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THE EMERGENCE OF PLATE ARMOR

An Interactive Qualifying Project Report

submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

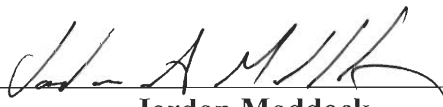
in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by



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Date: April 27, 2001

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(now FORGONE)

- 1. Armor
- 2. Medieval Technology
- 3. Medieval Tactics

Abstract

The evolution of plate armor is evaluated and discussed in the context of overall social change and the development of medieval warfare. Research into the history of armor, weapons, tactics, technology, and economics of the era was performed resulting in a web page to present the research to an introductory- and intermediate-level researcher.

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1 Introduction

Possibly the defining characteristic of medieval Europe, the knight clad in plate armor is truly an enigma. Between the 12th and 14th centuries Europe gradually covered its best warriors in armor predominantly made out of plates of iron and steel. While a more effective defense, the question arises: Why then? Mail had been used for centuries before and the limitations were certainly well known. Plate armor must require more than simply a desire for change to allow its development.

The rise of plate armor is an unresolved topic that finds no clear solution. With many primary sources destroyed through time and a large number of competing influences, the reason behind the transition from mail to plate armor in medieval Europe remains unclear. Other cultures that used mail had no such transition, and yet were subject to many of the same influences as the Europeans. Why then do we only see plate armor used in Europe? While many scholars have put forth the increasing effectiveness of the crossbow and longbow, these seem like simple answers that do not reflect the full story. This project looked at a variety of possibilities for the evolution of plate armor and how they affected its development.

1.1 Armor Overview

The armor of the Middle Ages is one of the defining characteristics of the period. Two distinct types of armor existed in Europe, mail and plate. By far the most common defense and found throughout the medieval world, mail was formed by interlocking rings of metal riveted or welded shut to provide a simple but effective protection against cutting edges. The drawback, however, was that it did not protect against the impact of a blow,

only the cut. Also, mail was not terribly effective against projectiles. Plate armor consists of articulated plates of iron or steel that provide a rigid defense against impacts. While many of the same developments that could have led to the appearance of plate armor occur elsewhere in the medieval world, only in Europe did plate armor develop.

1.2 Objectives and Methodology

The rise of plate armor has intrigued scholars for years. This project looked at the research already performed and tried to incorporate factors that had not been as emphasized in previous research. Finally, we presented our research in a manner that will allow both scholars and laypersons to benefit. This allows our project to be both a beginning point for further research and a summary for those only curious.

To perform this project, we researched the economic, technological, and tactical history of Europe in the Middle Ages as well as the development of plate armor on its own. Previous work on this topic had pointed to the use of the crossbow or longbow, as suggested by Richardson and Gies. While these do look like likely candidates, there is much more that could have contributed to the rise of plate armor over the mail that had remained dominant for centuries.

Research was performed both at the Higgins Armory and the WPI campus. The Higgins Armory is the only North American museum dedicated exclusively to arms and armor. The major tasks of the project were:

- Researching the development of plate armor.
- Researching the evolution of military tactics and weapons.

- Researching the economic and technological developments relating to plate armor.
- Create a web page to present the data in a logical, user-friendly format.

The development of plate armor is discussed in Appendix 1. The evolution of military tactics and weapons is discussed in Appendix 2. The economic and technological developments are discussed in Appendix 3 and Appendix 4 contains the entire web page.

APPENDIX A1 A General History of Armor

It seems that, while not exactly the birth of plate armor in Europe, the second half of the 13th century is the period where the transition from mail to plate really begins. That is not to say that the transition was confined to this period – indeed, elements of plate armor were emerging in the 12th century, while others did not become popular until well into the 14th and 15th centuries. It should also be noted that though mail declined in popularity and effectiveness during the period, it was in use to some extent as long as armor in general was around.

One of the earliest elements of armor to use plate protection was the helmet. However, the development of plate defense for the head does not follow the transitional timeline we see with protection for the rest of the body. The evolution of the helmet is therefore discussed at the end of this paper, separate from the general discussion.

A1.1 Dominance of Mail and Early Plate (pre-1250)

The Paladins of Charlemagne's court (c. 750) wore on their bodies either mail hauberks, scale shirts, or, more unusually, coats of lamellar armor (Edge and Paddock 1998, 9). While this time period is rather early for the scope of this project, it does not even approach the date of the origin of mail.

The shirt of mail, formed of interlinked metal rings, first appears in Celtic graves, and the Roman author Varro attributed its invention to the Celts. It was first used in the Classical World in the third century BCE and became widely disseminated. The mail

hauberk of Charlemagne's day was normally knee-length or a little shorter, and was pulled on over the head. It had a plain round neck opening with a front slit, and invariably had short sleeves. At the center front and back it was split from hem to groin level to enable the wearer to ride (Edge and Paddock 1998, 9).

The earliest surviving hauberk dates from the 12th century and is preserved in the Prague Cathedral as supposedly being that of Saint Wenceslaus. The early hauberks were made of riveted mail, probably weighing over 30 pounds. The sleeves, by the 11th century, extended midway down the forearm. Most depictions of the hauberk from the same time have a rectangle covering the upper chest, outlined with broad bands, suggesting that the vulnerable neck opening was protected by a lined reinforce of mail (Edge and Paddock 1998, 19).

Early Anglo-Saxon manuscript sources imply that the hauberk was rare and highly prized. Only leaders or important warriors possessed one, but they grew to become an integral part of the early knight's equipment and an indication of his profession, status, and rank (Edge and Paddock 1998, 21).

Manuscripts also describe different types of mail, such as "double" and "triple" mail. Hauberks made of two or three layers of mail would have been exceptionally heavy to wear, so it is more likely that "double" and "triple" mail refer to the closeness of the mesh. "Banded" mail in contemporary illustrations, especially from the 12th and 13th centuries, may represent alternating rows of riveted rings and rings made by punching complete closed circles of metal from a thin sheet of iron, adding strength, since there is no weak point on unriveted rings. In Europe from the 14th century onwards, it is extremely rare to find any exception to wholly riveted mail (Edge and Paddock 1998, 21).

The body armor of the 11th century also continued relatively unchanged into the 12th, still consisting primarily of the mail, or, occasionally, scale hauberk with an integrated coif (Edge and Paddock 1998, 45).

By the middle of the 12th century mail chausses on the legs were far more common than they had been a century before, and there are many more extant contemporary illustrations of them in use. For the most part, the type which laced up at the back of the calf was still more popular than the full mail stocking gartered at the knee (Edge and Paddock 1998, 45).

The foot was more commonly protected in the 12th century, and the arms also; in the last few decades of the century the sleeves of the hauberk became longer, ending in mitten-shaped gloves called mufflers, which were slit at the wrist to permit the hands to be withdrawn at will (Edge and Paddock 1998, 45).

Overall, the equipment of the knight varied little throughout Europe during the 13th century. The main body defense remained the mail hauberk. This reached to mid-thigh and had an integrated coif which had a ventail or flap of mail which could be drawn across the mouth and closed with a strap. This is clearly shown on the wooden effigy attributed to Robert of Normandy in Gloucester Cathedral, England. By mid-century the mufflers attached to the end of the sleeves often had separate fingers (Edge and Paddock 1998, 53-56).

Mail is not a rigid defense and, although it will stop a cut, the force of a blow is transferred directly through it, causing blunt trauma. Furthermore, it gives inadequate protection against a thrust with a sharply pointed weapon or from arrows or crossbow bolts, all of which can burst the links apart. These problems were dealt with in two ways:

partially by wearing rigid defenses over the mail, such as the coat of plates and the reinforced surcoat, and partially by the adoption of quilted and padded undergarments. The latter were separate defenses which could be worn in addition to the hauberk, or instead of it (Edge and Paddock 1998, 57).

The quilted defenses were referred to as aketons or gambesons. Evidence suggests that aketon refers to garments worn under the mail while gambesons were worn over or instead of it. These were both usually made of two or more layers of linen stuffed with tow, rags, or other material. When worn under the armor the aketon had long sleeves and reached to the knee. The gambeson is often referred to in contemporary accounts as being worn by the common soldiers and, indeed, is part of the equipment required by the Assize of Arms of 1185 of Edward I of England (Edge and Paddock 1998, 57).

The earliest medieval reference to plate armor below the neck appears to be the account given by Giraldus Cambrensis of the Danish attack on Dublin in 1171. In this the Danes are wearing *laminis ferreis arte consutis*, or “iron plates skillfully sewn together” (Blair 1958, 37). It is likely that this is not actually referring to the coat of plates construction, and is simply a description of lamellar or scale armor. Either way, it represents a precursor to development of plate armor.

Very early evidence of the use of a plate defense constructed from a single piece of metal is found in Guillaume le Breton’s account of the fight between Richard, Count of Poitou (later King Richard I of England) and William de Barres. In the fight, the combatants are described as wearing a plate of worked iron beneath the hauberk and aketon. The fact that Guillaume died c. 1225 gives us concrete evidence of the use of

plate armor no later than the early 13th century (Blair 1958, 38). The extent to which it was used so early on is not known, but lack of evidence suggests it was relatively rare.

Although the knight does continue to wear mostly mail, continuous development of plate really begins around 1250.

A1.2 The increasing integration of plate (c. 1250 – c. 1300)

From the end of the 12th century, there are references to a rigid defense known as a cuirie or cuirass (Edge and Paddock 1998, 56). The term cuirie first appears in texts of the third quarter of the 12th century, and occurs frequently until the middle of the 14th. It is almost certainly synonymous with cuirass, a term first recorded in an inventory of the effects of Eudes, Comte de Nevers, drawn up after his death in 1266. The cuirass was a defense for the torso, worn between the surcoat and hauberk. It was often made of leather, and was rigid enough for the guard-chains for the helm and sword to be attached to it, suggesting it was made from cuir-bouilli (a hardened form of leather, derived from the French term *cuir*, meaning leather). It was sometimes reinforced with metal plates, sometimes lined with fabric, and sometimes had arm-defenses of leather or possibly quilted cloth. The cuirie, or cuirass, is shown on two English monuments, one from the Temple Church in London and the other from Pershore Abbey, Worcestershire, both of which date to the 1260s. By the 15th century, cuirass referred to the metal breast- and backplates taken as a single unit (Blair 1958, 38, Edge and Paddock 1998, 57).

The first reliable indication of emerging usage of plate is an increasing appearance in contemporary illustrations of reinforcing plates (poleyns) laced or strapped to the knees of the chausses, or, more frequently, the gamboised cuisses. They start off rather small,

but after c. 1270 they become large and hemispherical, completely covering the front and sides of the knees (Blair 1958, 39). Not until the end of the 13th century, and then only very rarely, was any defense worn for the lower leg other than the mail chausse (Edge and Paddock 1998, 61). In the last quarter of the century gutter-shaped shin guards of steel known as schynbalds appeared. These were short and protected only the front of the leg and were simply strapped on over the chausses, according to Edge and Paddock (61), but Blair suggests that they were probably worn under the chausses, due to his observation that the schynbalds are rarely illustrated before the second decade of the 14th century (39). There are references to schynbalds in a list of armor supplied to Edward I's sons, Edward Prince of Wales and John Duke of Lancaster, for the campaigns in Scotland in 1299. The defenses for the leg likely developed before those for the arm because when the knight was mounted the legs were particularly vulnerable to infantrymen (Edge and Paddock 1998, 60).

Disc-shaped plates, called couters, attached to the elbows of the hauberk, are found as early as c. 1260 on the effigy of William Longespée the Younger, although Blair is unable to trace any other examples earlier than the first decade of the 14th century (Blair 1958, 39).

Around 1290 numerous references to gauntlets constructed of baleen (often referred to as whalebone, although it is not bone at all) first appear, probably consisting of leather faced with plaques of baleen. Steel-plated gauntlets, probably made the same way, are first mentioned in 1296, but the vast majority of knights continued to use mufflers of mail (Edge and Paddock 1998, 59).

Development of plate defenses for the limbs was surely accompanied by a corresponding development of armor for the torso. Unfortunately, for quite a long period, these body defenses were obscured in illustrations, engravings, etc. by the surcoat.

The surcoat was sometimes reinforced with rows of fairly long, rectangular plates, set vertically and riveted to the inside of the fabric. These can be clearly seen on the sleeping guard from part of a sculpture of the resurrection of Christ from Wienhausen, now in the Provinzial Museum, Hanover. Only one known 13th-century illustration of this arrangement exists, in the third quarter of the century, but examples dating from the first three decades of the 14th century are found in Italy and Scandinavia (Blair 1958, 39, Edge and Paddock 1998, 57).

Another body defense appeared mid-13th century. It was shaped like a cross with an opening near the junction where a mail coif was permanently attached. The long side covered the back, while the other three protected the front and wrapped around the sides, buckling in the rear. These sides were lined with oblong plates which were riveted onto the garment at their ends. Plates from this type of garment were excavated at the Castle of Montfort in the Holy Land, and must date to before 1271, when the castle fell to the Saracens (Edge and Paddock 1998, 57). Garments of this type, cloth or leather lined with metal plates, were the most widely used type of body defense throughout the 14th century. It is now usually referred to as a coat of plates, but was known then as a *pair of plates*, *hauberk of plates*, *cote à plates*, or simply *plates*.

