MILITARY SCIENCE IN WESTERN EUROPE IN THE SIXTEENTH CENTURY

PROLOGUE:THE NATURE OF ARMIES IN THE 16TH CENTURY

What was an “army” in western Europe in the 16th century?

Standing peacetime armies of any substantial strength were virtually unknown. They were too expensive, logistically unfeasible, and regarded as dangerous by populace and parliament alike. Much of the nominal military might of a country during peace was often in the form of sections of the nobility, whose traditional role it was to command and fight during war (e.g. France’s compagnies d’ordonnance, heavy cavalry companies). While feudalism as a military system was much diminished, feudal obligations in war could remain in some form. English nobility, for example, were required to provide strictly defined military materiel proscribed by title, while the kings of France could call the ban and arriére-ban, requiring military service (or a proxy) of all those holding land directly or indirectly.

During peacetime, soldiers were largely those stationed in garrisons, as on borders. These garrisons had to be maintained during a war, so they did not substantially contribute to the army in wartime. The nucleus of a regiment might exist, but vast numbers of additional forces still had to be raised. A few examples will serve: Venice in 1600 had only about 9,300 men as standing garrison soldiers, scattered in various coastal and island forts; France in 1566 (between civil wars) maintained only 16,000 standing troops (out of a population of some 20 million); and the Netherlands, war torn for decades, by the end of the century had a formal strength of only about 14,000 permanent troops. Considering that an effective field army typically ranged from about 20,000 to 50,000 men, clearly large numbers of troops needed to be raised on the eve of any major action.

Thus, the majority of soldiers during wartime were impromptu recruits, and/or mercenaries. In German speaking lands of the Holy Roman Empire, the recruits commissioned by Maximilian in 1487 were the origins of the Landsknechts. Each regiment was newly recruited as needed, and dismissed when it was no longer required, or funds dried up, promoting a mercenary mindset.

A given army often included numerous nationalities and languages. The normal Landsknecht regiment included one interpreter per 400 men, and interpreters were commonly budgeted for in the staffs of the field armies of the French, and of German reiter regiments as well. Fluency in multiple languages was a valuable skill for a captain, given that it was not uncommon for armies to consist of a majority of foreign nationals.

A few examples will serve to illustrate: Henry VIII’s invasion force to France in 1544 included Scots, Spanish, Gascons, Portuguese, Italians, Albanians, Greeks, Germans, Burgundians, Tartars, and Turks; Spanish were the minority in the Spanish Army of Flanders which included Italians, Burgundians, Germans, and Catholic Dutch; and the French armies routinely were 1/3 to 2/3 foreign, drawing mostly from Swiss, Germans, and Italians.

The most common mercenaries were: Swiss (exclusively to France after 1516), Germans (Landsknechts, and later reiters, to anyone who would pay), Italian condottiere (literally, “contractors”, professionals who supplied and commanded companies of mercenaries to whatever employer within or without Italy), and Gascons (typically in companies, usually to France, occasionally to England).

Sometimes troops of the same nationality or cause appeared as mercenaries on both sides of a battle, and might refuse to fight each other!. The Duc de Sully recorded that at the Battle of Dreux in 1562, the Swiss on either side bullied each other with pikes lowered, while the Protestant Germans in Catholic French employ fired their pistols into air rather than shoot the Huguenots (French Protestants) whom they were hired to fight.

The unreliability of economics of the time (even Philip II, with his flow of New World gold, declared bankruptcy repeatedly) meant that soldiers quite frequently went months, or even years, with no pay, and had to live off plunder. The mercenary mindset meant that more than a few battles were loss because the forces dwindled due to desertion when the payroll was late in arrival. The expression “Point d’argent, point de Suisses” (“no money, no Swiss”) was a truism of its day. The most famous example is probably Bicocca, where Swiss troops, angry at the lack of pay, demanded of their French employer that they be allowed to fight immediately in hope of plunder. When acceded to, the Swiss proceeded to ignore orders to hold while French artillery worked on softening up Imperial fortifications, but rather charged boldly in— to a waiting wall of Imperial firepower, which ended the battle, annihilating much of the Swiss Confederation’s experienced soldiers in the process.

England relied chiefly upon a militia system whereby all able-bodied men between the ages of 16 and 60 had to respond to a levy. Each militiaman had to provide his own arms and armor (with additional equipment supplied by towns, nobles, and the wealthy). This militia levy yielded an impressive 180,000 men in 1575. From 1573, the best of the militia met for periodic training under experienced soldiers. These groups were referred to as "Trayned Bands" and mustered by county, nominally thrice per year, 10 days per session. By 1588, there were 50,000 men in the Trayned Bands.

Other countries used militias, although chiefly to provide force in internal affairs, such as rebellions, and to defend individual cities. France utilized such a militia, the "Francs-Archers" until 1535. It may have been discontinued following French noble reluctance to maintain armed commoners (and for good reason). Spain had militias in some of its fortified cities, called "Hermanadades", only until 1505, but provincial militia continued for internal peacekeeping.

While full armies were transient things, the superpowers of France and the Habsburg empires were at war in one theatre or another with such frequency and duration that they maintained some regiments for long stretches of time. The model of organization of its time, and the largest, was the Spanish Army of Flanders, which was involved in the "80 Years War" of the Dutch revolt. At its height, the Army of Flanders contained approximately 80,000 men on standing duty.

A few individual Spanish infantry bodies did maintain existence long enough to have a sense of continuity, at least organizationally. The original infantry formations of Spain were "colunelas" of about 600-1500 men. From 1534, these began to be formed into groups of three, and collectively called a "tercio". The tercios carried the name of the region in which they served originally; the tercios of Sicilia and Lombardia, for example, lasted beyond the end of the century (albeit with great fluctuation of station and manpower).

France, while lacking any such standing army, experimented with permanent infantry bodies, most notably the original French Legions formed in 1534 by François I. Inspired by Ancient Roman practice, he reorganized the infantry on a provincial basis, thereby forming the progenitors of the modern French army.

A 16th century army capable of major action seems to have had a minimum of 20,000 effectives (not counting baggage train, etc.). The upper end of an army of Spain and/or the Holy Roman Empire, or France was normally 50,000; and on rare occasions, as much as 80,000. Simple logistics acutely limited the duration of maintenance of such numbers in the field.

Finally, it must be born in mind that an "army" did not have the infrastructure that we associate with that term today. Victuals and other essentials were often supplied (if at all) by civilian hangers-on. Uniforms were for all extents nonexistent. At most, soldiers of a given army might wear a surcoat with a simple device (e.g. a red "X" for Burgundy or the Empire). The most common practice appears to have been the use of a simple colored sash, ribbon, or plume: Habsburg red, French blue, Dutch orange, Swedish yellow.
Spain was positively progressive in the benefits and organization of its army, though, providing retirement hostels and pensions for soldiers who had lost limbs, requiring licensing and medical inspection of camp prostitutes, and providing for administration of the sacraments in the field.

I) FIELD ENGAGEMENTS

The three arms of combat effectives: Infantry, cavalry, and artillery.

A) INFANTRY: hand weapons and firearms

1) Hand weapons

Hand weapons of chief importance included the sword and buckler, two handed sword, pole arms (halberd, bill, and many others), and the pike. The sword and buckler enjoyed some early popularity, especially among the Spanish, but fell out of use as an infantry weapon after 1520 (barring a brief experiment by the Dutch at the end of the century). While most soldiers carried a sword, it was increasingly a weapon of secondary resort. The two handed sword was most heavily employed by the Landsknechts, who are said to have used it both as a weapon and for cutting the heads off of enemy pikes. As time wore on, it too faded in popularity, although we find reference to its use in war by the Swiss in 1544, and Don Juan of Austria using one in the Battle of Lepanto (on ship!) in 1571. A great variety of pole arms were employed, with England clinging tenaciously to the bill as their national weapon until 1598, and the Swiss and Landsknechts including small numbers of them in their formations, but the halberd (and to a lesser extent the partisan) was, by the end of the century, most often a badge of rank, as of a guardsman or an officer, usually a sergeant.

The defining military hand weapon in the 16th century, however, was unquestionably the pike. While the weapon itself represented nothing significantly technologically novel, the manner in which it came to be used transformed warfare. The Swiss won a number of remarkable victories using the pike in the 15th century, which prompted its adoption throughout Western Europe. The key to their success was the degree of organization and discipline which they employed.

The Swiss had been using the pike phalanx since at least 1422 after their defeat by Milanese cavalry at Arbedo. By the Zurich War (1443-50) they were employing it as their primary formation. In 1476-1477 they crushed the army of Charles the Bold, Duke of Burgundy, despite the modernity of the Burgundian army (including its artillery train) and killed the Duke himself. This series of victories began the 40 year reputation of Swiss invincibility, and led rulers throughout Europe, beginning with the Habsburg Maximilian (himself heir to Burgundian holdings) to adopt the pike phalanx. The Renaissance fixation upon all things classical only added to the allure, as many looked to the histories of ancient Greece and Rome for suggestions on how best to train for and use the pike phalanx.

The weapon itself is essentially a long spear, of a variety of configurations. The length which came to be the norm was 18 feet, especially as used by the Swiss. Shorter pikes were found, with the English using pikes on rare occasions as short as 12 feet (it was not unknown for soldiers to cut a few feet off their pikes to lessen the weight) up to 18, and Spanish and Landsknechts using pikes of 14 to 18 feet. The hafts were most commonly of ash, typically of about 1 _ inches diameter. The head could be as simple as a spike, or be a blade of diamond or leaf shape, as much as 10 inches long. To prevent the heads from being cut off (e.g. with a two handed sword), metal plates called cheeks, straps, or languets, running some length down the haft were attached. Tufts of tassels were sometimes attached around the head, and Landsknechts were known to attach a fox's tail for good luck. As well, velvet was sometimes wrapped around the haft at the gripping points, at least by the English. Overall, the weapon could weigh from 7 to 11 pounds, and required good strength and stamina to hold in position for long stretches of time.

The key to effective use of the pike was the pike phalanx (also called the pike square), a formation of pikemen in well ordered ranks and files. The dense formation of pike presented a bristling wall of points which nothing could safely approach. Given the length of the weapon, a tightly formed pike square could have five ranks of points protruding forward of the first rank of men. The maintenance of order was essential, as any holes in the formation could allow entry, by a charging horse, or a footman with a shorter, more maneuverable weapon. The need for order required drilling, which significantly influenced military culture. The training and command of the Swiss pike phalanx led the way; a formal training center, the Fechtschul of Bern, existed by 1495, and the elected Hauptmann may be regarded as the forerunner of the infantry sergeant.

The Swiss mindset in war, that of complete discipline, is what made the pike so deadly in their hands. They would stop to take neither prisoners nor plunder, accepted no ransom, and killed anyone who deserted his place in battle. Each man was a part of a whole, relentlessly advancing en masse in a manner often described by modern writers as like a steamroller. The men in the rear chiefly provided momentum and filled the gaps of fallen men in the forward ranks.

The Swiss originally attacked in some arrangement of three pike squares, often in staggered echelon, Vorhut (vanguard), Gewalthut (center), and Nachhut (rear). The typical layout of each square was to have the ensigns (flag bearers) in the center, surrounded by Halberdiers, with many layers of pikemen surrounding them. Armor was often used by the pikemen in the first few ranks (called "corselets" or "picche armata"), although braces were rare and gauntlets more so, with subsequent ranks ("picche secche") unarmored or only lightly so. Maneuvering commands were spread chiefly by the use of drummers, which seems to have been a novel system, quickly adopted by other countries.

Pike squares ran into the 1000's of men. At Fornovo (1495) there were 3000 men in a phalanx 60 meters on each side; at Bicocca (1522) the Swiss pike were arrayed 75 by 100 men. The formations employed by other countries were often of similar size. The Spanish reinforcements at the battle of Dreux (1562) included pike squares only 35 men deep, but it was felt necessary to combine three or four of them.

There were several notable imitators of, and improvements on, the Swiss pike square as the century wore on. The first, as previously mentioned, were the Landsknechts in the German and Austrian regions of the Holy Roman Empire. Blaise de Monluc recorded at the battle of Ceresole, and pictorial evidence supports, that the Germans held the pike towards its end, i.e. at length, while the Swiss held theirs near the middle. The Swiss were given to holding the pike high, even overhead, with the point aiming down into the enemy, while the Germans angled theirs up, keeping the haft low or at shoulder height. The Spanish colunelas and later the tercios contained a substantial proportion of ordered pikemen. Even the English Trayned Bands eventually adopted the pike, laying down the bill by royal order in 1596. The height of systematic training and deployment of the pike square (and indeed all infantry) of the century was probably that instituted by the Nassaus, especially Count Maurice, in the wars against the Spanish for Dutch independence. Maurice systematized the orders for handling the pike (and arquebus and musket) and his manual thereof, drawn by Jacob de Gheyn, was of enormous influence in the 17th century.

As well-ordered, drilled infantry became increasingly necessary, the command structure of armies and skills of officers had to evolve as well. The soldiers had to be aligned before entering battle, and the officers (most commonly referred to as sergeants) responsible for this duty had to be able to determine the appropriate numbers of ranks and files of each type of infantryman. To this end, printed tables were available (the most popular being Cataneo's "Tavole Brevissime" printed in 1567), and some sergeant's batons even had square root tables on them. Increasingly, noble birth and martial skill were insufficient for military fitness. Literacy (in modern and classical languages) and mathematical skill were also valued. The individual sergeants who marshalled companies of men into formation were in turn ordered by the sergeant major(s) of the regiment or army, who assisted the chief commanders (sometimes called lieutenant general or generals) in conveying technical plans. Field commanders included captains and colonels, who maintained order and morale in the field, as well as providing tactical direction of their units.

Soldiers were trained to maintain their order while on the move. The normal distance between infantrymen, especially pikemen, was three paces front to back, and one left and right. Thus a "square" of infantry, which refers to the same number of ranks and files, wasn't really square, but rather approximately a 3:7 ratio in width to length. A "square of ground" formation is a true square, with three ranks per seven files. A well trained infantry square could adopt different distances as the situation required— "order" being about 3 feet between files; while "open order" was double that, to increase frontage; "double distance" was about double that again, or 12 feet apart, used when under artillery fire to lessen the damage done by a single ball; while tighter orders included "close order" of 18 inches, or "closest" order of less than a foot, these last two being used by pikemen to receive a cavalry charge.

The ability of the well ordered pike square to resist the previously dominant cavalry was one of its most notable strengths. It was quickly determined that a horse could not easily be made to charge into a wall of densely packed pikes, and to do so was usually suicidal. The Landsknechts even used a special formation, the "Igel" or "hedgehog" to receive a cavalry charge, in which all sides faced outward and angled their pikes upward, planting them to receive the charge. The latter action remained in use into the 17th century, with de Gheyn clearly illustrating the manner of bracing the pike against the foot with one hand, while preparing to draw a sword with the other. Nonetheless, desperate charges could succeed in breaking the momentum of a pike square, pinning it, as performed by French gendarmes at Marignano and Ceresole.

If order was maintained, the pike square was similarly impenetrable to footmen with shorter weapons, whom they effectively rolled over as at Seminara and Novara. The best hope for meeting it with hand weapons was to oppose it with another pike square. The resultant collision was referred to as a "push of pike". Each square would halt the other's progress, with brutal confused struggle and slaughter in the front ranks. Again, the side which maintained a cohesive front, quickly replacing its fallen with men from rear ranks, generally fared best. However, ranks of ill-trained pikemen, or those disordered by terrain, cannon fire, or other factors, could be penetrated by those armed with shorter, maneuverable weapons, who would carve them up from within. This was an early Spanish strategy, whose sword and buckler men were successful against pikemen at Barletta and Ravenna (which Machiavelli unfortunately regarded as vindication of his classically inspired theory of the unworthiness of the pike phalanx).

