysis of the remains, there were various instances wherein the number of individuals that comprised a ‘FCS’ was called into question. In some instances, such discrepancies were clear. The case of FCS #57 and #59, in which the lack of articulation made it immediately noticeable that there were the remains of at least three individuals, rather than two. Other examples include FCS #82 and #83, the two individuals found within the Pilot’s Cabin. While there is no confusion as to the number of individuals uncovered from that particular location, how the bones have been assigned to the two individuals is less certain. The age suggested by the skulls, along with the age suggested by an epiphyseal line on the humerus implies the remains may not have been correctly assigned to each individual.

There has been no investigation into the accuracy of the FCS Collection since the initial work conducted by Stirland in the 1980s and 1990s. Further study would build on this work, and has the potential to improve the accuracy of those classed as ‘FCSs’. A preliminary study could highlight any discrepancies within the current collection; based on the articulation of the bones, ageing of different elements, and in some cases, the number of the bones present. For example, in the case of FCS #42 there are two C7 vertebrae, and two T1 vertebrae present as part of the remains. No other cervical or thoracic spine is present to determine which, if either, of the two vertebrae are correct for that individual. As the human remains, along with the other items uncovered from the wreck, were excavated by sector (Stirland 2013; 67) it is important to maintain these groupings. Remains found in the same sector are more likely to be associated with each other than those in different sectors. The vast majority of the human remains were not found articulated which increases the difficulty of designating specific individuals. However, dive logs from the original dives record which bones were brought up from each sector during each dive. Re-analysis of all bones brought up from a particular sector, along with the FCSs assigned to that sector may increase the accuracy of the FCSs. This has the possibility of being beneficial in sectors where there are only a small number of individuals within the area. Areas on the Upper Deck, and around the companion ways on the lower decks will prove to be more problematic. Large numbers of individuals result in it being harder to ascertain the minimum number of individuals, let alone complete skeletons. The Upper Deck also provides the additional challenge of being more exposed, thus the human remains often display a more advanced level of erosion than seen on those found on the lower levels. This increased level of erosion affects the articulation of the bones, resulting in it being far more difficult to correctly associate the remains as one individual.

While some bones, such as the pelvis, sacrum, vertebrae, and skull, can be closely articulated with each other, this is not the case for all bones. The shoulder only has a small area of articulated bone between the humeral head and the glenoid fossa, with all other attachments of the arm being muscular (Moses *et al* 2013: 164). This results in the humerus, scapula, and clavicle being difficult, if not impossible, to correctly articulate when only dry bone remains. Thus, even with the original dive records to refer to, it may not be possible to identify any 'new' FCSs. A re-analysis of the existing FCS Collection may also result in there being fewer FCSs than previously supposed.

The names of only a few individuals are known from contemporary records of the *Mary Rose*, including Vice Admiral Sir George Carew and Captain Roger Grenville (maryrose.org). To these, an additional name has been suggested through the name 'Ny Coep', inscribed on a wooden bowl uncovered from the Upper Deck of the wreck (Weinstein 2005: 448). However, the personal identification of these individuals; linking the remains of the individual back to a specific name (Christensen *et al* 2014: 379), is likely impossible with no other archaeological evidence to distinguish the individuals. Despite this, there is still great interest in the crew of the *Mary Rose*, as shown through the popular public reception of the 2019 documentary '*Skeletons of the Mary Rose: The New Evidence'* (Channel 4, Avanti) that revealed the ancestry of certain crew members. A member of the public may not necessarily be able to accurately imagine what life on board a Tudor warship would have been like, but the analysis of the skeletal remains helps reveal a more human face to the history of the *Mary Rose*.

10.2 The Importance of the *Mary Rose*

Other battlefield assemblages reveal how soldiers were killed during battle, and what weapons may have been used to strike the final blow. Excavations from the Battle of Visby, Gotland revealed the remains of 1185 individuals killed during the battle in 1361, unusually many individuals were buried still wearing their armour (Tracey and DeVries 2015: 41, 42). Many individuals found had evidence of distinctive sword and puncture wounds, particularly to the head and the likely cause of death (Tracey and DeVries 2015: 117). Excavations conducted at Towton, England, also revealed the remains of soldiers exhibiting weapons trauma, particularly to the head (Novak 2007: 90). The examination of human remains at both these sites reveal the effects of warfare on the death of individuals; how they died, and the weapons used. The *Mary Rose* provides a different view of warfare. The death by drowning results in a wider range of the fighting force being accessible; not only those who were killed because of a weapons-related trauma. It enables the age, stature, and health of a crew to be assessed; it is a more accurate representation of a fighting force in its entirety. It includes fighting individuals who would have manned the cannons on the Main Deck, or shot arrows from the Upper Deck, but also individuals from the Hold who may not have taken an active role in the fight, but were still part of the crew of a warship. The presence of a Surgeon's Cabin and stocked medical chest, combined with the medical and surgical texts of the 16th Century reveal the level of medical care that would have been offered to those wounded in battle, or in the course of their duties on board. This study shows that the Surgeon would undoubtedly have been able to care for the crew of the *Mary Rose*.

Skeleton Recording Sheet (FCSs)

Number: FCS 79 (#178)

Found: 1981 H321, 326, 357, 324, 228. Skull: H321a

Location: Orlop Sector 6

Age: YA/A (early-mid 20s)

Sex: Male

Height: 169.57cm ±3.72cm

Bones Present:

Skull and spine Pitting on Occ and Parietals, small lump on right supraorbital/glabella- button osteoma?

Skull				
Bone	Left	Right	Bone	
Parietal	✓	✓	Frontal	✓
Temporal	✓	✓	Occipital	✓
Orbit	✓	✓	Sphenoid	✓
Nasal	✓	✓	Vomer	✓
Lacrimal	✓	✓	Ethmoid	
Zygomatic	✓	✓		
Maxilla	✓	✓	Hyoid	
Palatine	✓	✓	Wormian	
Mandible	✓	✓	Inca	

Spine: Osteophytes and lipping T3-T6 and T9-T12 (biggest on T10 and T11)

Vertebrae			
No.	Present	No.	Present
C1		T6	✓ OLF SN
C2	✓	T7	✓ SN
C3		T8	✓ SN
C4	✓	T9	✓ SN
C5	✓	T10	✓ OLF SN
C6	✓	T11	✓ OLF SN
C7	✓	T12	✓ OLF SN
T1	✓	L1	✓
T2	✓	L2	✓
T3	✓	L3	✓
T4	✓	L4	✓
T5	✓ OLF	L5	✓

Mandibular teeth in good condition despite many maxillary teeth missing AM

Dentition															
X	–	–	–	•	X	X	X	X	X	X	X	X	–	C	C\P
8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8
8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8
•	•	•	X	X	C\S	X	X	X	X	X	•	•	•	•	NP

Single Bones				
%	<25	25-50	50-75	>75
Sternum				✓
Sacrum				✓
Coccyx	✓			

Manubrium present
C1 Attached
Depressions on anterior S3

Key			
Present	•	Not Present	NP
Loss A.M	–	Pulp Exposure	P
Loss P.M	X	Un-erupted	U
Caries	C	Erupting	E
Abscess	A	Sampled	S

Right 3rd Molar- just roots remain

Upper Body

Upper Right					
Bone	P J.E	P 1/3	M 1/3	D 1/3	D J.E
Humerus	✓	✓	✓	✓	✓
Radius	✓	✓	✓	✓	✓
Ulna	✓	✓	✓	✓	✓
%	<25	25-50	50-75	>75	Ribs
Clavicle				✓	11
Scapula				✓	

Upper Left					
Bone	P J.E	P 1/3	M 1/3	D 1/3	D J.E
Humerus	✓	✓	✓	✓	✓
Radius	✓	✓	✓	✓	✓
Ulna	✓	✓	✓	✓	✓
%	<25	25-50	50-75	>75	Ribs
Clavicle				✓	12
Scapula				✓	

UA- Unattached but present

X

Right Hand	1	2	3	4	5
Metacarpals					

X

Left Hand	1	2	3	4	5
Metacarpals					

		Scaphoid	Lunate	Triquetral	Pisiform	Trapezium	Trapezoid	Capitate	Hamate
X	Right								
X	Left								

Hand Phalanges		
Proximal	Medial	Distal

X

R Ulna- Spurring on tuberosity

R Radius- Pitting and PR on tuberosity

R Humerus- Small OD on distal end

- Exostosis on head

L Ulna- PR on tuberosity (minor spurs, less than is present on the right

- Small spurs on olecranon

Scapulae- Both large with big acromions and coracoid processes

Lower Body

	Lower Right					
	Bone	P J.E	P 1/3	M 1/3	D 1/3	D J.E
	Femur	✓	✓	✓	✓	✓
	Tibia	✓	✓	✓	✓	✓
X	Fibula					
	%	<25	25-50	50-75	>75	
	Patella				✓	
	Ilium				✓	
	Ischium				✓	
	Pubis				✓	

Lower Left					
Bone	P J.E	P 1/3	M 1/3	D 1/3	D J.E
Femur	✓	✓	✓	✓	✓
Tibia	✓	✓	✓	✓	✓
Fibula	✓	✓	✓	✓	✓
%	<25	25-50	50-75	>75	
Patella				✓	
Ilium				✓	
Ischium				✓	
Pubis				✓	

	Right Foot	1	2	3	4	5
X	Metatarsals					

Left Foot	1	2	3	4	5
Metatarsals	✓				

		Talus	Calcaneus	Cuboid	Navicular	1st Cun	2nd Cun	3rd Cun
	Right		✓					
X	Left							

	Foot Phalanges		
	Proximal	Medial	Distal
X			

L+R Patellae- Spurs on anterior surface

L Fibula- Badly eroded with rust/metal staining

L Tibia- Similar to fibula regarding erosion and rust stains

R Femur- Slight OD on distal end

- Spurs on lesser trochanter

L Pelvis- Spurring around the edge of obturator foramen

R Pelvis- Sup. Acetabulum healing fracture- dislocation?

