

The Military Revolutions of the Hundred Years' War

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The Journal of Military History: v.57 (1993)

The Military Revolution

The concept of the "military revolution" first entered the historical literature with Michael Roberts's famous inaugural lecture, "The Military Revolution, 1560-1660," at the Queen's University of Belfast more than thirty years ago.² Roberts proposed that the art of war in early modern Europe was radically transformed over that space of a century. A tactical revolution based on the use of linear formations of drilled musketeers had led to a massive increase in the size of armies, which in turn had dramatically heightened the impact of war on society. The new armies of Maurice of Nassau and Gustavus Adolphus, larger and more disciplined than any seen before, had made it possible to execute more complex strategic plans.³

The idea of the military revolution rapidly became the "new orthodoxy" in early modern military history, passing almost unchallenged until 1976,⁴ when Geoffrey Parker's article, "The 'Military Revolution,' 1560-1660-a myth?" appeared. Parker argued that Roberts had overemphasized the importance of Gustavus Adolphus at the expense of French, Dutch, and Hapsburg developments; underemphasized the importance of siege warfare; and put the starting date of the revolution perhaps half a century too far forward. Still, Parker concluded that he had "failed to dent the basic thesis" propounded by Roberts.⁵ Subsequent studies stretched the parameters of the Military Revolution even further, and argued that its key significance lay in the development of state governmental bureaucracies which the revolution made necessary.⁶

The next major step in the development of Military Revolution historiography came with the 1988 publication of Parker's *The Military Revolution: Military Innovation and the Rise of the West, 1500-1800*. In that work, Parker posed the question which has come to define the significance of the Military Revolution as an historical phenomenon: "Just how did the West, initially so small and deficient in most natural resources, become able to compensate for what it lacked through superior military and naval power" and thus to conquer global empires covering over a third of the world's surface by 1800?⁷ To answer that question, scholars of the subject have looked primarily at the period after Charles VIII's invasion of Italy in 1494, when the French demonstrated so dramatically the power of the new siege artillery. Thus, these historians have made the advent of the Military Revolution more or less synchronous with the early modern period, and tied it even more closely to the development of the *trace italienne* and earthwork artillery fortifications.⁸

Without doubt, the rapid development of fortifications against artillery during the Wars of Italy, the concomitant improvements in siege and field artillery, and the subsequent growth of army sizes all play important roles in answering Parker's question. So, too, do the reforms of Maurice of Nassau and Gustavus Adolphus. All of these aspects of the Military Revolution have been considered at some length by the works cited above.

I believe, however, that the focus on the centuries after 1500 obscures the importance of the period in which the most dramatic, most truly revolutionary changes in European military affairs took place: the period, roughly, of the Hundred Years' War (1337-1453). The armies that dominated the battlefields of Europe from the mid-eleventh century through the early fourteenth were composed primarily of feudal warrior-aristocrats, who owed military service for lands held in fief.⁹ They served as heavily armored cavalry, shock combatants, relying on the muscle power of man and steed, applied

directly to the point of a lance or the edge of a sword.¹⁰ They fought more often to capture than to kill. The armies which conquered Europe's first global empires, on the other hand, differed from this description on every single count. They were drawn from the common population (albeit often led by aristocrats); they served for pay; they fought primarily on foot, in close-order linear formations which relied more on missile fire than shock action; and they fought to kill.¹¹ The tremendous revolution in warfare represented by these changes was well underway by the middle of the Hundred Years' War, and solidly in place by the end of that conflict.

This paper will argue that twice over the course of the Hundred Years' War new developments revolutionized the conduct of war in Europe, in each case with consequences as significant for the history of the world as those which took place during Parker's Military Revolution (1500-1800). The first was the transition outlined in the paragraph above, which I shall refer to as the "Infantry Revolution."¹² The second, the "Artillery Revolution," occurred when gunpowder weapons reversed the long-standing superiority of the defensive in siege warfare. Each of these transformations fundamentally altered the paradigm of war in Europe, with far-reaching consequences for the structures of social and political life, and thus each truly deserves to be termed a "military revolution" in itself.

When we consider that these two "revolutions" were followed in the succeeding centuries by a revolution in fortification (which once again reversed the balance between offense and defense) and then another in the administration of war (Roberts's original "Military Revolution"), we are led to reconsider whether the answer to Parker's question can possibly be a single "Military Revolution." In the last section of this paper, I will address that issue, and propose an alternative paradigm based on the biological concept of "punctuated equilibrium evolution." In essence, I will argue that Western military dominance derived from a series of sequential military revolutions, each an attempt to reverse a disequilibrium introduced by the previous one, rather than from a single "Military Revolution."¹³ First, though, we must consider the warfare of the earlier Middle Ages, and the two revolutions which so dramatically altered its character over the course of the fourteenth and fifteenth centuries.

War in the "Age of the Horse"

In 1898, C. W. C. Oman described the period from 1066-1346 as the age of "the supremacy of feudal cavalry."¹⁴ Recently, some scholars have attempted to dispute this conception, arguing that "cavalry was never militarily superior to foot soldiers" and that infantry played an equal or greater role on the medieval battlefield.¹⁵ It is true that Oman, Delbruck, and other earlier authors failed to acknowledge the significant role of infantry in the High Middle Ages, but the fact remains that "medieval warfare was characterized by the dominant role of the heavy cavalry."¹⁶ At Tinchebray in 1106, Bouvines in 1214, Dunbar in 1296, and Falkirk in 1297 (to consider only battles cited by authors who emphasize the role of the infantry), it was a cavalry charge that decided the battle.

Throughout this period, infantry on the battlefield generally acted in a purely defensive role, using a tight formation "like a great wall" of pole-arms and crossbowmen to protect the cavalry while it formed up for a charge. The importance of this "wall" derived in part from the men-at-arms' practice of riding from place to place on palfreys and mounting their chargers only immediately before battle, making it critically important for them to be protected while changing horses and forming up. To use the metaphor of single combat, the infantry served as a shield to the cavalry's sword.¹⁷ Infantry could be very important, but it could not defeat an enemy unless he bashed his head against it.

The effectiveness of the cavalry is not hard to explain. The medieval knight, supported as he was by the labor of others, had plenty of time to train for combat.¹⁸ His better diet made him larger and stronger than most of the commoners who formed the infantry.¹⁹ Most importantly, the capital he had invested in horses, arms, and armor magnified his capabilities. Mail armor, reinforced by a leather cuirass or a padded gambeson, made him nearly invulnerable on the battlefield. The mobility afforded by his horses, in addition to its obvious strategic value, enabled him to pursue a defeated enemy effectively, to flee rapidly if himself defeated, and to avoid unwanted battles with slow-moving infantry forces. The combination of armor and mobility made him particularly effective as a forager, giving him a critically important role in extended sieges, which were more likely to be broken by lack of food than by enemy action.²⁰ Of course, the extremely high cost of this equipment, which in the mid-thirteenth century cost about £32 (over ten years' wages for a foot archer),²¹ strictly limited the number of knights and men-at-arms in medieval armies. By contrast, a well-equipped Bowman of the early fifteenth century could buy all his arms and armor—a bow, sheaf of arrows, sword, bascinet, and brigantine – for £1 6s 8d. A crossbowman could potentially pay as little as 15s 4d for a crossbow, sword, bascinet, and jack-about one-fortieth the cost of the knight's equipment.²²

The huge population and vast agricultural wealth of France, however, meant that the French could muster large numbers of men-at-arms despite their cost. Furthermore, French men-at-arms were widely regarded as the finest in the world.²³ Within the feudal military “ecosystem,” the royal army of France dominated;²⁴ thus, it is no surprise that the Infantry Revolution first developed among the neighbors and opponents of France: the English, the Flemings, and the Swiss.²⁵

The Infantry Revolution

In the thirteenth century, infantry played an important role on the battlefield, but it did not win battles. In the opening decades of the fourteenth, however, we can observe the first glimmerings of the revolution which was to overtake European warfare a generation later. At Courtrai in 1302, Bannockburn in 1314, and Morgarten in 1315, infantry armed with pole-arms triumphed over feudal cavalry.²⁶

The importance of these early victories, however, should not be overemphasized. In each case, the infantry were able to achieve victory only because of peculiarities of the terrain, and the mistakes of their enemies. The Flemings at Courtrai chose a position which prevented the French from forming up properly before charging; and when the men-at-arms began their assault, their horses were severely hampered by the swampy ground – “caught by the net as bird is in snare,”²⁷ as a contemporary song had it. Unable to break through the serried ranks of the Flemish pikemen, they were equally unable to retreat, and were slaughtered. The Scots put the English in a very similar situation at Bannockburn (1314), and the battle ended in much the same way.²⁸ At Morgarten, the Swiss ambushed the Austrians in a narrow mountain pass and gave them no chance to form up. or to flee. On different terrain, though, the French chivalry remained quite capable of defeating even the staunch Flemings' communal levies, as the battles of Mons-en-Pevél (1304) and Cassel (1328) showed.²⁹

The battle of Laupen (1339), where Swiss halberdiers and pikemen resoundingly defeated the cavalry and infantry of the Burgundian nobility, was something different. “For the first time almost since the days of the Romans,” as Oman rightly points out, “infantry, entirely unsupported by horsemen, ranged on a fair field in the plains, withstood an army complete in all arms and superior in numbers.”³⁰ Something new was afoot in European warfare, as the battle of Crecy confirmed seven years later.³¹

Using the “pike-and-shot” combination of dismounted men-at-arms and archers which they had developed in the 1330s in Scotland, the English at Crecy devastated a French force (primarily men-at-arms fighting on horseback) approximately three times as numerous as themselves. Over the succeeding decades, major cavalry actions on the field of battle became rare, with even the French usually choosing to fight on foot.³²

The new success of infantry forces in Western Europe rested on a number of developments. In the case of the English, the development of the six-foot yew longbow, substantially more powerful than the approximately four-foot Welsh elm bows of the early thirteenth century, played an important role. According to P. H. Blyth,³³ for a given draw strength and distance a six-foot longbow stores 25 percent more energy than a four-foot-eight-inch bow. The longbow, however, is drawn to the ear rather than to the chest (as the Welsh bow was ³⁴), increasing draw distance by several inches. Since the draw force of a longbow plotted against draw distance shows a nearly linear relationship, and the total energy stored is equal to the area under that line, each extra inch of draw adds more stored energy than the previous one. Those extra few inches are, therefore, of critical importance.

Thus, a six-foot longbow which at a twenty-eight-inch draw had the same draw weight as a four-foot-eight-inch bow, would have a substantially higher draw weight at its full thirty-two-inch draw, and would in total store about half again more energy than the shorter bow at the shorter draw. It seems reasonable to hypothesize that this increase could make the difference between ineffectiveness and lethality when attempting to penetrate an enemy’s armor. Even arrows fired from the strong shortbows of the Moslems in the Crusades of the late twelfth century proved rather ineffective against European armor.³⁵ In contrast, a later medieval writer held that “the most important thing in the world, for battles, is the archers.”³⁶ Of course, the draw weight increased with draw distance, so the longbow required a very strong archer to use it effectively.³⁷ Archaeological evidence shows that some medieval archers used longbows with draw weights up to 180 lbs., and the average was probably around 100.³⁸ England developed a pool of strong yeomen archers over decades of more-or-less constant warfare against the Scots and the Welsh—it is no coincidence that Cheshire archers, considered the best in England, came from the Welsh marches.³⁹ The French, despite numerous attempts, never succeeded in producing a comparable body of skilled archers.⁴⁰ Indeed, one could argue that France failed to join in on the Infantry Revolution until the late fifteenth century, and that many of her military failures prior to the advent of the Artillery Revolution in the mid-fifteenth century could be ascribed to that fact.