By far the greatest threat to the pike square, however, was projectile weapons, and as the 16th century progressed, this meant chiefly shot. Even the inaccurate small arms fared well against a "target-rich environment", and firing cannon against a pike square was not unlike bowling. A skilled gunner would try to fire along the diagonal of a square, so that a single ball might kill tens of men. It was to this end that pinning a pike square, as by cavalry charges or the use of terrain features, natural or engineered, was aimed—an immobile pike square was helpless against massed fire, as seen at Ravenna, Marignano, and Bicocca.

2) Firearms; science, technology, and tactics

Black powder weapons had been known in Europe for centuries (the earliest evidence being from 1326), although the 16th century saw their widespread adoption and marked development as an effective technology, especially as handheld weapons. It must be noted that earlier projectile weapons continued to be seen. The crossbow was still a common sight in the beginning of the century. The French continued to use the crossbow into the 1520's, and the English stubbornly refused to abandon the bow until 1595. In all fairness, the bow does have certain advantages over the 16th century gun, namely economy, accuracy, and rate of fire. However, to produce the skills and strength to accurately and effectively use the bow requires a lifetime of training, whereas basic use of the gun can be taught in a few days. Moreover, a tired malnourished archer is of little value, while the gun fires its ball just as hard regardless of the condition of the shooter. Finally, the gun had the advantage of being able to pierce contemporary armor (more on this later), unlike the bow.

The earliest black powder weapons in Europe of which we have evidence were of a primitive mortar type.
In essence, a metal pot or tube, closed at one end, was filled with gunpowder, a ball (originally, a metal arrow) was placed on top, and the powder was lit through a hole (the touch hole) punched in the side. It was quickly realized that by mounting a sealed tube of metal with a touch hole onto a stick, that the weapon could be made portable. We first hear of such "gunnis cum telar", or "guns with handles" in the 1340's or 50's. The addition of a perpendicular rest, or hook, to the wooden stave allowed it to be rested on a parapet for defense of a fortified area. Hence the name "hakenbüchse", German for "hooked gun", which gave the names for the later long arms called in English "hackbut" or the French "arquebuse", which gave us the familiar English "arquebus".

These early "handgonnes" were ignited by sticking a hot wire or smoldering piece of slowmatch (cord impregnated with saltpeter) into the touch hole. This method was still used with some guns in the early 16th century. This meant that only one hand could be used to support the weapon, and so one had to look away from the target to find the touch hole. In the field, the handgonne (with a flattened stock) was usually braced against the chest, which sharply limited the amount of recoil that the operator could take. All this changed by 1411 with the invention of the serpentine lock.

The serpentine lock was a simple S-shaped rod which held slowmatch on one end, so that when the other end (essentially, a trigger) was pressed, the match would lower onto the touch hole. This is the earliest form of the matchlock, and with refinements, would continue to be used throughout the 16th century.

The invention of the matchlock meant that both hands could support the gun while firing, allowing the stock to be braced against the shoulder, which permitted a larger charge to be used. Accuracy was also improved, since one didn't have to look away from the target to find the touch hole. By the early part of the century, a small pan ("priming pan") of fine gunpowder ("priming powder") connected to the touch hole was added, which the match ignited instead.

The matchlock was sturdy and cheap to build, explaining its continued popularity as military hardware. However, the need to carry a burning slowmatch at all times was an obvious inconvenience. A variety of ignition devices (or "locks") were invented in the 16th century which set off the charge by generating a spark which would fall into the priming pan. The first one to be developed was the wheelock.

The wheelock was invented in Germany or Italy, by 1515 (there is a drawing of one in da Vinci's notebooks from 1508, but no evidence that he actually built it). The fundamental mechanism for generating the spark is a clockwork-like serrated wheel, which was wound up ("spanned"), holding it under tension. A lump of pyrite held in a clamp at the end of an arm ("cock") was lowered, and when the trigger was pulled, the cover of the priming pan would open and the wheel would spin against the pyrites. Sparks would be generated, much like a modern lighter, igniting the priming powder. This allowed the weapon to be carried ready to fire, without needing to have a burning match at hand. Unfortunately, the mechanism was fairly delicate, and would clog up with powder residue after being fired a few times, making it prone to failure. Nonetheless, the wheelock saw considerable use in war, although mainly by the cavalry (since smoldering slowmatch was especially difficult to handle on horseback, not to mention spooking the horse). Cavalry wheelock pistols came into use in the 1540's, probably initially among the Germans. "Pistol", incidentally, appears to come from a Bohemian word, "pistala", meaning "pipe".

A mechanically simpler, and hardier, mechanism was still wanting. The answer was to generate a spark by striking a piece of flint against a plate of steel. The tension released by pulling the trigger was now in the cock, which was spring loaded. Several variations were evolved, which are collectively known as "firelocks".

Probably the first firelock, dating to the 1550's, was the snaphaunce (from the Dutch for "pecking chicken", referring to the fact that pulling the trigger made the cock snap forward). A metal plate, called the frizzen, was pulled into position over the priming pan. When the flint held in the cock struck the frizzen, it moved the frizzen out of the way, allowing sparks to fall onto the priming powder. Later models added a priming pan cover, to protect the priming powder from wind, weather, or just falling out. In the miquelet ("Spanish lock"), this pan cover and the frizzen were a single piece, so the impact of the cock against the frizzen simultaneously generated a spark and uncovered the priming pan.

Next to be developed were safety mechanisms. The final refinement of the firelock was the invention of the half-cocked position, in which the cock would not fire if drawn halfway back, but had to be "fully cocked" before firing. The first such design was the dog lock ("English lock"). Dog locks usually also had an external swiveling arm that engaged the cock, physically preventing it from rotating forward until moved out of the way. The final refinement of the firelock was the true flintlock (of which the earliest known is from 1607). The flintlock differed from the dog lock in its internal mechanism for maintaining tension on the cock, in that the sear (the part acted on by the trigger, and that holds the tumbler in place) was in line with the tumbler, rather than perpendicular to it as in earlier firelocks. The external safety arm was dispensed with, leaving the half cocked position as the single safety mechanism.

Despite these technological advances, the sturdy, simple matchlock dominated among infantry. The delicate and expensive wheelock, and the later advanced firelocks, remained chiefly cavalry weapons. Economics remained the limiting factor in equipping the rank and file soldiers.

There are only two forms of firearms which are relevant to a discussion of the infantry. Both are muzzleloading long arms. The first is the arquebus (Italian sciopetta, French arquebuse, Spanish arcabuz), which was invented some time in the mid to late 15th century, probably in the 1450's. It was clearly in military use by 1503 (where it was employed by the Spanish at Cerignola). It weighed in around 10 pounds, with a barrel about three feet long, typically firing a half ounce lead ball of about .66 caliber.

The earliest claim for the existence of the musket is 1521, by the Spanish in the siege of Milan (although this is debated). The weapon was clearly extant by the 1540's. It remained characteristically Spanish/Imperial for years, not reaching France, for example, until the 1560's. The musket was essentially a much larger arquebus. Barrels could reach five feet, and the earliest muskets could weigh around 30 pounds, though this soon decreased to something closer to 15 to 20 pounds. The musket weighed so much that the musketeer had to carry a forked rest to support it, complicating the loading process. This larger gun had a one inch bore, and its 2 to 2.5 ounce ball could reach further, and penetrate thicker armor, than could that of the arquebus. At Pavia, at very close range, musketballs were reported to have passed through one armored gendarme into another. The weight of it was so prohibitive, though, that only strong men, who earned extra pay, could carry it and tolerate its recoil. The number of muskets relative to arquebuses among the shot seemed to increase through the century, but the weight of the musket itself decreased. The 17th century "musket" was thus little different in size from the arquebus of the early 16th.

Before discussing the capabilities and tactical use of firearms, it will be helpful to understand something of the nature of black powder itself. These properties influenced the design and define some of the physical constraints of 16th century firearms and artillery.

2a) gunpowder and ballistics—science and technology

Gunpowder probably originated in China, at least by 1044, and probably as early as the 9th century. It reached Europe and North Africa in the 13th century; the earliest formula recorded was by Roger Bacon in 1267, of a formulation suitable for fireworks although not for shot. The ideal composition of black powder is in general 75% KNO_3 (potassium nitrate, or saltpeter), 10% S (sulfur), and 15% C (carbon), the latter in the form of charcoal. The limiting factor was saltpeter, which was scarce in Europe, and was initially imported at great expense from India. The first primitive artillery piece had been developed in Europe by 1326. But it was not until saltpeter farms began in Europe, probably in the 1380's, that gunpowder became economically viable as a significant military resource.

The clearest description of saltpeter production dates from 1561, by Gerard Honrick. Black earth (i.e. compost, largely fecal), urine (especially of drinkers of alcohol), dung (preferably from horses fed with oats), plaster of Paris, and oyster shells, are placed in a dry area paved with bricks. The mixture is turned every two weeks for at least a year. The walls and floor are swept of crude saltpeter, which "will hang like snowe upon them".

This seemingly crude method, like the purification system that follows, is amazingly sophisticated, although in period the mechanism was of course a mystery. The urine provides a source of ammonium ions, NH_4^+, which are elevated following alcohol consumption, while sodium (Na^+) is lowered. The ammonium is converted to nitrate ions (NO_3^-) by the bacteria *nitrosomonas* and *nitrobacter*. The growth of these bacteria requires calcium carbonate ($CaCO_3$); a nutritional growth medium (the black earth and horse manure); aeration (the biweekly turning); and a regulated pH range, which is provided by calcium hydroxide ($Ca(OH)_2$), which forms from the calcium oxide (CaO) in plaster of paris. Notably, horses fed oats produce dung relatively high in potassium (K^+) and low in (Na^+). Crude saltpeter thus contains, chiefly, the cations (positive groups) K^+, Na^+, Ca^{+2}, and the anions (negative groups) NO_3^-, CO_3^{-2}, OH^-, and Cl^- (the latter, chloride, from, among other sources, urine).

The problem of course is to purify out the K^+ and NO_3^- ions. Removing chlorides is relatively simple. The crude saltpeter ("leachate") is boiled, solubilizing all salts, then cooled to room temperature. Chlorides are more soluble than nitrates or hydroxides at room temperature, so NO_3^- salts precipitate out of solution, leaving other cations mostly dissolved. The salt at the bottom of the cooled vessel is thus partially purified.

Unfortunately, this still leaves substantial contamination of the desired saltpeter (KNO_3) with $Ca(NO_3)_2$ and $NaNO_3$. These latter two salts are unfortunately hygroscopic, meaning that they absorb water from the air. Saltpeter or gunpowder therefore rapidly became unusably moist unless kept in a tightly sealed container. For some time this was managed by preparing gunpowder in "knollen" (literally, "dumplings"), or cakes, so that while the outside would be moist, the inside would be dry. These would then be crumbled or ground before use, which was preferable to the earlier practice of storing powder in a finely ground state (called "serpentine") with its attendant problems of moisture absorption.

It was discovered that the chunks from knollen, if poorly ground, were more powerful than serpentine. Unfortunately, early metallurgy and gun design made this coarse powder dangerous; it was too strong, able to rupture the weak barrels. It was therefore necessary for an army carrying powder as knollen to carry powder mills to finely grind them to serpentine. Serpentine burns more slowly, less efficiently, and provides less power, but was safer to use until stronger barrels were developed, and a system to control grain size (called "corning") was developed.

For some time this was the state of the art of powder development, until the further purification process of lixiviation was developed, first described around 1540 by Biringuccio. The leachate was mixed with quicklime ($Ca(OH)_2$) and wood ash, which contains potash (K_2CO_3). The Ca^{+2} in the leachate reacts with the potash to yield insoluble $CaCO_3$, thereby removing Ca^{+2} from the leachate, while boosting K^+ levels . By combining the two methods, leachate could be purified to a mix of mainly saltpeter, with lesser amounts of $NaNO_3$. This process was quite adequate to provide relatively humidity resistant, munitions grade saltpeter. Lixiviation allowed corned gunpowder to be prepared well in advance at a desired grain size, which has enormous effects on its propulsive properties. It appears that both corned and serpentine powder were used between 1420 and 1520, after which corned powder was almost exclusively employed. In brief, corning consisted of making a paste of gunpowder, and using rollers to pass it through a sieve to produce particles of defined size which were then dried.

To understand the effect of particle size on ground powder, and the influence that this has on gun design, it is necessary to explain a bit about the process by which black powder burns. Black powder is not an explosive per se, but rather deflagrates (i.e. burns rapidly), at a temperature of 2100 to 2700 degrees Celsius. This combustion is fairly dirty, leaving decomposition products of about 57% solid matter; this residue was often responsible for a misfire, when the gun wouldn't operate without cleaning. The remainder of the burnt powder converts into gases, thereby expanding in volume by a factor of between 274 and 360 times. It is this rapid expansion of gases that propels projectiles with deadly force.

Gunpowder burns only on the surface of the grain, not inside it, at a constant rate of about 0.2 feet/sec. The smaller the grain, the faster it burns up (since it has a higher surface to volume ratio than a larger grain). This being the case, one would expect serpentine to burn faster than corned powder, yet this is not the case. The reason for this stems from the fact that combustion of gunpowder consists of two distinct processes which occur at different rates; ignition (the burning on the grain's surface) and propagation (by which ignition of adjacent grains is initiated).

Ignition, as stated, occurs at a constant rate of about 0.2 feet/sec, but requires less energy to initiate when the powder has a smaller grain size. A spark will therefore ignite fine powder more easily than coarse, hence the use of fine "priming powder" in ignition systems based on flint and steel or other spark-based systems.

Propagation, on the other hand, occurs between grains via a spray of molten salts at about 500 degrees Celsius at a rate of about 30 feet/sec, over 100 times faster than ignition. This explains why corned powder burns more rapidly— the space between grains allows propagation to occur, and that in turn causes rapid initiation of multiple ignitions. Serpentine, on the other hand, is so finely ground as to lack enough internal space for effective propagation, favoring the slower process of ignition.

It is the rate of burning, and therefore of generation of gas, that accounts for the differing propulsive powers of gunpowder based on particle size. Because of the mechanism of propagation, corned powder burns faster than serpentine, and because of an elevated surface to volume ratio, fine grain corned powder burns faster than large grained. The problem facing the gunner is to determine what grain size and how much powder to use to generate the most force (and therefore range and power of projectile) possible without rupturing the gun. This is a function of a few factors, including the weight of the projectile, the strength of the barrel (including its breech) and the length of the barrel. The ideal is to have a powder charge burn just fast enough that gas pressure fills the barrel to the maximum safe pressure, and continues to expand to fill the empty space created as the projectile propels down the barrel. In period, this was more art than science. Luckily for the soldier, the possibility of rupture was far less for a firearm than a cannon (since the firearm generally has a thicker wall relative to its bore than does the cannon). This explains the standardized three powder grades which had been settled on by the middle of the 16th century: fine (priming), medium (firearm), and coarse (cannon).

So much for powder. What of the projectile? For firearms, the normal shot is a ball of lead. Lead melts relatively easily, so the soldier can cast his own shot in the field, but is dense enough to carry a significant amount of momentum for its size. Unfortunately, a spherical projectile develops considerable drag, losing velocity rapidly (about 2.5 meters per second for every meter traveled, three times faster than a modern conical bullet), and this is one factor limiting the effective range of period shot.

The other, and more critical limiting factor is that of accuracy. Most military firearms were smoothbore, as opposed to rifled. This means that the ball leaves the barrel with unpredictable (if any) spin. Since spin imparts lift to one side of the ball, that means that the ball is deflected randomly. Also, in the days before precision machining, the size of the bore of the gun, and of the mold for its ball, were not a guaranteed good fit. In fact, a typical margin of 5-10% ("windage") was left to ensure that the ball would fit. For precision shooting, the extra space would be taken up with a patch, but in war, speed of loading was more important. This slack between ball and bore was another source of inaccuracy, since the ball was essentially rattling around in the barrel until it exited. This explains why the usual command was not to "aim" and fire, but rather "level" and fire.

Guns with rifled barrels, albeit expensive, existed in the 16th century. The predictable spin imparted by rifling increases accuracy, but in a muzzleloading weapon, the ball has to be loaded into a rifled barrel with a ramrod and hammer. This was clearly unacceptable in the field, and so rifling was chiefly found on hunting pieces. However, some rifled military guns were made to be used by snipers.