A1.3 Overshadowing Mail

The most important source of information about the coat of plates type of armor comes from the mass graves at Wisby. The Battle of Wisby was fought in 1361 between the Gotlanders and the Danes, and after the battle the dead were buried in graves along with some of their equipment (Edge and Paddock 1998, 73). Excavations of the graves at Wisby began in 1905 under the supervision of Doctor Oscar Vilhelm Wennerstein, the then curator of the Gotlandic Archives. A total of five excavations examining the mass graves were performed between 1905 and 1930, some producing almost no evidence of armor at the time, and some proving very fruitful, uncovering mail coifs, gauntlets, arrowheads, iron lames and buckles, large portions of mail shirts, and especially armor plates, including a number of coats of plates that were discovered almost fully intact (Thordeman 51-62). There are also plenty of examples of the coat of plates before Wisby, though. After his death at the Battle of Courtrai in 1302, the inventory of the goods of Raoul de Nesle listed his arms as consisting of gambesons, mail hauberks, basinets, kettle hats, padded cuisses and both half and full greaves, and pairs of plates (Edge and Paddock 1998, 73). From the last decade of the thirteenth century, references to the coat of plates become more and more common until after c. 1320 there is hardly an inventory, account, or will in which armor is mentioned that does not include an example (Blair 1958, 40). It was usually worn between the surcoat and hauberk, and therefore can rarely be identified in illustrations until the third decade of the 14th century, when the front of the surcoat was shortened. The pair of plates is also clearly seen on the brasses of Sir John III d'Abernon, about 1340-5, and Sir Hugh Hastings, c. 1347 (Richardson 41). Usually, the plates were riveted to the inside of the garment, but there are also examples of them riveted to the

outside, as in the *Romance of Alexander*, an illuminated manuscript of c. 1340 preserved in the Bodleian Library (Edge and Paddock 1998, 73).

Throughout the 14th century leg harnesses showed a gradual development with a great deal of variation. At the beginning of the century many knights wore simply mail chausses with little or no additional defense, those that were worn simply being gamboised cuisses and cup-like steel poleyns, and occasionally schynbalds or shin guards of plate (Edge and Paddock 1998, 81).

Mail chausses continue to be shown commonly until 1350 and occasionally, in Spain and Germany, to the end of the century. However, after 1310 schynbalds are rare, being replaced by full and demi greaves. There were referred to in the Nesle inventory of 1302. By 1330 greaves constructed of two pieces hinged and strapped together were quite common (Edge and Paddock 1998, 81).

Plate defenses for the feet (sabatons) were apparently introduced in the second decade of the 14th century, although they are rarely illustrated before c. 1320. They occur, for example, on the de Cabrera effigy of c. 1314, where they are shown as pointed shoes studded with rosette-headed rivets, presumably indicating a coat-of-plates construction (Blair 1958, 43).

The most popular form of sabaton consisted of a series of overlapping, horizontal lames, shaped to the pointed shoe of the period and covering the top of the foot. One of the earliest illustrations of this form occurs on the brass of Sir William Fitzralph at Pebmarsh, Essex (c. 1323), but after this it is shown frequently, except in Germany, where plate sabatons are rare until after c. 1340. The plates were presumably riveted to a leather

lining and secured to the shoe by laces knotted through pairs of holes on top or by straps passing under the foot (Blair 1958, 43-44).

Development of plate defenses for the arms lagged slightly behind the leg defenses but otherwise followed very similar lines. Couters of the type shown in the Longespée effigy begin appearing more and more in contemporary art from c. 1300 on. Some late 13th- and early 14th-century texts mention bracers of leather, but Blair can find no illustration that depicts them (Blair 1958, 45).

Towards the end of the 13th century plate defenses for the hands started to evolve. The mail mufflers worn throughout the century all but disappeared by 1330. The new types of gauntlet were originally either deep-cuffed cloth gloves plated with baleen (Froissart mentioned these as being part of the equipment of the men of Bruges at the battle of Roosebeke in 1382), or cloth or leather gloves lined with plates, constructed in a similar manner to the coat of plates. A number of this type were excavated from Wisby (Edge and Paddock 1998, 81).

From the mid-1300s, the gauntlets most commonly associated with the 14th century appeared. These were of hourglass form and consisted of a large plate shaped for the back and sides of the hand, constricted at the wrist and flared to form a short cuff. This plate was embossed for the shape of the knuckles and the base of the thumb, and the gauntlet was completed by small, overlapping plates to protect the fingers and thumbs. This whole gauntlet was stitched to an internal glove either of leather or cloth. Sometimes the plates themselves were covered in cloth, as is a gauntlet from Brick Hill Lane, London, now in the Royal Armouries. The finger defenses were sometimes accompanied by

gadlings or spikes attached to the knuckles, which could be used in the manner of knuckle-dusters (Edge and Paddock 1998, 81).

The earliest illustration of full plate arm defenses goes back to the effigy of Don Alveró de Cabrera. Here, the tight-fitting sleeves of the surcoat are studded with rivets in a manner similar to that on the bevor, the chest, and the sabatons, indicating they were probably lined with plates. The earliest true vambrace, the term for the complete arm defense excepting the shoulder, appears in illustrations during the 2nd decade of the 14th century, and consists of two gutter-shaped plates, completely encircling the arm, and a cup-like couter strapped over the sleeve of the hauberk. Each vambrace was often accompanied by two disc-shaped plates, called besagews; one was secured by laces to the outside of the elbow to protect the elbow joint, and the other to the front of the shoulder to defend the armpit. This form is found as late as 1347, but is rare after c. 1335 (Blair 1958, 45).

Italian arm harnesses, as represented by the armor preserved at Churburg, consisted of a short gutter-shaped upper cannon riveted to laminated couters and lower cannons of tulip form, that is, narrowing to the wrist and flaring at the cuff. Quite often, these seem to have been worn without spaudlers or indeed any defense for the shoulder other than the mail sleeve of the hauberk (Edge and Paddock 1998, 80).

By c. 1325 the lower cannon of the arm defenses started to be constructed of two plates to completely encircle the arm. On the continent knights were quite often depicted wearing mail inside the upper defenses but outside the lower. In Germany, separate tubular or gutter-shaped defenses for the upper and lower arm, worn with or without

separate couters, were all attached individually by points or straps to the undergarments (Edge and Paddock 1998, 80).

At about the same time in England, gutter-shaped upper and lower cannons made an appearance. These were joined to a couter with a small disc-like wing by small laminations, with a separate laminated spaulder for the point of the shoulder. By the 1340s these spaulders were permanently attached to the upper cannon. This upper cannon was hinged down one side and strapped across the other (Edge and Paddock 1998, 80).

During the last years of the 13th century, references to all types of plate armor became increasingly common, though it was not always made of metal. Armorers experimented with a variety of materials, most notably baleen, horn, and cuir-bouilli, in addition to iron, steel, and latten (a form of brass), although this was probably used more decoratively than structurally. After c. 1330 illustrations of knights armored entirely or almost entirely in mail are rare (Blair 1958, 41).

A1.4 The Dominance of Plate (c. 1350 - c. 1400)

Some forms of the pairs of plates found at Wisby were constructed so as to form separate breast- and backplates which joined at the shoulder and laced or buckled down one side. By the 1350s effigies start to show the evolution of a single large plate covering the upper chest, accompanied by smaller plates to cover the shoulders. By the 1360s or so the plate had increased in size and covered the chest as far as the diaphragm. The skirts of the armor were depicted on funereal sculptures as vertical rows of rivets in a cloth cover, which represented the fastenings for horizontal hoops of iron or steel. By the 1370s the

waist lames had disappeared; the breastplate itself extended down to the top of the hips where it ended in a skirt, or fauld, of horizontal lames.

Although literary evidence for an independent breastplate, without any form of backplate, dates as early as the 1340s, the first known depiction dates only from the 1370s, and shows the breastplate being worn over the coat of plates. In Italy and Germany it was sometimes worn independently with a short fauld, being held on by cross-straps at the back, as shown in the silver altar piece from Pistoia Cathedral (c. 1376). Not until the last two decades of the century can it be considered common wear (Edge and Paddock 1998, 74-75).

During the later part of the 14th century, a body defense known as a brigandine was developed. This was a piece of body armor which seems to have been similar to scale armor in construction, using small overlapping plates that slid over each other as the body moved to give greater flexibility. These plates were riveted to a canvas garment that was usually covered in some finer material. One of the earliest mentions of this sort of defense comes from the letters of Francesco di Marco di Datini, a merchant of Prato in Italy, dated 1368. The earliest English reference to a brigandine is in the inventory of Thomas Duke of Gloucester, son of Edward III, dated 1397 (Edge and Paddock 1998, 76).

For the duration of the 14th century, the knight continued to wear his hauberk under his armor, but after about 1350 it only reached to just below hip level and was often bordered by brass rings meshed like mail and shaped into a zig-zag fringe. Beneath this he wore his aketon, which, by the mid-14th century, had become shortened to the same length as the hauberk and was strongly waisted in form (Edge and Paddock 1998, 79).

The usual English term for the defense for the lower leg during the mid 14th century was *jamber*, but the French term greave occurs occasionally from c. 1370 onwards and, after c. 1400, completely supplants the English. The normal construction of the greave, which remained in use until the 17th century, was for each greave to be made of a front and a rear plate hinged together down one side – usually the outside – and fastened with straps and buckles on the other. Such greaves became common after c. 1330 (Blair 1958, 42-43).

By the 1370s plate cuisses consisting of a single plate were common and had embossed lower edges to fit over the wearer's knees. These were articulated to the poleyns by rivets. Also at this time, the poleyns developed a heart-shaped side wing to protect the tendons at the back of the knee (Edge and Paddock 1998, 82-83).

By the last quarter of the 14th century, the upper leg defenses consisted of a single plate protecting the front of the thigh with a hinged side plate for the outside of the leg. At the bottom of the main plate a small articulating lame was riveted to allow the poleyn to pivot. The poleyn had a lower lame which was either strapped over or was attached to the greave (Edge and Paddock 1998, 83).

Armor was expensive and only the very rich could afford to keep up with changes in style. Almost to the end of the 14th century many knights made do with armor composed mainly of mail, supplemented by a few pieces of plate (Edge and Paddock 1998, 93).

By the time of the brass of Ralph de Knyveton from Aveley, Essex, c. 1370, the form of the coat of plates is clearly visible, the plate arm defenses are fully articulated, and the greaves are worn with fully articulated sabatons. With the evolution of cuisses of plate

by the end of the century, the development of the plate harness was essentially complete (Richardson 1997, 41).

A1.5 The 'Disappearance' of Plate (after c. 1400)

Until the 1420s, the main shoulder defense was generally mail, but by the end of the second decade of the century laminated pauldrons appear for the left arm, with a smaller one being worn on the right arm. Large pauldrons remained in use throughout the 15th century, but became more rounded after 1440 and spread out across the wearer's back to overlap. The upper edges of the pauldrons were flanged to protect the neck (Edge and Paddock 1998, 107).

From about 1420 the German knight would have worn simple laminated spaudlers, consisting of a domed plate for the point of the shoulder, supporting a number of laminations down the arm. Below these were worn simple gutter-shaped upper and lower cannons joined by leather straps, and a moderately sized shell-shaped couter which was laced to the arming doublet. These were accompanied by a besagew to protect the gap between arm harness and breastplate and remained in common use until the second half of the next century. From about 1450 it was common for the spaudler to be riveted to the upper cannon (Edge and Paddock 1998, 101).

A1.6 Evolution of the Helmet

The helmets depicted on the Bayeux Tapestry already show elements of plate construction. They are similar to the late Roman *spangenhelms*, which were built around

a framework of bronze or iron strips, with the infills being made from beaten panels of iron riveted onto the main frame (Edge and Paddock 1998, 17-18).

Helmets forged entirely in one piece can be traced back to the 10th century. There is one preserved in the Cathedral Treasury in Prague which is said to have belonged to Saint Wenceslaus of Bohemia, who died in 935. The iron skull is forged in one piece, with an iron nasal and bottom reinforcing rim riveted in place. Another similar helmet is in the Vienna Waffensammlung – it is forged entirely in one piece including the nasal guard (Edge and Paddock 1998, 18).

Conical helmets of the “Norman” type, such as those seen in the Bayeux Tapestry, seem to have proved an effective defense against the sword, axe, and mace, since they continued to be used by the knight in various parts of Europe until the 1250s. They were, however, increasingly replaced by a domed version, the most popular form of which is known as the *cervelière*, or basinet. This was a small hemispherical skull cap which was often worn beneath the mail coif, though it was also increasingly worn under the great helm or simply on its own *over* the coif (Edge and Paddock 1998, 18, 55). Originally, the *cervelière* and the basinet were synonymous. By the 1330s, though, the *cervelière* was totally displaced by the true basinet (Edge and Paddock 1998, 71).

At first, there were three basic types of the basinet. One was deep and conical with an arched face opening, extending down to the base of the neck and often including a visor. Another was small and globular, only reaching to just below the ears. The third was of a tall conical form, just reaching to the tops of the ears. These types appear regularly until the 1350s. After that, the basic form was of medium height with a conical skull extending in the back and on the sides to cover the cheeks and the nape of the neck.

By the end of the century it was extended to the base of the neck and the cheekbones, and the apex of the skull was slowly moved backwards to give an almost vertical rear face (Edge and Paddock 1998, 71).

The aventail was a fan-shaped curtain of mail extending from the base of the basinet to the point of the shoulder, protecting the neck and throat but leaving the face exposed. It was at first riveted directly to the basinet, but later was attached by staples called vervelles which passed through a leather band at the top edge of the mail; a cord was then threaded through the staples above the leather. This had the advantage that the aventail could be removed for repair and cleaning. At the very end of the 14th century, the mail aventail was replaced by a plate defense to produce what is known as the *Great Basinet*. There is a good example of this type in the Doges' Palace, Venice. The whole helmet, except the visor, is raised from a single piece of steel. (Edge and Paddock 1998, 72-73).

Throughout Europe in about 1380 the visor that was sometimes found on the basinet began to develop a pronounced projecting conical snout with flanged sights and mouth slit, pierced with numerous small breaths. This type of visor was accompanied by another innovation in design in the form of a new type of pivot which allowed the visor to be removed when not required. This worked by incorporating hinges into the arms of the visor in front of the pivots. The hinges were equipped with removable pins, often with their own small guard chains to prevent loss (Edge and Paddock 1998, 72-73).

From the beginning of the 13th century the flat-topped helmet current at the end of the twelfth century was fitted with a face guard which contained two slits for the eyes, called sights, and was pierced by holes for ventilation, called breaths. These are clearly

shown on the Shrine of Charlemagne in Aachen Cathedral, made between 1200 and 1207 (Edge and Paddock 1998, 53).