Sex and Age Estimations

Cranium Sex Traits	
Trait	Result
Overall Cranial shape	M
Nuchal Crest	PM
Mastoid Process	M
Supraorbital Margin	M
Supraorbital Ridge/glabella	M
Mental Eminence	M
Overall Result	M

Pelvic Sex Traits	
Trait	Result
Overall Structure	M
Overall Shape	M
Greater Sciatic Notch	M
Sub-Pubic Concavity	M
Ischiopubic Ramus	M
Ventral Arc	M
Overall Result	M

Overall Sex: MALE

Dental Wear Age Estimation (Brothwell)					
Maxilla			Mandible		
Tooth	Right	Left	Tooth	Right	Left
1st Molar			1st Molar	17-25	17-25
2nd Molar		17-25	2nd Molar	17-25	17-25
3rd Molar			3rd Molar	17-25	
Averages				17-25	17-25
Overall Age Estimate	Late teens- mid 20s (YA)				

Pubic Symphysis Age Estimation		
	Right	Left
Todd Phase	3	4
Suchey-Brooks Phase	3	3
Estimated Age	20s+ (A)	

Auricular Surface Age Estimation		
	Right	Left
	2	2
Estimated Age	Mid-late 20s (A)	

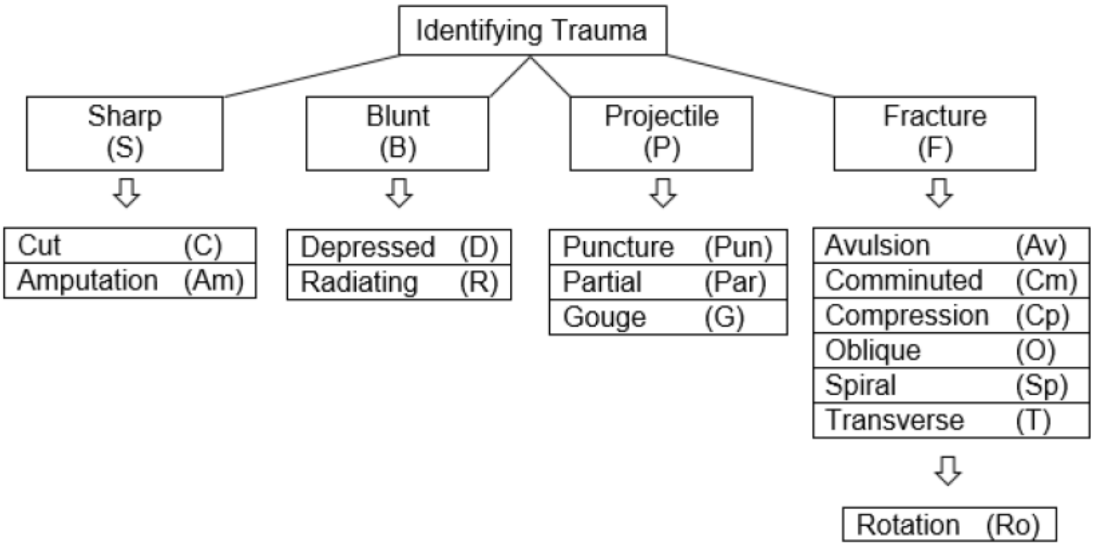
Cranial Suture Age Estimation (Meindl and Lovejoy)					
No.	Site	Score	No.	Site	Score
1	Midlambdoid	0	10	Superior Sphenotemporal	0
2	Lambda	1	11	Incisive Suture	3
3	Obelion	2	12	Anterior Median Palatine	0
4	Anterior Sagittal	1	13	Posterior Median Palatine	1
5	Bregma	1	14	Transverse Palatine	1
6	Midcoronal	0	15	Sagittal (endo.)	
7	Pterion	0	16	Left Lambdoidal (endo.)	
8	Sphenofrontal	0	17	Left Coronal (endo.)	
9	Inferior Sphenotemporal	0	**Total 1-7** 5	**Total 6-10**	0
				Overall Score	5

Key	
Score	Closure
0	Open
1	Minimal
2	Significant
3	Complete

Overall Age Estimation: Young Adult/Adult

Estimating Stature

Long Bone Measurements		
Bone	Max. Length (cm)	
	Right	Left
Humerus	34.30	33.60
Radius	24.35	24.15
Ulna	26.85	26.80
Femur	46.75	47.55
Tibia	38.55	39.45
Fibula	-	38.95



Healing Estimate (Long Bones)		
1	Haematoma Formation	24 Hours
2	Cellular Proliferation	3 Weeks
3	Callus Formation	3-9 Weeks
4	Consolidation	Varies (weeks-months)
5	Remodelling	6-9 years

Traumatic Injury:

Acetabulum shows fracture to the rim, suggestive of a dislocation

Evidence of bone remodelling, healing in process- certainly happened prior to death

Osteophytes and SN on spine suggesting degeneration and possible OA of the spine

Extensive tooth loss, no direct evidence it is caused by trauma rather than poor dental health- as seen in other individuals.

Appendix B

Table B1: FCS Stature Estimation Results

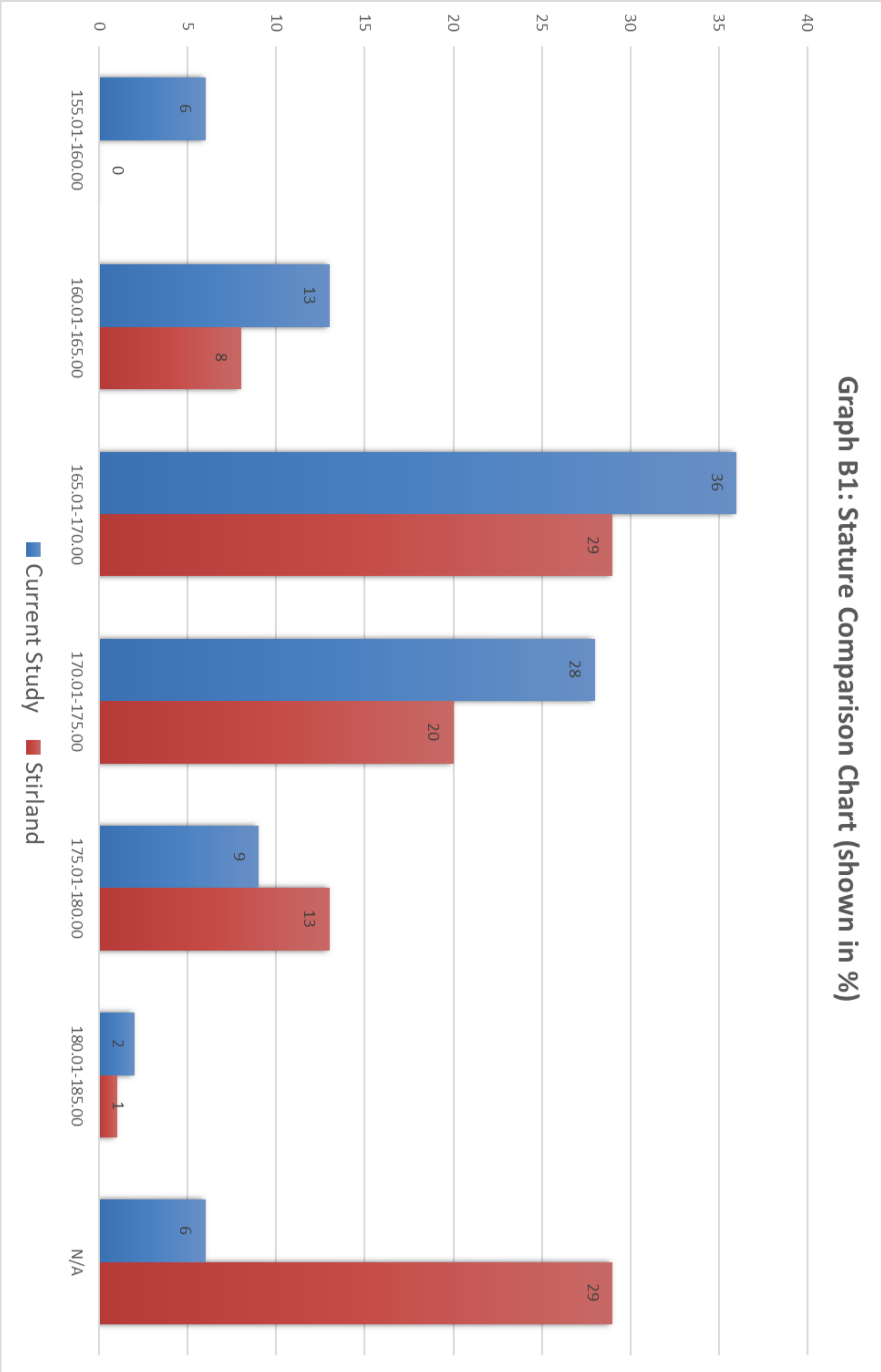
FCS #	Stature	±	Method
1	163.02	1.96	Mays 2016 OLS Male
2	163.79	3.53	Trotter 1970 Black Male
3	171.34	4.30	Trotter 1970 Black Male
4	165.37	1.99	Mays 2016 RMA Male
5	165.38	3.76	Mays 2016 OLS Male
6	166.83	3.63	Trotter + Gleser 1958 Black Male
7	N/A	-	N/A
8	166.68	1.96	Mays 2016 OLS Male
9	169.68	1.96	Mays 2016 OLS Male
10	159.23	1.99	Mays 2016 RMA Male
11	166.68	1.96	Mays 2016 OLS Male
12	167.88	2.99	Trotter 1970 White Male
13	168.01	2.72	Mays 2016 OLS Male
14	179.34	1.96	Mays 2016 OLS Male
15	169.57	2.72	Mays 2016 OLS Male
16	164.14	1.99	Mays 2016 RMA Male
17	160.37	3.96	Trotter + Gleser 1958 Black Male
18	168.51	3.27	Trotter 1970 White Male
19	165.24	1.96	Mays 2016 OLS Male
20	167.38	3.96	Trotter + Gleser 1958 Black Male
21	165.89	1.96	Mays 2016 OLS Male
22	161.85	1.96	Mays 2016 OLS Male
23	166.72	3.91	Trotter + Gleser 1958 Black Male
24	N/A	-	N/A
25	160.63	4.57	Trotter + Gleser 1958 Black Male
26	173.18	3.74	Trotter + Gleser 1958 White Male
27	169.49	3.76	Mays 2016 OLS Male
28	177.94	4.05	Trotter + Gleser 1958 White Male
29	169.81	4.66	Trotter + Gleser 1958 White Male
30	171.30	4.24	Trotter + Gleser 58/70 White Female
31	158.73	3.96	Trotter + Gleser 1958 Black Male
32	171.71	1.76	Mays 2016 OLS Female
33	171.32	3.96	Trotter + Gleser 1958 Black Male
34	173.16	4.00	Trotter + Gleser 1958 White Male
35	173.99	1.96	Mays 2016 OLS Male
36	179.92	3.37	Trotter 1970 White Male
37	171.65	1.99	Mays 2016 RMA Male
38	163.01	2.08	Mays 2016 OLS Female
39	165.89	1.96	Mays 2016 OLS Male
40	170.59	2.99	Trotter 1970 White Male
41	171.71	1.76	Mays 2016 OLS Female
42	166.16	1.96	Mays 2016 OLS Male
43	178.07	1.99	Mays 2016 RMA Male
44	170.73	3.76	Mays 2016 OLS Male
45	177.54	2.78	Mays 2016 RMA Male
46	170.40	3.29	Trotter 1970 White Male

FCS #	Stature	±	
47	170.37	3.63	Trotter + Gleser 1958 Black Male
48	169.05	3.63	Trotter + Gleser 1958 Black Male
49	170.08	3.68	Trotter + Gleser 1958 Black Male
50	171.91	3.62	Trotter + Gleser 1958 White Male
51	173.45	3.53	Trotter 1970 Black Male
52	167.31	3.63	Trotter + Gleser 1958 Black Male
53	163.41	3.63	Trotter + Gleser 1958 Black Male
54	165.80	3.53	Trotter 1970 Black Male
55	N/A	-	N/A
56	N/A	-	N/A
57	-	-	-
58	165.98	3.33	Mays 2016 OLS Female
59	-	-	-
60	171.08	2.30	Mays 2016 OLS Male
61	166.80	3.62	Trotter + Gleser 1958 White Male
62	170.20	1.96	Mays 2016 OLS Male
63	168.11	1.96	Mays 2016 OLS Male
64	180.36	4.31	Trotter + Gleser 1958 White Male
65	174.63	3.76	Mays 2016 OLS Male
66	176.12	3.86	Trotter + Gleser 1958 White Male
67	169.06	3.29	Trotter 1970 White Male
68	173.70	1.99	Mays 2016 RMA Male
69	N/A	-	N/A
70	176.37	3.57	Trotter + Gleser 58/70 White Female
71	167.98	1.96	Mays 2016 OLS Male
72	162.92	2.72	Mays 2016 OLS Male
73	169.03	2.72	Mays 2016 OLS Male
74	167.85	1.96	Mays 2016 OLS Male
75	168.37	1.96	Mays 2016 OLS Male
76	169.17	2.13	Mays 2016 RMA Female
77	161.13	3.96	Trotter + Gleser 1958 Black Male
78	156.99	3.63	Trotter + Gleser 1958 Black Male
79	172.68	3.27	Trotter 1970 White Male
80	172.77	3.63	Trotter + Gleser 1958 Black Male
81	170.46	1.96	Mays 2016 OLS Male
82	164.67	3.94	Trotter + Gleser 1958 Black Male
83	180.71	4.05	Trotter 1970 White Male
84	159.76	1.96	Mays 2016 OLS Male
85	161.82	1.99	Mays 2016 RMA Male
86	158.28	1.99	Mays 2016 RMA Male
87	166.49	3.27	Trotter 1970 White Male
88	167.92	3.96	Trotter + Gleser 1958 Black Male
89	178.13	4.00	Trotter + Gleser 1958 White Male
90	166.89	3.63	Trotter + Gleser 1958 Black Male
91	172.55	3.74	Trotter + Gleser 1958 White Male
92	171.47	3.94	Trotter 1970 White Male