The growing importance in the English tactical system of dismounted men-at-arms, who used lances like pikes in a close-order formation designed to stop an enemy’s cavalry charge, was, of itself, a less dramatic break with the past. What made these horsemen on foot so effective was their integration with the archers. Because the English formations had missile superiority, their dismounted men-at-arms could not be dispersed by enemy archers, in the way that the English themselves dispersed the pike formations of the Scots.⁴¹ Even so, we must assume that the English victories, combined with the partial success of Flemish pikemen, encouraged others—including but not limited to the Swiss—to develop effective infantry armies, even though not provided with missile troops the equivalent of the English archers. For, once the possibility of victory through common infantry ⁴² was demonstrated, further experimentation became inevitable. Infantry possessed important advantages over cavalry. A common infantryman could be equipped for much less than a man-at-arms; he was paid less;⁴³ he could be trained more quickly;⁴⁴ and the ranks of the infantry could be filled from a much broader

section of the population.⁴⁵ Nothing demonstrates the importance of these factors better than the fact that the lone county of Flanders could muster a larger army at Courtrai than could the entire kingdom of France. Because of its broader recruitment pool and lower costs of equipment and training, a military system based on common infantry—and only such a system—could turn surplus agricultural population into large numbers of soldiers for export to the world at large.⁴⁶ Thus, the Infantry Revolution was a necessary precondition for the European conquests of the sixteenth through eighteenth centuries.

Social Impact of the Infantry Revolution

The significance of the Infantry Revolution, which reached fruition in the 1340s and 1350s, extends far beyond its immediate impact on the conduct of war. That there is a relationship between military power and political power is self-evident; thus, it should come as no surprise that the growing importance of common infantry on the battlefield was reflected in the political influence of the commons, especially in those nations such as England and Switzerland where the Infantry Revolution was the most completely embraced.⁴⁷ It is true that this growing importance of the commons derived as much from governments' need to secure the financial support of the people to sustain long-term war efforts as from the need to secure their military services,⁴⁸ but part of the reason why the great nobles needed the consent of the commons before appropriating their wealth lay in the increased ability of the people to resist oppression by military means, an ability due in large part to the Infantry Revolution.⁴⁹ The Great Revolt of 1381 in England, for example, was triggered by the regressive poll taxes of 1377-80. The rebels were generally armed with longbows, and their leader, Wat Tyler, had seen service in France.⁵⁰ They did not accomplish all their goals, but they did succeed in abolishing the poll tax. Contemporary rulers well understood this connection between the military and the political power of the commoners: Charles VI of France gave up his attempt to impose universal training with the bow when he realized that the common archers "if they had been gathered together, would have been more powerful than the princes and nobles." ⁵¹

It is little more than a striking coincidence that the French Estates-General met for the first time in the year of the battle of Courtrai.⁵² The connection between the Infantry Revolution and the increasing importance of the Commons (who were elected by, and to a significant extent represented, the common freemen of the shires,⁵³ though the MPs themselves were usually drawn from the gentry) in the English Parliament, however, cannot be so easily dismissed. In wars against the Scots and Welsh, the English borough and shire levies had proved increasingly important since the late thirteenth century. Tactics based on the use of the longbow developed almost simultaneously with the regularization of Parliament under Edward I, and earned for that monarch a reputation as the "father" of both innovations.⁵⁴ Not until the reign of Edward III, however, did the importance of the Commons in Parliament come to equal that of the Lords – just as the importance of the archers drew even with that of the men-at-arms on the battlefield.⁵⁵

The first record of the Commons meeting separately from the Lords in Parliament occurs in 1341, shortly after the English bowmen proved their worth at Dupplin Muir (1332), Halidon Hill (1333), Cadzand (1337), and Sluys (1340). At about the same time, the Commons began to take the initiative in legislation on a regular basis, acceding to new taxes only in return for political concessions.⁵⁶ In 1351, for example, the Parliament added control over indirect taxation (i.e., the wool subsidies) to its established right to grant direct taxation.⁵⁷ I do not mean to suggest that the connection between these two series of events is a simple and direct one. Still, there can be little

doubt that a connection does exist, and that the military enfranchisement of the nonaristocratic population contributed to its increased political influence.⁵⁸ Thus it should come as no surprise that the minimum property qualification which gave a man the right to vote in Parliamentary elections was set at the low level of 40 shillings of land income per year – the same amount which legally obliged him to own a bow, and put him in the class from which most foot archers were drawn.⁵⁹ In at least one other case, indeed, the connection between growing military and political power was quite simple and direct: as J. F. Verbruggen has pointed out, the Flemish guilds, which provided the framework for their communal levies, “acquired political power, made their own legal systems, and controlled their own finances” from the battle of Courtrai on.⁶⁰

On a less elevated plane, the social impact of the Infantry Revolution made itself felt on the battlefield, with remarkable consequences for the European conception of war. War under the feudal regimes of Western Europe in the twelfth and thirteenth centuries often seemed more like sport than serious business. In the Flanders War of 1127, which involved about a thousand knights fighting for over a year, only one died by the hand of an enemy; an equal proportion of the total losses of the war resulted from excessive horn-blowing.⁶¹ At Bouvines, which Ferdinand Lot described as “un Austerlitz medieval,” the victorious French are said to have lost only two men-at-arms (out of about three thousand); perhaps seventy to one hundred of the fifteen hundred defeated German knights were killed. At Lincoln in 1217, three knights were killed and four hundred captured.⁶² Orderic Vitalis tells us that at Bremule (1119), where nine hundred knights of two royal armies came head-to-head, only three were killed.⁶³ Such low casualty figures characterized European warfare before the onset of the Infantry Revolution. The French at Courtrai, in contrast, lost a thousand knights; in return, they slew some six thousand Flemings at Cassel in 1328.⁶⁴ Agincourt brought an end to the lives of over sixteen hundred French knights, and perhaps eight thousand other men. Over eight thousand died at Verneuil (1424).⁶⁵ Without question, the Infantry Revolution made the European battlefield a much more sanguinary place.

How are we to explain this contrast? Orderic Vitalis explains the low casualties at Bremule by saying “they were all clad in mail and spared each other on both sides, out of fear of God and fellowship in arms; they were more concerned to capture than to kill the fugitives.”⁶⁶ He tactfully leaves out what may well have been the primary motive which led them to “spare each other on both sides”: ransom. The phrase “worth a king’s ransom” remains in common use today to indicate a huge sum of money, and with good reason: the ransom of Jean II of France was set at 3,000,000 crowns (£500,000) in 1360. This figure was truly exceptional – equal to some twenty years worth of English ordinary royal revenue ⁶⁷ – but even lesser captives could bring tremendous sums. Henry of Grosmont apparently received over £80,000 for his share of the ransoms of the prisoners taken at Auberoche and Bergerac; the Duke of Alençon brought £26,666; and Bertrand du Guesclin, the low-born soldier who became Constable of France, brought 100,000 francs (about £11,000).⁶⁸ Lesser knights brought lesser sums, but still enough to make capturing them far preferable to killing them.

When common infantry became a major force on the battlefield, much changed. The commoners, in general, did not command large enough ransoms to make their capture worthwhile. Nor did they share in the “fellowship in arms” which bonded chevaliers even of different nationalities. Quite the opposite: the class differences between knight and bourgeois or peasant often encouraged extreme bloodthirstiness. From Morgarten onward, the Swiss were famous for neither asking nor giving quarter. The Flemings at Courtrai took no prisoners. The victorious French at Roosebeke, having defeated the

Flemish infantry, “had no mercy on them, no more than if they had been dogs.”⁶⁹ Simple technical factors also contributed to the increase in casualties evident during the Infantry Revolution. Pikes and longbows, by their very nature, are intended to kill an opponent before he can come in striking distance of the wielder, and it is difficult to offer or accept a personal surrender at a distance. The value of the pike, furthermore, rested entirely on its use in a tight formation, and, again, it would have been impossible to take prisoners without breaking formation.⁷⁰ Halberds, goedendags, and bills, it is true, do not keep the enemy at such a distance. They are, however, slow and unwieldy weapons. Thus, a halberdier must strive to down his enemy with his first blow, for he is unlikely to get a second; and a full-arm swing from a halberd will rarely leave the person struck in much shape to surrender.⁷¹

Considering these social and technical factors, it is easy to see why the battlefields of the Infantry Revolution became such bloody places. It is hard to overemphasize the consequences of this development. Ever since, Europeans have had an unusually lethal approach to warfare. Geoffrey Parker has outlined the importance of this European conception of war in the European conquests of the early modern period, but he does not identify its origin. He contrasts the “bloody and devouring” warfare of the Europeans with that of the Narragansett Indians, who “might fight seven years and not kill seven men.”⁷² As we have seen, the same was true of Western Europeans in the twelfth and thirteenth centuries, but not after the advent of the Infantry Revolution.

The Infantry Revolution, however, was only the first of a series of periods of rapid change in European warfare which bring into question the concept of a single, overarching Military Revolution. Even as the Infantry Revolution reached its full maturity, early signs of the next “military revolution” – the Artillery Revolution – began to appear.

Gunpowder artillery first appeared in Europe almost exactly a century before it revolutionized warfare in the 1420s-40s. Roger Bacon’s recipe for gunpowder dates back to 1267, but gunpowder seems not to have been used for war until the third decade of the fourteenth century. The earliest depictions of cannon in action, which antedate the earliest documentary reference, appear in the manuscript of Walter de Milemete’s *De Officiis Regnum*, completed in 1326.⁷³ According to the Scottish chronicler John Barbour, the English used some type of gunpowder weapon (“crakkis of wer”) during the Weardale campaign of the following year. Guns, probably much like the Milemete weapons, were employed by German knights at the siege of Cividale in 1331.⁷⁴ Already by 1333, cannon had taken their place alongside catapults, springalds, and tre-buchets as important siege engines. In that year, the English besieged Berwick and made meny assaute with gones and with othere engynes to the toune, wherwith thai destroide meny a fair hous; and cherches also weren bete adoune vnto the erthe, with gret stones, that spytously eomen out of gones and of othere gynnes. And notheles the Scottes kepte wel the toune, that tho ii knyghtes [Edward III and Edward Balliol] might nought come therin long tyme. and notheles the Kynges abiden there so longe, til tho that were in the toune faillede vitales; and also thai were so wery of wakyng that thai wiste nought what to Done.⁷⁵

This account is worth quoting at some length because it concisely sums up the way in which gunpowder artillery was used throughout the fourteenth century. The gunstones were fired into the town, where they knocked down houses and churches, not against the walls.⁷⁶ The gunpowder artillery was used in conjunction with older forms of siege engines. And, most important, the use of guns did not appreciably lessen the duration of the siege; the defenders still had to be starved out.