Period muskets and pistols from Graz, Austria were tested in 1988-1989 for their accuracy and penetration power. Among the findings were that the period pieces had a muzzle velocity quite comparable to modern firearms, short only of assault rifles. Of course, the drag of the ball causes a rapid loss of momentum with distance. A smoothbore musket and a rifled musket were tested for the ability to hit a target 167 cm high by 30 cm wide (i.e. about human size) at 100 meters, and two pistols similarly tested at 30 meters. The guns were completely immobilized, so skill of the operator was irrelevant. Under these circumstances, the rifled musket would hit somewhere on the target 83% of the time, the smoothbore 50%, and the pistols 99% and 83%. In the reality of war, however, it must be borne in mind that the average musketeer is not going to take leisurely aim with a perfectly steady hand at a stationary target.

The weapons were also tested for armor piercing capacity. Shot from a variety of weapons penetrated mild steel an average 2.7 mm (about 11 gauge) at 30 meters, or 2 mm (12.5 gauge) at 100 meters. One of the pistols was fired at a distance of 8.5 meters at a breastplate made in Augsburg around 1570, made of coldworked steel 2.8-3mm thick, or about 8.5 gauge. The breastplate was mounted on a sandbag covered in 2 layers of linen, to simulate an undershirt. Surprisingly, the bullet pierced the breastplate, but not the linen! The bullet dissipated its force piercing the plate, and didn't even generate metal splinters. However, a modern 3 mm steel plate lined with linen didn't fare so well. It appears that the metal working skill of the armorer was critical.

This was recognized in period as well. In 1590 Sir Henry Lee tested German and English breastplates with a pistol. He reported that the German ones were barely dented, while the English were pierced "clean through". Lee concluded looks weren't everything: "yt is better to have an armore of evill shape and good metell than of goode shape and evill metell". It became common practice, as is well known, to "proof test" armor by firing at it with a musket at the breastplate and sometimes with a pistol at the backplate. The dents were a sign that the metal was of the best quality.

In conclusion, then, it might be fair to say that against an armored opponent, guns were in fact very dangerous— but only at close range. And in general, those who could find and afford the very best quality armor had little to fear from shots that landed on armored areas. The unarmored, however, could only hope that they would be spared by the great inaccuracy of the weapon. Sir Roger Williams wrote in 1590 that a musket could kill an unarmored man or horse at 600 paces, but that assumed it could hit him. A soldier had little to fear from a single shooter at any great range. The key therefore to effective battlefield use of shot was to concentrate fire. If one man with an arquebus can hit the broad side of a barn, then 100 men with arquebuses stand a better chance of hitting a given part of the barn. The problem was how to train and coordinate the individual soldiers so as to maintain a reasonable rate of fire, and direct it appropriately on the battlefield.

2b) small arms— tactics

Units of shot (the collective term for arquebusiers and musketeers) were much smaller than that of pike, typically around 100 or fewer men. Coordinated action was also not drilled so extensively, at least until the very end of the century. These facts stemmed from their main roles in the field. They were often used as preliminary skirmishers, comprising a portion of the "forlorn hope" or "enfants perdues" sent in the front of the formed armies, and were also important in scouting and raids. However there were two fashions in which they were chiefly employed. First, shot were deployed to fire en masse on an attacker from some fortified position (which required that the enemy be lured into attacking). Second, they could serve in tight association with pike to provide it with a counter to enemy shot, while using the cover of the pikemen as protection from which to fire on the enemy infantry, thus acting offensively.

The efficacy of shot was always limited by inaccuracy and reload time. Reloading took over a minute, more likely two, under the most ideal of conditions. The battlefield, and potentially ill-trained recruits, were far from ideal. Two notable techniques used to speed up loading involved premeasured powder charges. "Cartouches", or cartridges, made of linen or paper, sometimes with the ball already inserted, were used by the 1540's. The end was bitten off the end of the cartouche, and the contents dumped in the barrel. A variation was the use of the "bandeleere" of reusable wooden bottles carrying measured powder.

Training could also minimize reload time. In the 1590's, the Nassaus, Count William Louis and Count Maurice of the Netherlands introduced training to make the shot more efficient at reloading and also developed maneuvers to maintain constant fire by a given unit. They standardized the commands of each individual action of loading and firing, both for the arquebusier, and for the musketeer with his additional encumbrance of the forked rest. Their drill manual, commissioned between 1596 and 1598, illustrated by Jacob de Gheyn, was published in 1607, and became an incredibly influential work. For most of the century, however, the shot was a more chaotic bunch.

The problem of accuracy was superseded by concentrating fire on a given area. One Spanish and Italian method was the deployment of the shot in staggered half moons to allow the most shot to have a line of sight to a given area. The more common method was volley fire, in which an entire rank of shot would fire at once. Henri of Navarre taught his front rank of arquebusiers to kneel, so that the first and second ranks could fire simultaneously. Volley fire takes entire ranks out of action for the duration of the reloading time. To maintain continuous volley fire would be ideal, but the maneuvers and training necessary to effect it did not develop until the end of the century under the Nassaus.

The maneuver that they developed was the countermarch. William Louis described it in a letter of Dec. 8, 1594. He was inspired by reading a description of an ancient javelin drill by the classical Greek mathematician Aelian Tacticus (who also wrote on the pike phalanx). The first rank of arquebusiers fired, then moved to the back of the line to reload while the second rank fired. The number of ranks needed depended on the length of time to reload: each rank needed to be ready to fire by the time it reached the front of the line. At first, this seems to have been 10 ranks. In one configuration, Maurice assembled them alongside the pike, in groups of four files, with gaps between the groups to allow room for the countermarch.

For most of the 16th century, though, the shot operated without continuous volley fire. Its reputation grew initially from its efficacy against the formidable pike square, especially when that pike was prevented from reaching the shot easily by earthwork fortifications, as at Ravenna and Bicocca. Massed small arms fire was even effective against armored cavalry if the cavalry was hindered in its movements by a trench, as at Cerignola, or by marshy ground and trees, as at Pavia.

Yet without the protection of terrain or earthworks, or a pike square to merge into, the shot was surprisingly vulnerable to a cavalry charge. The combination of speed and armor gave the heavy cavalry an advantage against the shot. A man armed with arquebus or musket had a hard time standing his ground to get off his one, inaccurate shot (assuming that his weapon was loaded!) against a moving target. For example, a unit of arquebusiers had the misfortune to be caught isolated on open ground by heavy cavalry at Riberac in 1568, and were consequently run down. At Ivry in 1590, French Royalist heavy cavalry rode repeatedly through arquebus fire with little harm; moreover, when the enemy cavalry turned to attack the gunners of the Royalist artillery, the arquebusiers guarding the cannon were mowed down.

The cavalry remained a viable and potent force throughout the century, and not for this reason alone. Their tactics evolved to adapt to the changing face of war in the age of pike and shot, while retaining much of their traditional battlefield role.

B) CAVALRY

A variety of forms of horsemen existed in our period. The heavy cavalry (or “gendarme”, “man-at-arms”, “lancer”) were the fully armored, generally noble horsemen, originally armed with the heavy lance and sword, and later with the pistol. When we think of “knights in armor” the heavy cavalry are what come to mind.

The “light cavalry” includes several classes, and is something of a catch-all for anyone who fought from horseback with less armor than heavy cavalry. Two such types of French cavalry are the deceptively named archers and chevaux-légers, both of whom were French horsemen with slightly lighter armor (for example, they were allowed open faced helmets, and might not have knee cops) and lighter lances (and lower status) than the gendarmes; nonetheless, they could fairly be regarded as heavy cavalry (if not by the class conscious gendarmes). The French coustilliers were more lightly armored, and were armed with a sword and short spear. Other light cavalry included the Spanish jinetes, who were used through the 1520’s. They typically wore little armor, chiefly a chain hauberk and morion or steel cap, carried a light spear and small shield, originally leather and heart-shaped, and served as skirmishers and scouts. Similar in nature and functions were the stradiots, mercenary light cavalry, originally Albanians in Venetian service, but the term came to be applied to Venetian light horsemen in French employ. Stradiots were usually armed similarly to jinetes, but at least originally carried a distinctive form of throwing and thrusting spear, the assegai, which was bladed at both ends, and a curved saber.

The middle of the century saw the evolution of various forms of pistol carrying cavalry, or pistoleers. These included the German reiters, and equivalents of other countries, such as the Spanish herreruelos, and eventually the English cuirassier. Armor styles varied, but the pistoleer typically had at least a helmet and cuirass; and tassets on the upper legs were common. The lower legs were almost always protected only by boots, which provided a place for another pistol.

Horses were also used by arquebusiers and musketeers, who would use them to scout or to reach a target rapidly (as to seize a strategic point in advance of the main body of their army), but dismounted to fire. These soldiers are therefore more properly regarded as “mounted infantry”. They include the French “arquebusier à cheval”, Spanish “hargulatier”, and Dutch and English “dragoon”, among other fine distinctions.

The heavy cavalry had been the elite arm of the army throughout the middle ages and Renaissance. The French continued to enjoy the deserved reputation of having the finest horses and heavy cavalry troops (gendarmes) in Europe. The Spanish, on the other hand, seemed to lack quality warhorses, and this may explain part of their precocious development of infantry tactics. Nonetheless, it remained the social norm for nobility to serve in cavalry roles in the 16th century, although there were of course exceptions. François I, with his founding of the legions, had to actively encourage the (chiefly lesser) nobility to serve as infantry captains. The association of noble and horse meant that the command structure was often tied to the cavalry, such that the outcome of cavalry combat continued to decide the course of the battle to a surprising degree.

The traditional role of the heavy cavalry was that of shock troops, meaning that they struck at an assembled formation of enemy troops with great speed and momentum, with the goal of disrupting them. In an age where orders carried only as far as a voice or drum, and wherein disciplined formation was mandated, this continued to be an extremely effective tactic. In addition to disrupting communications, penetrating enemy ranks allowed cavalry to wheel about and attack the enemy in its rear. The speed of the cavalry was also of great use in approaching the flank of an enemy. The coming of the pike square, however, made these goals far more problematic.

For the first half of the century and beyond, the chief weapons of the cavalry were the same as they had been through the middle ages, namely the lance as the primary weapon, with backups of a sword, ax, mace, or similar one handed weapon. The lance itself, commonly up to 16 feet long, was designed to focus the enormous momentum of the rider and horse, often against another horseman. The lance was metal-tipped wood, and while it would rarely pierce armor (François de la Noue held it a miracle if anyone was killed by a lance), it could break the neck of another horseman, or more commonly dismount him, leaving him for footmen to finish off. Alternately, it was common practice, French notions of chivalry aside, to aim for the breast of an enemy’s horse; the Spanish, Dutch, and eventually English all practiced this maneuver. The normal formation of lancers was “en haye”, meaning in line, i.e. in a single rank. It must be remembered that the lance would normally break against an armored opponent, or otherwise frequently be lost upon use (e.g. stuck through an infantryman). Hence the lancer’s need for auxiliary weapons until he could obtain a fresh lance.

The sword could be used from horseback to cut or thrust, against cavalry or infantry. Cutting was usually a “back cutting” motion, executed as the rider passed his enemy. One tactic favored against another sword armed horseman was to attach him on his left side, especially from behind, where he couldn’t reach. Another favored target was the opponent’s reins. The estoc is a form of horseman’s sword, common in the early 16th century, which bears special mention. It had a long (typically 40-50 inch) sharp-pointed blade, normally of concave triangular cross section, and a wide cross bar hilt, frequently S-curved perpendicular to the conventional plane of the blade. Unlike a normal sword, it was not made to cut, but rather to be rigid for thrusting through the gaps in an opponent’s armor. It was never meant for use other than from horseback, and, contrary to some assertions, is thus profoundly unlikely to have been the progenitor of the rapier.

With the growing predominance of the pike square, which proved resistant to cavalry charges, the lance fell out of favor, as it was chiefly effective only against other horsemen. Its appearance in the Eighth French War of Religion in the late 1580’s and 1590 represents something of an anachronism, owing largely to archaic, even romantic notions, of chivalry. It must be noted that in these battles, such as Coutras and Ivry, that the lancers fared very poorly against modernized cavalry. By the 1590’s, it appears that only the Spanish clung to the lance, and even they abandoned it by the middle of the 17th century.

What were these changes in cavalry practice? The problems facing the cavalry were, first, to defend themselves against shot, and second, to be able to effectively attack the pike. The first was addressed in part by improvements in armor. Barding, horse armor, provided some protection. For the rider, the “proof testing” of cuirasses has already been described. Beyond that, the horsemen had to rely on simple courage that their speed combined with the inaccuracy of shot would keep them from being hit. To attack the pike, though, one approach with great appeal was to adopt firearms. The development which made this possible on horseback was the invention of the wheelock pistol.

A number of types of cavalry pistols were developed, of varying sizes, names, and details of construction. Two common types were the German fauströhre, (with about an 18 inch barrel, weighing around five pounds, firing a 20 gauge ball) and the French carbine (about 17 inch barrel, and one inch bore). Thus the "pistol" was often a surprisingly large affair, by modern standards, with two feet in length not being uncommon. Since these were most commonly carried in holsters on the saddle, the size was not prohibitive, as long as it could be fired with one hand (since the other had to hold the reins).

The cavalry pistol seems to have first appeared in the 1540's, and spread with great popularity. The pistol was rapidly accepted by the nobility, perhaps because it was more refined and expensive than the matchlock used by commoners. The mounted pistoleer became a recognized specialized type of soldier, of which the most renowned were the German reiters. A given reiter normally carried (in addition to a sword and often a mace) a pair of pistols in saddle holsters, and sometimes a third in the right boot or the belt. Like the Landsknecht infantry whom they overlapped, reiters were often found as mercenary troops in the armies of different countries. In 1588 Henri of Navarre had about 8000 of them in his employ, and they formed a large proportion of Dutch cavalry forces as well.

Arming the cavalry with pistols gave them the means to attack pikemen without getting into pike range. However, pistols fired from horseback are predictably inaccurate. Conventional wisdom was to fire only at extremely close range. Just as volley fire developed in the infantry to concentrate fire, a maneuver which appears to have originated among reiters sought to concentrate and maintain fire from horseback. This maneuver was the caracole, or limaçon, which was essentially a pistoleer countermarch, although it predates the infantry maneuver by decades. The term "caracole" refers to the spiral shell of snails, suggesting the circular path employed. Reiters would form up en masse in squadrons of about 300-500, in about 12 to 16 ranks, and charge toward their enemy, firing their pistols when in range. They would then veer off (to the left, since they fired with the right hand) and retire back to the end of their unit, and reload while the successive ranks executed the same maneuver. The efficacy of the maneuver was debated by military men of the time, and it remains unclear today. One shortcoming of the system is that it fails to properly employ shock, in that the enemy was rarely disorganized by the inaccurate shooting of one rank of reiters at a time. The other was that reiters often had a bad reputation for being scared to get too close to their target, and would fire at too great of a distance, without bothering to aim. They also could precipitate a charge of they enemy, to whom the retiring ranks of the caracole might appear to be fleeing. During a disordered retire, they could run into the next advancing rank of the caracole, or break the line of attack of other cavalry (as at Ivry).

The solution to truly effective pistol cavalry tactics was to combine the technology and reach of the pistol with the decisiveness of shock. This combination was the hallmark of Henri of Navarre, later Henri IV of France, from the 1580's. He disdained the use of the lance, employing in its place the pistol and sword. Without the lance, he could form his squadrons of fully armored cavalry en masse about six ranks deep, sometimes in blocks, and sometimes in a wedge. By firing pistols as they charged, they added to the disruptive effective of the charge on the enemy, and once within the enemy force they would continue the fight, rolling up the enemy's flanks, with sword and with any unfired pistols. This combination proved deadly to lancers at Coutras and Ivry.

The combination of shock and pistol spelled the end of the lance. The pistol had superior ability to penetrate plate, could be used at greater distance, and was effective even when stationary. Moreover, it permitted the use of tight order which had the advantage of the more easily penetrated en haye formation favored by lancers, as noted by French contemporaries. Even before Henri of Navarre's innovation, pistol-armed German reiters were shown to have the advantage of the lance-armed gendarmes whom they slew in great numbers at the battle of Dreux.