Table B2: Comparison of Stature Estimation with those of Stirland

FCS #	Stature	±	Stirland	±
1	163.02	1.96	163	3.27
2	163.79	3.53	170	3.27
3	171.34	4.30	177	3.27
4	165.37	1.99	167	3.27
5	165.38	3.76	N/A	-
6	166.83	3.63	171	3.27
7	N/A	-	176	3.27
8	166.68	1.96	168	3.27
9	169.68	1.96	N/A	-
10	159.23	1.99	161	3.27
11	166.68	1.96	168	3.27
12	167.88	2.99	168	3.27
13	168.01	2.72	N/A	-
14	179.34	1.96	180	3.27
15	169.57	2.72	N/A	-
16	164.14	1.99	167	3.27
17	160.37	3.96	N/A	-
18	168.51	3.27	170	3.27
19	165.24	1.96	167	3.27
20	167.38	3.96	N/A	-
21	165.89	1.96	168	3.27
22	161.85	1.96	165	3.27
23	166.72	3.91	170	3.27
24	N/A	-	N/A	-
25	160.63	4.57	N/A	-
26	173.18	3.74	175	3.27
27	169.49	3.76	N/A	-
28	177.94	4.05	N/A	-
29	169.81	4.66	N/A	-
30	171.30	4.24	N/A	-
31	158.73	3.96	169	3.27
32	171.71	1.76	174	3.27
33	171.32	3.96	N/A	-
34	173.16	4.00	N/A	-
35	173.99	1.96	175	3.27
36	179.92	3.37	180	3.27
37	171.65	1.99	174	3.27
38	163.01	2.08	N/A	-
39	165.89	1.96	170	3.27
40	170.59	2.99	176	3.27
41	171.71	1.76	174	3.27
42	166.16	1.96	170	3.27
43	178.07	1.99	179	3.27
44	170.73	3.76	180	3.27
45	177.54	2.78	167	3.27
46	170.40	3.29	166	3.27

FCS #	Stature	±	Stirland	±
47	170.37	3.63	174	3.27
48	169.05	3.63	170	3.27
49	170.08	3.68	174	3.27
50	171.91	3.62	172	3.27
51	173.45	3.53	178	3.27
52	167.31	3.63	172	3.27
53	163.41	3.63	168	3.27
54	165.80	3.53	170	3.27
55	N/A	-	N/A	-
56	N/A	-	N/A	-
57	-	-	N/A	-
58	165.98	3.33	N/A	-
59	-	-	N/A	-
60	171.08	2.30	N/A	-
61	166.80	3.62	168	3.27
62	170.20	1.96	172	3.27
63	168.11	1.96	170	3.27
64	180.36	4.31	N/A	-
65	174.63	3.76	172	3.27
66	176.12	3.86	177	3.27
67	169.06	3.29	166	3.27
68	173.70	1.99	174	3.27
69	N/A	-	N/A	-
70	176.37	3.57	178	3.27
71	167.98	1.96	N/A	-
72	162.92	2.72	N/A	-
73	169.03	2.72	171	3.27
74	167.85	1.96	169	3.27
75	168.37	1.96	170	3.27
76	169.17	2.13	N/A	-
77	161.13	3.96	168	3.27
78	156.99	3.63	161	3.27
79	172.68	3.27	175	3.27
80	172.77	3.63	178	3.27
81	170.46	1.96	172	3.27
82	164.67	3.94	168	3.27
83	180.71	4.05	182	3.27
84	159.76	1.96	163	3.27
85	161.82	1.99	165	3.27
86	158.28	1.99	161	3.27
87	166.49	3.27	170	3.27
88	167.92	3.96	N/A	-
89	178.13	4.00	176	3.27
90	166.89	3.63	169	3.27
91	172.55	3.74	173	3.27
92	171.47	3.94	174	3.27


Graph B1: Stature Comparison Chart (shown in %)
0
5
10
15
20
25
30
35
40
155.01-160.00
160.01-165.00
165.01-170.00
170.01-175.00
175.01-180.00
180.01-185.00
N/A
6
0
13
8
36
29
28
20
9
13
2
1
6
29
Current Study
Stirland

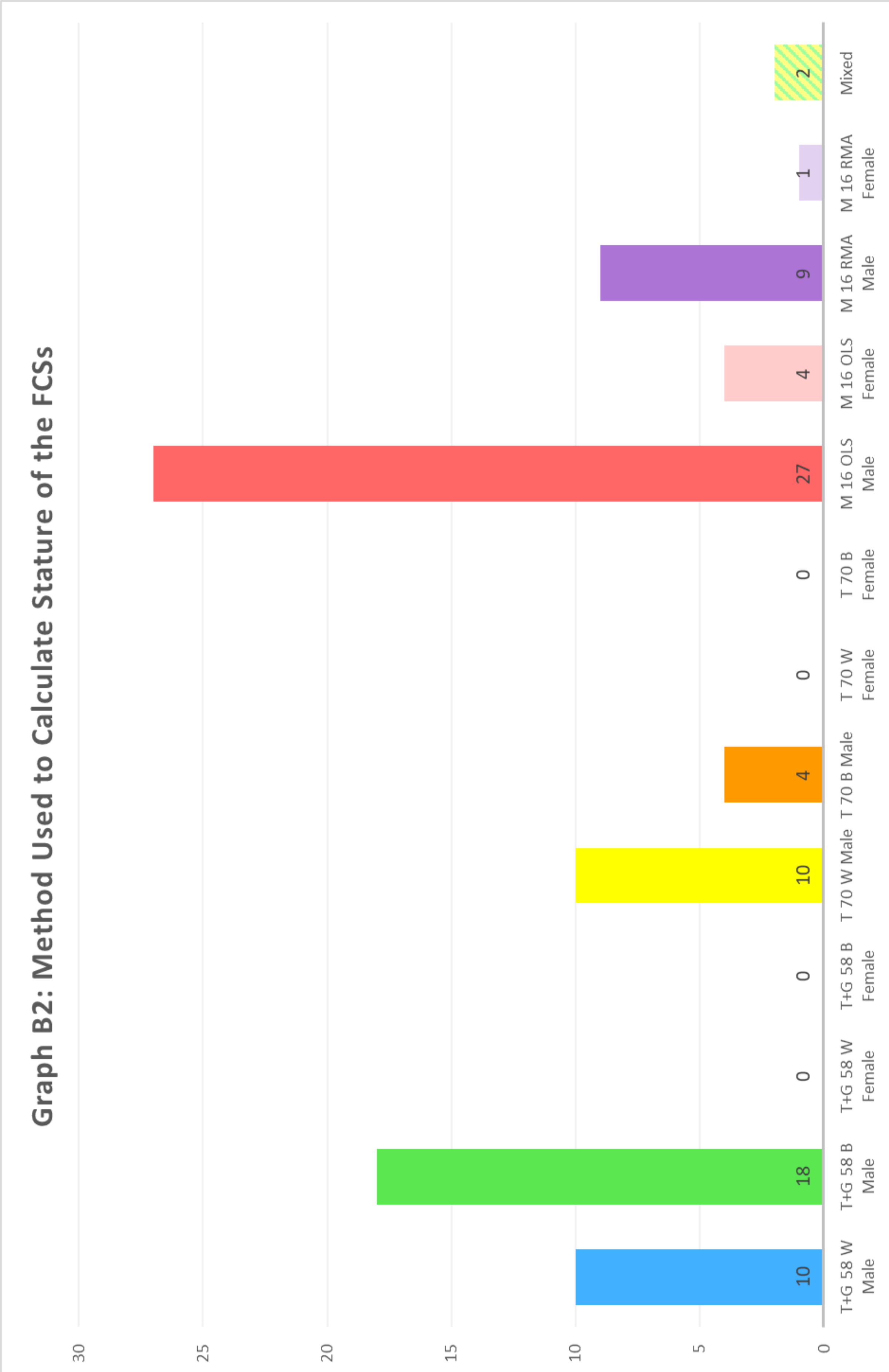

Graph B2: Method Used to Calculate Stature of the FCSs
0
5
10
15
20
25
30
T+G 58 W Male
10
T+G 58 B Male
18
T+G 58 W Female
0
T+G 58 B Female
0
T 70 W Male
10
T 70 B Male
4
T 70 W Female
0
T 70 B Female
0
M 16 OLS Male
27
M 16 OLS Female
4
M 16 RMA Male
9
M 16 RMA Female
1
Mixed
2

Table B3: Ageing of the FCSs

FCS #	Pelvis	Skull	Age
1	A	N/A	**A**
2	N/A	N/A	**(A)**
3	YA/A	N/A	**YA/A**
4	N/A	N/A	**(YA)**
5	A	YA	**YA/A**
6	A	N/A	**A**
7	*	*	**(A)**
8	Ero A?	A	**A**
9	Ad	Ad	**Ad**
10	A	A	**A**
11	MA	MA	**MA**
12	MA	*	**MA**
13	A	N/A	**A**
14	A	N/A	**A**
15	Ad/YA	N/A	**Ad/YA**
16	A	*	**A**
17	N/A	N/A	**(A)**
18	A	N/A	**A**
19	A	N/A	**A**
20	Ad/YA	N/A	**Ad/YA**
21	YA	N/A	**YA**
22	YA	N/A	**YA**
23	A	*	**A**
24	N/A	Ad	**Ad**
25	N/A	N/A	**(A)**
26	A	N/A	**A**
27	N/A	YA	**YA**
28	Ad/YA	N/A	**Ad/YA**
29	N/A	N/A	**(YA)**
30	N/A	N/A	**(A)**
31	Eroded	U/YA?	**U/YA?**
32	N/A	YA	**YA**
33	Ad/YA	N/A	**Ad/YA**
34	A	N/A	**A**
35	MA	A	**A/MA**
36	Ad/YA	N/A	**Ad/YA**
37	YA	Ad	**Ad/YA**
38	N/A	N/A	**(A/MA)**
39	Ero A?	A	**A**
40	A	U	**A**
41	A	N/A	**A**
42	A/MA	N/A	**A/MA**
43	A	N/A	**A**
44	A/MA	N/A	**A/MA**
45	U	N/A	**A**
46	A/MA	N/A	**A/MA**