The cannon of the early fourteenth century were both small and inexpensive. A gun, probably weighing forty pounds, was purchased for just 13s 4d in 1353, when a springald cost 66s 8d.⁷⁷ At this point, gunpowder artillery had no more power than traditional siege engines (and, indeed, far less than some), but this cost advantage, combined with the psychological impact of a new and frighteningly loud weapon, ensured that its use would grow rapidly. Edward III had at his disposal for the siege of Calais in 1346 at least 10 cannon (including two “grossa”) and materials for over 5,000 lb. worth of gunpowder.⁷⁸ The French had 24 iron cannon made in 1345 at Cahors for the siege of Aiguillon, and at least 32 cannon were provided for the siege of Saint-Saveur-le-Vicomte in 1374-75.⁷⁹ Froissart claimed that the English had 400 guns at the siege of St. Malo in 1378, though most were probably handguns.⁸⁰ Over the six years from 1382-88, the English Privy Wardrobe purchased 87 cannon.⁸¹ By 1409, Christine de Pisan could argue that no less than 248 guns were needed to take a strong place, including 32 firing shot of 200 lb. or more.⁸²

Even as the number of cannon employed increased, so too did their size. The early guns were very small, and shot pellets of lead or iron, or sometimes iron “lances” feathered with bronze. A much larger cannon prepared for the siege of Saint-Saveur-le-Vicomte in 1375 fired stone shot of a hundredweight, and Froissart records the use of a gun firing 200-pound stones two years later. The Count of Holland purchased 400-pound stones for his “grooten donrebusse” in 1378.⁸³ Two bombards purchased by the Duke of Burgundy in 1409 hurled stones of 700-750 and 800-950 pounds.⁸⁴ Faule Mette, cast circa 1411, fired stones of over half a ton. The massive Pumhart von Steyr, forged c. 1420, fired an 80-cm stone weighing over fifteen hundred pounds.⁸⁵

How did this increase in the size and quantity of gunpowder artillery affect actual campaigns? At first, not much. The English managed to destroy the strongpoint of Romorantin in 1356 by using cannon to send “Greek fire” into the courtyard, but gunpowder artillery could prove equally useful to the defense. At Breteuil in the same year, for instance, the besieged English used cannon to destroy a French assault tower.⁸⁶ Furthermore, the guns were simply not powerful enough to do much damage to castle walls. Even at the end of the fourteenth century, siege guns could do little more than knock in the roofs of towers.⁸⁷ The balance between offense and defense remained firmly tilted towards the latter; as late as c. 1420, a German author held that the defender of a well-equipped castle, provided with artillery and good gunners, “whatever his enemy may attempt, will be able to hold off the enemy . . . until he is relieved or the enemy is given a good thrashing and departs the siege.”⁸⁸

The siege of Harfleur by Henry V in 1415, for which we have several contemporary accounts, provides us with a clear picture of the use of gunpowder artillery in the early fifteenth century. As at Berwick almost a century earlier, the main role of the cannon was to wreak devastation within the town in order to encourage the besieged to surrender. With his twelve great guns, Henry “plaid at tenys with them that were in the toune” so that “really fine buildings, almost as far as the middle of the town, were either totally demolished or threatened with inevitable collapse.”⁸⁹ In this case, the devastation succeeded in bringing the defenders out to treat with the king, praying him that “he schuld make his gunneres to sese, for it was to [t]hem intollerabil.”⁹⁰

Gunpowder artillery also had a new part to play at Harfleur, one not seen at the 1333 siege of Berwick. At Harfleur, the guns were fired not only into the town, but also against the walls and wooden bulwarks defending it. Although certain passages suggest that Henry hoped to knock assailable breaches in the walls,⁹¹ as was to become common practice a generation later, it seems more likely that his intention was, rather, to silence

the guns and catapults with which the defenders harassed his army.⁹²

The many long sieges of the 1410s and early 1420s show that artillery was not yet then capable of rapidly battering its way into a strong fortress garrisoned by determined defenders.⁹³ The siege of Rouen lasted nearly six months, from 31 July of 1418 to 19 January of 1419, even though the town “was battered severely, within and without, because the English had there so many large bombards.”⁹⁴ At the end, it was starvation, not the bombards, which brought the inhabitants to terms.⁹⁵ The town of Cherbourg was starved out after seven months in 1418; Melun after eighteen weeks in 1420; Meaux after seven months in 1421; Montaguillon after six months in 1423. The strong castle of Chateau Gaillard in Normandy held out for six months, until the cords the garrison used to draw up drinking water wore out. The English began besieging Guise in January of 1424, but did not enter the town until February of 1425.⁹⁶

In all the cases cited above, the chroniclers give lack of supplies as the primary reason for the eventual surrender of the besieged.⁹⁷ Around the middle of the 1420s, however, we begin to hear of garrisons surrendering, not because of hunger, but because the besiegers’ guns have rendered their position indefensible.⁹⁸ According to the French chroniclers, this was the case at Le Mans, Sainte-Suzanne, Mayenne-la-Juhez, Montmiral, and Gallardon, all in 1423.⁹⁹ At Sainte-Suzanne, then the second largest town of Maine, “the count of Salisbury had nine large bombards and many large cannon and fowlers [lighter cannon] sited and set up. These bombards and cannons, after eight or ten days, began to fire incessantly, day and night, so that they beat down the walls of the said town from more than a bow-shot away.”¹⁰⁰ The following year the Duke of Bedford besieged Gaillon, “a very strong place,” and “it was battered so effectively, that the garrison surrendered on having their lives spared.”¹⁰¹ In Bohemia, too, we first hear in the early 1420s of “large cannon, with which one might knock down strong walls”.¹⁰²

These events did not yet demonstrate the complete triumph of gunpowder artillery over medieval fortifications. As mentioned above, the siege of Guise in 1424 lasted over a year, and Ferte-Bernard managed to hold out against Salisbury for several months in the same year. In 1429 the English had to spend six months starving out the castle of Torcy; the French garrison of Chateau Gaillard had once again to be starved out that year; the siege of Laigny-sur-Marne took over five months in 1432; and as late as 1440 Harfleur was able to resist an English siege for over three months.¹⁰³ Each of these places, however, was exceptionally strong, and each was attacked by a relatively weak English siege train.

The powerful Burgundian artillery of the 1430s, on the other hand, could demolish the walls of most fortifications. In 1430, the Burgundian siege train was able to “do so much damage to the walls of the castle [of Choisy] that the garrison capitulated” in a mere few days. Similarly, at Avalon in 1433, the Burgundian artillery was “pointed against the gates and walls, and damaged them greatly, breaches being made in divers parts.”¹⁰⁴ By 1437, even the English artillery was capable of leaving a stronghold with “a great part of the walls . . . thrown to the ground, so that it was in no way defensible.”¹⁰⁵

By the late 1440s the Franco-Burgundian artillery could destroy even the most powerfully defended places. Mighty Harfleur, which had held out so long against the English in 1440, made terms after a seventeen-day bombardment in 1449.¹⁰⁶ After a sixteen-day siege in 1450, almost the entire wall of Bayeux was “pierced and brought down.” The story was much the same at Dax and Acx: “their walls were so battered in many places that by diverse breaches they could be taken by assault.” At Blaye, in 1451, it took only five days before “the town walls were completely thrown down in many

places.”¹⁰⁷ A contemporary English document lists one hundred strongpoints taken by the French in 1450, including Chateau Gaillard, St.Saveur-le-Vicomte, Cherbourg, Roche-Guyon, and Rouen, all of which had earlier required long sieges to capture.¹⁰⁸ In 1451, all of Guienne fell rapidly to the French despite the deeply ingrained pro-English sympathies of the inhabitants of the duchy.

Based on the above accounts, it seems fair to say that a revolution occurred in the art of war around the 1420s to 1430s, as gunpowder artillery overturned the centuries-old dominance of the defensive in siege warfare. What was the nature of this revolution?

At first glance, contemporary descriptions of the 1450 campaign might lead the historian to attribute the incredible French successes to the Vaubanesque system of siegecraft so carefully described by Leseur and Chartier. The former author’s passage on the siege of Dax is worth quoting at length:

The watch ordered and set, our prince sent for a force of pioneers and miners, who, all night long, he had make broad approaches and deep ditches and trenches, [and] set up his large artillery, and put the protective mantles there; and he was so diligent that the said artillery was ready to fire at dawn. And in the same way my lord the prince made huts by filling wickerwork and faggots with earth, in the manner of a broad mound, to shelter the watch from the artillery of the town; and the trenches were so advanced the next day that one could go safely under cover from one quarter of the siege to another, and in the same way one could come by the said approaches to the artillery, and even up to their fosses. And always, day and night, the said pioneers worked on them ... Furthermore, the large artillery was fired assiduously day and night. Inside of a few days it had done great damage, so that the defenses of the towers . . . and a great part of the forward walls were thrown down to the ground; and our said artillery made large and wide breaches there, over which watch was held; and we fired the large culverines at these, so that, when the enemy wished to make shelters or otherwise repair them, our culverines often killed and wounded their men and knocked them down to the ground, them and their shelters.¹⁰⁹

Jean Chartier, in his *Chronique de Charles VII*, also emphasized the “marvellous . . . approaches, fosses, entrenchments and mines which the abovesaid [Bureau brothers] had made before all the towns and castles which were besieged” during the reconquest of Normandy in 1450.¹¹⁰ Decades later, Jean de Bueil’s *Le Jouvencel* continued to advocate the same method of siegecraft.¹¹¹

There is no doubt that the Bureau brothers’ methods were admirable, impressive, and contributed significantly to the success of the French artillery in the middle of the fifteenth century. However, an account of the siege of Harfleur, written in 1416-17, already describes much the same method of approach and bombardment from covered positions.¹¹² Thus, we must look elsewhere for the developments which enabled the artillery of the 1450s to tumble down the walls of the strongest fortresses.

It has been argued that gun design remained essentially stagnant until well into the fifteenth century, and that the most important advances were made after the artillery pioneers Jean and Gaspard Bureau became Treasurer and Master of Artillery of France, respectively, around 1440.¹¹³ In fact, however, cannon developed steadily throughout the fourteenth century, and very rapidly in the early fifteenth. Indeed, the developments in cannon design most critical for the Artillery Revolution appeared in the years 1400-1430. These developments included changes in the design and manufacture of the guns themselves, in loading methods, and in powder formulation.

Probably the most important of these involved the lengthening of gun barrels. In 1400 most large bombards seem to have had barrel-lengths about equal to 1 – 1.5 times the

diameter of the balls they shot. By 1430 at the latest, the ratio of barrel length to ball diameter had grown to 3:1 or more.¹¹⁴ In addition to increasing the accuracy of the shot (making it possible to concentrate the force of a large number of shots on a smaller area), this increased the amount of time over which the pressure of the exploding gunpowder accelerated the ball, and thus significantly increased the muzzle velocity of the shot. Since the kinetic energy of the ball is a function of the square of the velocity, this meant a major increase in the effectiveness of the newer guns. As contemporary gunners realized, it also meant an increase in range.¹¹⁵

The lengthening of bombard barrels had an equally important indirect effect. In the early years of the fifteenth century, with the shorter-barreled bombards, a rather complex loading process had to be employed.¹¹⁶ The gun crew filled the chamber with gunpowder for the rear three-fifths of its length. The next fifth was left empty, and the last fifth filled by a soft wood plug cut to fit the chamber bore exactly. Then the cannonball was fixed in place in the barrel with soft wood wedges. Finally, to get the tightest possible seal (thus minimizing pressure loss to windage), wet mud mixed with straw was put in place and allowed to dry. After the bombard had been fired, it had to be allowed to cool before more powder could be packed in.¹¹⁷ This elaborate procedure so slowed down the firing process that one master gunner, who achieved the remarkable feat of firing his bombard three times in a single day and hitting different targets each time, was forced to make a pilgrimage from Metz to Rome, because it was thought that "he could only have been in league with the devil."¹¹⁸

Guns with longer barrels, however, ameliorated this problem. Since the ball was under pressure from the expanding gas for a longer period of time, somewhat more gas loss due to windage could be allowed, and the wet loam seal dispensed with. This, in turn, permitted more rapid firing.¹¹⁹

As guns of this sort became more common, there was an important change in the process used to manufacture them. In the late fourteenth century, the barrels of large iron bombards were made either by forging a large iron plate into a cylinder, or by spiraling out a broad iron band, forming a cylinder in the same way that the coils of a spring do. These methods, however, could not be scaled up past a certain point.¹²⁰ Sometime in the early fifteenth century, probably shortly before 1420, gunsmiths developed a new technique which made possible large guns with long barrels: they built up large iron guns out of long staves.¹²¹ The staves were set in place around a cylindrical mandrel, then reinforced with bands of white hot iron, which were hammered down the cylinder like the hoops of a barrel.¹²² The hoops shrank as they cooled, binding the staves tightly together.¹²³

At about the same time, a metallurgical innovation made the prodigious quantities of iron used in this process ¹²⁴ less expensive: the addition of limestone to the flux during the ore refinement process. This increased the temperature necessary to make the slag free-running, so that it could only be used with developed blast furnaces,¹²⁵ but it changed the structure of the slag from $2\text{FeO}\cdot\text{SiO}_2$ to $\text{CaO}\cdot\text{SiO}_2$. The two atoms of iron thus removed from each molecule of slag were no longer wasted, increasing the iron output from a given quantity of ore and making iron cheaper.¹²⁶ Meanwhile, as the manufacture of large iron cannon became more routine, the services of cannon-smiths grew more affordable. The cost of cannon – which were priced in direct proportion to their weight – fell significantly (about a third) as a result of these changes.¹²⁷