Single rank en haye formations or en masse wedges or blocks remained the main cavalry formations. Late in the century, the Dutch began to deploy multiple block-arranged cavalry squadrons, often in checkerboard fashion to provide tactical flexibility. These types of formations, used at Zutphen, Nieuwpoort, and Turnhout, were learned by the English reinforcements in the Netherlands, along with the "lunarie", a concave crescent formation intended to encircle an enemy unit.

The strength of the cavalry remained its ability to execute shock tactics against other cavalry, or against unprotected shot (as at Riberac and Ivry). The pike square, however, remained nearly impervious to the cavalry, if well-ordered. The cavalry could succeed in attacking the flank of a pike square only if it was disordered, as by artillery or terrain, or frontally engaged with other pike, as happened at Ceresole. Against an unengaged pike square lance-armed cavalry was limited to halting the momentum of pike with charges, as at Marignano and also at Ceresole, in order to render it susceptible to fire. The addition of the pistol seems to have permitted cavalry to harry pike protected by shot, if not to decisively engage it. The battle of Dreux, however, represents a possibly unique exception to these generalizations. Rebel Huguenot (Protestant) gendarmes, armed with lances, were able to pass through a Swiss pike phalanx, which was nonetheless able to retain order. The Swiss were also assailed by pistol-armed German reiters in great numbers, who wreaked great slaughter upon them. The gendarmes and reiters then wheeled and charged the Swiss repeatedly in their flank, eventually breaking them up into separate, although still active, segments. The Swiss were commended for their remarkable performance, nonetheless, having withstood multiple cavalry charges, and accounting themselves well against any who closed with them.

While the advantages of the cavalry were speed and armor, the weakness was surely the horse itself. It could be killed more easily than its rider, by shot or lance, or by pike if forced to charge a pike square. If the harness was damaged by cutting the reins, the horse could be dangerous to its rider. Its mobility could be thwarted by obstacles natural or man made, as witnessed by the defeats of French cavalry at Cerignola, and Pavia, and of the Spanish at Ceresole, rendering the cavalry susceptible to massed small arms fire.

There remains to be discussed the final arm of the 16th century army, equally deadly to infantry and cavalry, however heavily armored: the artillery.

C) ARTILLERY

Artillery had been known in Europe in at least a crude form since the 1320's. The first record of their use dates to 1331, in which cannon of some form were used (effectively or not) in the siege of Cividale in Friuli. The first war in which firearms were decisive, however, was the Bohemian Hussite civil war in the 1420's. The French victory over the English in the 100 Years War can be directly attributed to the development and reform of the royal artillery train by the brothers Jean and Gaspard Bureau in the 1440's and 1450's. A few decades later, it was this arsenal, modernized, which was later used to great effect in Charles VIII's invasion of Italy in 1494, an event that, (aside from the Protestant Reformation) precipitated much of the mass conflict of western Europe throughout the 16th century.

Before we continue, an aside on terminology: for ease of communication the term "cannon" will be used in places as a generic term for artillery pieces, or heavy guns. In period the cannon was a specific kind of gun, as will be described in its place. The term "gun" is itself an interesting case. "Gun" seems to come from the Old Norse "Gunn", meaning "war", by way of the habit of naming medieval siege engines with Germanic female names: e.g. Gunnhilda. The habit of naming guns continued throughout the Renaissance and later, with such picturesque 15th and 16th century examples as "Great Devil", "Bumblebee", "Earthquake" and "No More Words". Perhaps the most personal example was of a gun commissioned by Duke Alfonso of Ferrara, after he took Bologna from his enemy, Pope Julius II. Ferrara melted down Michelangelo's statue of Pope Julius, and had it made into a gun which he christened "Giulia".

From the earliest pot shaped primitive mortars described earlier, were developed the hooped bombards in the early 15th century. These were tubes made of wrought iron staves beat into shape around a mandrel, then held together with hot iron hoops that shrank upon cooling. These primitive cannon were open at the breech, which made them easy to load. With such "breechloading" guns, whether bombards or other types, the breech was sealed by using an entirely separate piece. Often this piece was the powder chamber itself (often shaped much like a beer mug), which was closed at one end, and wedged into place against the main body of the gun. The distinguishing characteristic of the bombard is the increased thickness of the barrel wall of the powder chamber relative to that of the bore (to add structural strength). Usually the powder chamber of bombards had a smaller bore than the barrel. In some pieces the powder chamber was continuous with the barrel, but the external diameter dropped off acutely at the transition. The necessity of plugging the breech after loading limits the power of all breechloaders; if the charge was too strong, it would blow the powder chamber or breech block off the rest of the gun.

Wrought iron cannon continued to be used through the 16th century, despite the development in the mid 15th century of the vastly superior (and proportionately more expensive) cast bronze guns. It was the latter which allowed Charles VIII of France to rapidly seize, although not hold, Naples.

The siege train of Charles VIII represented the cutting edge of artillery of its day. There were several novel features thereof that were radical improvements on early guns. It is worth quoting a contemporary observer, Francesco Guicciardini:

"…the French brought a much handier engine made of bronze, called cannon, which they had charged with heavy iron balls, smaller without comparison than those of stone made use of heretofore, and drove them on carriages with horses, not with oxen, as was the custom in Italy… the balls flew so quick, and were impelled with such force, that as much execution was done in a few hours, as formerly, in Italy in the like number of days."

Guicciardini notes several features that characterize the new artillery. These pieces were so effective that they were to remain the dominant form of heavy artillery for most of the century. We will examine the relevant features of these guns in turn.

First, they were made of bronze, not iron. While the raw material was three to ten times more expensive, the lower melting point of bronze (a copper / tin alloy) meant that the guns could be cast, i.e. made in a mold, of a single piece. The technology of cast bronze gun manufacture was a direct development of bronze church bell foundries. In fact, church bells were often regarded as valuable booty of a captured town for this reason. A cannon would be cast breech down in a buried mold of the appropriate shape, with a central cylinder (to exclude the space of the bore) suspended in it, and once the metal hardened, the cylinder would be removed and the cannon pulled up from the ground, breaking the mold in the process.

The design advantage of cast guns over wrought ones meant that larger powder charges could be used, up to 110% of the shot weight in powder, instead of the 15% limit of earlier guns. Since there were no gaps between staves for gas to escape, the new guns were safer. Single-piece bronze guns also could not rattle apart or rust. Casting also allowed an integral breech, again allowing a larger powder charge to be used. The trade off was that cast guns were necessarily muzzleloaders, which slowed their reloading time.

It would be nearly 50 years before the technology to reliably cast iron guns would be developed. From 1543 the English led in production of relatively cheap cast iron ordinance. For quite some time, however, bronze pieces remained less likely to rupture during use. The reason behind this was partly owing to the quality of iron and consistency of the manufacturing process, and partly due to the metallurgy of bronze itself. The copper and tin in bronze solidify at different rates as the metal cools. Copper solidifies first, while the liquid tin migrates to the last part to harden. Tin is more ductile (i.e. less brittle) than copper. Since the gun is cast breech down, this means that the muzzle cools before the breech, and the outer face before the bore. Thus the breech is more ductile than the muzzle, and the bore more ductile than the outside of the cannon. The differential of copper and tin concentration helps force transfer from the bore to the outside of the barrel, preventing fragmentation of the barrel, and makes a breech rupture less likely. The low level of tin at the muzzle, however, makes it more likely that a barrel will fragment at the muzzle as the ball exits. Gun founders compensated for this by adding a flare to the muzzle to thicken it. Notably, Ottoman pedreros were cast breech up, and lack the flared muzzle.

Next, Guicciardini mentions the iron balls used by the French. This was one of the of the Bureau brothers' artillery reforms during the 100 Years War. Cast iron balls were simpler to make than whole cast iron cannon, and so were earlier to be developed. Earlier ammunition had been made of stone, by masons who would cut each ball to the required size. As the century wore on, economics made iron more of a bargain as the cost of skilled labor outweighed that of raw iron. More importantly, though, iron is about three times as dense as stone. This has several important consequences. Since a smaller iron ball can carry the same amount of kinetic force as a larger stone ball, then a cannon of smaller bore can be used, which makes the cannon cheaper to manufacture and easier to transport. Alternately, the same gun can be used with an iron ball instead of a stone ball, but with more powder, delivering more force (assuming that the gun can tolerate the charge).

While iron balls rapidly became the standard, other projectiles were used. Smaller, antipersonnel guns occasionally used lead balls that were cast around iron "dice", i.e. cubes, apparently because the iron cubes could be easily forged, and then low melting lead cast about them; the iron core increased the final density of the shot above that of pure lead. Stone actually continued to be favored for naval applications, since it would fragment upon hitting the hull of a ship, making a bigger hole and simultaneously serving as an antipersonnel fragmentation weapon. The same effect was achieved directly in smaller, antipersonnel guns, by loading them with shrapnel—nails, gravel, or chopped flint were common scattershot of choice. Similarly, long iron chains were occasionally loaded into cannon as area of effect weapons. Finally, it bears mention that the explosive shell was invented in 1543, although its disconcerting habit of blowing up in the cannon limited its popularity.

The final aspect of the new artillery that greatly improved its utility was that of it carriage. This can be thought of in two aspects: first, the wooden carriage itself; and second, the trunnions, the metal lugs on the sides of the cannon that engaged the carriage.

The earliest carriages were essentially sledges, lacking wheels, and had to be dragged by oxen, which slowed their rate of deployment and made traversing the uneven or nonexistent roads even more difficult. The first wheeled carriages were essentially flatbed carts. The newer carriages had, in addition to wheels, long tails; these tails could be planted against the ground to provide a stable platform for the gun once in position. Teams of horses could drag these carriages fast enough to keep up with the army. The new carriages also eased the process of adjusting elevation, by leaving room between the wheels for the gun to pivot. Wedges, or "quoins" placed under the breech end of the gun arrested its elevation. Pivoting was made possible by trunnions, of which the earliest reference is in 1465. These are lugs cast as part of the gun, which projected perpendicular to the barrel at the pivot points. These innovations made it possible to get the gun to its target more easily, to situate it stably, and to aim it more readily.

A bewildering array of often fanciful names were applied to different kinds of guns were throughout the course of the century. Many of these are presented in Table I. For our purposes, it will suffice to mention the major types by design and function, and some approximate divisions into classes by size.

The mortar, one of the first types to be developed, was relatively short for its diameter, in other words fairly squat. It was fired with its muzzle angled nearly upright, to lob projectiles at high trajectories. This was especially useful for propelling shot, including the occasional bomb or incendiary device, over walls into fortified areas for antipersonnel purposes.

Bombards, distinguished by the thickened wall around the powder chamber, as described earlier, included mortar types and long artillery types. They were commonly of wrought iron but could be of cast bronze (in which case they were of one piece, although with an internal powder chamber), and typically were huge and meant to hurl stones. Improved metallurgy eliminated the need for the thickened chamber wall, and allowed the use of cast iron shot. Bombards, with their distinct powder chambers, became a thing of the past, giving way to the more modern cannon types.

"Cannon" are, properly speaking, a particular type of large gun of the general type we think of as cannon. They are distinct from the other main type of large gun, the culverin. The cannons (of which there are full, half, and quarter cannon) are distinguished by relatively thin barrel walls and short overall length to bore ratios (about 18 calibers for a full cannon). Culverins (full or half), on the other hand, are the true "artilleria lunga", or long guns, of their day. They have somewhat thicker walls than do cannon, and are considerably longer relative to the size of their ball, ranging around 36 calibers. Gunners regarded the culverins as able to fire longer distances. The additional length of the barrel over that of the cannon did not in fact contribute almost any power to the ball. In actuality, the advantage of the culverin came from two factors, both related to safety. For one thing, the culverin walls were thicker than those of the cannon. The more subtle factor involves the breech strength. Europeans cast their guns breech down, and so the longer the barrel, the more pressure there is during the casting process on the breech. The weight of the extra metal of the long barreled culverin meant that the breech set up under high pressure, and this made it inherently stronger. As a net result, gunners had more faith in the integrity of culverins, and would use higher powder charges-- so they really did fire longer distances than cannon. By the end of the century, culverins on ships were cut down to fit onboard more easily, and were found to lose little practical range.

Somewhat smaller than full cannon or culverins were the pedreros (or petreri, or perriers), which, as their names suggest, were meant to fire stone balls, up to 24 pounds in weight. The value of stone balls against ships has already been discussed. Later in the century, the name continued to be used for this size of gun, even if it fired iron balls.

The remaining main types of artillery fall under the heading of antipersonnel guns. There are a host of these smaller guns, that can be found in Table I. They include "swivel guns", so named because they were mounted on swiveling rests, as on the rail of a ship or on the rampart walls of a fortified town or keep. Two such types are the moschettone, also called the moschette, a breech loader not to be confused with the (slightly) lighter musket; and the archibuge della mura or arquebuse à croc, an early wall-mounted heavy arquebus.

A useful general classification scheme is that of heavy, medium, and light artillery. Generally speaking, heavy artillery are enormous siege pieces, used to batter down thick reinforced walls. Heavy artillery includes the full cannon and full culverin, and cognate forms like the German hauptbüchsen, scharfmetzen, singerinnen, and so on. These were exceedingly heavy and slow to transport, assemble, aim, and load. Charles VIII was only able to transport his heavy artillery to Naples by using the royal navy to ship them to a rendezvous point.

Medium artillery includes large field pieces, which were useful to fire on large numbers of assembled personnel (like a pike square or tightly ordered cavalry squadron), to batter an earthwork or lesser fortifications, or fire on an artillery battery, for example. They include half cannon, pedreros, and the German sau ("sow").

The remaining smaller guns, chiefly of an anti-personnel use, whether field or swivel guns, are regarded as light artillery. Many of these were still sizable pieces, such as the half-culverin, quarter-cannon, and saker. Among the smaller field pieces was the falkaune.

These designations give an impression of a regularity of size, weight and caliber. Unfortunately, they are best regarded as helpful generalizations. Period gunnery was far from standardized, even within a single royal artillery collection. Several factors contributed to this problem. For one, guns were initially made using unique molds, often elaborately decorated, which were broken at the end of the casting process. For another, given the expense of manufacture, an enemy's artillery was a prized spoil of war, so a field army might include the captured weapons from past conquests along its own. As well, guns might continue to be used for many years, so that different vintages, made on different standards, might also be used side by side.

Nonetheless, attempts were made to standardize the calibers of national artillery collections. Henri II of France tried to standardize the royal guns to only six sizes, and Emperor Charles V tried to reduce the number of Imperial gun classes to a standard seven. Neither of these efforts were wholly successful, in part for reasons already mentioned. It was not until the turn of the century that France (under the guidance of the Master of Artillery Maximillian de Béthune, Duc de Sully) actually implemented a standard system of ordinance, as did Prince Maurice of Orange in the Netherlands in 1599.

Why was standardization such a concern? Without knowing the exact size and weight of ball need for a given gun and the amount of powder to use with it, a gunner's job was as much art as science. The logistics were also complicated, since if a unit had 4 sakers and 3 demiculverins, they might nonetheless need seven different sizes of shot, one for each gun. This sort of individualization was actually the norm, though. Each given gun usually came with its own powder scoop, so that a gunner knew how much to use. The gunner would also have to determine what size ball to use by measuring the bore of the gun, and make sure that he had shot to fit it. Accuracy was also compromised, since a gunner had to get the feel of each given gun (with a particular powder charge and weight of shot) before being able to aim well. This sort of arbitrariness was one of many logistical problems that plagued the Spanish Armada. Given that the ships thereof had guns made in multiple countries, with different definitions of the inch and the ounce, the shot were rarely interchangeable from one gun to another.

Gunners therefore required a great deal of specialized equipment . Special calipers, rulers, and rings were used to determine the bore of the barrel and the utility of a given ball for it. Measuring the powder, as mentioned, was usually performed with an individual scoop made for each gun. The equipment differed slightly depending whether the gun was a breech loader or muzzle loader.