FCS #	Pelvis	Skull	Age
47	YA/A	N/A	**YA/A**
48	Eroded	N/A	**(A)**
49	N/A	N/A	**(A)**
50	Eroded	N/A	**(A)**
51	A/MA	N/A	**A/MA**
52	U	N/A	**(A)**
53	Ero YA?	N/A	**(YA/A)**
54	N/A	N/A	**(YA)**
55	Ad	U	**Ad**
56	Ad/YA	U	**Ad/YA**
57	-	-	**-**
58	Ero YA?	N/A	**(YA)**
59	-	-	**-**
60	N/A	N/A	**(YA)**
61	YA/A	N/A	**YA/A**
62	Ad/YA	N/A	**Ad/YA**
63	A	N/A	**A**
64	N/A	Ad/YA	**(U)**
65	Ad/YA	N/A	**Ad/YA**
66	A	N/A	**A**
67	A	N/A	**A**
68	YA	N/A	**YA**
69	N/A	YA/A	**YA/A**
70	N/A	*	**(A)**
71	Ad	N/A	**Ad**
72	N/A	YA	**YA**
73	YA	YA	**YA**
74	Ero YA/A?	N/A	**YA/A**
75	YA/A	YA	**YA/A**
76	N/A	N/A	**(A)**
77	A	N/A	**A**
78	YA	N/A	**YA**
79	A	YA	**YA/A**
80	Ad/YA	YA	**Ad/YA**
81	Eroded	A/MA	**A/MA**
82	A	Ad/YA	**U**
83	YA/A	A	**YA/A**
84	MA	*	**MA**
85	U	N/A	**(A)**
86	A	YA	**YA/A**
87	YA	N/A	**YA**
88	*	N/A	**(A)**
89	MA	N/A	**MA**
90	N/A	N/A	**(A)**
91	Ad/YA	N/A	**Ad/YA**
92	YA	A?	**YA/A**

Table B4: Age Comparison with Stirland

FCS #	Current	Stirland
1	A	YA
2	(A)	Ad
3	YA/A	YA
4	(YA)	YA
5	YA/A	YA
6	A	YA
7	(A)	YA
8	A	YA
9	Ad	Ad
10	A	MA
11	MA	MA
12	MA	YA
13	A	YA
14	A	MA
15	Ad/YA	Ad
16	A	MA
17	(A)	A
18	A	MA
19	A	MA
20	Ad/YA	YA
21	YA	Ad
22	YA	YA
23	A	YA
24	Ad	Ad
25	(A)	A
26	A	YA
27	YA	MA
28	Ad/YA	Ad
29	(YA)	Ad
30	(A)	YA
31	U/YA?	YA
32	YA	YA
33	Ad/YA	YA
34	A	YA
35	A/MA	MA
36	Ad/YA	Ad
37	Ad/YA	YA
38	(A/MA)	OA
39	A	YA
40	A	YA
41	A	YA
42	A/MA	YA
43	A	YA
44	A/MA	MA
45	A	YA
46	A/MA	MA

FCS #	Current	Stirland
47	YA/A	YA
48	(A)	YA
49	(A)	YA
50	(A)	YA
51	A/MA	YA
52	(A)	YA
53	(YA/A)	YA
54	(YA)	YA
55	Ad	Ad
56	Ad/YA	Ad
57	-	
58	(YA)	YA
59	-	
60	(YA)	Ad
61	YA/A	YA
62	Ad/YA	YA
63	A	YA
64	(U)	YA
65	Ad/YA	YA
66	A	YA
67	A	YA
68	YA	YA
69	YA/A	YA
70	(A)	YA
71	Ad	Ad
72	YA	YA
73	YA	YA
74	YA/A	YA
75	YA/A	YA
76	(A)	YA
77	A	YA
78	YA	YA
79	YA/A	YA
80	Ad/YA	YA
81	A/MA	MA
82	U	YA
83	YA/A	YA
84	MA	MA
85	(A)	YA
86	YA/A	YA
87	YA	YA
88	(A)	MA
89	MA	MA
90	(A)	A
91	Ad/YA	YA
92	YA/A	YA

Table B5: FCS Sex determination

FCS #	Pelvis	Skull	Sex
1	M	N/A	**M**
2	N/A	N/A	N/A
3	M	N/A	**M**
4	N/A	N/A	N/A
5	PM	M	**PM/M**
6	M	N/A	**M**
7	M*	M*	**M**
8	M	M	**M**
9	PM	PM	**PM**
10	M	M	**M**
11	M	M	**M**
12	M	*	**M**
13	M	N/A	**M**
14	M	N/A	**M**
15	PM	N/A	**PM**
16	M	*	**M**
17	N/A	N/A	N/A
18	M	N/A	**M**
19	M	N/A	**M**
20	PM	N/A	**PM**
21	PM	N/A	**PM**
22	PM	N/A	**PM**
23	M	*	**M**
24	N/A	U/PM	**U/PM**
25	N/A	N/A	N/A
26	M	N/A	**M**
27	N/A	M	**M**
28	PM	N/A	**PM**
29	N/A	N/A	N/A
30	N/A	U	**U**
31	M	M	**M**
32	N/A	U/PM	**U/PM**
33	PM	N/A	**PM**
34	M	N/A	**M**
35	M	M	**M**
36	PM	N/A	**PM**
37	M	U	**PM**
38	N/A	N/A	N/A
39	M	PM	**M**
40	M	M	**M**
41	M	N/A	**M**
42	M	N/A	**M**
43	M	N/A	**M**
44	M	N/A	**M**
45	PM	N/A	**PM**
46	M	N/A	**M**

FCS #	Pelvis	Skull	Sex
47	M	N/A	**M**
48	M	N/A	**M**
49	N/A	N/A	N/A
50	M	N/A	**M**
51	M	N/A	**M**
52	U/PM	N/A	**U/PM**
53	M	N/A	**M**
54	N/A	N/A	N/A
55	PM	PM	**PM**
56	PM	U	**U/PM**
57	-	-	**-**
58	PM	U	**U/PM**
59	-	-	**-**
60	N/A	N/A	N/A
61	M	N/A	**M**
62	PM	N/A	**PM**
63	M	N/A	**M**
64	N/A	U	**U**
65	PM	N/A	**PM**
66	M	N/A	**M**
67	M	N/A	**M**
68	M	N/A	**M**
69	N/A	M	**M**
70	N/A	*	
71	PM	N/A	**PM**
72	N/A	M	**M**
73	M	M	**M**
74	M	N/A	**M**
75	M	M	**M**
76	N/A	N/A	N/A
77	M	N/A	**M**
78	M	N/A	**M**
79	M	M	**M**
80	M	M	**M**
81	M	M	**M**
82	M	M	**M**
83	M	PM	**PM/M**
84	M	*	**M**
85	PM	N/A	**PM**
86	M	M	**M**
87	PM	N/A	**PM**
88	*	N/A	
89	M	N/A	**M**
90	N/A	N/A	N/A
91	M	N/A	**M**
92	M	U	**PM**

Table B6: FCS Sex comparison with Stirland

FCS #	Current	Stirland
1	M	M
2	N/A	M
3	M	M
4	N/A	M
5	PM/M	M
6	M	M
7	M	M
8	M	M
9	PM	M
10	M	M
11	M	M
12	M	M
13	M	M
14	M	M
15	PM	M
16	M	M
17	N/A	M?
18	M	M
19	M	M
20	PM	M
21	PM	M
22	PM	M?
23	M	M
24	U/PM	M
25	N/A	M
26	M	M
27	M	M
28	PM	M?
29	N/A	M
30	U	M
31	M	M
32	U/PM	M
33	PM	M
34	M	M
35	M	M
36	PM	M
37	PM	M
38	N/A	M
39	M	M
40	M	M
41	M	M
42	M	M
43	M	M
44	M	M
45	PM	M
46	M	M

FCS #	Current	Stirland
47	M	M
48	M	M
49	N/A	M
50	M	M
51	M	M
52	U/PM	M
53	M	M
54	N/A	M
55	PM	M
56	U/PM	M
57	-	
58	U/PM	M
59	-	
60	N/A	M?
61	M	M
62	PM	M
63	M	M
64	U	M?
65	PM	M
66	M	M
67	M	M
68	M	M
69	M	M
70	*	M
71	PM	M
72	M	M
73	M	M
74	M	M
75	M	M
76	N/A	M
77	M	M
78	M	M
79	M	M
80	M	M
81	M	M
82	M	M
83	PM/M	M
84	M	M
85	PM	M
86	M	M
87	PM	M
88	*	M
89	M	M
90	N/A	M
91	M	M
92	PM	M

Appendix C: The History of Medicine

App C 1 Early Evidence of Surgery: Trepanation

Before the written word enabled the recording of information, some of the earliest evidence of surgical and medical practice can be found in human skeletal remains. Trepanation, the removal of bone from the skull, is considered to be one of the oldest know surgical procedures (Lorkiewicz *et al* 2018: 626; Gross 2009: 3; Kaufman *et al* 1997: 208). The earliest evidence of trepanation is thought to date to the late Palaeolithic and the procedure has continued to be practiced right up until the present day in both Western and non-Western medicine (Gross 2009: 3; Campillo 1984: 275). Despite the early beginnings of the practice; millennia before the knowledge of germs and infection became widely accepted, skulls with signs of trepanation also provide evidence of the survival of the patient. Despite the evidence of this survival however, it is often difficult to determine with any accuracy how long the individual survived post-procedure with cranial healing patterns often difficult and subjective (González-Darder 2019: 54). While defects in long bones tend to show extensive callus and new bone formation during the process of remodelling, similar reactions are not seen in the bones of the skull (Nerlich *et al* 2003: 49).

While there is evidence for trepanations being carried out from an early period, particularly during the Neolithic (Chauvet *et al* 2010: 421), the exact reason for such procedures has been much debated (Lorkiewicz *et al* 2018: 626). Ancient cultures, such as the Egyptians, Greeks, and Romans, identified a more therapeutic use for trepanation. Hippocrates used it as a form of treatment for head injuries, and Galen and Heliodorus used it for the treatment of splintered fractures of the cranium and close head trauma (Mariani-Costantini *et al* 2000: 305). Galen in particular recognised its use at relieving intracranial pressure (Missios 2007: 3,6). In accordance to their practices, Hippocrates and Galen wrote treatise describing their methods for trepanation which allowed for the continuation of the procedure into Medieval Europe (Missios 2007: 1). Alongside these therapeutic and neurosurgical reasons, trepanation can also represent more ritualistic or magical procedures (Kaufman *et al* 1997: 208). While much evidence of trepanation suggests that the procedure was carried out on a living individual, there are also examples of post-mortem trepanation in which roundels of bone are used as amulets; likely a by-product of the ritual trepanation (Kaufman *et al* 1997: 208, 209). Though the lack of healing may also represent the fact that the patient died shortly after the procedure; as it can take up to five days for a healing response to appear in cranial bone (Barbian and Sledzik 2008: 265).

With regards to carrying out trepanation, according to Kaufman *et al* (1997) and Campillo (1984) there are three main methods:

1) Drilling with a hard, sharp stone; or in later instances a trephine drill, to create a neat-edged, conical orifice
2) Scraping with a hard, sharp stone, that leaves a surrounding abrasive ring and an elliptical orifice
3) Cutting with an incisive instrument, often leaving straight-edged holes

A further method is put forward by Verano (2017), known as 'grooving' in which a circular or oval piece of bone is removed by repeated cuts around the area, similar to cutting but with less oblique and straight edges.