More or less simultaneously with these developments, an important change took place in a related area: the manufacture of gunpowder.¹²⁸ Around 1400, recipes for gunpowder began to appear which came quite close to the ideal proportions of saltpeter,

sulphur, and charcoal.¹²⁹ But then, in the second decade of the century, it appears that the science of powdermaking took a retrograde step, moving significantly farther away from the “ideal” proportions.¹³⁰ Considering the high cost of gunpowder,¹³¹ it seems strange that gunners would adopt a less effective form of it. The explanation of this seeming paradox lies in yet another new technique: the engraining or “corning” of powder. Although there is evidence that the English may have employed this process as early as 1372, it seems that it did not come into use on the Continent until the around 1410; it was in almost universal use by 1420.¹³² Corned powder, which was mixed together wet and then dried into kernels, had a number of advantages over the earlier “serpentine” powder, which was sifted together dry. Sifted powder tended to separate into its component elements when transported, but corned powder was immune to this deterioration. Most importantly, the structure of corned powder allowed the burning to progress mainly between, rather than within powder grains, resulting in a much more rapid evolution of the solid into gas.¹³³ Some contemporary master gunners claimed that engrained powder was three times as powerful as the sifted form.¹³⁴

This posed a problem, however: the commensurate increase of the pressure in the chamber of the gun was more likely to burst the cannon than improve its effectiveness.¹³⁵ This, it seems reasonable to assume, explains the shift away from the “ideal” proportions in the mixing of gunpowder: engrained powder with less saltpeter would be both cheaper and more powerful than sifted powder with the “perfect” proportions, but not so much more powerful that it would be likely to burst the gun. Thus, between 1400 and 1430, a whole series of interconnected innovations synergistically improved the power and efficiency of gun-powder artillery. The development of the hooped-staves method made it possible for even the largest iron cannon to have longer barrels, the adoption of which increased accuracy, power, and rate of fire. The new iron refining process, and the increasing skills of the gunsmiths, made guns cheaper to buy; and corned powder made them both more powerful and cheaper to use. The number and size of guns in use increased rapidly. Put together, these developments were enough to reverse the centuries-old superiority of the defensive in siege warfare, and bring the walls of medieval castles crashing down.¹³⁶

Further important improvements were made in the 1450s to 1470s, including the general adoption of the modern two-wheeled carriage, trunnions, and iron cannonballs. Large bombards increasingly gave way to smaller, cheaper, more easily transportable guns, particularly cast bronze muzzle-loaders.¹³⁷ However important these latter changes may have been from a technical point of view, though, it was the earlier changes which held the greatest importance for the actual conduct of operations, as the above analysis of the sieges of the 1410s to 1430s shows.

Impact of the Artillery Revolution

The idea that the introduction of gunpowder led to sweeping changes in the political structure of Europe has been a familiar one from the days of Adam Smith, David Hume, Carlyle, and Macaulay. More recently, J.F.C. Fuller, Ferdinand Lot, and William H. McNeill have made similar arguments.¹³⁸ Others have tried to refute their case, but the logic of the argument is as powerful as it is simple.

Artillery was expensive. As early as 1442, the French government was spending more than twice as much on its artillery train as it spent on more traditional war materiel – arrows, lances, bows, etc.¹³⁹ The central governments of large states could afford to acquire and maintain large siege trains: their subjects and smaller neighbors, in general, could not. The imbalance between offensive and defensive in siege warfare led to a corresponding inequity in strategy: the offensive gained, the defensive suffered.

In the early fourteenth century, Pierre Dubois observed in his military treatise that A castle can hardly be taken within a year, and even if it does fall, it means more expenses for the king's purse and for his subjects than the conquest is worth. Because of these lengthy, dangerous and arduous sieges, and because battle and assaults can be avoided, leaders are apt to come to agreements which are unfavorable to the stronger party. 140

Under such circumstances, local powers could effectively keep the interference of the central government to a minimum. The Artillery Revolution altered the situation dramatically. Regional interests lost their ability to defy central authorities; small states and semi-independent regions were gobbled up by their larger neighbors.

There were many exceptions, of course, but the process by which France and Spain became unified nation-states owed much to the Artillery Revolution. In France, the central government rapidly asserted its control over Normandy, Aquitaine, and Brittany, then turned to the conquest of Burgundy. In Spain, to quote Geoffrey Parker, "thanks to their command of a siege-train of some 180 guns, the 'Catholic Kings' Ferdinand and Isabella were able to reduce within ten years (1482-92) the Moorish strongholds in the kingdom of Granada that had defied their forbears for centuries." 141 When the French marched into Italy in 1494, their artillery "could do in a few hours what in Italy used to take days." 142

The Florentine historian Guicciardini accurately perceived the impact which the Artillery Revolution had on warfare. Before, when the "slow and uncertain" methods for besieging towns led to long wars, "the ruler of a state could hardly be dispossessed." Effective siege cannon, however, "infused so much liveliness into our wars that . . . whenever the open country was lost, the state was lost with it." 143 Before, a power on the defensive could hole up in its fortifications and wait for the enemy to run out of energy, money, or food. After the Artillery Revolution, defense had to be defense in the field – a truth which had already been clearly demonstrated by the French reconquest of Guienne in 1453.¹⁴⁴ This appears to have led to a significant increase in the frequency of battle.¹⁴⁵ After 1520, as the impact of the sunken-profile trace italienne earthwork fortress made itself felt, (in what could be dubbed an "Artillery Fortress Revolution") the frequency of battle again declined. 146

The increased importance of battle after the Artillery Revolution tipped the scales of war even further in favor of large states and centralized governments, for only they had the resources to maintain sizable standing armies like the *compagnies d'ordonnance* established by Charles VII of France in 1445 and by Charles the Bold of Burgundy in 1471-73. In addition, by the 1450s, artillery was beginning to be as much a help in battles as in sieges-witness the battles of Formigny and Castillon.¹⁴⁷

The great cost of artillery, and the larger armies engendered by the growing importance of open battle, put a premium on the ability to produce and manage large amounts of cash. This created a self-reinforcing cycle, which continued to spiral upwards at least until the advent of the Artillery Fortress Revolution of the early sixteenth century. It went something like this: central governments of large states could afford artillery trains and large armies. The artillery trains counteracted centrifugal forces and enabled the central governments to increase their control over outlying areas of their realms, or to expand at the expense of their weaker neighbors. This increased their tax revenues, enabling them to support bigger artillery trains and armies, enabling them to increase their centralization of control and their tax revenues still further, and so on.¹⁴⁸ One scholar has estimated that the tax revenues of central governments in Western Europe doubled in real, per capita terms between 1450 and 1500;¹⁴⁹ this feedback loop

between military capability and economic mobilization ability helps account for that phenomenon.

Looking backward from the period of the Artillery Fortress Revolution, more than one scholar has tried to argue that “the view that the advent of cannon changed the balance between the attackers and the fortified defense is simply not supported by the evidence.”¹⁵⁰ The contemporaries of the Artillery Revolution, from Chartier and Leseur to Guicciardini and Machiavelli, did not agree. Indeed, the fifteenth-century Italian architect Francesco de Giorgio Martini wrote that “the man who would be able to balance defense against attack, would be more a god than a human being.”¹⁵¹ Their accounts, and the other evidence presented in this article, make it clear that gunpowder did reverse the balance between offense and defense around 1430 as the result of a rapid series of technical innovations built onto a century of gradual development. True, this superiority of the offensive itself eventually succumbed to another military revolution – but in the century between the initial triumphs of gunpowder artillery in the 1420s to 1440s and the flowering of the sunken-profile, bastioned-trace earthwork fortress in the 1520s to 1540s, gunpowder artillery wrought a true revolution in European warfare, with great consequences for the continent and the world.

Paradigms: Revolution vs. Punctuated Equilibrium Evolution

Let us return to the question which launched our examination of the military revolutions of the Hundred Years’ War: “just how did the West, initially so small and so deficient in natural resources, become able to compensate for what it lacked through superior military and naval power?” I have argued that in order to answer that question we must turn our gaze back to the early years of the fourteenth century, when the Infantry Revolution reached maturity and cannon first appeared. It is clear that between that time and the end of the eighteenth century, the European military “macroparasite”¹⁵² became far more effective than any the world had known before, and that this advancement of the craft of war played a crucial role in the rise of the West to global dominance. But that covers a span of a full half a millennium.

The concept of “revolution” in history is a flexible one, flexible enough to encompass phenomena as diverse as the Glorious, French, Copernican, and Industrial revolutions. In each case, though, “revolution” refers to a rapid reversal in the state of affairs. The length of time involved can range from a year to a century, depending on the scope of the revolution – depending on whether it is a government, a social structure, an idea, or an economy which is overturned – but in none of these cases does the time-frame during which the reversal takes place exceed a single (maximum) human life span.

Furthermore, a revolution – however extended – must be in essence a single change, from state X to state Y, from front to back or top to bottom. Over the five centuries between 1300 and 1800, however, Europe experienced not one but several military revolutions, even considering land forces alone, each of which dramatically altered the nature of warfare over a short span of time. First, in the fourteenth century, the “Infantry Revolution,” when common Swiss pikemen and halberdiers and English archers overturned the centuries-long dominance of aristocratic shock cavalry. Second, the “Artillery Revolution,” which reversed the equally long-standing superiority of the defensive in siege warfare and provided a major impetus for the unification of France and Spain under central authorities. Third – getting into the period of the traditionally defined Military Revolution, and away from the period analyzed in the body of this paper – the “Artillery Fortress Revolution,” based on the trace italienne and sunken-profile earthwork walls, which reinstated the superiority of the strategic defensive. Fourth, the “Military Revolution” which Michael Roberts outlined in his seminal paper-

drill, military bureaucratization, and the growth of army size. 153 We are, thus, dealing not with one revolutionary change, but with a whole series of revolutions which synergistically combined to create the Western military superiority of the eighteenth century.

Is the answer to our question, then, a matter of evolution? Evolution normally implies advancement through a near-infinite number of infinitesimal changes, and that, clearly, is not the conceptualization we want. Each of the component revolutions mentioned above, it is true, involved a certain amount of slow, steady evolution both before and after the “revolutionary” period. Cannon evolved for a full century before they were able dramatically to change the European way of war, and they continued to improve steadily (if slowly) for centuries after-ward.¹⁵⁴ But the concept of evolution, as commonly conceived, does not adequately address the critical period of rapid innovation from 1410 to 1430.

There is a paradigm, however, which may be able to provide a conceptual framework broad enough and sturdy enough to support analysis of the diverse events which must go into an explanation of the growth of Western military superiority. In 1972, Stephen Jay Gould and Niles Eldredge proposed a new model for the evolutionary formation of species, which they dubbed “punctuated equilibrium.” They argued that evolution proceeded by short bursts of rapid change interspersed with long periods of near stasis rather than constant, slow alteration. Their theory aroused much controversy, and over the intervening years it has become clear that their initial formulation did not give sufficient play to gradual, incremental change. ¹⁵⁵ But many scientists have accepted Gould and Eldredge’s basic point – that much, though not all, evolutionary change occurs during short periods of rapid development. This newer conception of punctuated equilibrium evolution, combining both incremental and “revolutionary” change, seems to describe the process of military innovation extraordinarily well. After a long period of near-stasis, infantry began to evolve very rapidly around the beginning of the fourteenth century. Cannon appeared at about that time, evolved incrementally for a century, then in a burst of rapid advancement revolutionized war in Europe. Artillery fortifications began to develop at about the same time as artillery reached its height; ¹⁵⁶ evolved gradually over the course of a century; then in their turn effected a military revolution. A similar process of punctuated equilibrium evolution in military technology continues even today.

It might be argued that, so long as we all know what we are talking about when we say “Military Revolution,” my objections are mere quibbling, only a question of semantics. But, as George Orwell showed so effectively in 1984, words shape ideas, and ideas shape the world. By attempting to subsume the innovations of five centuries into a single phenomenon, we may be imposing an artificial teleological unity onto a series of inherently distinct, separate developments. And, in doing so, we may be clouding our understanding of a critically important area of history, an area which fully deserves to be studied through the clearest possible lens.