For a breech loading gun, the gunner would measure the powder with the scoop into the detachable powder chamber, which was then sealed with a wooden plug. The charged chamber was inserted into the carriage so that it abutted the bore of the gun, and secured with a wedge driven in with a mallet. The ball was then rolled into the barrel via the muzzle.

For cast, muzzle loading guns, charging was performed by ladling the powder down the barrel. This was done either with the powder scoop directly, or by using a linen sack (a cartridge or "cartouche") which had been filled earlier with the appropriate measure. Next wadding was shoved down the barrel and packed firmly with a ramrod, to ensure that the powder built up proper pressure when ignited. Last came the ball, again rolled down the barrel.

The touchhole was then pricked clean, a bit of priming powder added, and ignited. Ignition was usually by way of a linstock, a device that held a burning length of slowmatch. Linstocks were often ornate. Many were in the forms of dragons, which hold the slowmatch in their jaws. Other common designs for linstocks were hands (seemingly gripping the slowmatch) or a polearm shape, such as a boar spear or partisan. After the gun was fired, it would have to be sponged out, to extinguish any burning fragments of wadding or particles of powder, and allowed to cool before reloading. The latter process was sometimes accelerated by further sponging with vinegar.

Even with practice, the whole process was quite slow. Breechloading guns were obviously faster, and a medium sized piece, with multiple beer mug shaped powder chambers filled by assistants might be fired as often as twice a minute until the barrel overheated. As discussed, though, these pieces were significantly less powerful than cast guns. The muzzleloaders would take a bare minimum of two minutes two load and fire, for medium or light pieces. The longer the gun, the longer the process (since the scoop, ramrod, sponge, et. al. were more unwieldy). For a heavy siege piece, six minutes per shot was considered the fastest possible. The real limiting factor was cooling time, though. Francesco de Marchi in 1599 gave the number of rounds that could be reasonably fired from different classes of guns in a 12 hour shooting day. He allowed a maximum of 90 shots per day (i.e. about one shot every eight minutes) from a cannon firing a 20 pound ball, but only 20 shots from a 100 pounder culverin.

Gunners were also responsible for calculating (or estimating) the distance to their target, and the elevation of the gun needed to hit it. The Renaissance flowering of mathematics was applied to question of trajectory. Among the first, and most influential works, were two books on the topic based on Aristotelian physics by Niccolò Tartaglia, who also invented the gunner's quadrant. The quadrant was a device to be inserted in the bore of the gun that employed a plumb line and graduated arc to indicate degrees of inclination. It inspired a host of related quadrants that could be used by sighting down the barrel. A plethora of measuring devices followed from military engineers. Mathematicians developed means of range finding based on principles of triangulation, and instruments and tables to assist the process. Angles would be measured from the end points of a measured baseline, and the distance to the target determined trigonometrically, or more commonly graphically.

There is good reason to believe that most of these elegant devices and learned treatises were little employed in the field, unfortunately. Many of them may have simply served as presentation pieces to nobles from whom theorists were seeking patronage. While some degree of instrumentation was clearly favored for bombarding fortifications the most common method of aiming in combat was probably "by the line of metals", otherwise referred to as "point blank" (from the ability to hit the "punto blanco" , or "white spot" as the center of a target). The gunner would line up the gun with the target, adjusting horizontally by sighting between his upthrust thumbs, and sight straight down the top of the barrel. The slight taper of the outer walls of artillery (i.e. guns are thicker at their breech than at their muzzle) resulted in a slight angle of elevation, so the ball would rise and then drop back through the line of sight in about 200 to 300 yards, the point blank range. Empirical adjustments of elevation on that method were apparently good enough for most combat purposes.

The guns would be moved left to right for aiming by the use of a "training lever" that was applied to the rear of the carriage. Inclination, as we have already discussed, was adjusted by pivoting the gun on its trunnions using a quoin to hold it at the desired angle.

How far could period artillery effectively fire? Surviving test-firing records of the Venetian Republic indicate that a 60 pounder was effective (i.e. both powerful and accurate) to 640 meters. The same gun actually had a maximum range of three kilometers, although aiming it at this range was matter of luck. The engineer Eugenio Gentilini published tables of maximum and point blank ranges for a wide variety of guns from the hand held musket to the 120 pound culverin in 1598. The point blank ranges fall mainly within the 200-300 yard range, while the extreme ranges are around 2.5 kilometers for light artillery, and 3.5 and 4.0 km, respectively, for heavy cannon and culverins. Realistically, field artillery pieces were normally fired at an ideal range of about 300 yards, up to a maximum of 1000.

A skilled gunner would not just be able to hit his target, but know how to place the shot to do the maximum of damage. As mentioned, the ideal shot was on the diagonal of a troop formation ("enfilading" fire), so that a single ball would hit the most people. It must be remembered that, unlike with explosive shells, a flat trajectory was preferred to a high one (which would simply embed a cannon ball into the ground). An additional factor to take into account was the ricochet. A ball would usually bounce after hitting the ground, with enough speed to remain deadly, even after the second bounce. This factor further encouraged the gunner to aim for "depth" of troops and to fire at closer ranges, when the ball could retain its power as it traveled through many files of the enemy, rather than at the extreme range of the shot's power. To give an idea of the power of a single shot, it is recorded that one ball killed 33 fully armored Spanish heavy cavalry during the enfilading artillery fire at Ravenna.

Artillery may be seen as the most destructive arm of the 16th century military. It was effective against infantry and cavalry alike. Its power was limited by a number of factors, though. For one thing, the rate of fire of a single piece was generally slow, and so a truly effective artillery train had to consist of a number of pieces. The expense, weight, and overall logistical problems associated with such a mass of metal and powder meant that a field army rarely had an adequate supply of artillery in our period. The weight of the weapons also made them impossible to remove in the face of a charge, and so gunners had to be protected by a reserve of troops. Often, this was not adequate to stop a determined cavalry charge, as at the battle of Ivry. The ideal was to situate the guns behind an earthwork, such as a ditch, to prevent enemy access. Even so, the operation of period artillery, with its relatively flat trajectory, required a line of sight to operate. If troops passed in front of their own guns, the artillery could not fire. This is exactly what happened in the French cavalry charge of Pavia. It was a common theme that artillery fire would precipitate a cavalry charge against the gunners, which would be met by a counter charge, thereby tying the gunners' hands. This came to pass at Ravenna, Coutras, and Ivry. Guns alone would not win the battle. The challenge lay in balancing the several arms of the army.

D) INTEGRATION OF ALL ARMS

We have outlined broadly the strengths and weaknesses of the infantry (pike and shot), of the cavalry, and of the artillery, and of how field fortifications factored into each of them. The commanders and sergeants of a field army containing all these arms had to configure them in such a way as to allow deployment of their strengths, while mutually compensating for the others' weaknesses.

The simplest combination is that of a pure infantry force, as the basic configurations of the Spanish tercios, or Landsknecht regiments in the "Gevierte Ordnung" (square order). The problem facing these forces was how to protect the pike from enemy fire. The solution was to place shot on the exterior of the pike square, so that they could shoot at the enemy's shot, and give the formation a chance to close so that the pike could engage.

Several variations on this theme were employed. The most common arrangements of shot relative to the pike square can be broken down into three main types: sleeves, surrounds, and horns. Sleeves of shot are files of shot, placed on both flanks of the pikemen. A surround is a similar arrangement, but enclosing the formation on all four sides. Horns are blocks of shot, placed at each corner, although sometimes they were only placed at two corners, usually in front. Horns are often combined with a shallow surround of shot. The advantage of sleeves and horns is that even once the pike has closed, the shot, being on the flanks of the pikemen, can continue to fire. The shot in horns of the Landsknecht Gevierte Ordnung would fire and then retire to the rear to reload. The tactic was further refined by Dutch shot, after the Nassau brothers instated the countermarch volley. Upon coming to push of pike, Dutch musketeers in sleeves of shot would retire to the sixth rank of pikemen and maintain continuous volley fire.

An apparently unique arrangement was tried by at Ceresole by Blaise de Monluc, who claimed to have invented it. Gascon arquebusiers were placed in the second rank of the French pike square, with orders to hold their fire until they were almost in hand-to-hand range. Curiously, the Landsknechts of the Imperial pike square that they faced had come up with the same trick, using pistols. There was enormous slaughter of the first ranks of both sides. The experiment does not seem to have been repeated-- probably the enormous risk to the shot was deemed unacceptable.

Other types of infantry could be worked into this scheme, as well. The inclusion of small numbers of sword and buckler men in the Spanish colunelas up until the 1520's is one such example. The troops that had the most developed combination of infantry arms, though, were the Landsknechts. They, like the Swiss whom they copied, had a flag-bearing ensign at the center of each company of pikemen. The ensign was usually surrounded by men with halberds, whose duty was to protect the ensign in case the pike square should be penetrated. These individual companies would be combined in a variety of configurations so as to create a single huge pike phalanx. In one form of the Gevierte Ordnung, to the assembled pikes would be added a rank in front and rear of men with two-handed swords, whose job it was to make openings in the enemy's formation, and to attempt to break the heads off of pikes. The entirety would then be enveloped with a surround of arquebus. Monluc speaks of the Swiss using two handed swords as well at Ceresoles, although not how they were integrated with pike.

A final common theme to the pike and shot combination should be noted. It was usual to have a loose line of skirmishers in front of an infantry square. These were most often scattered arquebusiers, or possibly swordsmen or pole arm men. They were assigned to draw out the enemy or attempt to create openings in it. The life expectancy of such troops is reflected in the names applied to them: the Landsknechts called them Verlorene Haufe, meaning "lost hopes", as did the Dutch. The French term for them is hardly better: enfants perdus, meaning "lost children". Among the Landsknecht, assignment to the Verlorene Haufe was sometimes a punishment for criminals.

While thick sleeves of shot, or horns, conveyed superior firepower on an infantry square, shallow sleeves or surrounds had one advantage to the shot. When cavalry charged against the shot, they could merge into the ranks of the pikemen, who would defend them from cavalry. Thus the shot protected pike from shot, and pike protected shot from cavalry.

The infantry square was the basic building block upon which field armies were constructed. With the addition of cavalry and artillery, it became a fully equipped unit. The deployment of these final two arms was dictated by their functions. Namely, cavalry needed to be able to charge the enemy, and artillery needed a clear line of sight to fire.

The usual position of cavalry, therefore, is in one (or both) of two locations, which allow them ease of egress and ingress. In the first, the cavalry situate between multiple infantry blocks, to create lanes through which they may charge and retire. The French, and to a lesser degree, the Spanish deployment at Ceresole follows this pattern, as does that of the French royal army at Dreux.

The second and more common position is on the flanks of the assembled infantry. The latter has the advantage of permitting the cavalry to respond easily to charges on the assembled field army by enemy cavalry. It also permits easier initiation of flanking charges, and discourages the enemy cavalry from conducting flank charges. This is the deployment used by the French royal army at the battle of St. Denis, and by the Spanish and Dutch (in "checkerboard" fashion) at Nieuwpoort.

A highly developed integration of cavalry and infantry is that of the "Hungarian Ordinance", a formation used by the Imperial forces that relieved Vienna when it was besieged by Turks in 1532. This formation combined the two positions, with two bodies of cavalry centrally situated within surrounds of shot and artillery (with openings through which they might pass), and a wing of cavalry on either side for flanking maneuvers (and defense against the same).

A reserve of cavalry, if it could be spared, would often be held waiting at the rear of the assembled force. This reserve would be employed as needed or as the opportunity arose, to exploit openings made in the enemy by whatever means, as well as to respond to attacks to the rear, or to shore up the defenses of any weakening part of the total formation.

During the French Wars of Religion, i.e. civil wars, one finds the cavalry playing the dominant role, usually comprising the entire center of the field army. This appears to be a uniquely French predilection, stemming from their faith in their gendarmes. It is not surprising, then, that in battles fundamentally between French noblemen differing mainly in their faith (and political agenda), that the cavalry was the center of attention.

As for the deployment of the artillery, the line of sight required for its function dictates chiefly three possible positions. The first is on high, directed down at the fighting (as Navarre was fortunate to have at Coutras, where he positioned his guns on the top of a hill). The second is in a line in front of the army, as employed by both sides at Ceresole, and at Ivry, and by the entrenched Imperialists at Ravenna. This configuration, while convenient for the gunners, precludes any other engagement-- as soon as the army sends out forces in front of the guns, the shooting obviously must stop. This makes the most sense in the defense of a defile, as Navarre's forces attempted in the battle of Arques. With light field pieces, though, this approach can be modified to provide a "surround" of artillery, as in the Hungarian Ordinance. The last, and most common (because it is the most effective on open terrain) is to position the guns on the flanks of the forces. This permits enfilading fire, which maximizes damage. It also may allow the artillery to continue to fire while the infantry and cavalry advance in the center. The flank artillery deployment was used at Nieuwpoort by both Spanish and Dutch. At the battle of Ravenna, the French were able to deliver crushing artillery fire on the entrenched Imperial cavalry because to their guns on their right flank were added the guns of their ally the Duke of Ferrara, who deployed his on the left flank, creating a double enfilade on the Imperialists who were effectively trapped by their own entrenchment.

Of many possible configurations dictated by tactical goals, preexisting or engineered landscape, available forces, and other circumstances, certain themes emerge. Ideally, the infantry square should contain well-ordered pike, to defeat other hand-weapon armed infantry, and to protect the shot from cavalry. The pike should be surrounded by shot, to protect the pike from other shot, and provide cover to the shot from the cavalry charges. The cavalry should be in a position to exert shock tactics against disordered infantry, to attack enemy cavalry, and to run down unprotected shot and gunners. The artillery should be in a position to fire upon the greatest depth of enemy forces, without endangering its own troops, in order to draw out and create disorder in the enemy for the infantry and cavalry to exploit.

A mock battle from a review of Charles V's forces in Munich in 1530 shows this idealized combination of all arms, in miniature scale. Two staggered pike phalanxes, with ensigns in the center, stand arrayed. The sergeants marshalling them into order are identifiable by their polearms. On the flank can be seen, first, multi-barreled guns, and second, a squadron of heavy cavalry. A textbook presentation is the diagram "The Battell in Figure, shewing how everie Weapon should be placed to fight" from the Pathwaie to Military Discipline of 1581. A phalanx of pike, with ensigns in the center file and mounted commander in the center, are flanked on three sides by sleeves of shot. Lance-armed heavy cavalry squadrons are deployed in wings on the flanks. The artillery is lined up in front while a supply train brings up the rear. The lesser command staff can be made out, as trumpeters by the cavalry, drummers and fife players among the shot, and sergeants behind the pikemen.

Ideally, the leader of such a force should direct the multiple arms, observing and controlling the action rather than heroically engaging. The use of sergeants in the field, and of company captains would theoretically facilitate sucha chain of command.   The failure of François I at Pavia is at least in part a result of his inability to maintain cohesion of his multiple detachments of troops, while his Imperialist enemies were able to coordinate their attacks. Similarly, Ceresole was nearly lost to the French when the French commander, Enghien, charged off in a panic to fight a hopeless engagement, rather than following the course of the battle. This impetuousness is similar to the character that Alessandro Farnese, Duke of Parma, (regarded as the greatest general of the century) denounced in his adversary, Henri IV, when he asserted that he expected to be fighting a general, but only found a captain of irregular horse. The days when a leader's role was chiefly that of heroic inspiration were largely gone. A man like Henri IV was something of an anachronism beside the geometrically configured, rigidly ordered regiments of the Spanish or Dutch. The modern tactics and technology demanded a corps of specialists, and a cool and trained head to coordinate them.

Perhaps the single greatest limiting factor on the new tactics was that of communication. Word could still only spread as far as the voice could carry, or at most the trumpet and drum. While messages could be carried by light cavalry, once battle was joined much of the flexibility of formation was in the hands of company captains. To some measure, then, the course of the battle was determined by its initial array. The disposition of the component arms, as we have elaborated, dictated the strengths and weaknesses of the field force as a whole; in that sense, the form of the army dictated its function. It was then, to some extent, the art of the skilled commander to recognize the lay of the land, the forces of the enemy, and the resources at his disposal, and configure his troops so as to maximize their potential. Once the varied forces were deployed, the training and discipline of each of the arms of the army were critical in their ability to fulfill that potential. In balancing the varied arms, and in training them to function efficiently, lay the heart of the new military science.