Evidence of trepanation may be apparent within the skull of the individual, along with the method by which it was carried out. However, the reason for such a procedure; whether carried out for a definitive surgical purpose or for ritualistic reasons, is often less apparent. It is often not possible from simply examining skeletal remains, to ascertain whether the individual was suffering from a cerebral condition that would require surgical intervention (Piggott 1940: 121). Despite the lack of clarity as to why some prehistoric trepanations were carried out, the physical manipulation and alteration of the skeletal tissue represents the earliest know evidence of a surgical procedure. The invasion of the 'inner' body through the skull seems to mark a starting point of treating the symptoms or cause of a particular malady through the medium of surgery.

App C 2 The Ancients 200AD

App C 2.1 Egypt

Within the Ancient World one of the most advanced medical cultures belonged to the civilisation of Ancient Egypt. So well renowned was their knowledge that the classical authors of Homer and Herodotus mention in their writings about the skills of the Egyptian physicians. Homer going as far to state that all Egyptians were descended from Paeon, who was the physician of the Gods (Ghalioungui and Dawākhilī 1965: 11). The recognition of their medical skill, known as the 'necessary art', also caused foreigners to make the journey to Egypt to seek treatment themselves and Pharaohs would send their personal physicians to foreign rulers to treat their ailments (Ghalioungui and Dawākhilī 1965: 9). Ancient Egypt provides some of the best written evidence for medical treatise with the survival of 12 medical papyri that vary considerably in content between them, showing a wide scope of medical treatment available. The Turin papyrus, for example focuses heavily on what would be considered 'magical' treatments, on the other hand the Edwin Smith Papyrus focuses far more on rational surgical treatments (Risse 1972: 912). The 'magic' referred to in the texts is a translation of the word '*heka'*, a supernatural force that was believed to have the power to change and influence events and occurrences (Pinch 1994: 9). Such magical treatments stated in the papyri invariably consisted of three distinct elements; an incantation, a ritual, and an amulet. Of these the most important element was considered to be the spoken words of the incantation, with the belief that words of the spoken spell would reach and cure the patient of their ills (Davis 2008: 183). The ritual element of the treatment would consist of gestures or acts performed either on the patient themselves or a representation of the patient; such as a wax image or doll. The ritual element of the treatment may also be accompanied my music and dancing to help transform the individual physical and mental state. In addition to this, substances such as water, wine, oil, incense and perfumes may be used. The final element of a magical treatment would include the use of amulets; the intrinsic power of their shape and material were thought to be able to provide magical protection for the wearer (David 2008; 183).

Despite the strong belief in the magical aspects of medicine and healing, not all Egyptian medical treatise rely on magic; the Edwin Smith Papyrus is of particular importance due to the surgical nature of some of the treatments. An exact date cannot be placed on this papyrus; it is thought to date to around 1700-1600BC, around the XIII Dynasty of the Middle Kingdom, and certainly no later than the Second Intermediate Period (Sanchez and Burridge 2007: 1). Overall the papyrus contains 48 cases, 14 of which relate solely to head trauma. Some of the injuries and trauma described in the papyrus have also been noted as not unlike cases that may be seen in a modern day Accident and Emergency Department, suggesting the severity of some of the wounds being dealt with in ancient times (Rose 2009; 240 and Sanchez and Burridge 2007: 2). The Edwin Smith provides the earliest known example of scientific medicine; treatment that is based on the observation of the patient and a knowledge of anatomy (David 2008: 189). The papyrus itself is set out in a logical manner enabling it to be used easily as a teaching or referencing text. Two different coloured inks are used; black and red. The black ink is used to write the majority of the text, while the red ink is used to highlight separate cases as well as to emphasise important elements of the treatments themselves. Each case consists of a diagnosis of the wound or ailment, followed by the probable outcome of treatment, something that is described in one of three ways: a condition that the physician is able to treat successfully, a condition that the physician is able to treat but the outcome is uncertain as to whether or not it will be successful, and lastly a condition that the physician is unable to treat with any hope of success (Breasted 1930: 6, 7). The cases in the papyrus that link to a certain element of the body are also invariably laid out in order of increasing severity (Breasted 1930: 36); suggesting its value as a teaching or referencing text. From all the major medical texts uncovered from Ancient Egypt, the Edwin Smith papyrus represents the most clearly organised text, demonstrating surgery as a speciality within medicine (David 2008: 189). The subject matter of the Edwin Smith Papyrus, combined with its logical format, make it one of the most important and extensive medical treatise of the ancient world and it is still of interest to medical professionals today. The papyrus is the first known example of the word ‘brain’ being mentioned in any ancient medical treatise, in addition to this there also seems to be an understanding that injuries of the head and/or spine may also be connected to possible neurological complaints (Sanchez and Burridge 2007; 2).

App C 2.2 Greece and Rome

Despite the extensive medical knowledge possessed by the Ancient Egyptians, medical culture in the West began in Classical Greece and Rome. As with the medicine of Ancient Egypt, Ancient Greek medicine also demonstrates both rational and magical cures; that while there were rational healers, there were also those who offered up a religious means of diagnosis and cure; people such as diviners, exorcists and priests (Conrad et al 1995: 16). Again, as with the Egyptian medical papyri there is some written knowledge from the Classical Civilisations that have survived through the centuries; the earliest known surviving Western medical text dates to 420BC and consists of part of the Hippocratic Corpus (Nutton 1995: 12). The survival of these medical texts has been affected by several conditions, one being the method of recording information in the format of scrolls (Nutton 2004: 6), much like Egyptian papyri. Not only were these long, continuous documents difficult to write, they also made the finding of specific information laborious in such a long document. A method to combat these difficulties appeared by the 2nd century AD with the introduction of Codices, a process of recording more in line with the style of a modern book with separate pages (Nutton 2004:6). Medical knowledge that was not transferred from the previous scrolls to the new codices were invariably lost; with the exception of the Egyptian Medical Papyri. In addition to the loss of the original scrolls, the change in writing style in Greece also lead to information slowly disappearing from circulation (Nutton 2004: 6). The continual survival of any of the medical texts from the Classical world was also dependant on the copying and recopying of the information, such as from a scroll to a codex, and various institutions and individuals having the interest and monetary ability to buy such works; thus keeping the knowledge in circulation. Some texts were lost as the knowledge they contained was superseded by the work of contemporary physicians, or the information was deemed to specific or specialised. Many books, including some of those written by the famous physician, Galen, were also lost to fire (Nutton 2004: 4).

App C 2.3 Hippocrates and Galen

One of the key figures in medicine, even today, is Hippocrates who is often declared to be the ‘Father of Medicine’ (Magner 2005: 93), with medical students today taking the *Hippocratic Oath* as they graduate from student to doctor. Hippocrates himself lived between c.460-360 BC and is credited with establishing medicine as both an art and a science. Despite the emphasis placed on his work, very little is actually known of the man himself; some key biographical details would not emerge until several centuries after his death, leading some to speculate about the validity of such particulars. He was said to have been born on the Island of Cos and died in Larissa at the great age of 95 or 110 years old, his ancient biographers provide an astonishing ancestry stating that on his paternal side he was related to Asclepius, and on his maternal side the demi-god Hercules. Not everyone in the ancient world was quite so accommodating in their praise however; one went as far as accusing Hippocrates of purposefully burning down the library of Cos in order to eliminate any medical traditions that would compete with his own (Magner 2005: 93). Despite the various opinions on the man himself the essays attributed to him (50-70 in number) form the basis of Western medicine. Hippocratic medicine was venerated due to the emphasis it placed on the patient, instead of the illness or ailment, and the fact that it relied heavily on observation and experience rather than philosophical doctrines. In contrast to earlier medical belief systems it also paid little heed to elements of magic and superstition- that all phenomena were a part of nature, and thus treated as such (Magner 2005: 95; Getz 1998: 36). Despite the more modern, secular approach to illness and treatment the Hippocratic tradition was still very much grounded in the concept of the Four Humours. These humours made up the living body and consisted of the elements; Air, Fire, Earth, and Water, and it was the imbalance in these four humours that were the cause of illness in individuals. The treatment put forward by the Hippocratic tradition to cure or prevent such ailments was either a change in lifestyle by means of diet and exercise, or medical or surgical intervention (Getz 1998: 30; Magner 2005: 98, 99). Although surgery under Hippocrates referred to the treatment of fractures, wounds, dislocations and other traumatic injuries, as opposed to the modern concept of surgical treatment (Magner 2005: 101). The treatment of wounds in the Hippocratic tradition is generally limited and conservative in nature, with any internal surgery being avoided, with part of the *Oath* specifically stating that any treatment involving the use of a knife should be left to the surgeon (Porter 2003: 110). Unlike some religion-based medicine, the Hippocratic tradition made no pretence towards miracle cures; a disease or illness of a rational cause would have a rational cure. A lasting facet of the tradition was *'primum non nocere',* translated to 'do no harm' and the basis for the Hippocratic Oath to this day (Porter 2003: 29, 30).

If Hippocrates was the Father of Medicine, then it could be argued that Galen is the Prodigal Son. Galen hailed from Pergamum in Asia Minor, born in August/September around the year 129 AD, he was the son of the wealthy architect

Aelius Nicon (Evans 1945: 288; Nutton 1973: 161). His father intended for his son to enter into either philosophy or politics, and no expense would be spared to realise this aim, however Asclepius himself supposedly came to Nicon stating that his son was destined to go into the profession of medicine. At the age of sixteen, Galen was launched into detailed medical studies. After his father's death in 148/149 AD Galen left his learning at Pergamum and travelled to various centres famed for their medical teachings including Smyrna, Corinth and finally to Alexandria. After almost ten years and having returned from Alexandria, Galen was appointed to the post of doctor for the gladiatorial fighters by the high priest of Asia in c.157 AD (Nutton 1973: 162). In 162 AD Galen travelled once again, this time to the city of Rome where his skills in anatomy would make him famous. It is also in Rome that the role of a physician begins to take on a wider scope; that it was not enough to be merely a practical healer but a physician must also master logic (the art of thinking), physicis (the science of nature), and ethics (the rule of action). These principles and the writings of Galen would go on to dominate the practice of medicine and its teachings for the next one and a half millennia (Porter 2003: 32). The longevity of Galen's work is astonishing and is undoubtedly reliant on its use in teaching for its continual transmission over the centuries. The Galenic tradition is essentially a literary tradition- his writings were passed down, to the point whereby in medieval times, a 'physician' was someone who learned the written word and wrote it down; they did not engage in anything as vulgar as the low class trade of surgery (Poynter 1961: 24). In Galen's own works the role of the physician is different to that of the surgeon. There are few references to the practice of surgery in the writings of Galen though this could partly be due to the fact that he was never able to complete his proposed treaty on surgery, though in his work 'On Examining the Physician', he states that operations are not the province of physicians, but rather of surgeons (Nutton 2004: 239) opening up the divide between the two medical factions that would continue for centuries. He did however write commentaries on the Hippocratic works 'Joints' and 'Fractures', and gymnastic trainers in Rome would often refer patients to him who were suffering from complicated dislocations. With the exception of bloodletting, surgery was generally seen as a last resort, with the best physicians able to cure ills and treat disease without having to turn to a knife (Nutton 2004: 240).