End Notes

1. A number of scholars have been kind enough to read drafts of this article and offer me their corrections and comments: thanks are especially due to John F. Guilmartin, Jr.; Andrew Ayton; Russell Hart; Geoffrey Parker; John Lynn; Williamson Murray; and the students in the Ohio State University seminar on “Technologically Oriented Military History” (Winter-Spring 1991), particularly Capt. Peter Mansoor. Thanks are also due to the Ohio State University for the Research and Graduate Council Fellowship which

supported me while I researched and wrote this article, and the U.S.- U.K. Fulbright Commission for the grant which enabled me to put the finishing touches on it.

2. Stephen Glick has pointed out, however, that Sir Charles Oman may have prior claim to the concept: Oman's 1898 essay, *The Art of War in the Middle Ages*, refers to the time when pike-and-shot infantry took the premiere part in withstanding the Ottomans as "the military revolution of the sixteenth century." C. W. Oman, *The Art of War in the Middle Ages*, revised and edited by John H. Beeler (Ithaca, N.Y: Cornell University Press, 1953), 162.

3. Michael Roberts, "The Military Revolution, 1560-1660," reprinted in his *Essays in Swedish History* (Minneapolis: University of Minnesota Press, 1967).

4. Geoffrey Parker, "The 'Military Revolution,' 1560-1660-a myth?," *Journal of Modern History* 48 (1976): 195n.; Geoffrey Parker, *The Military Revolution: Military Innovation and the Rise of the West* (Cambridge: Cambridge University Press, 1988), 2.

5. Parker, "The 'Military Revolution,'" 214, et passim.

6. E.g., Michael Duffy, ed., *The Military Revolution and the State, 1500-1800*, *Exeter Studies in History* 1 (Exeter: University of Exeter, 1980), 3; John A. Lynn, "The Growth of the French Army During the Seventeenth Century" *Armed Forces and Society* 6 (1980). Cf. William H. McNeill, *The Pursuit of Power* (Chicago: University of Chicago Press, 1982), Chs. 3 and 4, and John Lynn's review article, "Clio in Arms," *Journal of Military History* 55 (January 1991).

7. Parker, *Military Revolution*, 4. All the participants on the Military Revolution Roundtable at the 1991 American Military Institute conference in Durham, NC, i.e., myself, John F. Guilmartin, John A. Lynn, and Geoffrey Parker-agreed on the centrality of this question.

8. Previously cited works by Roberts, Parker, Duffy. Others include: John A. Lynn, "The trace italienne and the Growth of Armies: The French Case," *Journal of Military History* 55 (July 1991); Simon Adams, "Tactics or Politics? 'The Military Revolution' and the Hapsburg Hegemony, 1525-1648," in *The Tools of War*, ed. J. A. Lynn (Champaign: University of Illinois Press, 1990); David A. Parrott, "Strategy and Tactics in the Thirty Years' War: The 'Military Revolution,'" *Militargeschichtliche Mitteilungen* 18 (1985); and Jeremy Black's new book, *A Military Revolution? Military Change and European Society, 1550-1800* (Atlantic Highlands, N.J.: Humanities Press, 1990), which emphasizes the military changes which took place in the century after 1660. His work, though it seriously underestimates the military changes of the sixteenth century, does have important contributions to make for the seventeenth- and eighteenth-century phases of the process of Western military innovation which fit nicely with the "punctuated equilibrium evolution" model which I will develop later in this article.

9. They held primacy in importance, though often not in numbers. This statement will be developed further below. For the area between the Loire and the Rhine, feudal armies exercised their dominance from even farther back-from Carolingian times-but by mid-eleventh century (i.e., after 1066) feudal warfare was well established in England, Italy, and Germany as well.

10. In the twelfth century, many battles were fought by dismounted cavalry, but there is a difference between dismounted cavalry and infantry, especially "common" (i.e., non-aristocratic) infantry. See below.

11. Parker, *Military Revolution*, 118, points out that this last was an important difference between the Europeans and many of those whom they sought to subdue.

12. This term has been used by John F. Guilmartin in his article "War, Technology of" in the 1991 *Encyclopaedia Britannica*, 539. He uses it, however, to refer to the progress of

infantry over the entire period c. 1200-1500, whereas I limit it to the rapid and revolutionary rise to prominence of infantry in the years c. 1302-46.

13. I will not make any attempt to produce a developed explanation of why this process of punctuated equilibrium military evolution “took off” in the West and not elsewhere in the world. I suspect that the answer has something to do with the combination of two factors: (1) the fragmented and competitive political structure of Europe; (2) the technological orientation towards problem solving which appeared in Europe in the High Middle Ages. The former provided the need for military innovation; the latter helped provide the means.

14. Oman, Art, 47.

15. The quote is from B. Lyon, “The Role of Cavalry in Medieval Warfare: Horses, Horses All Around and Not a One to Use,” *Mededelingen van de Koninklijke Academie voor Wetenschappen, Letteren en Schone Kunsten van België* 49 (1987), Nr. 2, 90. Jim Bradbury makes a stronger case in the same direction (albeit taking a less extreme position) in his *The Medieval Archer* (Woodbridge, Suffolk: Boydell Press, 1985.)

16. J. F. Verbruggen, *The Art of Warfare in Western Europe During the Middle Ages: From the Eighth Century to 1340* (Amsterdam: North Holland Publishing Co., 1977), 23; cf. Philippe Contamine, *War in the Middle Ages*, tr. Michael Jones (London: Basil Blackwell, 1984), 31. For a particularly well-balanced case study of the role of infantry in high medieval warfare, see R. C. Smail, *Crusading Warfare (1097-1193)* (Cambridge: Cambridge University Press, 1956), especially 116-30.

17. Smail, *Crusading Warfare*, 128-30, says this tactic was in common use during the Crusades. Perhaps the most vivid descriptions of it are found in Guillaume le Breton’s account of the battle of Bouvines (1214); Beha al-Din’s description of Richard I’s forces at Arsuf (in Verbruggen, *Art of Warfare*, 215, 218), and especially Al-Heweri’s description of the “Franks” in his military treatise of 1211 (in H. Ritter, “La Parure des Cavaliers and die Literatur uber die ritterlichen Kunste,” *Der Islam* 18 (1929): 147).

18. See R. Allen Brown, “The Status of the Norman Knight,” in *War and Government in the Middle Ages*, ed. John Gillingham and J. C. Holt (Woodbridge, Suffolk: Boydell Press, 1984), 29, and Verbruggen, *Art of Warfare*, 28-39.

19. The *Chanson de Guillaume* implicitly recognized the connection between diet and military prowess: “By God, fair sire, he’s of your line indeed,/Who thus devours a mighty haunch of boar/And drinks of wine a gallon at two gulps;/pity the man on whom he wages war.” Although it deals with a different period, Geoffrey and Angela Parker’s *European Soldiers, 1550-1650* (Cambridge: Cambridge University Press, 1977), 22, gives some interesting statistics on this point. It seems that in that period, fewer than one common recruit in thirty was over five feet tall.

20. Richelieu was by no means the first to observe that “history knows more armies ruined by want and disorder than by the efforts of their enemies”; the same principle is emphasized in the military treatise of Vegetius, which was very popular in the Middle Ages. Geoffrey Lester, ed., *The Earliest English Translation of Vegetius’ De Re Militari* (Heidelberg: Carl Winter Universitatsverlag, 1988), 156, 158. For an outstanding discussion of strategy in the High Middle Ages, which will help make clear the importance of this capacity, see John Gillingham, “Richard I and the Science of War in the Middle Ages,” in Gillingham and Holt, eds., *War and Government in the Middle Ages*.

21. The “equipment” included a warhorse, palfrey, packhorse, armor, weapons, etc. The high cost of his equipment was reflected in the high wages he received when serving at his lord’s expense. See note 43, below.

22. See the *Calendar of Inquisitions, Miscellaneous. VII (1399-1422)* (London: 1968), 29,

61, 313; 32, 276, 188. Compare PRO E101/392/13.

23. In this context it is worth quoting Petrarch (b. 1304), who wrote: "In my youth, the Britons, who are called Angles or English, were taken to be the meekest of the barbarians. Today they are a fiercely bellicose nation. They have overturned the ancient military glory of the French by victories so numerous that they, who once were inferior to the wretched Scots, have reduced the entire kingdom of France by fire and sword." Quoted in R. Boutruche, "The Devastation of Rural Areas During the Hundred Years' War and the Agricultural Recovery of France," in *The Recovery of France in the Fifteenth Century*, ed. P. S. Lewis (New York: Macmillan, 1972). Note that the reason the English were once inferior to the Scots is that the latter perceived the potential of the Infantry Revolution before their southern neighbors, just as the English appreciated it before the French. Cf. Jean le Bel's similar comment: *Chronique de Jean le Bel*, ed. J. Viard and E. Deprez (Paris: SHF, 1904), 1:155-56.

24. Cf. Pierre Dubois's treatise, quoted in Verbruggen, *Art of Warfare*, 273.

25. The Scots, too, had an important role to play in the Infantry Revolution. Although not enemies of the French, the Scots suffered an equivalent inferiority in heavy cavalry vis-à-vis their traditional opponents, the English.

26. For Courtrai, see Verbruggen, *Art of Warfare*, 166-73. For Bannockburn, see J. E. Morris, *Bannockburn* (Cambridge, 1914). The account in Thomas Gray's *Scalacronica*, ed. J. Stevenson (Edinburgh: Maitland Club, 1836) is not very detailed, but it does note that the Scots at Bannockburn were specifically following the example of the Flemings at Courtrai, who had defeated the French forces by fighting on foot (p. 142).

27. Thomas Wright, *The Political Songs of England*, vol. III (Edinburgh: Privately printed, 1884), 43.

28. The battle of Bannockburn took place on "an evil, deep morass" on a very narrow front. *Scalacronica*, 142; John Barbour, *The Bruce*, ed. W. W. Skeat (Early English Text Society, 1889), 299. According to Oman, "the infantry of the Great Company in the east beat the Duke of Athens (A.D. 1311), by inducing him to charge with all his men-at-arms into a swamp." These four battles, all fought within the brief span of thirteen years, show a remarkable similarity. Taking into account Thomas Gray's comment (see note 26), I suspect that the later three battles were conscious attempts to replicate the success of the Flemings in 1302. Furthermore, the Scots at least believed (and almost certainly correctly) that the English had learned the advantages of fighting on foot from their defeat at Bannockburn. The French experiments with infantry tactics, in turn, were undertaken in imitation of the successful English. Cf. Geoffrey le Baker, *Chronicon*, ed. E. M. Thompson (Oxford: Clarendon, 1889), 143.

29. For Cassel, see le Bel, *Chronique*, 1:93-94, and Ferdinand Lot, *L'Art Militaire et les Armees au Moyen Age* (Paris: Payot, 1946), 274-78. For Mons-en-Pevel, see Verbruggen, *Art of Warfare*, 176-83.

30. Oman, *Art*, 89.

31. Pun quite intended. For Crecy, see le Bel, *Chronique*, 2:99 et seq., and le Baker, *Chronicon*, 82-85. Froissart, *Oeuvres*, 5:37-78. Alfred H. Burne, *The Crecy War* (Westport, Conn.: Greenwood Press, 1976), Chapter 7.

32. Although a cavalry reserve was often kept for pursuits or special tasks, such as attempting to ride down the English archers, as at Poitiers in 1356.

33. "The Design and Materials of the Bow," in Robert Hardy, *Longbow: A Social and Military History* (Cambridge: Patrick Stephens, 1976), 195.

34. See the illustrations reproduced in Bradbury, *Medieval Archer*. The Norman archers at Hastings, if we can trust the depictions of the Bayeux Tapestry, also used short bows

drawn to the chest (Bradbury, 32-34). It is interesting to note that both the Normans and the Welsh are clearly depicted as using a two-fingered draw, rather than the three-fingered draw used by longbowmen during the Hundred Years' War, indicating a weaker bow in the earlier period.