II) SIEGE WARFARE

A) EARLY FORTIFICATION

The invasion of Naples by the French in 1494 revealed the fragility of medieval fortifications before modernized artillery. The medieval theory of fortification was predicated chiefly upon defense of height, i.e. making a wall too high for an enemy to climb over. The medieval wall needed to be strong enough to resist medieval siege engines—trebuchets, mangonels, and other stone throwers, and the rams and picks of sappers. The vastly superior penetrative power of gunpowder powered artillery required a defense not primarily of height, but of depth, i.e. a wall too thick to knock down. While the most enduring of these structures were of masonry, cheaper (and more quickly erectable) earthworks were found to be quite effective. The idea was sometimes carried to its logical extreme, with entire fortified towns such as Salses in Rousillon countersunk, seemingly subterranean.

Of course, existing buildings and perimeter defenses were not replaced wholesale, but rather attempts were made to retrofit them to provide resistance to artillery. The most essential step was to thicken the walls, as with earth embankments ("contraforti") behind them, especially at the vulnerable base (where a slope, or scarp, would be built up on the outer face as well). Merlons and machicholations were removed, which were prone to shatter under fire, creating shrapnel. Towers would be lowered and reinforced with timber and earth, so that they could support the weight needed to serve as gun platforms. For small arms, gunports in the walls replaced arrow slits; these were (in modern parlance) either "keyholes" for a fixed line of fire, or "letterbox" (slots) to permit aiming. The final touch would be the digging of a ditch (itself a potentially complex structure) about the perimeter of the structure.

Many early attempts at resisting bombardment sought chiefly to maximize the counteroffensive gunfire of the fortified structure.   The simplest way to achieve this, as executed in Germany (epitomized in works of Albrecht Dürer) and in Poland in the early 16^{th} century, was to equip a fortified structure with multistory roundel guntowers. Dürer's schemes usually included an enormous ditch about the perimeter, which contained isolated gunchambers ("casemates" or "capanati") that provided overlapping fire, further endangering the approach to the base of the walls of the fortified town. While the sight of a tower bristling with gun barrels must have been imposing, the approach was not without shortcomings. The concussion from guns fired in enclosed rooms was profoundly unpleasant, if not deafening, and the buildup of smoke unbearable. Ventilation networks and high ceilings helped somewhat, but a more effective method was to simply leave barbicans open at the rear. This had the advantage of making a seized barbican useless to the enemy—with the inner wall missing, he would be exposed to fire from the center of the tower. The Germanic school of fortification was adopted by Henry VIII of England, who built a number of forts of circular guntower design to guard his southern coast.

B) THE NEW ITALIAN SCHOOL OF FORTIFICATION

It was in Italy, however, in which the science of fortification developed most fully, and the system developed there by engineers in the great Renaissance tradition came to dominate military architecture for over two centuries. Several requirements to resist modern artillery had to be combined: a low vertical profile, to minimize target; a surrounding wall that was thick enough to withstand cannon fire and could serve as a gun platform; a ditch that would prevent the enemy from scaling the walls; and a way of directing fire to any part of the surrounding terrain. The latter requirement, the elimination of blind spots, was necessary to deter the enemy from reaching the wall, or having reached it, from erecting scaling ladders or penetrating it by sapping or placement of explosives.

The system which was developed, referred to in Italy as “in the modern style” or the “new Italian school” was characterized by two main features. The first was an elaborate earthwork on the perimeter, continuous with the wall itself, made up of a ditch and elevated sections using the excavated dirt. The wall itself was extremely thick, usually with a substantial earthwork component, and had a flat top with a parapet to serve as a gun platform; such a wall is called a “rampart”. The second, and most innovative component, was a unique design of low-lying gun-supporting bastions to eliminate any blind spots from the field of counteroffensive fire. This gave the distinctive outline called the “trace italienne”.

Collectively, these elements are also referred to as the rampart and bastion system. The efficacy of the trace italienne in the Italian wars between the Habsburgs and Valois led those powers to adopt it. It was employed by France (on its border with the Netherlands) by the 1530’s, and by Spain from 1543. The system gradually spread through Europe, reaching as far east as Poland by the 1620’s, while typically conservative England only half-heartedly toyed with the new fortification in the 1540’s and late 1580’s, not really adopting it until the mid-17th century.

1) Permanent Structures

a) The ditch

Several features and functions characterize the fully developed earthwork ditch of the Italian system. For one, the sheer depth helped provide the required low vertical profile of the fortified structure (whose base began at the bottom of the ditch) relative to the surrounding terrain. The enormous width of the ditch allowed it to be equipped with capanati, the previously mentioned gunchambers. The structure of the earthwork itself (and the rampart it abutted) consisted of several sloping surfaces and terraces; together, these provide protection from enemy fire, an obstacle to enemy crossings, and platforms for counteroffensive fire.

The ditch had two faces. The inner face, abutting the rampart, was referred to as the scarp. It was battered, i.e. sloped, which helped to provide additional strength to the base of the rampart. The extra mass of the scarp also allowed the construction of internal chambers, such as countermine shafts, passages to handgun embrasures, and sally ports. The opposite face was called the counterscarp. A sort of ledge at the top of the counterscarp, suggested by Niccolò Tartaglia (the famous writer on trajectories) in 1556 created a walkway which provided a covered position for small arms, which was called the “via coperta” (“covered way”). The protection of the via coperta came from the lip created by the glacis, a slope made of the excavated dirt (“spoil”) from the ditch. The glacis added height and depth of dirt which protected both the gunners on the via coperta, and the fortified structure itself. The ditch itself could be made even more difficult to traverse by filling it with stakes, thorns, and brushwood.

Two other defensive potentials of the ditch bear mention. For one, it made the work of enemy miners substantially more difficult. One approach used by the besiegers was to mine, or dig, under the ramparts. With a ditch in place, the depth of the mine shaft would have to be greater than that of the ditch. Secondly, in coastal terrain, or otherwise wet land (e.g. marshy, by a river, or close to the water table), a ditch could be filled with water. While not entirely without shortcomings (water could breed insects and putrefy in the summer, or freeze over in the winter) a wet ditch generally made assault far more complicated, effectively creating a moat which the besiegers would have to overcome, and could not mine under. The watery terrain of the Netherlands was one of the factors that made the Eighty Years War of Dutch independence so protracted and expensive (Ostend, for example, held out for three years).

b) Ramparts and bastions

The rampart, as we have already noted, had two chief requirements. One, that it be strong (by virtue of thickness, which can be enhanced by a backing of earth, the contraforti); and two, that it be deep, to provide a platform on which guns and personnel could be placed. The addition of a raised lip, or parapet, to the top of the rampart provided shielding for the area behind it, the terreplein, which served as a gun platform.

The majority of the guns, however, would be placed on bastions, either directly, or on elevated platforms called cavaliers. A bastion therefore needed to be large, stable, and strong, to support the weight of artillery. Since the curtain (wall or rampart between bastions) needed to be defended from sapping and explosives, flanking fire from the bastions was essential to prevent the enemy from remaining unmolested at the base of the wall. Therefore, bastions had to be placed frequently enough that the distance between them was less than the effective accurate range of the guns on them.

Medieval bastions were usually round. This was unsuitable for the use of artillery defense, because a round tower creates a blind spot at its salient, where gunfire from the flanking walls cannot reach. Nor is there a way to shoot down into the blind spot from the round bastion, since the cannon couldn't be depressed far enough, nor was the fit of a cannonball sufficient to retain it in the barrel if depressed. The blind spot, as described, created a vulnerable spot in which besiegers could work unmolested if they could reach it. The solution was to build a bastion which filled out the edges of the theoretical blind spot. This hallmark of the new Italian school, probably invented by the Sangallo family in the late 1480's, was the angle bastion.

The angle bastion, as well as meeting the fundamental needs of a gun platform, was ideally designed to provide fire along its flanking wall, right up to the salient (corner) of its companion angle bastion on the far end. It was also well designed to allow fire across the ditch, to attack the siegeworks of the enemy. The angle bastion had two distinct sections of wall, providing different lines of sight, for these two purposes. The more peripheral walls comprised the faces, which met at the salient. The guns situated on the faces had a clear line of fire across the ditch. The inner, shorter sections of wall, ideally at an acute angle to the curtain, comprised the flanks. The flanks provided a line of fire along the length of the curtain and the adjacent angle bastions. The salient itself ideally had an additional passive defense, the puntone, a thick, acutely angled work of masonry to resist sappers.

The angle bastion also increased the number of guns that could be mounted, by increasing the amount of perimeter of gun platform per area relative to round bastions. The idea was carried further with the double bastion, invented around 1535. The double bastion had four faces and flanks each, allowing more guns to be emplaced (assuming there was that much artillery available). A more straightforward development was that of the double tiered bastion, which had two stories, providing an interior gunplatform with ports in the face and flank to fire through.

While the slightly acute angle of the flank of the angle bastion provided some cover to the gunners, a far better defense was devised, again by the Sangallo family, in 1501 in the form of orrechione (literally "big ears"), earlobe shaped protrusions where the face met the flank. These allowed the flank guns to be recessed further, creating the "retired flank" which was protected from enemy fire until they were directly up against the curtain.

c) Outworks

A distinct and complimentary approach to the defense of a place was the use of outworks, free standing structures outside a fortified place, which could provide mutually supporting fire complicating the besieger's approach. The classic form of outwork is the ravelin, a chevron shaped structure (i.e. open on one end) devised in 1497 by the Genoese at Sarzanello, to cover the gateway to the town. The value of these positional tactics were recognized by military engineers, and expanded, with larger ravelins being built outside curtains and ditches, serving a similar role to the capanati built in ditches. The Imperialist garrison of Pavia, besieged by the French in 1524-1525, employed small circular earthworks outside the town with room for about a dozen arquebusiers each to provide supporting fire.

2) Semipermanent Structures

a) Earthworks

Fortification was an expensive process— the cost of a single bastion was equivalent to a year's wage for 100 Imperial pikemen (or enough to support 400 peasant families). Consequently, many towns were only provided with more modern defenses under the threat of impending siege, when the citizenry would be forced by necessity to mobilize as labor teams. Under such conditions, time and materials prohibited the construction of extensive masonry works. Most of these steps were similar to those described for the retrofitting of medieval structures, e.g. digging a ditch and making a glacis from the spoil, creating contraforti, scarping walls, lowering towers, etc. An additional act of emergency demolition was the destruction of houses outside the city wall, which could provide shelter to the besiegers. The rapid construction of casemates or ravelins, however crude, could also provide an additional layer of defense.

Properly prepared earthworks could provide as much resistance to artillery as could stone walls. Dirt straight out of the ground would not suffice, though. Earth had to be sifted to remove rocks, as it was discovered that when unsifted earth was hit with cannon balls, the rock would turn into secondary, perfectly lethal projectiles. Nor was merely shoveling the sifted dirt into piles sufficient. Zitolo da Perugia, a bastion commander in Padua in 1509, had his arm severed by a ball that had penetrated 30 feet of loose earth parapet. The 16th century military engineer Francesco de Marchi performed tests on consolidated (manually pile-driven) earth, and found that 20 feet of densely packed earth would stop the heaviest iron balls at 100 paces. For this reason, it made good economic sense to combine masonry and earthworks in wall construction. Masonry ramparts actually were made of retaining walls of brick or stone, with some combination of earth, rubble, and mortar between them.

A compromise solution between durability and expense was the construction of semipermanent composite earthworks. Such works, as described by the engineer Giovanni Belluzzi, began with a timber framework of uprights driven into a foundation pit. Fascines (bundles of sticks) tied to the uprights made the front and rear retaining walls. These were filled with layers of stipe (brushwood) and sifted earth, pile-driven, interspersed with layers of clay to provide some waterproofing. Every few feet a layer of timber in a lattice would provide some stiffness. An outer vertical layer of piled slices of turf served as protection for the faces of the retaining walls against the weather. Finally, the deck would be created from a layer of fascines, covered over with well-rammed clay or mud. In wet terrain, or otherwise when a wet ditch would be created, a masonry (water-resistant) base would be required, but semipermanent ramparts of the type described would be built atop them. With maintenance, these composite earthen ramparts would last for years, and provided excellent resistance to shot. Some writers even considered these types of ramparts superior to masonry, as they wouldn't fragment into shrapnel when hit.

b) Gabions and grati

Smaller structures, also built of earth and sticks, are the ubiquitous gabions and grati. Gabions were large woven structures, basically wicker baskets, filled with earth. Gabions provided free-standing, relatively quickly built protection against fire. They were used by besiegers and besieged alike, to protect gun emplacements, to construct parapets, or to provide cover during the slow approach to the curtain. Grati were simply woven screens. While not providing any resistance to shot, they concealed movement, actions, and location of personnel so that enemy snipers wouldn't know where to direct their fire.

c) Natural features

In addition to all these man-made structures, naturally occurring features could provide some of the best defenses. Fortifications (and indeed the choice of location of a town or keep itself) took into account the lay of the land. Mountainous terrain could naturally close off several directions of approach to the structure. The merit of marshy land, with a water table close to the surface has already been discussed. Another related feature (which also worked in the favor of the Dutch) is the presence of waterways. A town or keep built against a river, or better still on a coastline, could be more easily relieved by friendly troops (with military aid and/or provisions), and a body of water on one side made that side harder to assail.

C) GAINING A FORTIFIED PLACE (CONDUCTING A SIEGE)

Gaining a well-prepared fortified place was an expensive and tedious process. Given the immature logistics of the period, an army was slow to assemble and mobilize, and an artillery train often lagged behind the infantry and cavalry, frequently arriving over the course of days, and not always at the same time as the powder and shot. Blaise de Monluc warned the Duke of Anjou of the perils of delay before the siege of La Rochelle in 1573: "… if the besieger proceeds slowly in his preparations for a prompt and diligent attack, having failed to execute the necessary groundwork, the besieged gains the time to make himself twice as strong as he was beforehand in the part attacked." In fact, the siege failed in part because the artillery and its materiel straggled in "at a snail's pace" as Anjou complained to his brother the king.

1) Intimidation, deception, and bribery

The fastest and cheapest way to gain a fortified place was by its surrender. Sometimes a show of force was all that was required. If the morale of the inhabitants was high, or the defenses adequate, the option existed of obtaining entry or surrender through a combination of bribery and deceit. The Spanish were able to win several forts in the Eighty Years War by simply bribing the garrisons. In 1578, the Protestant Dutch rebels were able to gain entry to, and seize Ypres from the Spanish by the ruse of a wagon led by a groom and a suspiciously hairy bride, which "broke down" at the gate.

2) Starvation

When a formal siege was required, either of two outcomes were in the mind of the besiegers. If the place could be cut off from relief, eventually starvation would force a surrender. Aiming for starvation was preferred if the inhabitants and structure were desired to be gained with minimal damage. This was certainly Henri IV's motivation when he tried to gain Rouen and Paris during 1591-1592 in the turbulent early years of his reign. If relief did not come soon enough, all that could be done was to extend the food supply by rationing, or taking the more drastic step of expelling "useless mouths", i.e. the weak, elderly, and any who were not helping with the active defense. Both were steps that Monluc ordered in the siege of Siena. Before the duke of Parma relieved Paris from Henri IV, the populace was reduced to eating rats, insects, shoes, and (it was rumored) their own dead.