By the 1220s, this helm had evolved a narrow, fixed neck-guard which extended round to join the face guard to form a flat-topped, cylindrical helmet known as the great helm, or *heaume*. Over the next twenty years, the front of the helm was extended downwards to protect the wearer's neck. The best example of this type of helmet was excavated in the Schlossberg bei Dargen in Pomerania, and is now in the Museum für Deutsche Geschichte, Berlin (Edge and Paddock 1998, 53).

This form of helm remained unchanged until the 1260s, after which its crown was given a taper, presumably as a result of the inability of the flat-topped helm to deflect a sword cut. In the last quarter of the century the crown was given an even more pronounced taper, as is clearly shown on the brass of Sir Roger de Trumpington in Trumpington Church, Cambridgeshire (Edge and Paddock 1998, 53). The sides and front were also extended to almost rest on the shoulders and chest of the wearer. This provided a glancing surface off which the blades of weapons would slide (Edge and Paddock 1998, 69).

The great helm was worn with a padded arming cap, worn either over or under a mail coif. Two forms are known. The more usual one is simply a heavily quilted version of the civilian coif; rather less common is the variety depicted on the front of the Wells Cathedral, c. 1230, which is an arming cap with an additional roll of padding set at about the brow of the wearer. This roll would ease the weight of the helmet off the top of the head and help to spread it more evenly on the skull (Edge and Paddock 1998, 55).

Throughout the 14th century, the great helm continued to be worn by the knight over a basinet, and varied little in its general form. However, after about 1350 its use tended to be restricted to the tournament, although it is sometimes illustrated in manuscripts being worn in battle as late as the early 15th century.

The end of the 12th century saw the introduction of a completely new type of helmet known as the *chapel de fer* or kettle hat. It is known as a kettle hat because of its close resemblance to a medieval cauldron or kettle. The lasting form of the helmet consisted of a round bowl with a wide brim, sometimes of one piece, but often assembled from a number of plates riveted together. The skull was formed by a cross of steel, with the spaces filled by plates. This was used extensively by knights and was often worn with a basinet and mail coif underneath. However, worn alone or with a coif, it remained the common soldier's favorite up until the mid-fifteenth century. It was popular because it offered protection from a downward cut, but gave all-round vision. It was also particularly useful in siegework, because the brim helped to deflect missiles from the face (Edge and Paddock 1998, 55).

APPENDIX A2 History Of Tactics

When studying the emergence of plate armor from mail it is necessary to look at the uses for armor, which mainly would be warfare. The tactical changes during the transition may give some more evidence for the factors that caused this change.

A2.1 Cavalry Tactics and the Use of the Lance

Early cavalry techniques involved the knights on horses with or without stirrups, equipped with a long sword and a long spear or lance. The spear or lance was used as a thrusting weapon against both cavalry and infantry. When used against infantry a downward thrust was applied to hit the soldier. When used against a mounted knight the spear or lance would be used in an upward thrust to puncture or dismount the knight. These tactics changed to those known as “mounted shock troop” sometime around or before the middle of the 12th century. The lance, instead of being used as a thrusting weapon, was placed firmly under the arm and used along with the force of the horse to charge into the lines of infantry. This tactic was more likely to allow the cavalry to break through the front line and cause the infantry to lose formation leading to major casualties, as the confusion allowed the cavalry to take advantage of the infantry. (DeVries 1992, 12-13)

A2.2 Infantry and the Emergence of Staff Weapon Tactics

Cavalry's domination of the battlefield began to change in the early 1300s when infantry tactics began to improve. For ages the standard in infantry weaponry was a spear, some shorter or longer depending on who and when, and a sword, again the type varying with the culture and time period. In the 14th and 15th century the spear evolved into a longer pike. The extra length added onto the pike made it better suited for use against the charge of cavalry. Staff weapons, which combined the length of the spear with the melee power of a mace, axe or hammer, can be dated far before the late middle ages but for the most part these weapons didn't become widely used until the 14th century. (DeVries 1992, 15) Staff weapons made their mark on infantry-based armies starting in the early 14th century, when infantry armed with these weapons began to effectively defeat cavalry-based armies. Staff weapon tactics used by the Swiss were so effective that foot soldiers were often seen overpowering mounted knights. To deploy troops in this way the infantry had to be of high morale and trained well as a unit to resist a charge from the well-trained and armed cavalry units that would bear down on them. A well-formed infantry unit could stand against cavalry when deploying spears and missile weapons as long as there were no infantry as well helping the cavalry. This in essence made infantry and archers necessary to complement the use of the cavalry. (Keen 1999, 76-78)

The Scots defeated the English with the use of staff weapons at Loudon Hill 1307, and Bannockburn in 1314. The Swiss also defeated the Austrians at Morgarten 1315, and at Laupen 1339. The armies of the Flemings successfully defeated the French at both Courtrai 1302, and Argues 1303, by deploying successful staff weapon based infantry. (DeVries 1992, 29-30) At Courtrai the French deployed crossbowmen to inflict casualties on the Flemish pikemen. The French then deployed their cavalry to charge the

pikemen. Because the French general called the charge too soon, the Flemish pikemen were allowed to devastate the oncoming French cavalry. (Keen 1999, 113-114)

A2.3 Men-At-Arms

The use of men-at-arms, that is knights dismounted for combat, was a tactic mainly used by the English. In the mid 14th century the English began using a three-man lance unit instead of the traditional knight with two squires, one with the knight's lance and the other leading the spare horse. The three-man lance was two knights and a squire: the knights would dismount and fight side by side in combat and leave the horses with the squire till the end of combat when the squire would bring back the horses. (Prestwich 1996, 49)

The battle of Crécy in 1346 is a good example of the English knights dismounting to fight side by side with the infantry and of the English use of strong defensive bow tactics to support the infantry. The French deployed their crossbowmen in front of their cavalry. The English archers were spread out in a defensive formation around the infantry, consisting of both the normal foot soldiers and the English men-at-arms. The English archers used the firing rate of the long bow to overpower the French crossbowmen. The French cavalry could not then effectively mount a charge upon the well-placed English men at arms and ended the day with defeat. (Hooper & Bennett 1996, 120)

A2.4 The Crossbow

The crossbow is believed by some to be the major factor in the change from mail to plate armor. The crossbow has a violent force behind the bolts that are fired. It is capable of penetrating shields and mail and keeping enough force to continue moving. Reports from the 12th century say that bolts fired from a crossbow could pierce through a man's shield and armor and into the wearer. (Hardy 1976, 35) The church saw the power of the crossbow and how it challenged the dominance of the knight on the battlefield. This prompted the Pope to make a stand against crossbows and he declared the Anathema, which stated that the use of crossbows against Christians was against God's will. For those that chose to follow the new law set forth by the church, the only valid use of the crossbow was against non-Christians, but even then it was frowned upon. (Hardy 1976, 35) The belt and claw, consisting of a hook attached to the belt that could be used to set the crossbow allowing for a more powerful bow, were first recorded in the late 12th century. In the 14th century the windlass, which was a mechanical device attached to the crossbow to allow you to crank the string back with pulleys, and the screw winder, which was a shaft that could be attached to both the bowstring and a turning screw, brought increased power to the crossbow. (Richardson 1997, 43-44)

A2.5 Longbow

Technological advances in the bow were slowed by the emergence of the crossbow in the 10th and 11th century but still made significant improvements. (Hardy 1976, 35) The bow of the 11th century was the short bow which still had the power to pierce through some mails when used right. The arrows were standard 4-feathered shafts with a

tanged head. Into the 12th century the development of smaller heads allowed for arrows to be better at piercing mail armor. (Hooper & Bennett 1996, 161) There were cases of longbows powerful enough to pierce through a mailed leg and then into the mount of the knight and inflict a mortal wound on the horse. (Bradbury 1985, 16) The longbow, even though proven effective in battle by the English in the 1300s, still required immense training and did not prove to be a major component in the armies of continental Europe.

APPENDIX A3 Economic and Technological Evolution

The development of plate armor is intrinsically linked to the development of the use of iron in medieval Europe and the development of Europe as a modern industrial center. As Europe progressed through the middle ages, a series of advancements in mining, smelting, and economics advanced Europe's ability to manufacture increasingly sophisticated personal arms and armor. Without the societal changes and the refinements in iron- and steel-making, plate armor would never have become the widespread symbol of medieval Europe.

A3.1 Metallurgical Advances in the Middle Ages

The most important metal in arms manufacture from the Romans to the twentieth century, iron is the centerpiece of any metallurgical study of European arms and armor development. Able to be converted to steel or mass produced from pig iron, wrought iron was the primary material used in personal arms and armor.

The first iron produced by mankind, wrought iron was produced by smelting iron ore in a charcoal oven, or bloomery, creating a "bloom" of iron and iron-rich slag. The bloom was then worked (wrought) with a hammer to remove slag and form the bloom into a usable shape. Wrought iron was popular for cheap armor throughout Europe and Asia.

To understand the relationships between iron and steel one must examine the chemistry that separates them. While wrought iron is almost pure iron, steel has had a small amount of carbon, a few tenths of a percent of the total by mass, diffuse into the

iron. This creates a mixture that has significantly better hardness than wrought iron yet retains the malleability to be shaped and to take a blow without shattering. If the carbon content goes higher, to several percent, pig or cast iron is created. This metal has a low melting point allowing it to be easily cast in molds, but is useless for arms and armor as it is far too brittle to sustain blows.

Steel has been used for centuries for the finest arms and armors. Iron can be converted into two types of steel: carburized and homogenous mild steel (a hard yet still malleable steel). These were made by packing the iron in a carbon-rich environment and heating for long periods of time, allowing the carbon to diffuse into the iron, creating steel. Carburized steel had just a layer of steel over iron while homogenous steel was a carburized steel element that was folded and reforged onto itself to distribute the carbon throughout the element.

Both carburized and homogenous steel could be further hardened by quenching, that is, suddenly cooling a piece from over 900 degrees Celsius. This creates a mixture of carbon in iron which is very hard yet brittle. Careful reheating and quenching can result in tempered steel which reduces the brittleness without excessive loss of hardness. (Williams 1978, 2-4) Both quenching and tempering were known to Theophilus in the 12th century.

The most important advance in metallurgy in the Middle Ages is the blast furnace, developed over the 14th and 15th centuries. While the blast furnace produces pig iron, a very brittle material worthless for arms and armor, wrought iron can be made from pig iron with remelting, removing some of the carbon to create an iron with only a few tenths of a percent carbon. The blast furnace allowed the production of "much more iron with

much less labor, reducing cost and multiplying applications." (Gies and Gies 1994, 202)

The advantage to creating pig iron is the economy of scale. Whereas a bloomery could smelt 60-70 kilograms of iron in a single operation, a blast furnace can smelt hundreds of kilograms at a time and operate continuously with power from a waterwheel. (Singer 1954, 71) While this was a boon to the producers of munition armor, where the material cost would be up to half the selling cost, in high-end armor commissioned by the wealthy, the material cost would be a nearly insignificant portion of the total cost. (Williams 1991, 79)

The major disadvantage of using pig iron in creating armor was the slag included in the final product. This can reduce the hardness and thus the protective capabilities of the armor by a significant amount. Bloomery iron could create a steel with fewer slag inclusions and therefore with superior defensive properties. The low volume of iron produced at a bloomery would raise the price to make it too expensive for the munitions armorer to use without prohibitively raising his prices. (Williams 1991, 79)

A3.2 Medieval Economics

During the fourteenth and fifteenth centuries Europe completed its transition to a mercantile-based economy and brought about the fulfillment of the Commercial Revolution. Significant achievements included the increasing urbanization of the continent and better economic systems to allow expanded trade. To fully appreciate these changes, one must look back to the beginnings of the second millennium CE.

After the First Crusade (c.1095), Europe began to develop from a barely civilized, developing region to a full economic power with bases in manufacturing and trade. Contact with the more advanced Muslim civilization increased with the victories in the Middle East and Spain, with the capture of Toledo, the new Muslim center of learning, coming in 1105. Europe began to export textiles and metal goods including arms and armor to Africa and the Near East instead of its formerly dominant fur and slave exports. (Gies and Gies 1994, 107) Cities changed into centers of commerce from their previous role as military and administrative headquarters.

Guilds, first of merchants (c.950) and later of craftsmen (c.1100), began to form from "associations of fellow drinkers" and became very powerful political organizations. (Gies and Gies 1994, 121-4) The mining industry reacted to the increase in demand by opening new mines, uncommon since the fall of the Roman Empire. The need to keep mines dry was a major source of innovation as deeper shafts were excavated and water tables breached. (Gies and Gies 1994, 168) Perhaps most important socially is a proliferation of blacksmiths throughout medieval Europe during the middle of the 12th century. By the end of the century, nearly every village had its own blacksmith. (Gies and Gies 1994, 126)

Technological developments included the widespread use of water wheels and a revival of bridgework techniques. This allowed the harnessing of the power of the rivers of Europe as bridges were built with mills and blast furnaces in the constricted flow between their piers. Water power was used to pump bellows for the blast furnaces and smithies of the time while powering trip hammers that beat the slag out of the product.

Crafts became specialized by town or region and guilds flourished, growing to dominate the cities.

The thirteenth century found Europe turning towards the sea as the Arabs and Mongols became increasingly hostile and land trade routes to the Orient had closed. Growth of trade brought about a demand for coin metal, leading to the opening of precious metal mines throughout Europe and stimulating underground mining development. Possibly the most important economic development was that of credit institutions that got around the Church's usury laws, allowing for the development of capitalist ventures and permanent corporations including the armory houses of Italy and Germany.

In short, Europe was moving from the feudal economy of the previous millennium to a modern commercial society. With the growth of commerce and the creation of wealth that accompanies it, the continent began to demand more resources, prompting technological achievement and increased productivity.