35. See Jean de Joinville, *Chronicle*, in Sir Frank Marzials, ed., *Memoirs of the Crusades* (London: Everyman's Library, 1964), 195, and Beha al-Din's account of Arsuf, quoted in Verbruggen, *Art of Warfare*, 215. Of course, these were composite recurved shortbows, but since they were more powerful than the Welsh selfbows, the point stands. The effects of the English archers' arrows at Crecy, Poitiers, Verneuil, or Agincourt were much more serious. E.g., see *Chronographia Regum Francorum* (Paris: SHF, 1891), 2:232.

36. Philippe de Commines, *Memoires*, ed. R. Chantelauze (Paris: FirminDidier, 1881), 23-24. He goes on to describe the archers in the Burgundian army at Montlhery (1465) as "the flower and hope of their army."

37. A failure to take into account the great strength needed to use a medieval longbow effectively has led many authors into the mistaken conclusion that a soldier could be trained to its use with relative ease. E.g., see Richard Barber, *The Knight and Chivalry* (Ipswich: Boydell Press, 1974), 199.

38. Bradbury's estimate of 50 lbs. as a typical medieval draw weight is far too low, and would not have produced the high pressures which caused the skeletal deformation of the archers on the wreck of the Tudor warship *Mary Rose* compressed left forearms, twisted spines, and flattened draw-fingers. Guilmartin, "War, Technology of," 541; Bradbury, *Medieval Archer*, 148, 157. Cf. Hardy, *Longbow*, 53. Robert Hardy revealed in a paper presented at the Hundred Years' War conference held at Oxford University, 8-10 November 1991, that the 138 longbows recovered from the *Mary Rose* ranged in power from 100-180 (!) pounds draw weight.

39. For a good discussion of the human element of archery, see John F. Guilmartin, *Gunpowder and Galleys* (Cambridge: Cambridge University Press, 1974), 151.

40. In 1384, for example, Charles VI of France prohibited any games except those involving the longbow or crossbow. Contamine, *War*, 217. Cf. note 51, below.

41. The beauty of the English archer and man-at-arms combination was that it could convert either into an offensively powerful cavalry-and-missile combination when used against infantry fighting on the defensive (e.g. vs. the Scottish schiltrons at Falkirk), or into an equally effective defensive "pike-and-shot" combination to destroy attacking cavalry and infantry forces (e.g., at Crecy, Agincourt). In the latter case, the archers' fire served to disorder and demoralize the attacking forces (when it did not wound or kill) before they smashed into the steady, tightly formed men-at-arms.

42. Here, and throughout this paper, "common infantry" refers to infantry drawn from nonaristocratic classes. I also consider troops like the English mounted archers, who rode from place to place but invariably fought on foot, as they had neither the training nor the mounts to fight on horseback, to be essentially infantry rather than cavalry. A mounted archer's horse could be had for £2 (E101/397/5), while a knight would likely spend at least ten times that amount for a courser, palfrey, and rouncy (E101/19/36).

43. A very important consideration when victory in war often went to the side with the last reserves of money. In 1326, for example, an English knight bachelor was paid twelve times as much as a footman (2s/day vs. 2d/day).

44. Although this advantage was less pronounced for longbowmen, who required years of training to build up the strength to use their bows.

45. The broader social base from which infantry forces were drawn became crucial later

in the “military revolution” of the sixteenth and seventeenth centuries. From the mid-sixteenth to the end of the seventeenth century, the French army grew from a maximum wartime strength of about 50,000 to one of about 400,000 (Parker, *The Military Revolution*, 24). Virtually every man of the 350,000 added came from the common population: as late as 1775, the total number of gentilshommes employed by the French military, including the navy and retired officers, was only 20-25,000 (Duffy, *Military Revolution and the State*, 4).

46. By the end of the Hundred Years’ War, the Berry Herald precociously described the English as follows: they “are all good archers and soldiers They also make war on all nations of the world by sea and land and all that they gain in the foreign parts to which they have gone they send back to their realm and through this it is rich.” Quoted in Contamine, *War*, 125. The Swiss, of course, also exported large numbers of mercenary infantrymen.

47. Stanislav Andreski provides an outstanding theoretical treatment of the relationship between military and political enfranchisement in his *Military Organization and Society* (London: Routledge and Kegan Paul, 1968).

48. See the poem in John Barnie, *War in Medieval English Society* (Ithaca, N.Y: Cornell University Press, 1974), 21. Edward Miller has noted that in the early fourteenth century “there is, in fact, a close correlation between periods of war taxation and `constitutional movements”’-he might have made it “periods of war taxation and recruitment.” Edward Miller, “War, Taxation, and the English Economy in the Late 13th and Early 14th Centuries,” in J. M. Winter, ed., *War and Economic Development* (Cambridge: Cambridge University Press, 1975)

49. Cf. G. J. Aungier, ed., *French Chronicle of London*, Camden Series, 28 (1844): 83.

50. Froissart, *Chronicles*, 5 vols., tr. Thomas Johnes (Haford: Haford Press, 1803), 2:469, 477, 479.

51. Jean Juvenal des Ursins, *Histoire de Charles VI*, in *Choix de chroniques et memoires sur l’histoire de France. XIVE siecle* (Paris: Pantheon Litteraire, 1838), 385. See Rymer, *Foedera*, vol. III, pars. 2, 704, for the very different English royal attitude.

52. But cf. Thomas N. Bisson, “The Military Origins of Medieval Representation,” *American Historical Review* 71 (1966): 1207.

53. One fifteenth-century list of participants in a Parliamentary election, for example, includes 1 knight, 8 esquires, 10 “gentilmen,” and 105 common freemen. See J. G. Edwards, “The Huntingdonshire Parliamentary Election of 1450,” in *Essays in Medieval History Presented to Bertie Wilkinson*, ed. T. A. Sandquist and M. R. Powicke (Toronto: University of Toronto Press, 1969), 385. One poem written around 1400, emphasizes the role of good “schire-knyghtis” as mere representatives of the electorate: “We are servants taking a salary and sent from the shires to show their grievances and to speak for their profit . . . and if we are false to those who send us here, then little are we worthy of our hire.” Mum and the Sothsegger, ed. Mabel Day and Robert Steele (London: Early English Text Society, 1936), 24-25.

54. For a good survey of the early development of the English Parliament, see G. L. Harris, “The Formation of Parliament, 1272-1377,” in R. G. Davies, ed., *The English Parliament in the Middle Ages* (Manchester: Manchester University Press, 1981) For the early development of the longbow and tactics based on its use, see Hardy, *Longbow*, 36-49.

55. Cf. G. Edwards, “Huntingdonshire Parliamentary Election of 1450,” 38, for the Parliamentary side; for the military side, see the Lanercost Chronicle’s description of Dupplin Muir and Halidon Hill, and Froissart’s descriptions of Cadzand, Hennebon,

Quimperle, Bergerac, Auberoche, and Crecy, all in the first two decades of Edward's long rule.

56. G. Edwards, "Huntingdonshire Parliamentary Election of 1450," 49. G. L. Harriss, *King, Parliament, and Public Finance in Medieval England to 1369* (Oxford: Clarendon Press, 1975), 259, 320, 359.

57. G. Edwards, "Huntingdonshire Parliamentary Election of 1450," 19-21. This was of great importance, as indirect taxation was then replacing direct subsidies as the largest source of royal income, as the research of Mark Ormrod is showing.

58. The increasing economic importance of the towns also played a part in their gain in political power, but wealth can only be exchanged for power if the transaction is protected by force: otherwise, he who holds the power is likely to take the wealth without making political concessions.

59. For the 40s. voting qualification, see *Rotuli Parliamentorum*, 4:350. Cf. S. J. Payling, "The Widening Franchise-Parliamentary Elections in Lancastrian Nottinghamshire," in *England in the Fifteenth Century*, ed. Daniel Williams (Woodbridge, Suffolk: Boydell Press, 1987), and G. Edwards, "Huntingdonshire Parliamentary Election of 1450," 386. For the 40s. "archer class," see Michael Powicke, *Military Obligation in Medieval England* (Oxford University Press, 1962), 193, 182, 190. During the same period, a horse archer's annual wage was nearly five times that amount, which shows that it was indeed a very moderate property qualification.

60. Verbruggen, *Art of Warfare*, 132.

61. Contamine, *War in the Middle Ages*, 256.

62. *Ibid.* Lot, *L'Art Militaire*, 1: 223-35; Joseph Dahmus, *Seven Decisive Battles of the Middle Ages* (Chicago: Nelson-Hall, 1983), 167.

63. Orderic Vitalis, *Ecclesiastical History*, tr. Marjorie Chibnall (Oxford: Clarendon Press, 1969), 6: 241.

64. Verbruggen, *Art of Warfare*, 173. Lot, *L'Art Militaire*, 1:277. Froissart (*Oeuvres*, 2: 225) reports that "there was a great slaughter of the Flemings, because none was given mercy."

65. Alfred H. Burne, *The Agincourt War* (London: Eyre and Spottiswoode, 1956), 87, 210. The French casualties at Crecy were similar: 1,542 men-at-arms and an uncertain number of commoners. Burne, *The Crecy War*, 184. At Poitiers, over 2,000 knights and men-at-arms lost their lives. *Ibid.*, 307.

66. Orderic Vitalis, *Ecclesiastical History*, 6:241.

67. Excluding customs revenue. Harriss, 523-26. "Ordinary" revenue does not include the direct taxes on movable wealth granted intermittently by Parliament.

68. Jonathan Sumption, *The Hundred Years War*, volume 1, *Trial by Battle* (London: Faber and Faber, 1990), 470. Philippe Contamine, "Rancons et butins dans la Normandie anglaise (1424-1444)," in his *La France aux XIVe et XVe siecles. Hommes, mentalites, guerre et paix* (London: Valorum Reprints, 1981), 260.

69. Froissart, *Oeuvres*, 10: 171. In the same battle, the Flemings' leader com-manded his troops under pain of death to take no prisoners, but "Kill all, kill all," *ibid.*, 158. Cf. 4:406 ("ces archiers qui tuoient gens sans merchy et sans deffence") and *Chronicles*, 1:306, 325, 2:356-57, 432, 448, 599, 609, etc., and Verbruggen, *Art of Warfare*, 170. Similarly, the Scottish men-at-arms who rode down the English archers at Bannockburn "slayand thamme without ransounne." Such a slaughter had been seen "neuir quhar, in na cuntre." Barbour, *The Bruce*, 308 (cf. 319).

70. Commanders often made ordinances to prevent this from happening. An Anglo-Burgundian ordinance of 1423, for instance, stated that "no person, whatever might be

his rank, should dare attempt making any prisoners on the day of the battle until the field should be fairly won. Should any such be made, the prisoner was to be instantly put to death, and with him the person who had taken him, should he refuse to obey." Enguerrand de Monstrelet, *Chronicles*, tr. Thomas Johnes (London: William Smith, 1840), 500. Similar ordinances were made by the English at Crecy and the Flemings at Roosebeke.

71. When the graves of those killed by the Swiss at the battle of Sempach were opened at the end of the nineteenth century, it was found that "the skulls were nearly all dreadfully split by halberd-strokes." C. W. Oman, *A History of the Art of War in the Middle Ages* (London: Meuthen, 1924), 251 n. Cf. Froissart on Roosebeke: *Oeuvres*, 10: 170. See Matthew Bennett, "La Regle du Temple as a Military Manual or How to Deliver a Cavalry Charge," in *Studies in Medieval History Presented to R. Allen Brown* (Woodbridge, Suffolk: Boydell Press, 1989), 17, for some interesting observations on the very different mechanics of cavalry vs. cavalry fights.

72. *Ibid.*, 118.