App C 2.4 Anatomy

It is during the classical period that the study of anatomy through human dissection first makes an appearance in the study of medicine and surgery. The dissection of humans, as opposed to animals, is thought to have been developed in Alexandria by at least two notable individuals; Herophilus and Erasistratus, and the less well-known Eudemus (Nutton 2004: 128). This study of anatomy in the 3rd century BC is the first time the subject appears in the Western Medical tradition (Nutton 2004: 128). While neither of their writings survive to the modern day, their work was well known by repute; with Galen praising Erasistratus's work on the heart and brain, in particular (Lloyd 1975: 173). Herophilus supposedly undertook the dissections of human cadavers in public and in addition to this Erasistratus also experimented on living animals (vivisection) and possibly human slaves (Porter 2003: 54). However, this foray into anatomy and dissection of humans seems to have been short lived, ceasing before the end of the 3rd century BC (Nutton 2004: 128). One reason for this could be due to the fact that there was never a formal institution of the sciences or medicine in Antiquity, therefore themes that appeared, such as human anatomy, rarely lasted for more than a generation or two. In the case of anatomy, it was also seen that all necessary data had already been collected by Herophilus and Erasistratus and therefore there was no need to continue human dissection as it would not produce and new material (Nutton 2004: 128, 138, 139).

Despite the dissection of humans ceasing in Alexandria, the subject of human anatomy would continue to be taught using the skeleton and external musculature that could be viewed in a living person. This was seen as more compatible with the Ancient Greek taboo of interfering with the body- a taboo that would continue up until Renaissance Europe (Nutton 2004: 129). The next major influence on the study of anatomy would come in the 2nd century AD with the work of Galen, whose writings would dominate the subject of medicine for the next millennium and a half (Porter 2003: 32). However, the concept of human dissection was still a hugely controversial issue and so Galen would use the next available option- apes. This dependence on apes would mean that certain discrepancies appeared and remained unchallenged until centuries after his death- with Vesalius claiming Galen had missed 13 muscles that appear in the human hand, but not in an ape (Siraisi 1997: 7).

App C 3 Anglo-Saxon and Early Medieval 500AD- 1500AD

App C 3.1 Eastern and Western Medical Traditions

Just over 100 years after the death of Galen, Emperor Constantine established Byzantium (Constantinople) as his capital of the Roman Empire in 330AD. This division of the Empire into the East and West became permanent by the end of the 4th century AD, with the East developing into the Byzantium Empire, and the West entering what is colloquially known as 'the Dark Ages' (Magner 2005: 135, 136; Nutton 2004: 293). This division in Empire was also reflected in a division of medical practice, with Eastern and Western traditions developing alongside each other. Despite the growth of secular medicine that had occurred under Classical authors, the spread of Christianity in the West influenced the practice of medicine, with more emphasis being placed on religious aspects of healing (Nutton 2004: 293; Porter 2003: 33). As a result, healing shrines flourished, with both saints and martyrs being invoked for health. While many saints were assigned to specific body parts, Saints Cosmas and Damien became the patron saints of medicine as a whole (Porter 2003: 33). By 600 AD the division between East and West was further emphasised by the Latin West splitting into several independent kingdoms. As a result, the economic foundation of the West was not as strong as that of the East, allowing for medical practices to diverge and develop along different paths (Nutton 2004: 293, 294). It was not until the 12th century that western medicine began to recover from the loss of the classical teachings. During this century, universities began to appear throughout Europe, and translated Islamic medical texts

The medical texts and knowledge gained during the classical era was retained more by the Eastern tradition, than that of the West (Poynter and Keele 1961: 139). Texts that had originally been written in Ancient Greek or Latin were preserved and translated by Arabic teachers (Poynter and Keele 1961: 139; Majeed 2005: 1486; Conrad 1995: 93). In comparison, Greek scholarship had all but disappeared within the West, taking with it much of the medical teachings (Poynter and Keele 196: 139; Baader 1984: 251). Within England, the first evidence of medical writings would not appear until the 10th century (Thomas 2011: 43). With the loss of the classical knowledge, the vacuum created enabled the newer religious elements to become more established in conjunction with medical practice in the Western tradition.

With the burgeoning relationship between religion and medicine in Western society, hospitals began to appear to cater to the general public. Many of these were linked to religious orders devoted to God (Porter 2003: 135, 136). The Eastern tradition also developed hospitals, often on a larger and more complex scale that their Western counterparts (Nutton 1995: 78). For example, from the 7th century onwards, those in Constantinople had separate wards for male and female patients, as well as specialised surgical wards (Porter 2003: 136). However, it would take several more centuries for such institutions to reach the shores of England. Hospitals were introduced to England around the turn of the 12th Century by the Norman conquerors, and by the end of the 14th century there were nearly 500 hospitals throughout the country (Watson 2006: 75, 76; Porter 2003: 137). However, due to the close ties between these institutions and the religious orders that supported them, the dissolution of the monasteries under Henry VIII resulted in many of the institutions closing. As a result, there were no medical hospitals outside London until as late as the 18th century (Porter 2003: 137).

App C 3.2 Monastic Medicine

The spread of Christianity and the establishment of the church as a centre for learning, and thus medical knowledge and practice, lead to the establishment of monastic medicine in Britain that continued until the early half of the 12th Century (Ackerknecht 1955: 75). For some more resolute Christians, the cause of illness and ailments could be attributed to sin, as opposed to a more rational or secular cause (Griffiths 2003: 61). With illness being attributed to the religious concept of sin, any resultant recovery was viewed as a miracle, with the individual having been cured through the power of God (Griffiths 2003: 64). In the early 6th Century, Benedict of Nursia (480-574 AD) produced a ‘rule book’ providing a guide for Christian Monasteries to follow, providing a balance of work, prayer and study (Slocum and Slocum 2020: 1). Adherents to this ‘Rule of St. Benedict’, placed emphasis of care of the sick as a Christian duty. However, some orders such as the Carthusians and Cistercians, took this rule to the extreme; eschewing medical care for religious care (Pollington 2000: 45).

Monastic medicine placed a large portion of medical care on religious elements such as prayer, rather than the physical ministrations of a healer. In one account, written in the *Vita Sancti Wilfrithi* [Life of Wilfrid] around 720 AD, a monastic brother falls from the roof of the church, breaking all his limbs. He is initially healed by prayer before his limbs are bound by a medical practitioner (Meaney 2000: 223). However, this account is unusual for even mentioning the medical practitioner. In *Lives of Æthelwold,* written c. 1000 AD, a similar account of an individual falling from a roof is told. Yet, in this later version the individual is able to get up and resume work, uninjured. This miraculous recovery is attributed to Æthelwold, and there is no mention made of any medical intervention (Meaney 2000: 223).

App C 3.3 Leeches and Leechbooks

The first mention of the 'professional Leech' is made at the beginning of the 7th Century (Bonser 1963: 5), with the first named leech, Cynefrith, appearing in the writings of Bede in 679 (Cameron 1982: 145). This naming of a leech also includes the first mention of a leech engaging in his practice. In this instance the procedure is of a surgical nature; the lancing of a tumour on the neck of St. Æthelthryth, Abbess of Ely (Cameron 1982: 145). Despite the surgical connotations of this first mention of a leech, the term 'leech', or '*læce'* in Old English, refers to a healer of any kind (Pollington 2000: 41). These leeches, as an early form of physician and surgeon, came from both religious and secular backgrounds (Roberts 2014: 445; Pollington 2000: 45). There is no direct evidence of women taking on this role, though it is thought that this may be due to records focussing on official, fee-charging practitioners, as opposed to local healers and midwives (Pollington 2000: 45).

England was unique in Europe for having medical texts published in the vernacular, rather than the classical languages of Latin or Ancient Greek (Cameron 1993: 1). Though this is not to say that the knowledge they contained was unique to England; some of the texts contained sections translated from the original Latin, alongside the indigenous elements (Cameron 1993: 1). The earliest Old English text dates to the 9th Century, though it is likely that earlier texts did exist but have subsequently been lost (Cameron 1993: 2). One of the most renowned texts from the Anglo-Saxon period is Bald's Leechbook, the text of which was likely copied from an older manuscript at Winchester c.950 AD (Getz 1998: 47; Nokes 2004: 51). It is referred to as 'Bald's' due to the name Bald appearing in in a metrical colophon within the text (Getz 1998: 47; Adams and Deegan 1992: 87, 83). The Leechbook itself is separated into two parts, with its treatment of the body being listed as descending from treatments of the head, down to treatments of the feet (Getz 1998: 47), a layout mirrored in later medical and surgical texts. The Old English text primarily consists of herbal remedies, in particular of Mediterranean origin, though some charms are also incorporated (Getz 1998: 48). It has been determined by Adams and Deegan (1992) that the original compiler of the Leechbook likely had access to the text, or parts of the text of the *Physica Plinii* (Adams and Deegan 1992: 112, 113). The Physica Plinii is a Latin text, likely compiled in the 5th-6th centuries, and ultimately derived from the medical elements of *Naturalis Historia* by Pliny the Elder (Adams and Deegan 1992: 89). It is thought that Bald's Leechbook was compiled in order to assimilate the best medical knowledge available from Classical sources into a single volume in Old English (Watkins *et al* 2011: 43).

Alongside Bald's Leechbook, other surviving Anglo-Saxon texts include the *Old English Herbarium* (c.950), and the *Lacnunga* (c.1000) (Watkins *et al* 2011: 1070). These texts, along with Bald's Leechbook comprise of the oldest surviving English medical writings (Thomas 2011: 43). The *Herbarium*, as with Bald's Leechbook is believed to be a compilation of earlier European texts originally written in Latin. Certainly, the European influence can be seen through the inclusion of various herbs and plants native to the Mediterranean, rather than the shores of England (Watkins *et al* 2011: 1070). This collection of medical texts shows that despite the spread of religious treatments and 'miracles', more secular medicine was still being practiced during the Anglo-Saxon era. However, due to the limited survival of early textual evidence it is difficult to determine when such practices became established in England.

App C 3.4 Religious Changes

The influence of religion on the practice of medicine began to wane during the 12th century when in 1130 the Council of Clermont forbade monks from practicing medicine. This was due to the belief that it caused disruptions to the orderly life of the monasteries, caused monks to neglect God and entice them into 'impurity' (Ackerknecht 1955: 76; Pouchelle 1990: 20). This separation of monastery and medicine was further compounded thirty-three years later in 1163, when the Council of Tours stated 'Ecclesia abhorret a sanguine' [the church does not shed blood] (Ackerknecht 1955: 81). While this was specifically aimed at the practice of surgery, it had an effect the overall practice of medicine as most practitioners at this time were religious, educated men. The edict about not shedding blood meant that many of these clergy/practitioners were no longer permitted to practice surgery. (Ackernecht 1955: 81). It was thought that the shedding of blood through surgical procedures was incompatible with ecclesiastic status, and such practise could result in a clergy member unwittingly causing the death of an individual (Pouchelle 1990: 20). This resulted in surgery becoming the domain of other less well-educated members of society. (Ackerknecht 1955: 76, 81). This change in the practice of surgery was further compounded in 1215 during the Lateran Council, when Pope Innocent III declared surgery to be left to laymen (Pouchelle 1990: 20). With these changes occurring in the 12th century, a gulf began to open up between those who practised physic, and those who practiced surgery. This gulf was still apparent in the 16th century with the different colleges devoted to different medical practitioners. Those who practiced 'physik' were university educated and considered to be of a higher class than surgeons and barber surgeons. This divide can still be seen in the modern practice of medicine and surgery. While both are now considered highly professional occupations, surgeons are referred to as Mr/Mrs/Ms as opposed to 'Dr', a throwback to when surgery was viewed more as a craft than an educated discipline (rcseng.ac.uk).