3) Assault

Typically, though, an attempt was made to gain a place by force, if deception had failed or was not an option. If a place capitulated from lack of morale or provisions in the course of the siege, that was just as well, but there was always the hope (rarely realized) of winning a place rapidly by assault. Taking a place by force involved two main techniques: bombardment and mining, and less commonly, sapping or planting explosives against the walls, or simple escalade.

a) Bombardment

i) Making the breach

Once the new Italian model of fortification had spread, the blitzkrieg success of Charles VIII's artillery train in Italy in 1494-1495 could no longer be hoped for. A successful assault often took months, and was enormously expensive. The Duke of Guise estimated in 1524 that to take a fortress of any strength required twenty-four heavy cannon, six or seven powerful culverins, eight or ten thousand shot, and 200,000 pounds of powder. Beyond these basic materials, one must also consider the number of pack animals, pioneers (laborers), and craftsmen required to simply transport and maintain the guns and carriages.

While a siege train could destroy approximately 120 feet of medieval wall in a day, against a modern masonry or earthwork wall an estimated 7,000 to 15,000 balls were needed for a single breach. And, as we shall see, a single breach was generally insufficient. When we compare this to the estimated firing rates of artillery discussed previously, and the size of a typical siege train, around ten to thirty guns, we can estimate an idealized fire of around 500 to 1000 shots per day from a battery of heavy siege guns. In extraordinary cases this could be exceeded, as when 3000 shots were fired in one day at the 1573 siege of La Rochelle, in a major bombardment preparatory to an assault. To attain multiple breaches would therefore require an adequately supplied average train about one to two weeks of constant fire to obtain a minimum of two breaches in up to date fortifications.

Rarely was any such train so well supplied, and there was more to a siege than just setting up the guns and making the breaches. If a place was sufficiently countersunk, the counterscarp of the ditch would have to be dug away just to get a line of fire at the ramparts, as was the case in the Turkish siege of Fort St. Elmo on Malta in 1565. Sieges typically ran far longer than any theoretical ideal. The fairly conventional siege of Montalcino, a town whose fortifications were incomplete at the time that it was besieged, ran for two and a half months. A well-prepared place, especially one on water, could hold out far longer. The Huguenot coastal stronghold of La Rochelle was under formal siege in 1573 for four months (seven, counting the initial land blockade). During that time, the royal French besieging army conducted some eight major assaults, detonated six mines, fired 25,000 cannon rounds over five months of bombardment, suffered some 5,000 to 10,000 casualties, maintained both land and sea blockades, and carried out extensive sapping following the digging of approach trenches—and finally failed, suing for peace. The supreme resistance to siege, though, was that of the Dutch city of Ostend, which held out against the Spanish for over three years, thanks to modern fortifications and occasional naval relief.

Multiple breaches were required, for one, because in addition to the main breach in the curtain, breaches would be required in the flanking bastions to silence enfilading fire which would decimate the party storming the main breach. Even at that, with a single point of attack, the defenders could concentrate their forces to repel the attackers. The ideal was therefore to have at least two points of attack, or feints at multiple points with one real attack, in order to divide the defenders' forces. The Spanish used a ploy in Flanders to achieve such an objective, by sending men on horseback to circle the perimeter of a town during an attack, shouting that various gates had been breached.

Making the breach was not just a matter of blasting away at a general area. Precise aiming was involved in directing the fire of siege guns. The earlier of two main techniques of making a breach was "chipping", in which the guns were trained at the top of the rampart, and the wall was gradually whittled down to the ground. The more sophisticated technique of "cutting" exploited the method of construction of masonry ramparts. Cutting involved directing fire so as to score a horizontal line one third of the way up the face of the retaining wall. The masonry skin would collapse from above, and the earth and rubble would, ideally, spill out to form an entrance ramp for the attackers.

ii) Storming the breach

Once the breach was made, and the assault begun, the danger to the attackers was enormous. This is because the attackers found themselves in the most unenviable of offensive configurations, i.e. the attack of a defile. In other words, they could only present a front as wide as the breach, while the forces of the defenders would be arrayed inside with weapons aimed at the breach. The odds were even greater in favor of the defenders if they had the time to build a concave retrenchment of the type known as a retirata, or "double Pisan rampart". The retirata was apparently first built in 1500 during the siege of Pisa by French troops sent to aid Florence (from whom Pisa had seceded). When the French breached the rampart of Pisa, they found a trench behind it, backed by yet another rampart. The idea became well-known, and was used throughout the century in sieges in Italy, France, Metz, and the Netherlands. Behind the parapet of the retirata, and in the windows of surrounding houses, would be the defenders, who would be waiting to fire on the attackers with small arms and swivel guns, at ranges that made armor of little use. The weapons would include artillery loaded with scattershot, such as chains, nails, and pikeheads. As the attackers entered the waiting ditch, there was the opportunity to fill it with scalding oil or molten lead. The men who stormed a breach backed with a retirata were effectively fish in a barrel.

b) Mining and countermining

Complimentary to the technique of bombardment in which an attempt was made to blast through or cut down walls, was that of mining. The idea behind the 16th century mine was to dig a shaft starting from a safe position, which terminated under the curtain. Explosives would be placed in the shaft under the curtain, which, when detonated, would blast away the supporting ground, causing the wall to come crashing down. The first known successful explosive mine dates to 1495, when Francesco di Georgio Martini drove a shaft beneath Castel Nuovo in Naples, and packed it with barrels of powder. The explosion dropped a section of the barbican, killing and dismembering French soldiers atop it. The explosive mine quickly became a common feature of siege warfare. One mine still survives, at St. Andrew's Castle in Scotland, from 1546-1547. The digging stopped when the wall was breached by bombardment. The shaft is 1.8 meters wide by 2.1 m high, tall enough to admit ponies.

To be effective, the mine had to be positioned correctly. There is reason to believe that a mine in the siege of Montalcino fell short of the rampart, because when it exploded, it failed to harm the wall, but rather caused rubble to fly out of the ground and strike the besiegers. Even if dug to the right location, explosive mines were not always effective. According to Guicciardini, the detonation of a mine in Bologna in 1512 lifted a wall and chapel into the air so that the attackers could see the city and the defending soldiers, but the wall fell back down into place "with all its parts as firmly connected as if it had never moved".

The explosive mine was also used by the besieged. They, too, could dig a shaft under their walls, with the intention of placing explosives under their attackers, especially under their artillery batteries. A more common reason for defenders to dig a shaft was for countermining. The countermine was intended to intersect an attacker's mine. The usual intent was to send in a raiding party, to kill the miners if necessary, but whose ultimate goal was to collapse the mine with a powder charge placed behind sandbags at a suitable distance from the wall, rendering the mine useless. If destroying the mine was not an option, then the countermine would be ventilated to the surface, and intersected with the enemy's mine. This was intended to take the force out of the mine's explosion by venting the expanding gases, thereby saving the rampart. Sophisticated surveillance shafts were part of highly developed countermines. During a siege, a listener would be kept on duty therein, using such detection equipment as an ear trumpet, or a drum with pebbles on its head to detect vibrations.

c) Approach to the wall

The third approach to destroying a wall, after bombardment and mining, was to reach the wall and attempt to break through it by sapping or the use of explosives, or climb over it. This added the peril of having to approach the besieged place under constant counteroffensive fire. Such a party was far more vulnerable to sniper fire than were gunners operating siege guns. The approach was usually conducted by laboriously digging a trench toward the walls, sometimes erecting a parapet of gabions with the spoil to provide extra shielding to the approach party. The attackers stood the risk of being counterattacked by a sortie of the besieged, which would result in fighting in the trenches. This sort of early trench warfare occurred in the siege of Thionville in 1558. Blaise de Monluc devised a method to provide reinforcements in case of such a counterattack, that came to be known as the arriére-coin ("back corner" i.e. redoubt). In his words, "At every twenty paces I made a back corner, or return, winding sometimes to the left hand and sometimes to the right, which I made so large that there was room for twelve or fifteen soldiers with their arquebuses and halberds. And this I did to the end that should the enemy gain the head of the trench and should leap into it, those in the back corner might fight them…"

i) Sapping

Once a party succeeded in reaching the walls, they could attempt the slow, laborious process of breaking through the curtain with rams, picks, and shovels, known as sapping. The methods of sapping changed little since the middle ages, nor had the risks to the sappers: defenders atop the ramparts employing such medieval favorites as boiling water, quicklime, and oil poured from above, as well as the perennial large object dropped on one's head. A surprising number of deaths during 16th century sieges are attributed on casualty rosters to "rocks". To this panoply were added devices of the age of gunpowder, namely incendiaries and grenades.

ii) Planting explosives

A potentially faster, through rarely successful alternate approach was to try to blow a hole in the wall using explosives. Having reached the wall, the approach party had to place the explosives, light the fuse, and flee to safety, while facing the same dangers that sappers would. It seems probable that sapping was preferred to explosives for creating a breach due to the difficulty of creating and directing enough force with bombs to break through a thick rampart.

One relatively sophisticated device for directing the force of an explosion was the petard. It was able to blast through thin walls, or more commonly through the timbers of gates. The petard was in the shape of a bronze bell, filled with fine powder, which was closed off by an iron-bound beam with screws, chain, or rope. Once propped up against its target, the fuse was lit, and the ensuing blast would blow the beam through the gate or wall. If the fuse was too short, the petardier was in danger of the explosion, hence the expression "hoisted on his own petard".

iii) Escalade

A final approach, common in the middle ages but much less so in the 16th century, was escalade, or climbing over the walls with scaffolding or ladders. At the end of the siege of Montalcino, bombardment and mining having failed, the attackers built a sort of siege tower, which was met with hastily constructed towers by the defenders, leading to fighting over the walls from scaffolding. Beyond the great risk to the assaulting party (who would be subjected to all the aforementioned substances and objects being dropped upon them, as well as having their ladders simply pushed away) all could come to naught if their ladders were not of the correct length. The English found this the hard way at Leith in 1560, when they apparently used ladders built to the height of the wall, "but not from that parte of the ground where the ladders were faine to stand".

d) Antipersonnel measures

While siege guns (i.e. the heaviest of cannon and culverins) were the main weapons of bombardment, other weapons were used by the besiegers, and by the besieged for counteroffensive measures. Besiegers could use mortars to lob shot, including explosive shells, at high trajectories over walls to demoralize the inhabitants. One more bizarre weapon that was deployed against the Sienese was swarms of bees, probably by lobbing beehives over the walls.

Weapons used to defend besieged places, beyond the various heavy and medium artillery pieces situated on the bastions and possibly on the ramparts, were mostly light swivel gun pieces, such as the previously described moschetti and archibugi della mura. If the place was inadequately supplied with guns, a single use weapon called the "tromba di fuoca" could serve. To make it, one split a log in half, reamed out the inside to make a crude barrel, and lashed it back together. It was then loaded with powder and scattershot, such as gravel, and used as a sort of shotgun.

Throughout bombardment, mining, and approach of the walls, small arms fire would be exchanged, as snipers on either side tried to pick off individual targets. The besiegers would thereby try to discourage the besieged from repairing damage to the walls, while the besieged would try to prevent their attackers from moving closer or from emplacing or firing artillery. The besieged would frequently make skirmishing sorties through "sally ports", to destroy or capture enemy powder stores or other provisions, to wreck protective screens, and so forth, as well as to pass correspondence in the hope of securing relief from allies.

4) Preventing relief

a) Land: siege lines

Preventing a successful relief was a major concern of the besieging forces. Months of work could be undone by the approach of a field army. Such an approach might force a withdrawal, which could be preferable to risking the loss of an expensive siege train. The siege of Pavia represents an early attempt to control the access to a besieged area, where the French stationed detachments of forces at various points by rivers and walls around the city. The very fact that these forces were dispersed beyond the ability to coordinate them contributed greatly to the disastrous French defeat by a relieving Imperial army. A superior method, which provided a greater degree of control, was the classically suggested method of "siege lines", or lines of circumvallation and contravallation.

Siege lines were obstacles of whatever construction (earth, fences, and wagons were all used) intended to do two things: to keep the besieged in (lines of contravallation) and to keep relief out (lines of circumvallation). Ideally, these lines would be concentric, encircling the besieged place. The area between them would be firmly controlled by the besiegers, who would direct force inward toward the fortified place from the lines of contravallation, and outward toward any relieving force, from the lines of circumvallation.

Probably the earliest use of siege lines in the 16^{th} century was during the siege of Milan in 1522 by Imperial forces under Propero Colonna. When the French under Lautrec attempted to relieve Milan, Colonna erected a false line of contravallation of snow to deceive the Milan garrison and prevent them from sortying, while he connected various strong points with a line of earthworks to keep Lautrec out.

Siege lines could include a variety of features, including preexisting structures. One such example is the siege lines created by Chiappino Vitelli, a military engineer in the service of the Spanish Duke of Alva. In 1572, during the siege of Mons in the Netherlands, the Prince of Orange arrived with German mercenaries in a relief attempt. Vitelli confounded their approach with lines of circumvallation connecting earthen forts with both banks and ditches.

b) Water: blockade bridges and naval blockade

Lines of circumvallation and contravallation could be extremely problematic when bodies of water were present. We have already alluded to the relief by water of places in such country. If relief by river was to be prevented, the river would have to be diverted by damming it (as was unsuccessfully attempted at Pavia) or otherwise blockaded. The most common way of doing so was with a blockade bridge, made of pontoon boats lashed together, stretching from one bank to the other. This is the method which the French had to settle for at Pavia. The Duke of Parma finally succeeded in his siege of Antwerp after he managed, in 1585, to construct a blockade bridge 1000 yards long across the Scheldt river, thereby closing off military relief efforts by Dutch naval forces. The blockade bridge was spectacularly damaged by the fireships of Federigo Giambelli, a disgruntled Mantuan engineer who had moved to Antwerp after repeated rejections by the officers of Philip II. Giambelli loaded two ships with about 7000 pounds of powder, masonry, gravestones, stone shot, scrap iron, beams, and bricks. These were ignited and let go on ebb tide to float into Parma's blockade bridge. One of them reached the bridge, destroying half of it and killing 800 Spanish soldiers in the explosion. Unfortunately for the Dutch, Parma had the blockade bridge rebuilt before relief efforts arrived.

Fortified places built on a coastline were the easiest to relieve by ship, and therefore the hardest to blockade. The only available option was to maintain a constant naval blockade by stationing a flotilla of warships off the coastline. This costly measure was required in 1573 in one of the several sieges by the French crown of the Protestant fortress of La Rochelle, on the southwest coast of France.

THE REASCENTION OF FORTIFICATION AND THE WANING OF OPEN BATTLES

As the science of fortification matured, the taking of a fortified place became progressively more expensive and tedious. Don Bernardino de Mendoza wrote in 1597 that fortified places fell "through want of men, powder, artillery, munition, and victuals" rather than through a successful assault. It is true that siegecraft coevolved with fortification. In a process continuing well into the 18^{th} century, siege warfare became an exercise in geometry. It was eventually possible to more or less neatly calculate the number and pattern of ditches to be dug for siege lines and approach trenches, the powder and shot needed for bombardment, and so on. The time and manpower required for these massive excavations were in large part responsible for the associated costs, and were only possible with the increasing size of armies that began in the 16^{th} century.

Conventional wisdom held that a high prevalence of fortified places in a country made conquering that country too slow and too expensive to be possible. Monluc held, and rightly so, that the number of fortified towns in France ensured the kingdom could not be conquered, even if Paris itself was taken: "There are so many other towns and places in this kingdom, which would suffice to absorb thirty armies, that it would be easy to recover and drive them back out of one before they had taken more, if the conqueror did not wish to depopulate his kingdom to populate his conquest."

Grand field engagements on the scale of those of the Italian Wars were little seen by the end of the century. As armor has always improved with the development of new weaponry, fortification evolved to meet the challenge of artillery. In the middle ages, much of the immediate goal of war was the taking of castles, from which the countryside could be controlled. Thus by the close of the 16th century, with the emphasis again on the control of fortified places, the complexion of conflict resumed in a sense its status quo. The enormously elevated costs of the new technology and tactics, however, made a war of conquest prohibitively expensive. Such wars would be fought, increasingly, not on the battlefields of Europe, but abroad.

III) NAVAL WARFARE

A) THE NATURE OF NAVIES IN THE 16TH CENTURY

National navies, like national armies, were distinctly underdeveloped in terms of materiel and organization in most countries throughout the 16th century. This is not to say that warships were unknown. At the beginning of the century, the Portuguese led in experience with gun-armed warships, commissioned by King João II for trade to West Africa and the islands of the Indian Ocean. The Nordic powers were fighting wars in the Baltic with gun-armed warships by 1509, and great ships of war were used in Brittany, France, England, and Scotland.