A3.3 The Armorer's Craft

The basics of armor making are simple: take plates of metal and cut, hammer, and weld them into the appropriate shape. This process becomes incredibly complex as the armor must satisfy the often conflicting requirements of protection, mobility, and fashion. The skill of the medieval metal worker was considerable, and by the sixteenth century even surpassed the skill of modern recreationists and craftsmen. (ffoulkes 1912, 51)

From prehistoric times, the basic tools of the metalworker have not changed, being hammer, anvil, and tongs. Variations of these implements and their degree of

craftsmanship and mechanization are the major differences between any two time periods. Listing inventories from a variety of sources in England and France, ffoulkes shows the armorer to have a large selection of specialized tools to work with.

The armorer would mark a pattern for the piece to be worked in a sheet of metal, then cut it out with shears. Careful filing, polishing, and hot and cold hammerwork by the armorer produced the piece. Hammers were kept polished so as to present the smoothest face while working a piece. From inventories of armorers, it is known that the armorer generally did not produce the iron sheet on his own but rather purchased it wholesale from specialty dealers. (Price 2000, 354) The sheets would be formed by platers working by hand or later with the assistance of water power and trip hammers.

The platers obtained their material directly from the bloomery hearth or the blast furnace and applied their technique to make a more useable product. Before the advent of water power, it seems that the end product was still difficult to work with, as ffoulkes quotes: "They could make but one little lump or bloom of Iron in a day, not 100 weight and that not fusible, nor fined, or malleable, until it were long burned and wrought under hammers." (Dud Dudley *Metallum Martis* 1665, 37, quoted in ffoulkes 1912, 43)

Armorers were derived from the more generalized blacksmiths, but unlike swordsmiths, did not begin to see specialization and concentration into armor production centers until the 12th century. By the 13th century Northern Italy and Germany were the two centers of arms and armor production for Europe, dominating the production of armor. (Price 2000, 5) The Italians led the export industry until about 1500 and had an important trade in arms and armor from at least the 13th century. (Pfaffenbichler 1992, 6) While other countries attempted to develop a domestic arms industry, they had very little

success. There are multiple instances of kings bringing armorers from Germany or Italy to found colonies and establish a local trade, but other than in England, this practice never seems to have been successful for more than a few generations. Even with the encouragement of the crown, English armor never received the same renown as Italian and German armor.

A major reason for the guilds remaining concentrated and colonies of armorers refusing to expand into a flourishing local industry is the secrecy surrounding the craft. Not trusting foreigners to keep the guild's secrets, they were simply never shared. While most locales had the capacity to make low-grade munition armor, the techniques of tempering the steel were closely kept by the guilds, thus creating a monopoly. The development of guilds also brought about a greater knowledge base for the craft, allowing an armorer to develop more advanced techniques rather than rediscover those already known. The concentration of craftsmen in guilds precedes the emergence of plate armor, beginning in the twelfth century, and looks to be a major factor in its development.

Italian armorers guilds organized production from the individual armorers who specialized in certain components and provided them prefabricated to others who would assemble and ship the final product. Each armorer had to prove his skill and undergo training as an apprentice in a guild regulated manner, ensuring the quality of the product. The guilds also provided political influence for the armorers as they grew to economically dominate several cities in northern Italy, Milan and Brescia being two of the major ones. The Italians dominated the arms and armor trade throughout the middle ages until the late fifteenth century when Germany ascended to the forefront of armor production. (Karcheski 1995, 61-2)

The German centers of production were Augsburg, Cologne, Landshut, Nuremberg, and later Innsbruck. Nuremberg is an interesting example as the city provided the quality assurance checks and organization that the guild would normally provide, due to guilds being banned after a craftsmen's revolt. This shows the importance of maintaining quality product and the city's reputation. (Karcheski 1995, 62-6)

The completed armor would be subjected to a blow from the most powerful weapon of the day, the mark being the "proof" that the armor would protect the wearer from harm. This was done with close range shots from projectile weapons or, more rarely, from actual sword blows. Once the armor was shown to be proof and passed all guild or town inspections, it would receive a mark of the producing guild, showing that it was of up to the guild's standards.

APPENDIX A4 Evolution of Plate Armor Web Page

The web page was written in HTML 4.0 and laid out in a directory-based format for ease of organization. The home page was in the lowest directory and each section had its own directory. The .inc files were stored in a directory for the includes and the pictures were stored in a separate directory. In each directory there was a pic.jpg that was a symlink to a modified picture with the -2.jpg ending in the /pics/ directory. This allowed the pictures to be centrally stored yet easily referenced in the include headed.inc. These are not further detailed in this document as they have no significant impact on the look of the web page and are essentially interchangeable. The text-heavy pages will only display the actual text as there is no variation in the html code between pages inside a directory. The pictures in the /pics/ directory are presented in their own separate entry along with where they are used rather than being listed in each page which pictures are used.

A4.1 Home Page and Incidentals

A4.1.1 /index.html

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<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.0//EN">
<html>
<head>
<title>Higgins Armory: Evolution of Plate Armor Home Page</title>

<meta name="keywords" content="armor, arms, museum, knight, knights,
medieval, joust, jousting, shield, weapon, helmet, history, chivalry,
middle ages, breastplate, Renaissance, Worcester, Massachusetts, Central
Mass, Central Massachusetts, horse, history, Higgins, WPI, universities,
college, colleges, undergraduate, education">

<meta name="authors" content="Adrian Wheelock, Ian Hobbs, Jordon Maddock
```

and Jeffrey Singman">

```
<!--#include virtual="headend.inc"-->
```

```
</td>
```

```
<td bgcolor="white" align=left valign=top rowspan=2>
```

```
<H1 class=center>Emergence of Plate Armor</H1>
```

The change from mail to plate armor in Medieval Europe has been a source of inquiry for years. A large number of factors were involved and this IQP looks at the possible driving forces behind the change and their ultimate impact. It was done through the Higgins Armory as an undergraduate requirement for Worcester Polytechnic Institute. (for more information, see our about section)

```
<table border=0 cellspacing=0 cellpadding=20 width=100%>
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```
<tr>
```

```
<td align=center valign=top rowspan=1>
```

```
<h3 class=maroon><a href="tour/index.html">Take the Guided Tour</a></h3>
```

A directed look at the evolution of plate armor. Ideal for first-time visitors.


```
</td>
```

```
<td align=center valign=top rowspan=1>
```

```
<h3 class=maroon><a href="indepth/index.html">An In-Depth Look</a></h3>
```

A self-guided look at our research.


```
</td>
```

```
<tr>
```

```
<td align=center valign=top rowspan=1>
```

```
<h3 class=maroon><a href="glossary/index.html">Glossary of Terms</a></h3>
```

Glossary of terms for reference.


```
</td>
```

```
<td align=center valign=top rowspan=1>
```

```
<h3 class=maroon><a href="links/index.html">Links</a></h3>
```

Links to other Arms and Armor sites.


```
</td>
```

```
<tr>
```

```
<td align=center valign=top rowspan=1>
```

```
<h3 class=maroon><a href="about/index.html">About the Project</a></h3>
```

Information about the Higgins Armory,

Worcester Polytechnic Institute, and

their relation to this site.

```
</table>
```

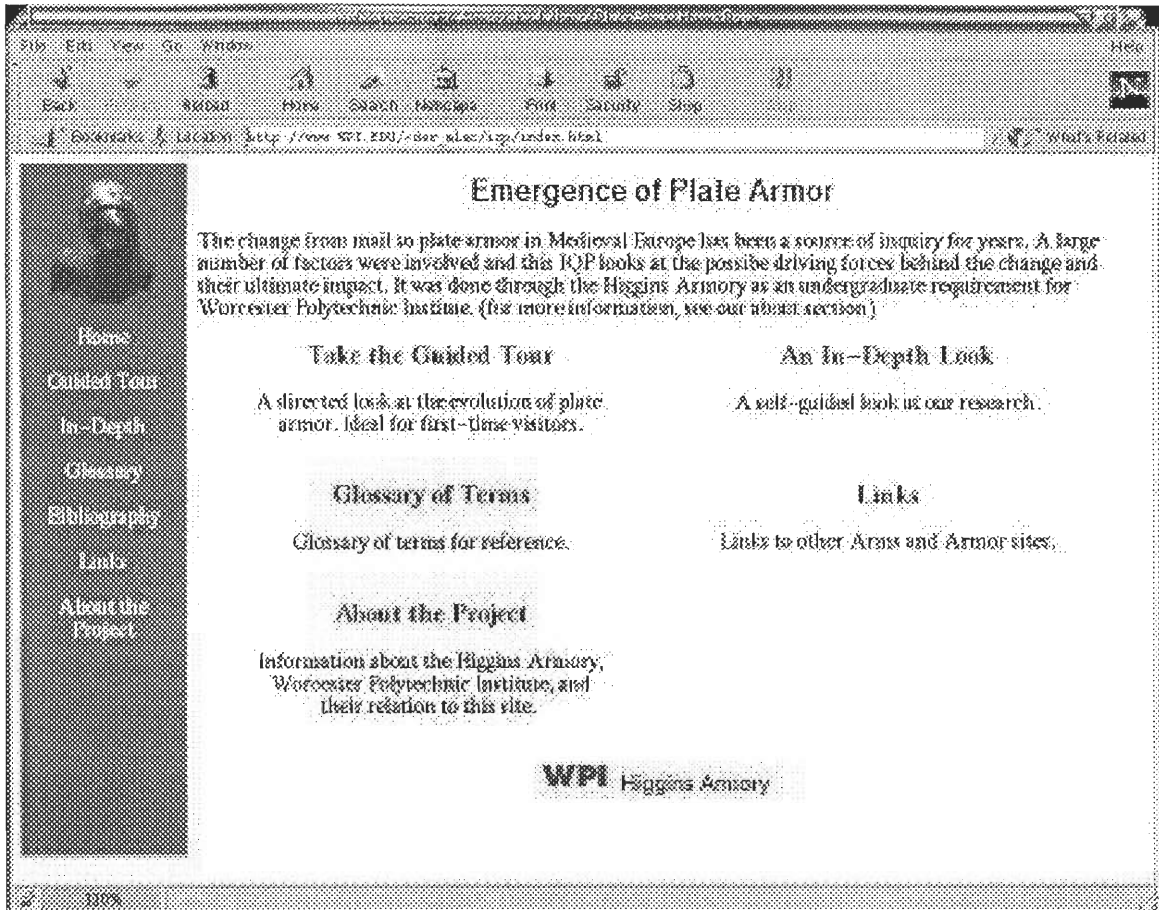


Figure 4.1: Screenshot of /index.html.

A4.1.2 /headed.inc

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A.plain:link, A.plain:active, A.plain:visited{color: white; font-size:90%; text-decoration:none}
.center{text-align: center; font-family: sans-serif; font-size: 24pt}
.maroon{color: #944b41} -->
</style>
</head>
<body bgcolor="white">
<table width="100%"border=0 cellspacing=0 cellpadding=10 height="100%">
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<a class=plain href="index.html">Home</a><br><br>
<a class=plain href="tour/index.html">Guided Tour</a><br><br>
<a class=plain href="indepth/index.html">In-Depth</a><br><br>
<a class=plain href="glossary/index.html">Glossary</a><br><br>
<a class=plain href="indepth/biblio.html">Bibliography</a><br><br>
<a class=plain href="links/index.html">Links</a><br><br>
<a class=plain href="about/index.html">About the Project</a><br><br>

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A4.1.3 /includes/bodyend.inc

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<td align=center valign=center >
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<font style="font-family:sans-serif; font-size:large">
<a href="http://www.higgins.org">Higgins Armory</font></a>
</td>
</table>
</TABLE>
</BODY>
</HTML>
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A4.1.4 /includes/hbodyend.inc

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<a href="http://www.wpi.edu/"></a>
<font style="font-family:sans-serif; font-size:large"> <a
href="http://www.higgins.org">Higgins Armory</font></a>
</td>
</table>
</TABLE>
</BODY>
</HTML>
```

A4.1.5 /includes/headend.inc

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90%; text-decoration:none}
.center{text-align: center; font-family: sans-serif; font-size: 24pt}
.maroon{color: #944b41}
P.cite {text-indent: -3em; margin-left: 3em}
P.anno {font-size: 10pt; margin-left: 3em}
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</style>

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<a class=plain href="../index.html">Home</a><br><br>
<a class=plain href="../tour/index.html">Guided Tour</a><br><br>
<a class=plain href="../indepth/index.html">In-Depth</a><br><br>
<a class=plain href="../glossary/index.html">Glossary</a><br><br>
<a class=plain href="../indepth/biblio.html">Bibliography</a><br><br>
<a class=plain href="../links/index.html">Links</a><br><br>
<a class=plain href="../about/index.html">About the Project</a><br><br>

```

A4.2 Guided Tour

A4.2.1 /tour/index.html

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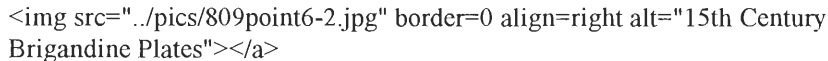
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Page</title>

<!--#include virtual="../includes/headend.inc"-->

</td>
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<H1 class=center>Guided Tour Main</H1>

```

This tour will take you through the evolution of plate armor and discuss the factors that influenced its development. If you wish a more in-depth look at the elements involved, go to the [in-depth](../indepth/index.html) page.

[pic](../pics/809point6.jpg)


To start the tour, click [here](before1250.html).