Appendix D: Overview of the FCS Collection

The following is an overview of the FCS Collection. Each FCS is listed with their sex, stature, and age, along with the condition of the remains and the how 'complete' the skeleton is. Those that are reasonably complete invariably have the spine, ribs, and pelvis present, along with more than 2 limbs. Those that are not particularly complete may consist of only the upper or lower body, or the spine, ribs, and pelvis with less than 2 limbs. Articulation refers to the association of the bones within the FCS. Good articulation can be seen in bones such as the pelvis, sacrum, and spine, which associate closely. Poor articulation may refer to fibulae being assigned to an individual, but no tibiae or femora, for example. This makes it harder to confidently assign remains to one specific individual. Additionally, any pathology is also noted.

FCS #	
1	H4 **Sex:** Male **Height:** 163.02 ± 1.96 **Age:** Adult Good preservation and relatively complete. Small transverse fracture to the distal end of the left fibula with non-union, bone still remodelling
2	H4/O4 **Sex:** N/A **Height:** 167.20 ± 3.94 **Age:** (Adult) Mixed level of preservation, right leg (femur, tibia, fibula) shows greater erosion and some P-M damage to the femur, compared to the left (femur and fibula).
3	H4 **Sex:** Male **Height:** 171.34 ± 4.30 **Age:** Young Adult/Adult Good preservation but only 13 bones present. Left humerus broken P-M

4	H4 **Sex:** N/A **Height:** 165.37 ± 1.99 **Age:** (Young Adult) Reasonable preservation, robust, mainly consists of long bones (2 humeri, 2 femora, 2 fibulae) Small periosteal reaction mid-shaft of right fibula
5	H4/O4 **Sex:** PM/M **Height:** 162.89 ± 3.33 **Age:** Young Adult/Adult Good preservation but limited remains. Very poor dental health with evidence of caries, A-M tooth loss, and possible abscesses.
6	H4 **Sex:** Male **Height:** 166.85 ± 3.75 **Age:** Adult Good preservation and relatively complete. OD on left distal humerus. L5 fused to the sacrum with lipping suggesting degenerative changes. Unfortunately, no other vertebrae present.
7	H2 **Sex:** Male **Height:** N/A **Age:** (Adult) On Display. Bi-lateral OsA
8	H2, Skull H2/H3 **Sex:** Male **Height:** 164.09 ± 1.96 **Age:** Adult Very Complete, mixed preservation. Signs of degenerative changes to the lower spine, SN, OLF. Left distal humerus OD.
9	H2 **Sex:** PM **Height:** 169.68 ± 1.96 **Age:** Adolescent 'Henry'. Good preservation, long bones not fused. Damage to the left acetabular rim suggests dislocation- very little bone remodelling.
10	H3 **Sex:** Male **Height:** 159.23 ± 1.99 **Age:** Adult Good preservation, relatively complete. Poor dental health with extensive caries and calculus. Evidence of infection/abscess on right maxilla.

11	H5, Skull H4 **Sex:** Male **Height:** 164.78 ± 1.76 **Age:** Middle Adult Good preservation and relatively complete. Nasal fracture. Hyoid bone and ossified larynx present. Poor dental health. Signs of OA in both acetabulae and femoral heads.
12	H5 **Sex:** Male **Height:** 167.44 ± 3.27 **Age:** Middle Adult Good preservation and relatively complete. Evidence of spine degeneration, SN, OLF, expanded articulating surfaces. EN on right patella. OD on the distal end of the left femur and humerus.
13	O4 **Sex:** Male **Height:** 165.23 ± 2.08 **Age:** Adult Good Preservation. Upper body reasonable complete with both fibulae and right tibia also present. Small SN, mid-thoracic vertebrae also have elongated spinous processes.
14	H5/O4 **Sex:** Male **Height:** 179.34 ± 1.96 **Age:** Adult Generally good preservation, reasonably complete, but P-M damage to left pelvis with heavy iron staining. OA in right hip- left is too damaged. PR to the right fibula..
15	O4 **Sex:** Male **Height:** 167.11 ± 2.08 **Age:** Adolescent/Young Adult Good preservation, long bones not yet fused.
16	O4 **Sex:** PM **Height:** 164.14 ± 1.99 **Age:** Adult Good preservation and reasonably complete. OD distal left humerus. Some lipping and pitting on cervical vertebrae, but not found lower down the spine. Vertebrae absent between C7 and T5
17	O4 **Sex:** N/A **Height:** 160.37 ± 3.96 **Age:** (Adult) Good preservation but limited articulation. OD on distal right humerus.

18	O4 **Sex:** Male **Height:** 168.51 ± 3.27 **Age:** Adult Good preservation. Consists of spine, pelvis, two femora, with 1 rib, 1 patella, and right radius. Nearly a complete spine, evidence of OLF
19	H7 **Sex:** Male **Height:** 164.37 ± 1.76 **Age:** Adult Good preservation, consists of mainly the torso and pelvis. Note in box states 'not English'. Sacrum S3-5 unfused sacral spine. SN and OLF in spine. Bilateral OsA
20	H7 **Sex:** PM **Height:** 165.18 ± 4.30 **Age:** Adolescent/Young Adult Good preservation but only 12 bones present. OD on distal right humerus, possibly also on left but difficult to tell due to iron staining.
21	H7 **Sex:** PM **Height:** 165.06 ± 1.76 **Age:** Young Adult Good preservation, mainly torso and femora. SN in spine, mid-lower thoracic. OD on distal right femur
22	H7 **Sex:** PM **Height:** 160.77 ± 1.76 **Age:** Young Adult Good preservation, mainly torso and femora. Sacral spine is united, but not fused. SN in lumbar spine
23	H8 **Sex:** Male **Height:** 166.72 ± 1.96 **Age:** Adult Good preservation but limited articulation and few bones. OD on distal right femur. Only 5 vertebrae, 1 small SN mid-thoracic. Appear to be 2 left 1st ribs
24	H8 **Sex:** U/PM **Height:** N/A **Age:** Adolescent Good preservation, but not particularly complete. OD on right olecranon. Mandible present but no cranium. Reasonable dental health with one particular instance of PD

25	H7/8 **Sex:** N/A **Height:** 160.63 ± 4.57 **Age:** (Adult) Good preservation but not particularly complete. Right tibia and fibula are on display and have a healed fracture. One thoracic vertebra present with small SN. OD on distal right humerus
26	O7 **Sex:** Male **Height:** 165.78 ± 3.41 **Age:** Adult Good preservation, more complete bottom half. Slight OD on distal right tibia
27	O7 **Sex:** Male **Height:** 169.01 ± 2.30 **Age:** Young Adult Good preservation but only includes the upper body. Bilateral OsA. SN and OLF in spine. Caries and PD in mandible, caries and granuloma/cyst in maxilla
28	O7 **Sex:** PM **Height:** 174.83 ± 2.30 **Age:** Adolescent/Young Adult Good preservation, reasonably complete, but missing lower legs. Large OD on both femoral heals, with SCFE on the right. SBO, no union of sacral spine. Damage/OD to proximal left radius.
29	O7 **Sex:** N/A **Height:** 169.81 ± 4.66 **Age:** (Young Adult) Good preservation but only 17 bones with limited articulation between them.
30	O7 **Sex:** U **Height:** 171.30 ± 4.24 **Age:** (Adult) Poor preservation due to erosion and P-M damage. Upper body only. OD on distal right humerus and proximal left radius. Skull is fragmented, possible trauma to left parietal.

31	O7 **Sex:** Male **Height:** 158.73 ± 3.96 **Age:** (Undetermined/Young Adult) Mixed preservation, erosion affecting some bones. Few bones with limited articulation. OA left distal femur, unfortunately the left tibia is absent. Degenerative changes to lumbar vertebrae. Poor dental health with A-M tooth loss and exposed molar roots.
32	O7 **Sex:** U/PM **Height:** 171.71 ± 1.76 **Age:** Young Adult Reasonable preservation but limited articulation. Mandible present with reasonable dental health- little wear with 2 small caries.
33	O8 **Sex:** PM **Height:** 168.32 ± 4.08 **Age:** Adolescent/Young Adult Good preservation and reasonably complete. Small SN in thoracic spine.
34	O8 **Sex:** Male **Height:** 173.16 ± 4.00 **Age:** Adult Good preservation, but only 11 bones. Slight SN and OLF in thoracic spine
35	O8 **Sex:** Male **Height:** 173.99 ± 1.96 **Age:** Adult/ Middle Adult Good preservation and relatively complete. SN in thoracic and lumbar spine. OD on left distal femur. OD on proximal end of 1st phalange of the left foot. Sacrum left ala fused with L5. Fairly good dental health, minimal wear and only a few early stage caries.
36	O8 **Sex:** PM **Height:** 179.21 ± 4.00 **Age:** Adolescent/Young Adult Reasonable preservation, some bones missing epiphyses. Damage to both superior acetabular rims, SCFE of the femoral heads.

37	H7 **Sex:** PM **Height:** 171.65 ± 1.99 **Age:** Adolescent/Young Adult Reasonable preservation, some P-M damage to the skull and scapulae. Reasonably complete, but missing lower legs. Unusually both patellae present, and ear ossicles. SN in thoracic spine. Sacral spine is united, but not fused. Dentition shows some caries, with one example particularly extensive.
38	O8 **Sex:** N/A **Height:** 163.01 ± 2.08 **Age:** (Adult/Middle Adult) Good preservation, but limited articulation. Pitting on articulating surfaces of the cervical vertebrae. Bilateral OsA. Tibiae in box are an unmatched pair- left longer than the right
39	U9 **Sex:** Male **Height:** 165.89 ± 1.96 **Age:** Adult Mixed preservation, some erosion damage. Consists of legs, spine and skull. OD on right distal femur. Possible SCFE in left femur. Depressed area on right parietal- possibly healed trauma. Damage to right acetabular rim suggesting a possible dislocation. Dental health is reasonably good, with no major evidence of pathology.
40	U9 **Sex:** Male **Height:** 169.57 ± 3.72 **Age:** Adult Mixed preservation with erosion damage. Long bones with skull, pelvis and spine. SN in thoracic spine. Articulation of C2 and C3 is questionable. Very poor dental health with extensive wear, even on anterior teeth, tooth loss, and exposed molar roots. Metopic suture.
41	U9 **Sex:** Male **Height:** 171.71 ± 1.76 **Age:** Adult Mixed preservation with erosion and P-M damage. Not particularly complete. OD left acetabulum- corresponds to femoral head OD. SN in thoracic spine. SBO of sacrum, Sacral spine completely open

42	U9 **Sex:** Male **Height:** 165.97 ± 1.81 **Age:** Adult/ Middle Adult Poor preservation with erosion and P-M damage. Not particularly complete. At least two different spine present, with 2x C7 and 2x T1
43	U9 **Sex:** Male **Height:** 178.07 ± 1.99 **Age:** Adult Reasonable preservation, with some erosion and P-M damage. Only 13 bones, mainly long bones. Evidence of OA on left distal humerus. Heavy iron staining on left ulna makes examination of the olecranon difficult.
44	U9 **Sex:** Male **Height:** 176.61 ± 3.72 **Age:** Adult/ Middle Adult Reasonably good preservation, but only 12 bones. Very obvious OA to right humerus and ulna. Both left and right radii also show lipping, suggesting both arms suffered OA. SN and OP on thoracic spine
45	U9 **Sex:** PM **Height:** 177.31 ± 2.13 **Age:** Adult Mixed preservation, upper body badly eroded with P-M damage. Virtually no articulation. OD proximal left tibia.
46	U9 **Sex:** Male **Height:** 170.40 ± 3.29 **Age:** Adult/ Middle Adult Reasonable preservation with some iron staining. OD to distal right femur. Linear groove on left humeral head- recent shoulder dislocation?
47	U9 **Sex:** Male **Height:** 168.99 ± 3.94 **Age:** Young Adult/Adult Good preservation but only 9 bones- the pelvis, sacrum and legs.
48	U9 **Sex:** Male **Height:** 172.78 ± 3.57 **Age:** (Adult) Mixed preservation with some erosion and P-M damage, particularly pelvis and sacrum. Only 13 bones. OD distal right radius.