73. There is a good color reproduction of one of the Milemete guns in Richard Humble, *Warfare in the Middle Ages* (Leicester: Magna Books, 1989), 147. J. R. Partington, *A History of Greek Fire and Gunpowder* (Cambridge: W. Heffer and Sons, 1960), 105, gives what purports to be a Florentine provisione, also of 1326, for the acquisition of cannon and iron balls for the defense of the Republic. The document is questionable, however: its "discoverer" was later sentenced to ten years in prison for stealing documents, altering them to make them seem more valuable, and then reselling them. See Bernhard Rathgen, *Das Aufkommen der Pulverwaffe* (Munich: Verlag Die Schwere Artillerie, 1925), 15.

74. Called "vasa" and a "scolpo." Rathgen, *Aufkommen der Pulverwaffe*, 14.

75. *The Brut, or the Chronicles of England*, ed. F. W. Brie (London: Early English Text Society, 1960), 282, version "0".

76. The same was true at the siege of Calais in 1346, where: "Gonners to schew their art/Into the town in many a parte/Schot many a fulle great stone." Quoted in Lt. Col. H. W. L. Hime, *The Origin of Artillery* (London: Longmans, Green and Co., 1915), 172.

77. T. F. Tout, "Firearms in England in the Fourteenth Century," *EHR* 26 (1911): 682-83; cf. Rathgen, *Aufkommen der Pulverwaffe*, 36. Of course, guns were much more expensive than older forms of artillery to operate, if not to purchase, because of the very high cost of gunpowder.

78. Tout, "Firearms in England in the Fourteenth Century," 689-91.

79. For Cahors: Napoleon III and I. Fave, *Etudes sur le passe et l'avenir de l'Artillerie* (Paris: J. Dumaine, 1846-71), 3:82n. For St. Saviour: *ibid.*, 4: pieces justificatives, xviii-xlii. The largest of these guns required 2,385 lb. of iron and steel to manufacture, but most were much smaller guns of cast bronze.

80. Froissart, *Chronicles*, 2: 246. Perugia, similarly, had five hundred "bombarde" made in 1364, but each was only a handspan long. Rathgen, *Aufkommen der Pulverwaffe*, 37.

81. Tout, "Firearms in England in the Fourteenth Century," 677--78.

82. Christine de Pisan, *The Book of Fayttes of Armes and of Chyvalrye*, tr. William Caxton, ed. A. T. P. Byles (London: Early English Text Society, 1937), 153-54. The largest of the guns was to throw five-hundred-pound shot. Although she claimed to have based her list on the advice of "wyse knyghtes that be expert in the sayde thynges of armes," this seems to be a rather extreme number. By comparison, the large and well-provided Bohemian armies besieging Carlstein in 1422 had only fifty-two guns, of which six were very large (Wenceslai Hagecii, *Bohmische Chronica* [(Cadan: J. S. Zlaticensem, 1596)],

fo. 114v); and the artillery train purchased for the Earl of Salisbury in 1428 comprised just seventy-two guns, of which only seven fired 100+ lb. shot (PRO: Exchequer, Accounts Various [(E101)], 51/27, 30).

83. M. Lander, ed. *Cent cinquante textes sur la guerre de Cent Ans dans le bailliage de Cotentin* (St.-Lo, 1978), 140; Froissart, *Oeuvres*, 18: 411; Karl Jacobs, *Das Aufkommen der Feuerwaffen am Niederrhein bis zum Jahre 1400* (Bonn: Peter Hanstein, 1910), 56, 86.

84. Joseph Garnier, *L'Artillerie des Dues de Bourgogne, d'après les documents conservés aux archives de la Cote-d'Or* (Paris: Honore Champion, 1895), 26-27, 265. I am indebted to Kelly DeVries for advising me of this valuable source.

85. W Hassenstein, ed., *Das Feuerwerkbuch von 1420* (Munich: Verlag der Deutschen Technik, 1941), 145. Schmidtchen, *Bombarden, Befestigungen, Buchsenmeister*, 32. Note that 80 centimeters is nearly twice the diameter of the shells fired by the 16-inch main guns of twentieth-century battleships.

86. Froissart, *Oeuvres*, 5:389, 376. In both cases the guns shot both fire and large bolts. Cannon were also used to drive the French besiegers away from Quesnoy in 1340.

87. Froissart, *Chronicles*, 2:246, 250. *Chronique de Du Guesclin*, ed. M. Fr. Michel (Paris: Bibliothèque Choisie, 1830), 121.

88. Hassenstein, *Feuerwerkbuch von 1420*, 31. Cf. the Royal Armouries Firework Manuscript, Royal Armouries Library (Tower of London), MS 1-34, fo. 36v-37v. For a concrete example, see the siege of Bourges in 1411, where an assault was driven off by fierce cannonfire. Pierre de Fenin, *Memoires*, ed. Dupont (Paris: SHF, 1837), 27.

89. The quotes are from the English Chronicle of the Reigns of Richard II, Henry IV, Henry V, and Henry VI (London: Camden Society, 1868), 40, and the *Pseudo-Elmham, Vita et Gesta Henrici Quinti*, ed. and tr. Frank Taylor and John S. Roskell (Oxford: Oxford University Press, 1975), 39. The number of Henry's guns is given in a contemporary letter; see Burne, *Agincourt*, 36. The reference to tennis alludes to the story of the tennis balls mockingly sent to Henry V by the French Dauphin.

90. John Capgrave, *The Chronicle of England*, ed. F. C. Hingeston (London: Rolls Series, 1858), 310; *Chronique Normande*, in *Henrici Quinti, Angliae Regis, Gesta*, ed. Benjamin Williams (London: English Historical Society, 1850), 168.

91. *Vita et Gesta Henrici Quinti*, 37; English Chronicle of the Reigns of Richard II, Henry IV, Henry V, and Henry VI; Sir Harris Nicolas, *History of the Battle of Agincourt* (London: Johnson and Co., 1832), 310.

92. *Vita et Gesta Henrici Quinti*, 39.

93. Contra the argument of B. H. St. J. O'Neil that "in the years 1369 to 1375, the French were able to batter down walls of fortresses both successfully and quickly." *Castles and Cannon* (Oxford: Clarendon, 1960), 33; cf. a similar statement in Rathgen, *Aufkommen der Pulverwaffe*, 4.

94. *Chronique Normande*, 188.

95. A poem written by an eyewitness to the siege, John Page, eloquently expresses the supply problems of the townsmen: "They etete doggys, they ete cattys;/They ete mysse, horse and rattys/. . ./For xxxd. went a ratte/For ij noblys went a catte./For vj d. went a mous;/They lefte but fewe in any house." Poem on the Siege of Rouen in *The Historical Collections of a Citizen of London in the Fifteenth Century*, 18 (Cf. 38). See also Monstrelet, *Chronicles*, 1:404, and the *Chronique Normande*, 191.

96. *Chronique Normande*, 191, 202; John Holinshed, *Holinshed's Chronicles: Richard II 1398-1400, Henry IV and Henry V*, ed. R. S. Wallace and A. Hansen (Oxford: Clarendon, 1928), 64-65, 109, 123-27; J. H. Wylie and W T. Waugh, *The Reign of Henry the Fifth*

(Cambridge: Cambridge University Press, 1929), 3: 107-9, 210-15, 351. Louis Bellaguet, ed., *Chronique du religieux de St. Denys (1380-1422)* (Paris: Crapelet, 1839), 6:446-48; Monstrelet, *Chronicles*, 421, 468-76, 498, 508-22; Thomas Gregory, *Gregory's Chronicle in Historical Collections of a London Citizen*, ed. J. Gairdner (London: Camden Society, 1876), 148; Jehan de Waurin, *Recueil des Croniques et anciennes Istories de la Grant Bretagne*, ed. William Hardy (London: Rolls Series, 1879), 3:32; R. A. Newhall, *The English Conquest of Normandy, 1416-24* (New Haven: Yale University Press, 1924), 131. 97. Although Waurin, 2:394, 401, and Fenin (*Memoires*, 174) emphasize the role of the artillery at Meaux.

98. There are several earlier examples of significant artillery successes, but these, in terms of the artillery revolution, are analogous to the harbinger infantry victories of Courtrai, Bannockburn, and Morgarten in that they were only possible because of special circumstances. In 1405, Henry IV's bombards flattened a substantial portion of the walls of Berwick (British Library, MS Vespasian FVII, f. 71), but from the south side where the fortifications were so low and so thin "that a man may stand within the wall and take another by the hand without the wall." James Wylie, *History of England under Henry the Fourth* (London: Longmans, Green and Co., 1884-98), 2: 271. The walls were in any case falling down for "verray feblesse." S. B. Chrimes, "Some Letters of John of Lancaster as Warden of the East Marches towards Scotland," *Speculum* 14 (1939): 20. Two years after that, Spanish "lombardas" were "demolishing a great part of the wall" of Zahara when the garrison surrendered . . . but the Moors had only recently begun to repair the fortifications of the town. Fernan Perez de Guzman, *Cronica del serenissimo rey don Juan el segundo deste nombre [of Aragon]* (1517), cap. xxxv-vi.

99. Le Mans, Sainte-Suzanne, Mayenne-la-Juhez: Jean Chartier, *Chronique de Charles VII*, ed. Vallet de Viriville (Paris: P. Jannet, 1858), 1: 45-47. Cf. Guillaume Cousinot, *Chronique de la Pucelle*, ed. V. de Viriville (Paris: Garnier Freres, 1892), 199-200. For Montmiral and Gallardon: *Chronique du religieux de Saint-Denys*, vi, 463. Artillery was equally effective at Quesnoy in 1421, but the place was only poorly fortified. See Waurin, 2:395-96.

100. Chartier, *Chronique de Charles VII*. The meaning of the last part of the sentence is unclear; it may mean that the guns made a breach in the wall more than a bow-shot wide.

101. Monstrelet, *Chronicles*, 509.

102. Franz Palacky, *Urkundliche Beitrage zur Geschichte des Hussitenkrieges vom Jahre 1419 an* (Prague: E. Tempsky, 1873), 151.

103. Monstrelet, *Chronicles*, 1: 566; Waurin, 3:346, 348.; Chartier, *Chronique de Charles VII*, 1: 47, 143-46; A. J. Pollard, *John Talbot and the War in France, 1427-1453* (London: Royal Historical Society, 1983), 53. Burne (*The Agincourt War*, 291) has the siege of Harfleur opening in August rather than July, which would make it just under three months, and the chroniclers (e.g., Chartier, *Chronique de Charles VII*, 1: 259) generally have the siege beginning in April, which would make it six months.

104. Monstrelet, *Chronicles*, 1: 570, 619.

105. Description of the newly recaptured castle of Castelnaud-de-Cernes in a grant by Henry VI. Malcolm Vale, *War and Chivalry* (London: Ducksworth, 1981), 132.

106. Charles VII made use of sixteen large bombards for the siege. Chartier, *Chronique de Charles VII*, 2:178-79.

107. *Ibid.*, 2: 205; Guillaume Leseur, *Histoire de Gaston IV, comte de Foix*, ed. H. Courteault (Paris: SHF, 1893-96), 119-21; Chartier, *Chronique de Charles VII*, 2: 254-56.

108. J. Stevenson, ed. *Letters and Papers Illustrative of the Wars of the English in France*

during the Reign of Henry the Sixth, King of England (London: Rolls Series, 1861-64), 619 et seq. Most of the one hundred strongpoints referred to were actually never besieged; they surrendered rather than make a hopeless attempt to resist.

109. Leseur, *Histoire de Gaston IV*, 119-20.

110. Chartier, *Chronique de Charles VII*, 2: 235-38. He adds that the French could have taken by assault any of the places which surrendered if they had wanted to.

111. Jean de Bueil, *Le Jouvencel*, ed. Leon Lecestre (Paris: SHF, 1887), 37.

112. *Vita et Gesta Henrici Quinti*, 37.

113. For the first, see O'Neil, *Castles and Cannon*, 24, and H. Dubled, "L'artillerie royale française à l'époque de Charles VII et au début du règne de Louis XI (1437-69); les frères Bureau," *Memorial de l'Artillerie française* 50 (1976), 563. For the second, see Dubled, *passim*, and Napoleon and Fave, *Études sur le passé et l'avenir de l'Artillerie*, 2:99.