To skip to a specific page, follow the links below:

- [Before 1250 CE](before1250.html)
- [1250-1300 CE](12501300.html)
- [1300-1400 CE](13001400.html)
- [After 1400 CE](after1400.html)
- [The Armorer's Craft](craft.html)
- [Why not Plate Armor Earlier?](whynot.html)

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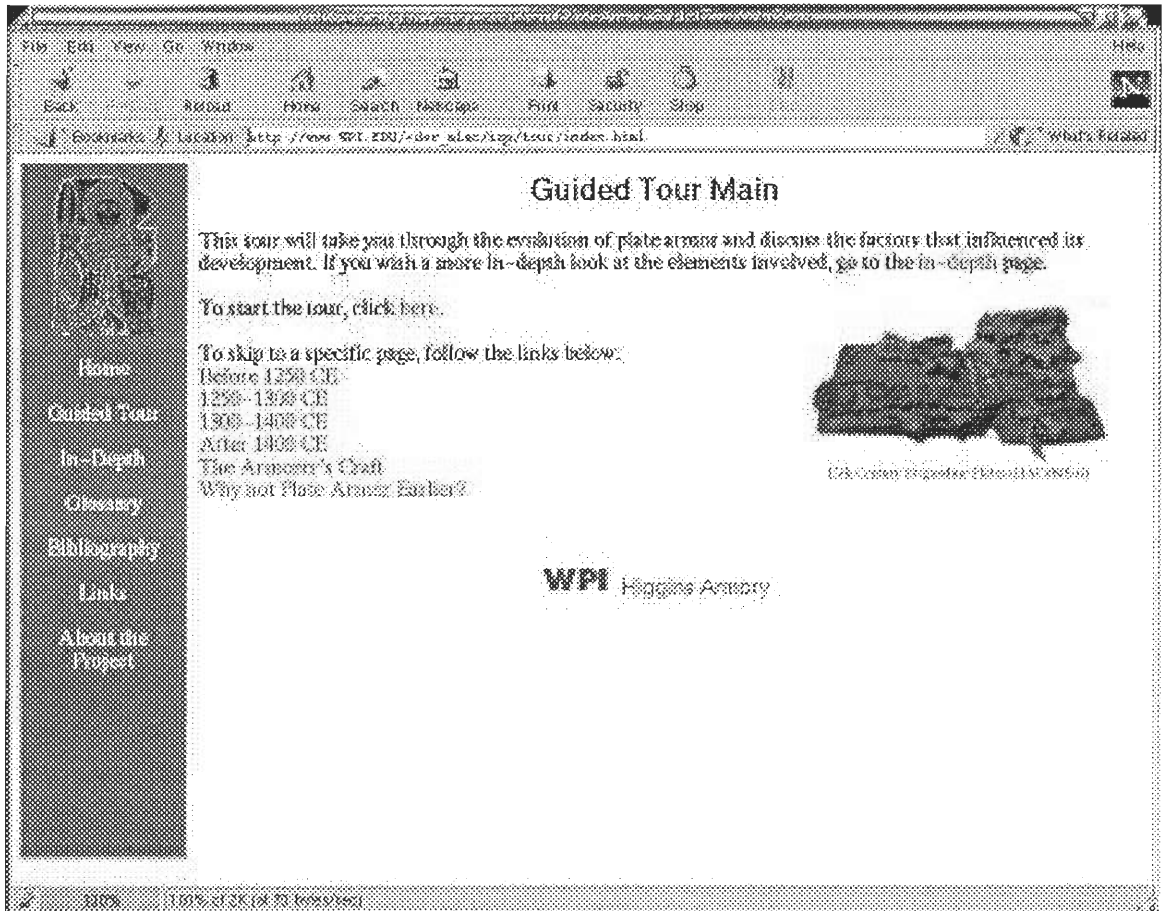


Figure 4.2: Screenshot of /tour/index.html.

A4.2.2 /tour/before1250.html

Before 1250 CE

Prior to the middle of the 13th century, mail is almost exclusively the armor material of choice. The earliest evidence of the mail hauberk dates back to the time of the Celts, and it continued to be worn for centuries, although decreasing in popularity as elements of plate are integrated. Nearly always does the hauberk also include an attached coif, mail defense for the head.

Mail chausses, for the legs, also became very popular in the 12th century, and mail protection for the foot also became much more common. With the introduction of mail mufflers, a sort of mitten-shaped defense for the hand, almost the entire body was covered in mail: head, torso, arms, hands, legs, and feet. The equipment of the knight, consisting of these mail defenses, changed little from the 11th century through the middle of the 13th.

Mail is not a rigid defense, and, while it is fully capable of stopping a cut, the very force from an attack is capable of causing severe trauma and breakage of bones. In addition, it is quite possible for an arrow or a crossbow bolt to pierce mail, bursting apart the links. To protect against all this, rigid defenses were incorporated into the knight's armor, leading eventually to the development of plate.

At this time cavalry dominated the battlefield. During the early to mid 12th century, shock troop tactics were being developed for use against infantry. This is where a unit of well-organized cavalry would charge against infantry using either spears or lances to break through the lines and cause disorder so that they might have the advantage. The rise of shock tactics was made possible by the stirrup and the couched lance coming into a more important role on the battlefield also at this time.

Bows and crossbows were not seen as essential units on the battlefield yet. The crossbow was still in its infancy not being able to fire much better than the standard longbow. The belt and claw, developed in the late 1100s was simply a belt containing a hook that could be used to reset the crossbow. Both the longbow and the crossbow show cases of penetrating mail armor at this time.

Technologically, development of armor towards plate begins earlier, after the First Crusade (c.1095). Europe then began to develop from a barely civilized, developing region to a full economic power with bases in manufacturing and trade. Contact with the more advanced Muslim civilization increased with the victories in the Middle East and Spain. Europe began to export textiles and metal goods including arms and armor to Africa and the Near East instead of its formerly dominant fur and slave exports. Cities grew and changed into centers of commerce from their previous role as military and administrative headquarters.

The thirteenth century found Europe turning toward the sea as the Arabs and Mongols became increasingly hostile and land trade routes to the Orient had closed. Growth of trade brought about a demand for coin metal, leading to the opening of mines throughout Europe and stimulating development of mining techniques.

In short, Europe was moving from the feudal economy of the previous millennium to a modern commercial society. With the growth of commerce and the creation of wealth that accompanies it, the continent began to demand more resources, prompting technological achievement and increased productivity.

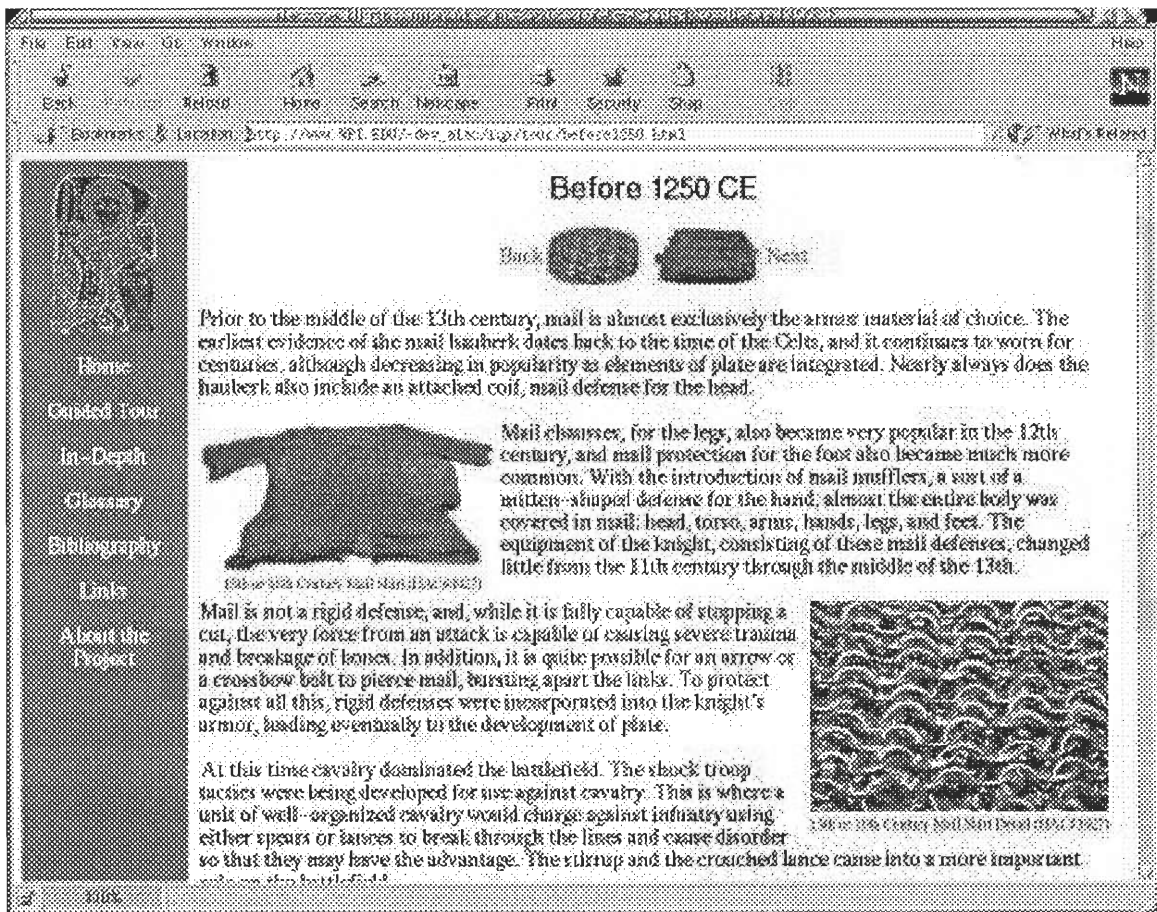


Figure 4.3: Screenshot of /tour/before1250.html.

A4.2.3 /tour/12501300.html

1250 - 1300 CE

This is when plate truly goes into continuous development. During this period, basic plate defenses are developed for nearly every part of the body. The rigid defense known as the cuirass, which is made of cuir-bouilli, is popular at this time, but actual metal plate springs up relatively quickly. Mail still remains quite popular despite the emergence of the new defenses. In fact, some of the earliest implementations of plate are designed to be strapped directly over the current mail defenses.

Metal plate defenses first appear for the legs, beginning with poleyns that are strapped to the knees of the chausses. They quickly grow to encompass the sides of the

knee, as well as the front. At the end of the 13th century, the first plate defense for the lower leg, the schynbald, appears. These, however, only protected the front of the leg, and were also strapped onto the chausses. A possible explanation for the development of leg defenses first was the vulnerability of the knights' legs while mounted.

Of course, the arms were also better protected by the end of this period. Disc-shaped couters, found as early as 1260, were devised to attach to the elbows of the hauberk. In addition, steel-plated gauntlets are first mentioned at the very end of the 13th century, but still the vast majority of knights prefer to use the mail mufflers.

Plate defenses for the torso start to come into continuous development as well, though articulation was probably a very large problem for the armorer. One of the key elements hindering attempts to learn more about the torso defenses of the time is the surcoat.

The surcoat was worn by almost all knights, always over any other armor that they were wearing. It was such a long garment that it covers evidence of other defenses in contemporary illustrations and engravings. However, plate was even integrated into the surcoat, which was sometimes reinforced with rows of long rectangular plates riveted to the inside of the fabric.

Another body defense, one that remains popular for some time, appears in the mid-13th century. Called a coat of plates, it was shaped like a cross when laid out, with a neck opening near the middle where a coif was attached. When worn, the long flaps would fall over the wearer's back and front, and the other two flaps folder around the sides and buckled in the rear. The entire garment was lined with oblong plates.

A4.2.3 /tour/13001400.html

1300 - 1400 CE

In the 14th century, plate begins to flourish. The knight's leg at the beginning of the century was still commonly protected with only mail chausses, but after about 1310, even the schynbalds developed in the previous period become rare, being replaced by the greave, which completely surrounded the lower leg.

Plate defenses for the feet, called sabatons, also were introduced early in the century. They often consisted of overlapping lames shaped to the pointed shoe of the time, covering the top of the foot. The lames were probably riveted to a leather lining and secured to the shoe by laces or straps.

The couters and gauntlets of plate developed previously became popular, and, in fact, the mail muffler all but disappeared by about 1330. The gauntlets also now included plates to cover the fingers and the thumb, these plates themselves sometimes including gadlings, spikes attached to the knuckles.

The vambrace, the complete plate defense for the arm (except the shoulder), first appears during the 2nd decade of the century. It consists of two gutter-shaped plates that encircle the arm and the couter strapped over the hauberk. Often accompanying the vambrace were disc-shaped plates called besagews. One was laced to the outside of the elbow and the other to the front of the shoulder to protect the armpit.

During this period, armorers also experimented with non-metallic material, such as baleen and horn. In addition, it is very rare to find a depiction of a knight armored entirely with mail after about 1330.

Toward the middle of the century, a single large breastplate, covering the upper chest, starts to evolve. Rather quickly, it increases in size to cover down to the diaphragm, and also begins to include a skirt comprised of horizontal hoops of iron or steel.

Despite the rapid increase in the development and articulation of plate defenses, mail still continues to be used. The hauberk, for example, is still worn under the knight's plate armor. It was also still necessary to defend such areas as the armpit and the crotch, over which plate was extremely difficult to articulate. In part due to the expensive nature of plate, only the rich could afford to keep up with the style, and almost up to the end of the century, many knights had to settle for armor consisting mostly of mail, with perhaps a few pieces of plate.

However, by the end of the century, the coat of plates is still quite popular while the breastplate continues to develop, plate arm defenses are fully articulated, and greaves are worn along with fully articulated sabatons. With the introduction of cuisses of plate, protecting the upper leg, the knight's plate harness was basically complete.

Many of the direct causes to the evolution of the plate armor occurred at this time with respect to tactics. The infantry started to implement staff weapon tactics against cavalry giving them an advantage over the mounted knights. The English began deploying their knights on foot to fight amongst the standard infantry as at the battle of Crecy in 1346. Advances in crossbow technology, such as the windlass and the crank and screw, enabled the weapon to be reloaded using a much higher string tension, resulting in a more powerful weapon.

Technological developments off the field of battle included the widespread use of water wheels, harnessing of the power of the rivers of Europe. Water power was used to pump bellows for blast furnaces and smithies while powering trip hammers that beat the slag out of the metal and formed it into usable plates. Armorer's guilds began to form and concentrate in Germany and Italy, dominating some towns.