49	U9 **Sex:** N/A **Height:** 169.41 ± 3.94 **Age:** (Adult) Reasonable preservation but only 12 bones, mostly long bones. OD left distal femur
50	U9 **Sex:** Male **Height:** 170.30 ± 3.27 **Age:** (Adult) Good preservation but only 11 bones. S4 and 5 sacral spine open.
51	U9 **Sex:** Male **Height:** 179.29 ± 3.74 **Age:** Adult/ Middle Adult Reasonable preservation, but only 12 bones. SN in thoracic spine.
52	U9 **Sex:** U/PM **Height:** 171.60 ± 3.27 **Age:** (Adult) Mixed preservation, sacrum and right pelvis badly eroded and with P-M damage. Only 10 bones. OC on both distal medial femurs (EX)
53	U9 **Sex:** Male **Height:** 159.40 ± 3.41 **Age:** (Young Adult/Adult) Reasonable preservation, some erosion damage. Only 12 bones, mostly long bones
54	U9 **Sex:** N/A **Height:** 165.83 ± 3.94 **Age:** (Young Adult) Reasonable preservation, slight erosion. Only 9 long bones. Slight OD on left olecranon.
55	U9 **Sex:** PM **Height:** N/A **Age:** Adolescent Mixed preservation, some erosion mainly on the lower body and P-M damage to the skull. More complete than others found on the Upper Deck. Young, no fused epiphyses.
56	U9 **Sex:** U/PM **Height:** N/A **Age:** Adolescent/Young Adult Reasonable preservation, some slight erosion. Few bones and limited articulation. Skull damaged P-M and consists of fragments- pitting on frontal and parietals. SN in thoracic spine. Epiphyses missing.

57	U9 Very fragmented, more than two individuals in box
58	U9 **Sex:** U/PM **Height:** 165.98 ± 3.33 **Age:** (Young Adult) Reasonable preservation. Consists of a spine, sacrum, pelvis, right radius and one skull fragment (right parietal). SN in thoracic spine.
59	U9 Very fragmented, more than two individuals in box
60	U8 **Sex:** N/A **Height:** 171.08 ± 2.30 **Age:** (Young Adult) Good preservation; includes 19 ribs, plus right arm with scapula, clavicle and two carpals. Not all bones are fused.
61	U8 **Sex:** Male **Height:** 165.06 ± 3.27 **Age:** Young Adult/Adult Good preservation, spine and legs present. SN and OLF in the spine. Healed OD on left distal femur. OD on both distal tibiae.
62	U8 **Sex:** PM **Height:** 170.20 ± 1.96 **Age:** Adolescent/Young Adult Good Preservation, not particularly complete. Slight OD on left humerus head and articulating glenoid fossa.
63	U8 **Sex:** Male **Height:** 168.11 ± 1.96 **Age:** Adult Good preservation, primarily pelvis, legs and upper arms. OD on left distal humerus. Possible eburnation on right femoral head.
64	U10 **Sex:** U **Height:** 180.36 ± 4.31 **Age:** Undetermined Reasonable preservation. Consists of mainly the upper body with one right patella(?). SN on the one Lumbar vertebra present. Metopic suture. Only two teeth in situ but no evidence of caries, A-M tooth loss, or cysts

65	U7 **Sex:** PM **Height:** 171.63 ± 3.33 **Age:** Adolescent/Young Adult Good preservation, not particularly complete. Young but still signs of SN in thoracic and lumbar spine
66	U7 **Sex:** Male **Height:** 173.88 ± 3.57 **Age:** Adult Reasonable Preservation, mainly the lower body, femora currently on display. Distal left fibula shows thickening, possibly a healed fracture.
67	H9 **Sex:** Male **Height:** 165.97 ± 3.57 **Age:** Adult Good preservation, reasonably complete, but limited articulation. Quite robust. SN in some thoracic vertebrae.
68	M6 **Sex:** Male **Height:** 173.70 ± 1.99 **Age:** Young Adult Reasonable preservation, mainly legs and upper arms. OD on left distal humerus. Possible healed OD on right distal femur. SBO, Sacral spine completely open. OsA on right scapula (left absent)
69	M6 **Sex:** Male **Height:** N/A **Age:** Young Adult/Adult Good preservation, consists of spine, ribs, skull, and right scapula with 1 right hand phalange and 1 foot phalange(?). Some OP and OLF on spine. Skull is robust, good dental health. Many teeth present with some wear.
70	H6 **Sex:** * **Height:** 176.37 ± 3.57 **Age:** (Adult) Good preservation, not particularly complete, articulation not great. Healed Od on left femoral head. OD on articulating surfaces of right calcaneus and talus. SN in thoracic and lumbar spine.
71	O3 **Sex:** PM **Height:** 167.27 ± 1.76 **Age:** Adolescent Good preservation, not particularly complete and virtually no articulation. Unfused epiphyses.

72	O3 **Sex:** Male **Height:** 171.53 ± 4.24 **Age:** Young Adult Good preservation, mainly consists of upper body, with a left tibia included. Mild SN in a few thoracic vertebrae. Few teeth present in skull but minimal wear and caries.
73	O3 **Sex:** Male **Height:** 165.09 ± 3.57 **Age:** Young Adult Good Preservation and reasonably complete. OLF on thoracic spine. OD on left calcaneus and right talus. Slight ‘polishing’ of right femoral head. Skull has metopic suture. Dental health is reasonably good, minimal wear.
74	M3 **Sex:** Male **Height:** 167.91 ± 1.81 **Age:** Young Adult/Adult Reasonable preservation and reasonably complete, some P-M damage, and metal staining. OLF present on thoracic and lumbar vertebrae. OD in right acetabulum.
75	M3 **Sex:** Male **Height:** 167.69 ± 1.76 **Age:** Young Adult/Adult Good preservation, not particularly complete, some metal staining. Poor dental health, few teeth left in situ but evidence of caries and A-M tooth loss
76	M3 **Sex:** N/A **Height:** 169.17 ± 2.13 **Age: (**Adult) Reasonable preservation, not particularly complete. Metal staining, and some metal deposits. SN in thoracic spine
77	M3 **Sex:** Male **Height:** 161.13 ± 3.96 **Age:** Adult Reasonable preservation, some metal staining. Lots of foot bones. Suggestion of OA on right femoral heal, but not associated changes to right acetabulum. OD on distal right tibia.

78	M3/4 **Sex:** Male **Height:** 152.90 ± 3.41 **Age:** Young Adult Reasonable preservation, not particularly complete. Some metal staining. Sacral spine open S3-S5
79	O6 **Sex:** Male **Height:** 169.57 ± 3.72 **Age:** Young Adult/Adult Good preservation and reasonably complete. OD on distal ends of left and right femurs. Fracture to right acetabular rim, likely caused by dislocation. SN and large OP on thoracic vertebrae. Button osteoma on skull. Poor dental health with extensive A-M tooth loss.
80	O6 **Sex:** Male **Height:** 176.72 ± 3.27 **Age:** Adolescent/Young Adult Good preservation and very complete- only really missing hands, feet and patellae. SN in thoracic spine. Dental health is relatively good, minimal wear or pathology.
81	O9 **Sex:** Male **Height:** 170.46 ± 1.96 **Age:** Adult/ Middle Adult Reasonable preservation, not particularly complete. Some erosion and metal staining. Note in box states 'Carpenter'. OD on distal left femur. Poor dental health with extensive wear, caries, A-M tooth loss, and cysts. SN present in cervical, thoracic, and lumbar vertebrae.
82	M2 **Sex:** Male **Height:** 163.09 ± 3.23 **Age:** Undetermined Good preservation but with extensive metal staining, quite complete. Presence of Vivianite. OD on right distal femur. Healed left rib fracture. Very slight SN on only a few vertebrae. Evidence of enamel hypoplasia, but otherwise dental health is reasonably good.
83	M2 **Sex:** PM/M **Height:** 178.22 ± 3.72 **Age:** Young Adult/Adult Reasonable preservation, reasonably complete, extensive metal staining and some P-M damage. Presence of Vivianite. SN in thoracic and lumbar spine. Reasonable dental health with no obvious pathology and minimal wear

84	M5 **Sex:** Male **Height:** 159.76 ± 1.96 **Age:** Middle Adult Good Preservation and very complete. OD distal left humerus. Good spine comparative to other individuals on board. Quite gracile and has been suggested as a Bosun- found near a whistle.
85	M8 **Sex:** PM **Height:** 160.66 ± 3.94 **Age:** (Adult) Reasonable preservation, reasonably complete, some P-M damage and staining. OsA left scapula (right absent)
86	M7/8 **Sex:** Male **Height:** 158.28 ± 1.99 **Age:** Young Adult/Adult Good preservation. Gracile, though skull is robust. Found outside Surgeon's cabin and with a Rosary. Eburnation to left humerus head. Good dental health, very minimal wear with some hypoplasia.
87	O7 **Sex:** PM **Height:** 166.49 ± 3.27 **Age:** Young Adult Reasonable preservation, not particularly complete, with some P-M damage
88	O10 **Sex:** * **Height:** 167.92 ± 3.96 **Age:** (Adult) Good preservation and reasonably complete, but limited articulation. Suggested to be the purser. Severe malformation of femoral heads and acetabulae- pelvis and femurs on display in the museum.
89	M10 **Sex:** Male **Height:** 175.53 ± 3.27 **Age:** Middle Adult Mixed preservation, reasonably complete, mainly long bones. Erosion, P-M damage and metal staining. SN in thoracic vertebrae. Possible peri-mortem butterfly fracture to left distal tibia.
90	U8 **Sex:** N/A **Height:** 165.41 ± 3.94 **Age:** (Adult) Good Preservation but only 10 bones, all long bones so virtually no articulation. Healed OD on right femoral head.

91	M3/4 **Sex:** Male **Height:** 171.63 ± 1.81 **Age:** Adolescent/Young Adult Mixed preservation, not particularly complete. Erosion and metal staining. OC distal right femur. OD right distal humerus.
92	H4 **Sex:** PM **Height:** 161.28 ± 3.57 **Age:** Young Adult/Adult Reasonable preservation with some P-M damage. Articulation not great. Mandible but no skull. Only one tooth in situ and evidence of PD

Glossary of Terms

Aft – Towards the Stern

Ballast – Gravel in the Hold to provide weight and stability to the ship

Bow – The forward part of the vessel

Caulking – Wadding in the seams of the timbers of the Deck or Hull to make it water-tight

Companionway – Ladder or staircase between decks

Decks – Upper: Uppermost deck of the ship

– Main: Widest deck, below the Upper Deck, location of most guns

– Orlop: Second lowest, storage of weaponry and supplies

– Hold: Lowest level of the ship, contained the ballast and the Galley

Galley – Cooking compartment

Gunport – Opening (usually square) through which a gun could be fired

Gunport Lid – A cover that enabled the gunports to be closed when not in use

Keel – Longitudinal strengthening beam in the bottom of the ship

Port – The left side of the ship, looking forward

Starboard – The right side of the ship, looking forward

Stern – The after part of the vessel

Waist – The low part of the vessel between the raised Forecastle and Sterncastle.

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