114. Schmidtchen, *Bombarden, Befestigungen, Buchsenmeister*, 17-18, 49. The master-gunner's book of 1411 in the Austrian National Library (Codex 3069, ff. 9v, 19v, cf. fo. 31) shows similarly proportioned guns. For bombards from the late 1430s on, in contrast, a barrel:ball ratio of 5:1, as recommended in the *Feuerwerkbuch*, seems to have been typical.

115. Hassenstein, *Feuerwerkbuch von 1420*, 71; Schmidtchen, *Bombarden, Befestigungen, Buchsenmeister*, 50-51.

116. It is described in detail in Codex 3069 of the Austrian National Library (written 1411), fos. 8v-9v. Cf. the nearly identical text (taken from Munich CGM 600) in Gustav Kohler, *Die Entwicklung des Kriegswesens und der Kriegführung in der Ritterzeit* (Breslau: W Koebner, 1887), 231.

117. Fowlers and other smaller guns, however, usually had longer barrels with removable powder chambers shaped like beer steins, of which each gun was supplied with two or more. These could be loaded from the breech; the balls did not need to be wedged nor sealed in place; and the chambers could be kept pre-prepared and replaced without waiting for the gun to cool fully. Thus they could fire much faster.

118. Schmidtchen, *Bombarden, Befestigungen, Buchsenmeister*, 44 (re. 1437). It seems from a few pieces of evidence, however, that a maximum of six to eight shots per day could be fired from large bombards of the shorter-barrelled type (contra Schmidtchen, 44). Perez de Guzman, *Cronica*, cap. xli-xliii; Partington, *History of Greek Fire and Gunpowder*, 114; Hagecii, *Bohmische Chronica*, fo. 114v et seq.

119. Schmidtchen, *Bombarden, Befestigungen, Buchsenmeister*, 49-50, contra Dubled's assertion that "the manner of loading artillery pieces hardly changed after the beginning of the [fifteenth] century" (p. 580).

120. The Amsterdam Bombard, probably one of the largest made by the spiral method, has a barrel length of 53 cm. and a caliber just slightly less. Thus, it would have fired a stone of about 400 lbs. Jacobs, *Aufkommen der Feuerwaffen*, 68-71.

121. The best description of this process is in Robert D. Smith and Ruth Rhynas Brown, *Bombards: Mons Meg and Her Sisters* (London: Royal Armouries, 1989), 20.

122. Thus the "barrel" of a gun.

123. From the very first, smaller guns and some large ones were also cast of bronze (or other copper alloys). From 1422, cast iron guns also begin to appear in inventories occasionally, some of substantial size. Garnier, *L'Artillerie des Ducs de Bourgogne*, 267.

124. For example, see the 17,700 lbs. of iron used for making guns for Henry IV (PRO, *Foreign Accounts*, E364/43/6), or the 35,150 lbs. of iron used to make seven large guns for the Earl of Salisbury's artillery train in 1428 (*Accounts Various*, E101/51/27).

125. Blast furnaces were in use in Belgium by 1340; by 1420 these were designed with separate hearths for firing and reheating. The Low Countries, in addition to being the center for the development of the blast furnace, were also the most important cannon-manufacturing area in Europe. See Alex den Ouden, "The Introduction and Early Spread of the Blast Furnace in Europe," *Wealden Iron Research Group Bulletin*, No. 5, 2nd ser., 1985. Thanks to Robert D. Smith for bringing this article to my attention.
126. A. R. Williams, "Medieval Metalworking," *Chartered Mechanical Engineer*, September 1978, *passim*.
127. T. F. Tout has shown that guns were generally priced by weight at 4d/lb. in the fourteenth century (Tout, "Firearms in England in the Fourteenth Century," 682-83), but by the 1430s the price had fallen to about 3d/lb. The bombard "Bedford," weighing 8,000 lb., was appraised at 1,000 l.t. in 1434, which works out to 2.5 s.t. (= 3.3 d. sterling) per pound (Stevenson, *Letters and Papers*, 566) Another great bombard, Mons Meg, was purchased in the 1450s by weight at 2 s.t. (2.66 d. sterling) per pound (Contamine, *War*, 49). The rate of 2 s.t. per pound also appears for a 4,000 lb. cannon in 1447 and a 12,000 lb. bombard in 1446 (Gamier, *L'Artillerie des Ducs de Bourgogne*, 57, 112). In England in 1428, the large iron guns purchased by John Parker, Master of the King's Ordnance, went for 2.2 or 2.4 d. per pound (PRO E101/51/27, 30). Smaller guns generally went at even lower rates: by the end of the Hundred Years' War, as low as 12-18 d.t. per pound. Gamier, *L'Artillerie des Ducs de Bourgogne*, 111, 115.
128. The paragraphs which follow offer a somewhat simplified history of the development of gunpowder after its introduction in Europe. As I intend to present the matter more fully in another article, I have kept the notes here to a minimum.
129. The ideal mix is about 75 percent saltpetre, 12 percent sulphur, and 13 percent charcoal. A widely used formula of c. 1400 called for 71/13/16 percents. See Napoleon and Fave, *Etudes sur le passe et l'avenir de l'Artillerie*, 3:107; Partington, *History of Greek Fire and Gunpowder*, 324.
130. E.g., the formulae in Hassenstein, *Feuerwerkbuch von 1420*, 61 et seq. (Cf. the Royal Armouries MS 1-35, fo. xxxvi et seq.); Gamier, *L'Artillerie des Ducs de Bourgogne*, 60; and Napoleon and Fave, *Etudes sur le passe et l'avenir de l'Artillerie*, 3:145-46. For a more extreme example, see *ibid.*, 124.
131. For example, Jean Bureau expected to spend 2,200 l.t. to purchase powder in preparation for the 1443 campaigning season. Contamine, *Guerre*, 666.
132. Contra the universal claim (Hassenstein, *Feuerwerkbuch von 1420*, 84, 61; Schmidtchen, *Bombarden, Befestigungen, Buchsenmeister*, 46; Contamine, *War*, 197; Dubled, "L'artillerie royale francaise," 571) that it was invented only c. 1420. See PRO, E101 (Exchequer: Accounts Various)/31/4, and Codex 3069 of the Austrian National Library, fo. 2, for (somewhat ambiguous) evidence of corned powder in England in 1372 and (fairly clear) in Germany in 1411. Napoleon and Fave, *Etudes sur le passe et l'avenir de l'Artillerie*, 3: 124, show that the use of the new type of powder was still not universal by 1417, however.
133. John F. Guilmartin, "Ballistics in the Black Powder Era," in R. D. Smith, ed., *British Naval Armaments* (London: Royal Armouries, 1989), 87. The more rapid evolution into gas meant that more of the force of the explosion was produced before the shot left the barrel of the gun, and therefore applied to the ball. Tightly loaded serpentine powder burned like a single giant "corn" of powder, relatively slowly.
134. Austrian National Library, Codex 3069, fo. 2; Contamine, *War*, 197; Napoleon and Fave, *Etudes sur le passe et l'avenir de l'Artillerie*, 3:146. The author of the *Feuerwerkbuch*, which Hassenstein dates at c. 1420, more modestly claims that corned

powder was half again as strong as sifted powder. Hassenstein, *Feuerwerkbuch von 1420*, 17; cf. Royal Armouries MS I-34, fo. 4v.

135. The bursting of cannon was fairly common in any case. At the siege of Aberistwyth in 1408, for example, the English lost their great guns “Neelpot” and “Messenger” as well as two smaller cannon, shortly after bursting “Kyngesdoghter” at Harlech. PRO E364 (Foreign Accounts)/49/3.

136. Contra the assertion of J. R. Hale that firearms “had little effect on the fortunes of campaigns as a whole or on the balance of political power.” J. R. Hale, “Gunpowder and the Renaissance: An Essay in the History of Ideas,” in his *Renaissance War Studies* (London: Hambledon Press, 1983), 390.

137. For these changes, see Dubled, “L’artillerie royale francaise,” *passim*.

138. Hale, *Renaissance War Studies*, 389-90; McNeill, *Pursuit of Power*, 89; Lot, *L’Art Militaire*, 2: 466.

139. Contamine, *Guerre*, 666.

140. Quoted in Verbruggen, *Art of Warfare*, 273. DuBois exaggerated the difficulties of siege warfare somewhat – castles could rarely withstand a full year’s siege, and often fell within a few months or even weeks due to treachery or mines – but his essential point is valid.

141. *The Military Revolution*, 8. The knowledge of artillery developed by the Spanish and Portuguese in fighting the Moors transferred easily to Iberian conquests in the New World, Africa, and Asia: it was a short step from Reconquista to Conquista.

142. Guicciardini, *History of Italy*, ed. J. R. Hale, tr. Grayson (New York: Washington Square Press, 1964), 153.

143. From his *Counsels and Reflections*. Quoted in Parker, *The Military Revolution*, 10. Comparison of these quotes from Guicciardini with Pierre Dubois (see quotation in the text at footnote 140) will do much to answer the “critical” question John Keegan poses in the introduction to his *The Mask of Command* (New York: Elizabeth Sifton Books-Viking, 1987), 8: “whether there is an alternative style of . . . strategy not of conquest but of security, and if so, how and why it came to be supplanted.” Strategy based on conquest generally flourishes only when the balance in siege warfare lies with the offensive, as in c. 1420-c. 1520.

144. Cf. Guicciardini, “History of Florence,” in *History of Italy*, 20; and Felix Gilbert, “Machiavelli,” in Peter Paret, ed., *Makers of Modern Strategy from Machiavelli to the Nuclear Age* (Oxford: Clarendon Press, 1986), 23.

145. Though it is, of course, impossible to isolate the effects of the Artillery Revolution from other factors.

146. For the “artillery fortress,” see John Lynn, “The trace italienne.” For the decline in battle, see McNeill, *Pursuit of Power*, 91. The frequency of battle seems to be a good barometer of military revolutions. There was a certain surge in frequency c. 1300-1345 as the Infantry Revolution hit the stage, then another, greater one after the advent of the Artillery Revolution. Battle went out of favor with the Artillery Fortress Revolution of the early sixteenth century, but came back into favor with the “Gustavian” revolution a century later. This dialectic could perhaps be extended to the periods of Vauban, Napoleon, and the First and Second World Wars.

147. See Burne, *Agincourt War*, 319, and “Lettre sur la Bataille de Castillon en Perigord, 19 juillet 1453,” *BEC* 8 (1846): 246.

148. Cf. the closely related “coercion-extraction cycle” proposed by S. E. Finer in “State and Nation-Building in Europe: The Role of the Military,” in *The Formation of National States in Western Europe*, ed. C. Tilly (Princeton: Princeton University Press, 1975), 96.

149. McNeill, *Pursuit of Power*, 105n, citing Richard Bean, "War and the Birth of the Nation State," *Journal of Economic History*, 1973, 33.
150. The quote is from Martin van Creveld, *Technology and War from 2000 B.C. to the Present* (New York: Free Press, 1989), 106. For similar statements, see Hale, *Renaissance War Studies*, 390-91, and Archer Jones, *The Art of War in the Western World* (Chicago: University of Illinois Press, 1987), 630.
151. Quoted in Gilbert, "Machiavelli," 15.
152. To use William H. McNeill's valuable concept.
153. One might continue this list with the changes in European military systems of the seventeenth century described in Jeremy Black's book; the changes of the French Revolutionary period; of industrialized war; and of the nuclear revolution. Once the process of punctuated equilibrium evolution in the European craft of war got started, it never stopped.
154. With bursts of more rapid development in the early seventeenth and late nineteenth centuries.
155. For a concise but informative recent summary of the course of the punctuated equilibrium debate, see Tim Beardsly's overview, "Punctuated Equilibrium: Darwin Survives as the Debate Evolves," *Scientific American* 265 (March 1990).
156. Vale, *War and Chivalry*, 141-42; J. R. Hale, "The Early Development of the Bastion," in *Europe in the Late Middle Ages*, ed. J. R. Hale (Evanston, Ill., 1965); Contamine, *War*, 203-4.

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