The most important advance directly related to the medieval production of armor is the blast furnace, developed over the 14th and 15th centuries. The blast furnace produces pig iron, a low melting point alloy easily cast in molds. It is useless for arms and armor, however, as it is far too brittle to sustain blows. Stronger wrought iron can be made from pig iron by remelting it, although there are generally more impurities that make it weaker than wrought iron produced at a bloomery. The advantage to creating pig iron is the economy of scale. Whereas a bloomery could smelt 60-70 kilograms of iron in a single operation, a blast furnace can smelt hundreds of kilograms at a time and operate continuously with power from a waterwheel. While this was a boon to the producers of cheap munition armor, where the material cost would be up to half the selling cost, in high-end armor commissioned by the wealthy, the material cost would be a nearly insignificant portion of the total cost.

A4.2.4 </tour/after1400.html>

A full plate harness was basically being worn by the beginning of the 15th century. However, developments continued to be made to better articulate the armor for mobility, and to decrease the possibility of heat exhaustion that was a very large concern when the knight was armored in a full suit of plate. The developments in the early part of the

century lead to what is now called white armor, a full suit of articulated plate. Even on this white armor, though, mail continued to be used in a limited fashion to defend parts of the body such as the crotch and armpit, where armorers still had a very difficult time appropriately articulating a piece that could directly cover these particular areas and still allow for enough mobility. In fact, judging by illustrations dated well into the 17th century, these areas were almost never covered by plate, and so, in a sense, mail never truly ceased to be used.

A4.2.5 [/tour/whynot.html](#)

Why Plate?

The rise of plate armor is an unresolved topic that finds no clear solution. With many primary sources destroyed through time and a large number of competing influences, the reason behind the transition from mail to plate armor in medieval Europe remains unclear. Other cultures that used mail had no such transition, and yet were subject to many of the same influences as the Europeans. Why then do we only see plate armor used in Europe? While many scholars have put forth the increasing effectiveness of the crossbow and longbow, these seem like simple answers that do not reflect the full story. This report looks at a variety of possibilities for the evolution of plate armor and how they affected its development.

Europe at the start of the second millennium CE was a relatively backwards region compared to the Arab culture bordering it to the east and south. This changed, however, with the crusades and the increased cultural contact they brought. Europe underwent two centuries of expansion and growth as the feudal system began to break down in favor of a

more capitalistic economy. Trade grew and Europe began expanding its industrial capabilities and infrastructure beyond that left by the Roman Empire. This included the opening of many new mines and many improvements in the amount of ore that a mine was capable of removing.

As the supply of metal increased, the more common it must have become in the eyes of the European. A proliferation of blacksmiths in the middle of the twelfth century emphasizes this point. As the number of blacksmiths grew, the capacity for specialization increased. This led to the development of specialist armorers, at first concentrating in the mercantile cities of Italy. As the trade specialized and the supply of iron increased, the capability of Europe to supply the amount of iron and the skill required for plate armor was met. This alone does not precipitate the development of plate armor, but the stage was set. Without the growth of medieval Europe's economic base, the capacity to manufacture and the cultural ability to conceive of such defenses would have been impossible.

Beyond technical reasons, medieval warfare itself was changing. Tactical changes that threatened the role of the knight on the battlefield influenced the necessity to develop armor that could better protect knights. Advances in infantry tactics and projectile weapons such as the longbow and crossbow have been put forward as influences on the change. The longbow's use was primarily English, which makes it unlikely that the longbow influenced a continent-wide change. The crossbow, whose use had spread during and after the crusades, had already taken its place on the battlefield throughout Europe. The strength at which crossbows could be made to fire allowed for the penetration of simple shields and mail defenses, requiring a stronger forms of defense than

mail. Better use of infantry and developing infantry weapons are most likely the chief battlefield influence on the change from mail to plate armor.

The emergence of infantry armed with staff weapons such as the halberd and the pike also caused a change in the way battles were fought. Infantry equipped with staff weapons were able to stand against charging cavalry. Weapons like the halberd, which feature long poles with an iron head attached to the end, were used to then attack the knights while they were held at bay by the front line of pikemen. The technique of dismounting knights to fight with the infantry is another tactic that may have influenced the emergence of plate: Knights on foot would want to retain an advantage having lost their mount. The use of plate armor instead of mail would allow these knights to fight more safely alongside ordinary infantry.

A4.2.6 /tour/craft.html

The Armorer's Craft

Armorers were derived from the more generalized blacksmiths that had become widespread in the 11th century. Armorers began to become specialized as early as the 12th century beginning in Northern Italy and Germany. These were the two centers of arms and armor production for Europe throughout the Middle Ages, known for their superb quality and craftsmanship. The Italians led the export industry until about 1500, at which point the Germans caught up and eventually overtook them in exports. While other countries attempted to develop a domestic arms industry, they had very little success. There are multiple instances of kings bringing armorers from Germany or Italy to found

colonies and establish a local trade, but other than in England, this practice never seems to have been successful for more than a few generations. Even with the encouragement of the crown, English armor never received the same renown as Italian and German armor.

Italian armorers were organized into guilds that organized production from the individual armorers who specialized in certain components and provided them prefabricated to others who would assemble and ship the final product. Each armorer had to prove his skill and undergo training as an apprentice in a guild regulated manner, ensuring the quality of the product. The guilds also provided political influence for the armorers as they grew to economically dominate several cities in northern Italy, Milan and Brescia being two of the major ones. The Italians dominated the arms and armor trade throughout the Middle Ages until the late fifteenth century when Germany ascended to the forefront of armor production.

The German centers of production were Augsburg, Cologne, Landshut, Nuremberg, and later Innsbruck. Nuremberg is an interesting example as the city provided the quality assurance checks and organization that the guild would normally provide, due to guilds being banned after a craftsmen's revolt. This shows the importance placed on maintaining quality product and the city's reputation.

A4.3 In-depth Explanations

A4.3.1 /indepth/index.html

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<a href="../pics/938.jpg"></a>
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<a href="../pics/d1306.jpg"></a>
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and Early Plate</a></h4>
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Integration of Plate</a></h4>
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<h4 class=maroon><a href="historyofarmor.html#oversmail">Overshadowing  
Mail</a></h4>
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Plate</a></h4>
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Plate  
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<h4 class=maroon><a href="weaponsandtactics.html#cavtactics">Cavalry  
Tactics and the Lance</a></h4>
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<h4 class=maroon><a href="weaponsandtactics.html#infactics">Infantry  
Tactics and Polearms</a></h4>
```

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<h2>Socio-Economic Considerations</h2>
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<h4 class=maroon><a href="sociopolit.html#metall">Metallurgical Advances in the Middle Ages</a></h4>
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<h4 class=maroon><a href="sociopolit.html#mecon">Medieval Economic and Technological Development Summary</a></h4>
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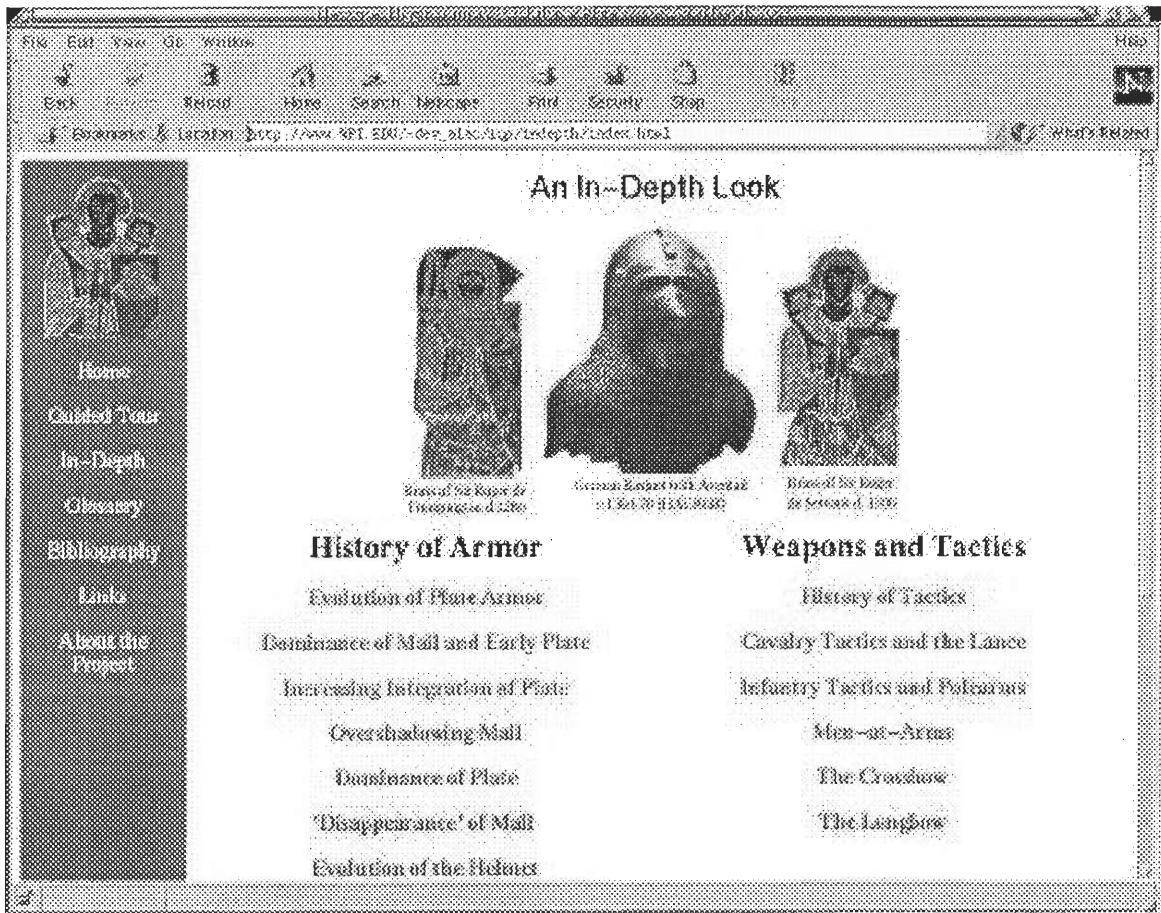


Figure 4.4: Screenshot of /indepth/index.html

A4.3.2 /indepth/historyofarmor.html

Text is identical to A1.

A4.3.3 /indepth/weaponsandtactics.html

Text is identical to A2.

A4.3.4 /indepth/sociopolit.html

Text is identical to A3

A4.4 Glossary

Found at /glossary/index.html.

Glossary

[code for one entry provided]

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<h4 class=maroon>Aketon:</h4>

A padded and quilted garment, worn under or instead of plate or mail.

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Alloy:

A mixture of two or more metals or of a nonmetal in a metal.

Arming Cap:

A quilted head defense, often worn between a helm and a mail coif.

Aventail:

A flap of mail attached to the coif or helmet which extended down to protect the neck and throat. It sometimes could also be pulled across the mouth to protect the lower face.

Backplate:

A plate defense for the upper back, often extending to the lower back and upper buttocks.

Baleen:

A horn-like material used in some plate defenses, taken from the upper jaw of certain whales; often mistakenly called whalebone.

Basinet:

An open-faced helmet with a globular or conical skull.

Besagew:

A circular plate attached to the front of the shoulder to defend the armpit.

Bevor:

Armor for the chin and upper throat.

Blast Furnace:

A tall (14-16 foot) hearth that reduces ore into slag and metal. Can achieve higher temperatures than the bloomery and can operate continuously with powered bellows.

Bloomery:

The most basic way of reducing ore to metal, a high temperature hearth that produces a small lump of metal called a bloom.

Bracer:

Defense for the lower arm.

Brass:

A funerary image of the deceased engraved in brass.

Breastplate:

Armor protecting the front of the torso.

Breaths:

Holes or slits in the visor of a helmet for ventilation.

Brigandine:

A flexible vestlike body defense composed of many small plates riveted inside a cloth covering.

Cannon:

Individual tubular defense for the upper and lower arm.

Chausses:

Mail protection for the legs.

Coat of Plates:

A torso defense consisting of iron plates riveted inside a cloth covering.

Coif:

A hood, usually of mail; often included an aventail.

Couter:

Plate defense for the elbow.

Cuirass:

A term referring to the breast- and backplates worn together.

Cuir-Bouilli:

Leather hardened in boiled water or wax, then dried over a form.

Cuirie:

An early torso defense, made of cuir-bouilli.

Cuisses:

Armor for the thigh.

Effigy:

A sculpted funerary image of the deceased.

Fauld:

Laminated plates, attached to the lower edge of the breastplate or cuirass to protect the abdomen.

Gadlings:

Spikes attached to the knuckles of the gauntlet.

Gamboised Cuisses:

Padded, quilted thigh defenses.

Gauntlet:

A plate defense for the hand, eventually replacing the muffler.

Greave:

Armor for the lower leg, and often the ankle.

Guard-Chains:

Chains that held weapons and other parts of the armor, such as the helmet, to the breastplate to prevent loss during battle.

Hauberk:

A mail shirt, including sleeves, reaching to somewhere between the knee and hip.

Kettle Hat:

An open-faced helmet consisting of a bowl and a broad brim.

Lame:

A narrow strip or plate of steel, often used to provide articulation.

Lamellar Armor:

Armor consisting of small plates attached to each other to give a rigid defense.

Latten:

A copper alloy, similar to brass or bronze.

Muffler:

A mitten-like extension to the sleeve of the hauberk.

Munition Armor:

The cheap, common armor procured in great numbers for the ordinary soldier.

Pig Iron:

A crude, high-carbon iron that is produced by the blast furnace. Requires further refinement to become wrought iron or steel.

Poleyn:

A cup-shaped defense for the knee.

Sabaton:

Armor for the foot.

Scale Armor:

Armor made from small, overlapping scales or plates sewn or laced to a cloth garment.

Schynbald:

A plate defense for the lower leg covering only the shin and strapped on over the chausses.

Sight:

The slit in a helmet or visor made to provide vision.

Slag:

Impurities in metal, usually removed either in the furnace or beaten out.

Spaudler:

Armor for the shoulder.

Surcoat:

A long cloth garment, sometimes reinforced with rows of plates, worn over armor.

Trip Hammer:

Large hammers used to beat slag out of metal and perform rough shaping into plates and powered by a waterwheel.

Tulip Form:

A description of cannons that narrow towards the wrist and flare at the cuff.

Vambrace:

Armor covering the lower arm.

Vervelles:

Staples which attached the aventail to the bassinet.

Wrought Iron:

The most common form of iron in the Middle Ages, contains nearly no carbon and a moderate amount of slag while being strong enough to be used in arms and armor.

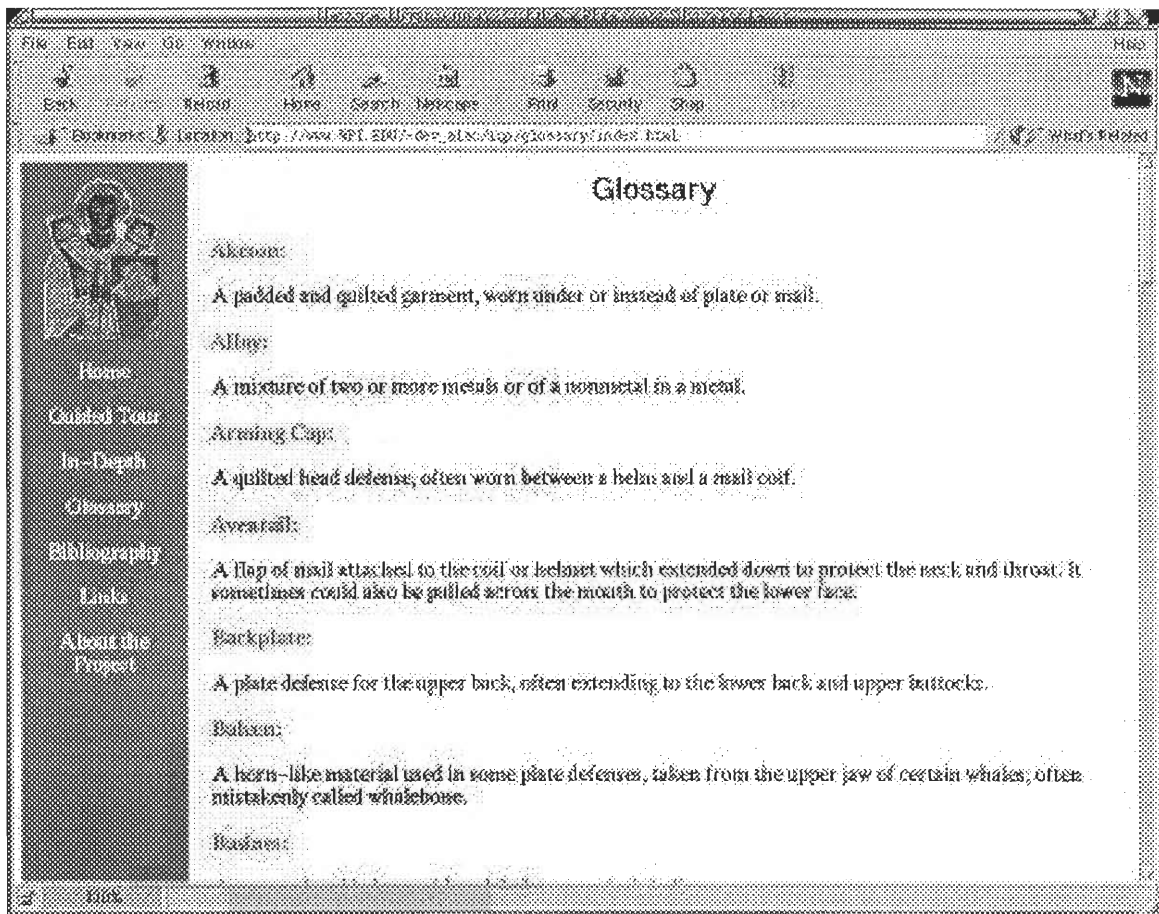


Figure 4.5: Screenshot of /glossary/index.html.

A4.5 Bibliography

Found at /indepth/biblio.html.

Blair, Claude. *European Armour Circa 1066 to Circa 1700*. London: B. T. Batsford, 1958.

Describes many variations of mail and their changes over time. Notes any speculations and areas where little is known. Describes the beginnings of plate for all parts of the body, but does not directly discuss the transition from mail to plate.

Bradbury, Jim. *The Medieval Archer*. New York: St. Martins Press, 1985.

Fairly good representation of the use of the bow. Details on how it was used where and how it came to be developed into European tactics. Also makes comparisons between the bow and the crossbow. In depth explanation of the significance of the bow in battles such as Hastings and its role in society.

Bradbury, Jim. *The Battle of Hastings*. Bridgend, UK: Sutton Publishing, 1998

Histories of the sides involved in the battle along with a good depiction of the battle and its effects on medieval warfare tactics.

Contamine, Philippe. *War in the Middle Ages*. New York: Basil Blackwell, 1984.

Bows, crossbow development, basic equipment used, ideals of the knights

DeVries, Kelly Robert. *Medieval military technology*. Ontario, Canada : Broadview press, 1992.

Very good overview of the importance of all the different weapons and armor used along with an overview on the importance of siege weapons and fortifications.

Edge, David and Paddock, John M. *Arms and Armor of the Medieval Knight*. Hong Kong: Crescent Books, 1998.

Raising of armies, equipment usage/developments

Ffoulkes, Charles. *The Armourer and His Craft*. London: Methuen, 1912.

A classic text covering many of the basics of arms and armor history and technique. Slanted towards the British development of a local arms and armor trade.

France, John. *Western Warfare in the Age of the Crusades 1000-1300*. New York: Cornell University Press, 1999.

Importance of armor, size and use of the war-horse, importance of the bows

Gies, Francis and Gies, Joseph. *Cathedral, Forge, and Waterwheel*. New York: Harper Collins Publishers, 1994.

An excellent reference for the development of European technology throughout the middle ages. Somewhat light on the development of arms and armor, but presents a more general view of technological and social change throughout the period.

Gogan, Art. *Fighting Iron*. Lincoln, RI: Andrew Mowbray Publishers, 1999.

A history of iron. More focused on later accomplishments but has a brief section on the use of iron in arms and armor in the middle ages.

Hardy, Robert. *Longbow: A Social and Military History*. New York: Arco Publishing Company, 1976.

Development/use of the longbow in England

Hooper, Nicholas & Bennett, Matthew. *Cambridge Illustrated Atlas of Warfare: The Middle Ages 768-1487*. London: Cambridge University Press, 1996.

Cavalry and training techniques, Importance of infantry, the role of mercenaries

Karcheski, Walter J. Jr. *Arms and Armor in The Art Institute of Chicago*. Boston: Bulfinch Press, 1995.

Mostly a history on the Harding Collection of the Art Institute, but there is information on the practices of Nuremberg armorers and their relation to the town.

Keen, Maurice. *Medieval Warfare: a History*. New York: Oxford University Press, 1999.

Castle warfare, The knight vs. infantry. The use of archers. Armor usage and horses.

Koch, H.W. *Medieval Warfare*. London: Bison Books, 1978.

Feudalism knights, siege technology

Oakeshott, R Ewart. *The Sword in the Age of Chivalry*. New York: Fredrick A. Praeger, Publishers, 1964.

Explanation of the swords used and when they were used. Some description of history and evolution.

Payne-Gallwey, Ralph. *The Book of the Crossbow*. New York: Dover Publications Inc., 1903.

A very good source to learn about the crossbow. Very little though on dates.

Prestwich, Michael. *Armies and Warfare in the Middle Ages: The English Experience*. London: Yale University Press, 1996.

Very useful; goes over many important issues of how armies were raised what they consisted of and types of formations and combat.

Price, Brian R., *Techniques of Medieval Armour Reproduction*. Boulder, CO: Paladin Press, 2000.

An excellent source on the recreation of armor with historical information inserted throughout.

Richardson, Thom. "The Introduction of Plate Armour in Medieval Europe." *Royal Armouries Yearbook* vol. 2 (1997): 40-45.

An exceptional article directly dealing with the beginnings of the transition from mail to plate.

Singer, Charles, et al., eds. *A History of Technology*. 5 vols. New York and London: Oxford University Press, 1954.

Very useful with articles on metallurgy and mining.

Theophilus. *On Divers Arts*. Trans. Hawthorne, John G. and Smith, Cyril. New York: Dover, 1979.

Contains information on metalworking techniques from 12th century. He does not go into metalworking for military use and concentrates on metals other than wrought iron.

Thordemann, Bengt. *Armour From the Battle of Wisby 1361*. Stockholm: Kungl. Vitterhets, 1939.

A thorough explanation of the history, battle, and excavations that took place at Wisby.

White, Lynn Jr.. *Medieval Technology and Social Change*. New York: Oxford University Press, 1962.

A view on cavalry tactics

Williams, Alan. *The Metallurgy of Muslim Armour*. Basingstoke, UK: Taylor and Francis, Ltd., 1978.

Excellent source of information on the differences between wrought iron, mild steels and hardened steels as well as how they were processed. Also has some dates as to when these techniques were applied in Europe.

Williams, Alan "Experiments with 'Medieval Steel' Plates." *Historical Metallurgy* Vol. 32, #2 (1999): 82-96.

Of technical significance in the difficulties of successfully tempering steels, but no information on the development of plate armor.

Williams, Alan R. "Slag Inclusions in Armour." *Historical Metallurgy* Vol 24, #2 (1990): 69-80.

Interesting comparison of sources of iron in various armors. Also contains information on the price of armor in the middle ages.

Wise, Terrance. *Medieval Warfare*. New York: Hastings House, 1976.

Scutage, crossbow/spear men, organization of units and how they were gathered, army formations

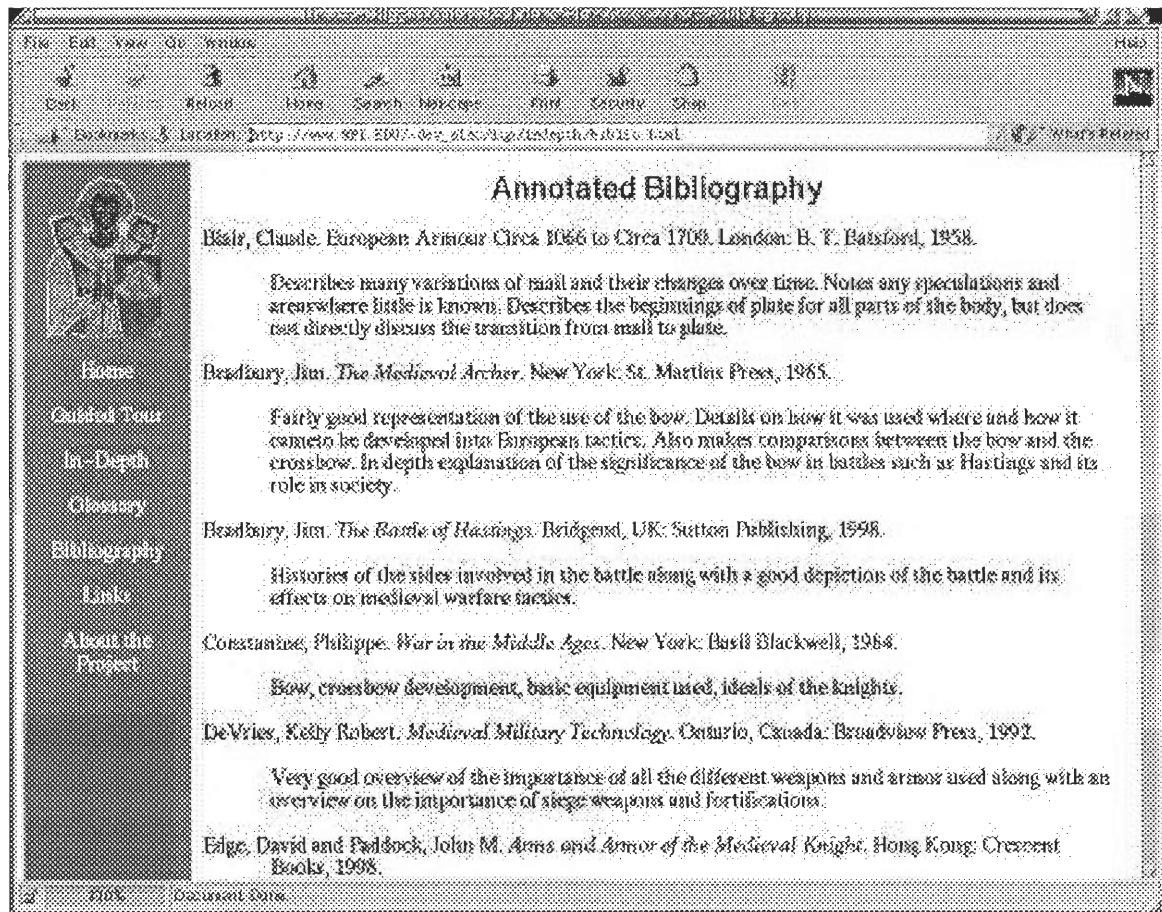


Figure 4.6: Screenshot of /indepth/biblio.html.

A4.6 Links

Found at /links/index.html.

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.0//EN">

<html>
<head>
<title>Higgins Armory - Evolution of Plate Armor: Links</title>

<!--#include virtual="../includes/headend.inc"-->

</td>
<td width="100%" bgcolor="white" align="left" valign="top" rowspan="2">
<H1 class="center">Links to other Arms and Armor Sites</H1>

<br>
<h2 class="maroon"><a href="http://www.higgins.org">The Higgins
Armory</a></h2>
The only dedicated museum to arms and armor in North America, it is one of
two institutions that really made this project possible.<br>
<h3 class="maroon"><a
href="http://www.higgins.org/Research/resources.shtml"> Higgins
Armory: Research Resources</a></h3>
Links to various museums, collections, and other scholarly sites on the
web.<br><br>

<h2 class="maroon"><a href="http://www.wpi.edu">Worcester Polytechnic
Institute</a></h2>
The web host of the project, see more in the <a
href="../about/index.html">About</a> section.<br><br>

<h2>Other Arms and Armor Links</h2>
<h3 class="maroon"><a href="http://www.armouries.org.uk/">The Royal
Armouries</a></h3>
One of the largest collections of arms and armor in the world, this
British museum is possibly the world center for arms and armor
research.<br><br>

<h3 class="maroon"><a href="http://www.metmuseum.org/home.asp">The
Metropolitan Museum of Art</a></h3>
One of the leading museums in the United States, it has a good selection
of arms and armor and is an excellent point to begin research on any
historical topic through the <a
href="library.metmuseum.org">Whatsonline</a> library indexing
system.<br><br>

<h3 class="maroon"><a href="http://www.artic.edu/aic/index.html">The Art<h3 class="maroon">
<a href="http://www.ceu.hu/medstud/manual/SRM/index.htm">
```

Self Representation in the Middle Ages</h3>A project similar to our own, only by students in Hungary focusing more on the cultural development of the Middle Ages. It does have a section on arms and armor and a large bibliography.

<h3 class=maroon>

The WWW Virtual Library History Index: Medieval Europe</h3>A large list of links to just about everything medieval compiled by Michigan State graduate students.

<!-#include virtual="../includes/bodyend.inc" >

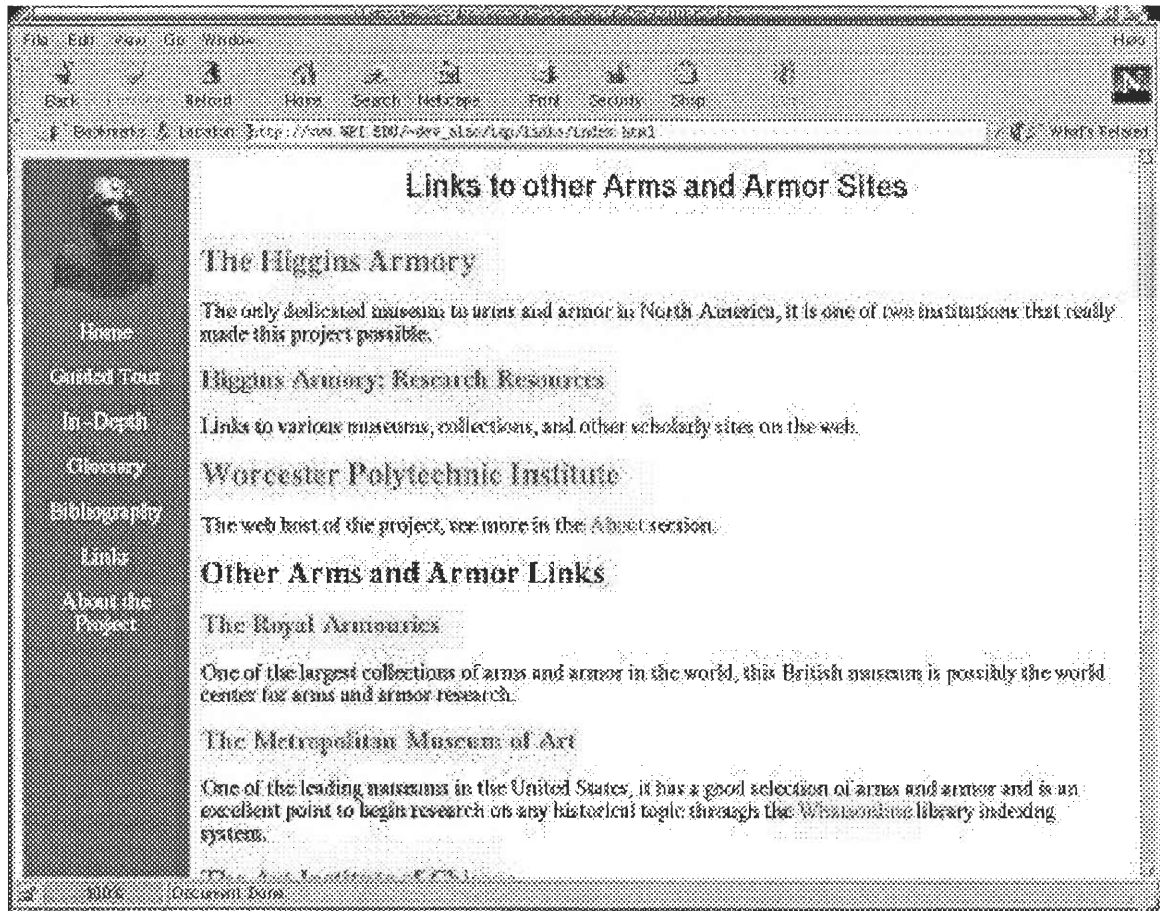


Figure 4.7: Screenshot of /links/index.html.

A4.7 About

Found at /about/index.html.

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.0//EN">
```

```
<html>
```

```
<head>
```

```
<title>Evolution of Plate Armor: About the Project</title>
```

```
<!-#include virtual="../include/headed.inc" >
```

</td>

<td width="100%" bgcolor="white" align="left" align="top" rowspan="2">

<H1 class="center">About This Project</H1>

This project was performed as part of the graduation requirements for a Bachelor of Science Degree at Worcester Polytechnic Institute (WPI) in association with the Higgins Armory. As part of the WPI Plan, all undergraduates must complete a series of three projects - the Sufficiency, the Interactive Qualifying Project (IQP), and the Major Qualifying Project (MQP). The WPI Plan calls for the integration of laboratory, classroom, and actual experience in team-based projects.

<P>

Dealing with society and technology, the IQP is the equivalent of three classes and is usually done during the Junior year. Its objective is to enable the student to understand how their professional life will affect the world around them.

<P>

Our project began in October 2000 and continued until April of 2001. We worked both at WPI and at the Higgins Armory to research our material and then compiled it into the format you now see before you. This unique opportunity was due to the position of our advisor, Jeffrey Singman as both a professor at WPI and the Paul S. Morgan Curator at Higgins. He has given us splendid guidance and tolerated our many faults for seven long months through this project.

<P>

Hope you enjoy this site and learn at least as much as we did from it!

-Ian Hobbs

-Jordan Maddock

-Adrian Wheelock

<P>

For more information on WPI and the Higgins Armory, visit their web pages through the links above or via our links page.


```
<P>  
<!--#include virtual="../includes/bodyend.inc" -->
```

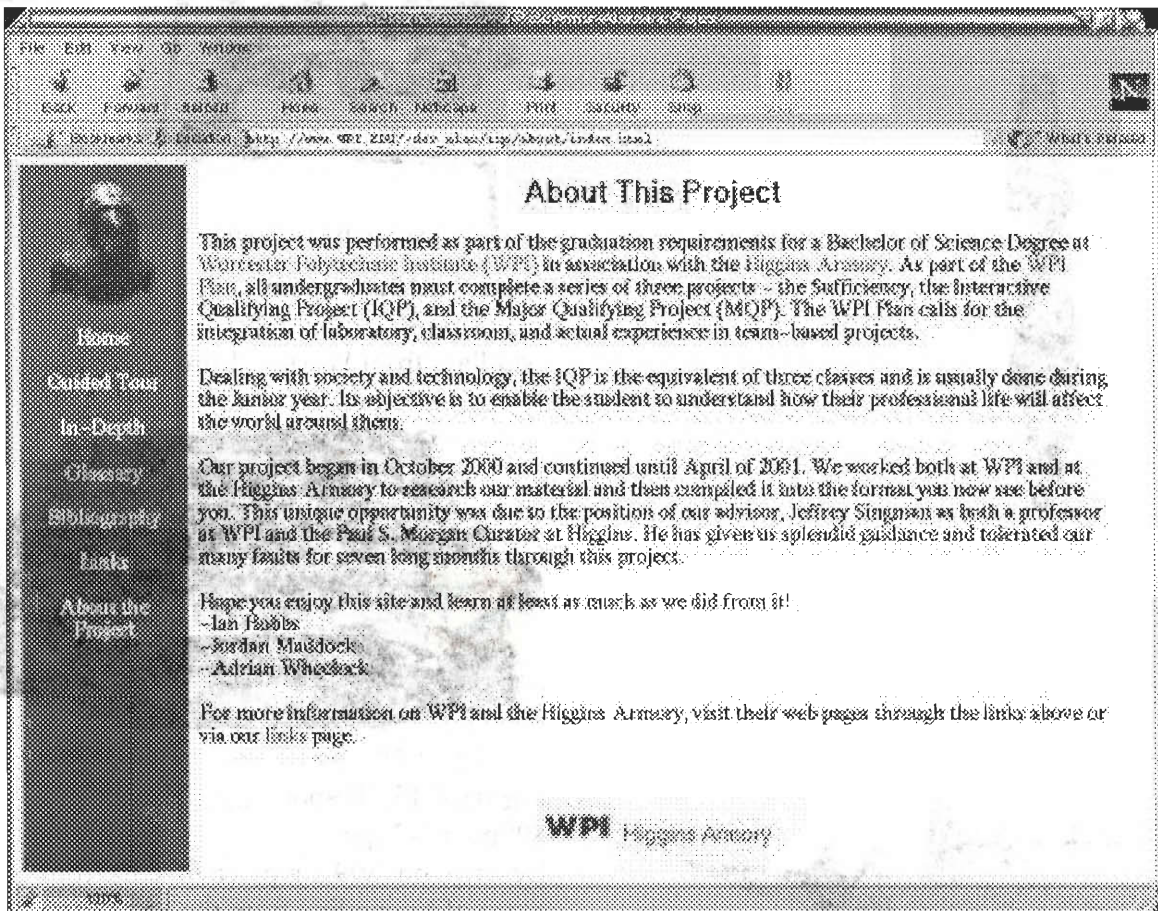


Figure 4.8: Screenshot of /about/index.html.

A4.8 Pictures

Found at /pics/.

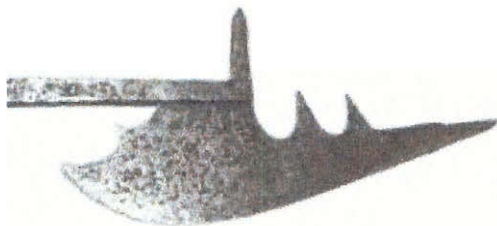


15th or 16th Century
European Pike Head (HAM#238.65)

Figure 4.9: 238point65.jpg

Description: 238.65 pike head either 15th or 16th century from Europe.

Found on: /tour/13001400.html

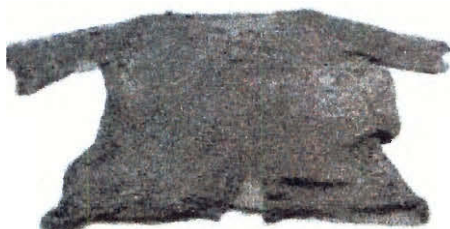


German 15th Century Halberd (HAM#2685)

Figure 4.10: 2685.jpg

Description: 2685 the head of a late 15th century German halberd.

Found on: /tour/13001400.html



15th or 16th Century Mail Shirt (HAM#3927)

Figure 4.11: 3927.jpg

Description: 3927 a 15th or 16th century mail shirt.

Found on: /tour/before1250.html



17th Century W. European Windlass (HAM#572.1)

Figure 4.12: 572point1.jpg

Description: probably 17th century windlass from Western Europe.

Found on: /tour/13001400.html



15th Century Brigandine Skirt Piece (HAM#809.2)

Figure 4.13: 809point2.jpg also as 809point2-2.jpg

Description: 809.2 a piece of skirt from a suit of brigandine from the 15th century.

809point2-2.jpg is a resized version.

Found on: /tour/13001400.html



15th Century Brigandine Plates (HAM#809.6)

Figure 4.14: 809point6.jpg also as 809point2-2.jpg

Description: 809.6 an example of brigandine plates from the 15th century.

809point6-2.jpg is a resized version.

Found on: /tour/index.htm



Figure 4.15: 938-2.jpg
 Description: 938 a 1360-1370 German Basinet with aventail.
 Found on: </index3.html> = [index](/links/index.html)
</about/index.html>



German Basinet with Aventail
 c.1360-70 (HAM/938)

Figure 4.16: 938-3.jpg
 Description: 938 a 1360-1370 German Basinet with aventail.
 Found on: </indepth/index.html>



Figure 4.17: d1289-2.jpg
 Description: Brass of Sir Roger de Trumpington.
 Found on: </tour/>



Brass of Sir Roger de Trumpington d.1289

Figure 4.18: d1289-3.jpg
 Description: Brass of Sir Roger de Trumpington.
 Found on: </indepth/index.html>



Figure 4.19: d1289-2.jpg
 Description: Brass of Sir Roger de Trumpington.
 Link to from: </indepth/index.html>



Figure 4.20: d1306-2.jpg
Description: Brass of Sir Robert de Stevens.

Found on: </indepth/biblio.html>
</glossary/index.html>
</indepth/>



Brass of Sir Roger de Setvans d. 1306

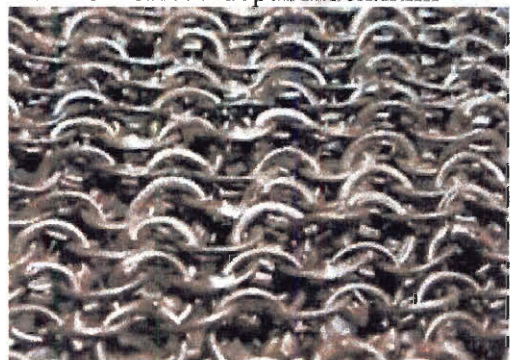
Figure 4.21: d1306-2.jpg
Description: Brass of Sir Robert de Stevens.

Found on: </indepth/index.html>



Figure 4.22: d1306-2.jpg
Description: Brass of Sir Robert de Stevens.

Link to from: </indepth/index.html>



15th or 16th Century Mail Shirt Detail (HAM# 3927)

Figure 4.23: maildetail3927.jpg
Description: 3927 a 15th or 16th century mail shirt.

Found on: </tour/before1250.html>



Figure 4.24: backnext.jpg
Found on: On all pages in /tour/
except /tour/index.html