Many of these "warships" which saw service in naval conflicts were in fact gun armed merchantmen, in the hands of private citizens. It was the rule for the crown of a sea-going nation to charter or conscript these armed ships in time of need. This was the case even as late as the English defense against the Spanish Armada in 1588, when Elizabeth needed to augment the royal naval fleet, which was fairly sizable by the standards of its day. Spain, prior to 1560, tried to promote the manufacture of armed large merchantmen that it could charter as needed by granting trade monopolies to merchants that owned them. The one notably well-equipped and organized navy of its day was that of Mediterranean style war galleys led by the Admiral Andrea Doria of Genoa (and later, his grandson Gian Andrea Doria). Even this fleet was not a national navy, but rather up for hire. The elder Doria in fact switched sides from French to Imperial employ in 1528.

The existence of such a fleet can be attributed to the Genoese and Venetian dominance of Mediterranean maritime trade at the beginning of the century. The English, French, and Spanish would buy or hire Mediterranean armed merchant galleys as needed. By the end of the century, the shift of trade and naval power and technology was to the North Atlantic sailing ships of the English and Dutch galleons and fluyts, merchantmen with cheap and reliable cast iron guns. They used these in trade to the Indies and Americas to protect themselves from (and prey upon) Iberian ships, who built the same to protect themselves from privateers. The escalation in armed merchantmen provided additional resources to the governments in time of war.

Attitudes toward the worthiness of service at sea varied from country to country, and retarded progress toward the development of a navally-trained officer core in many cases. In the Mediterranean, being a sea officer was seen as a valid career from the 15th century. While Italians, French, and Spaniards of low birth might all serve as entrepreneurial galley captains, it was only in the coastal Italian states that the profession seems to have been respected. Denmark-Norway had sea officers only from the 1560's, which was only formalized in the 17th century. The captains of the English Navy were a hodgepodge of lowborn shipmasters and armed merchants, and gentlemen with or without naval experience. The Dutch Navy was almost entirely non-noble, made up of armed merchants or privateers (such as the famous Sea Dogs).

Spanish seamen seem to have been held in especially low social esteem, because of the noble Castilian disdain for any occupation involving labor. Throughout the century, it was usual to have two chief officers on each Spanish ship, one noble infantry captain, and one lowborn ship's captain. Yet the Spanish normally awarded the prestigious title of Admiral to a nobleman with extensive maritime experience (the Duke of Medina Sedonia being a notable exception). Little is known of the French navy, which essentially dissolved during the Wars of Religion, but similar social forces seem to have been at work.

With respect to the rank and file, the Dutch seem to have been the only country to always have a ready number of seamen for hire. England and Scandinavia often resorted to conscription (although this was usually semi-voluntary, as militia forces). Spain and Portugal would hire merchants as needed. The Venetians, if they could not hire rowers, would resort to prisoner labor gangs, prisoners of war, and slaves (although the latter was a rare last resort).

Galley based naval forces evolved chiefly in Genoa (under Doria) and Venice. Sailing warship based navies developed in five countries in the late 15th to early 16th century. Four of the five based their navies out of cities that were both the center of the state government and maritime commerce. These were: Portugal (Lisbon), England (London), Sweden (Stockholm), and Denmark-Norway (Copenhagen). The fifth, France, split its navy among four admiralties: Brittany (originally a sovereign duchy, which provided the basis of the French navy), Normandy, and Guienne, which comprised the three Atlantic admiralties, and Provence (the Mediterranean admiralty). Prior to the 1560's Spain relied on maritime fleets for naval force in war, and lacked a permanent national navy of Atlantic sailing ships. It was not until 1580 that Spain acquired a significant sailing fleet (and base of shipbuilders), when Philip II assumed the title of King of Portugal and the Portuguese naval resources with it. The latest arrival was the Dutch navy, which emerged in the 1570's. The income from trade served the Dutch state well, which built, manned, and serviced its own warships, unlike the usual course of chartering private ships. Thus national fleets did evolve throughout the course of the century, chiefly among the Atlantic coastal powers, and in large part driven by foreign trade.

B) THE ROLE OF NAVAL FORCE IN MILITARY OPERATIONS

The primary objective of navies in the 16th century was rarely that of war at sea per se; the battle of Lepanto represents a nearly solitary example (outside of the Baltic at any rate) in which two major fleets met at sea, with one (the "Holy League" of Venice, Spain, the Papal state, and Malta) having as its sole intention the obliteration of the other (the Ottoman fleet).

The genesis of many of the warships of the day was in the control of trade by merchants. This role expanded and was adopted by national armed fleets involved in protecting state-controlled trade. The ocean-going galleons of Spain and caravels of Portugal are prime examples of this chiefly passive, defensive function. Control of shipping lines could be an economic means unto itself; Brittany derived approximately half its income in the late fifteenth century through the sale of shipping protection.

The control of shipping lines by warships also had immediate military value. When Andrea Doria contracted to Charles V in 1528, he greatly facilitated the transport of troops and materiel among the various parts of Charles' empire. Doria's fleet enabled Imperial control of sea communication from Spain to northern Italy, and thence to Austria, Germany, and the Netherlands along the so-called Spanish Road.

The second defensive role in which naval force was employed was that of coastal defense, i.e. protection against raids and invasions. The possession of a fleet of warships changed the response of a country to invasion by sea. If the defenders had a weak army, it would be to their advantage to try to defeat the enemy before it could land and deploy superior infantry (which would have been England's situation had the Spanish Armada succeeded in rendezvousing and embarking with the Army of Flanders). Without warships, a weaker country might prefer to keep its army on land in fortified places. A fleet of warships also served as a vital defense and deterrent against attacks on coastal towns. Recall that the naval centers of several countries were also centers of commerce and government, and therefore prime targets for naval assault.

The real masters of coastal defense in the 16th century were unquestionably the Ottomans. They combined coastal fortresses with galley fleets to create a nearly unassailable defense. These well-fortified fortresses would be located on the inland face of channel or gulf, which effectively forced hostile ships to funnel through a defile. The shores of such a channel, or entrance to a gulf, would be strengthened with gun emplacements that subjected the enemy to a gauntlet of heavy artillery. Meanwhile, under the cover of the artillery, highly mobile gun-armed galleys could sally out to meet and harass the enemy. If the enemy attacked the shore emplacements, he would be subjected to a flank attack by the galleys, and vice versa. This is the situation that prevailed in the fruitless attempts by the Portuguese on Jiddah in 1517, and by the Venetians on Prevesa in 1538.

Throughout the 16th century, the main offensive role of warships was as a component of amphibious assault. In this case, the chief objective of the navy was usually to disembark an invading force of infantry. The combat role of the warships would be limited to resisting (or eliminating) the defender's fleet as it strove to prevent the enemy from coming ashore. There are a number of examples of such attempts, mainly unsuccessful (owing to the logistical complexity of amphibious assault): several attempted English invasions of France by Henry VIII (Guienne in 1511 when they helped the Spanish to take Navarre; Brittany in 1513; via Calais in 1522 and 1523; and Boulogne in

1544), by France on England in 1545, by Spain on England in 1588, and by the Turks on Malta in 1565 and Venetian-held Cyprus during 1570-1571.

An alternate supporting function that a navy could provide to an invading land force was the delivery of provisions, including a siege train. This was a necessary step in Charles VIII's invasion of Naples in 1494. It would have been impossible to transport his siege guns over the Alps, and so he had his navy ship them to La Spezia while his army took the land route. This was also one of the duties of the Spanish Armada, which carried a siege train that was to be used by the Army of Flanders (who were meant to travel to England aboard barges under escort of the Armada).

Navies could also be employed in supporting roles to prevent (or attempt) the relief of besieged coastal places, as we have discussed previously, or to prevent the dispatch of troops by ship to counter an invasion attempt. The latter case may be exemplified by the Genoese naval blockade of Marseilles in 1524, which was meant to protect the invasion of Provence by Imperial forces led by the traitorous Constable de Bourbon.

A final and clearly offensive, albeit rare supporting role that could be played by a navy in an assault by infantry is that of coastal bombardment. Gun armed warships offshore of a coastal battle could provide devastating enfilade fire on enemy troops on land. This was provided by English warships firing on Scottish archers and pikemen at Pinkie in 1547 and on Landsknecht pikemen in French employ at Gravelines in 1548. Similarly, Dutch troops at the coastal battle of Nieuwpoort in 1600 received needed relief when Dutch men-at-war arrived and fired on the flank of arrayed Spanish troops, forcing them to break order and retreat from their chosen ground.

These are the grand tactical applications and potentials of the warships of the 16th century. To examine the technology of these ships in detail is an enormously complex undertaking. In the remainder of this paper, we will briefly examine the structures of these ships with regard to their effect on combat potential; on the armaments employed by ships and crew; and on the tactics of combat at sea.

In order to do so, we will successively examine two European theaters of naval warfare, which developed along distinct technological and tactical lines: the Mediterranean, dominated by the oar-propelled galley; and the North Atlantic, which supplanted the galley with the full-rigged sailing warship.

C) MEDITERRANEAN NAVAL WARFARE

The waters of the Mediterranean are, on the whole, relatively shallow and gentle, with light winds the norm. The coastlines for the most part gently slope into the water, without abrupt dropoffs or treacherous rock formations. These features permitted and encouraged shallow-drafted oar-propelled vessels of the galley type. Specific classes of warships of these types include the galley (with at least 130 oarsmen, usually 144, rarely up to 200; and between 80 and 300 soldiers), and its smaller cousins: the galiot (about 80 oarsmen and 60 soldiers), fusta (about 60 oarsmen and 30 soldiers), and the tiny bergantin (with only about 20 men total). To provide typical dimensions, the Venetian galleys at the Battle of Lepanto (1571) were 135 feet long by 23 feet wide (a slender 6:1 ratio). The galley was the standard warship of the 16th century for Mediterranean powers, of both Christian (mainly Italian) states and the Ottoman Empire.

A related vessel to the galley is the galleass, an enormous hybrid of oar and sail propulsion, derived from the merchant galley. It required over 300 men to row, and was slower under oar, though faster under sail, than the galley. The galeasses at Lepanto measured 160 feet by 40 feet (stouter than galleys, at 4:1).

Where still or light wind is common, the oar is a more reliable means of propulsion than the sail. Galleys do in fact have one or two sails, which provide some auxiliary propulsion. These are lateen sails, meaning that they are shaped like a right triangle. This shape is better than a square sail for sailing close to the wind, but the lateen can be more unstable with a strong backing wind. Before a battle the crew of a war galley would stow the mast, yard, and sail, relying rather on the much greater maneuverability provided by the rowing crew. The crew was situated on benches on deck, with a narrow aisle between them.

Shallow coastal waters and gentle shores mean that ships can typically be landed easily, without needing a dock. The shallow draft and low bulwark of the galley allows the crew to come ashore easily, rowing right up onto beaches and easily disembarking. Such a design is ideally suited to amphibious warfare. It has the added benefit of lowering the weight of the ship (essential given that human muscle provides most of the motive force). The low vertical profile of the galley makes the ship less of a target, and therefore harder to puncture, but it has the drawback of making the galley much easier to board by enemy troops. This feature of the galley is fundamentally insurmountable; if the deck is elevated, the oars must be lengthened to reach the water, and eventually they become too long for the crew to row.

Maneuverability and independence from reliability on wind represent two great advantages over sail-propelled vessels. The reliance upon human power, with the dietary demands of a large hard-worked crew, meant that the galley was quite limited in its range. Coupled to the increased number of mouths to feed was the need to minimize the weight of the ship, and therefore the amount of rations it could carry. The more men on board, the worse this factor became, especially in ships crammed full of unusual numbers of fighting men.

These design characteristics define both the strengths and weaknesses of galleys and related vessels, and the tactics which can be applied to their uses in war. To summarize, such ships are best suited to coastal amphibious warfare, of short range and/or duration; they are highly maneuverable; and they are susceptible to boarding.

We have discussed the use of galleys in coastal warfare in the context of European attempts on Ottoman coastal fortifications (at Jiddah and Prevesa). The variety of purposes of amphibious assault have also already been described: relief, or prevention of relief, of a besieged coastal place; and delivering or preventing the delivery of an assault force on a limited coastal target, or of a full-scale invasion force to take an entire island. These are roles to which galley fleets are well-suited, and which they played most commonly in the conflicts between the Ottoman Empire and Christian powers on the North African coast and various islands of the Mediterranean (such as Malta, Corfu, Rhodes, and Cyprus). We will therefore focus for the remainder on the technology and tactics of naval combat between galley fleets.

The galley has been described with good reason as an oar-propelled infantry platform. Since its earliest times, the war galley was furnished with infantrymen. The usual goal was to deliver the infantry to a coastal destination. However, if the fleet was met at sea, as by the enemy who would try to prevent their landing, then the low bulwark facilitated boarding actions. The goal was for the ships to come into contact, so that hand to hand fighting could begin on deck. Even after shipborne cannon became commonplace, boarding remained the preferred tactic, as will be seen.

This assault would be preceded by a flurry of missile attacks. By the 16th century, firearms were widely employed by both Christians and Muslims. The arquebus was the most commonly employed of small arms, but Spanish galley troops might include musketeers (who could penetrate even the thickest wooden pavises). While Europeans abandoned the crossbow early in the century, the Ottomans continued to use the recurve bow through Lepanto. Its superior rate of fire and accuracy in the hands of a skilled archer made it a viable weapon, even though the infantry of the Spanish and their allies generally wore reasonably good armor. Such armor was somewhat lightened relative to the normal harness, owing to the possible need to leap from ship to ship; the Venetians and Turks, however were generally more lightly armored as a rule. Once the ships had met, and boarding begun, the battle was waged for the most part as a hand to hand melee, being too cramped for any order to prevail. The shorter weapons prevailed, including one-handed swords (with shields), moderately long pole arms and “half-pikes”, and the occasional two-handed sword, as well as continuing small arms fire.

Galleys possessed two structures designed to facilitate boarding: the spur (sometimes called the “beak”) and the arrumbada. The spur is an ironshod protrusion from the bow of the galley, usually slightly angled upward. The goal was to charge the flank of an enemy ship, thereby lodging the spur among the rowing banks, so that it would ride up over their central aisle. The spur was sufficiently sturdy that it could penetrate light upper planking of bulwarks. It was flat on top, so that the boarding party could use it as a bridge. The arrumbada is a platform immediately behind the spur, on which the boarding party would muster, so that they could storm over the spur as soon as the ships collided. It also served as a gunning platform, as we will shall see.

The proliferation of artillery in the 16th century in no way displaced boarding tactics in galley warfare. If anything, it augmented them. Protracted gun battles at a distance were never feasible in galleys. The reason for this is two-fold. For one, the inaccuracy of period artillery meant that their maximum feasible range on a moving ship was on the order of 200-300 yards. A galley at top speed covered approximately 200 yds/min. Given the necessary reloading time, this meant that an enemy could close and board after only one volley. It was therefore seen as an advantage to hold fire until at close range, so that the shot would be sure to land, and that a single shot would do the maximum damage (deaths of up to 40 men from one ball are recorded). The second limiting factor is in the design of the galley itself. Given the narrowness of the galley layout and premium on space, the only place to mount artillery was on the centerline, on the aisle between the rowing benches; the guns had no room to traverse (aim from side to side). Moreover, since the stern of the galley was occupied with the rudder, command post, and any signaling equipment, guns could only be placed on the bow. This made aiming the guns identical with aiming the ship. Given these two factors, the inevitable course was to attempt to ram, and immediately before doing so, releasing a "boarding volley" with the inline guns. This boarding volley would hopefully cause so much damage to the enemy that the boarding party, waiting on the arrumbada, could storm across the spur before survivors could rally against them.

The armament of galley by the 1530's ideally included a centerline full cannon (50 lbs.), flanked by a pair of either demiculverins (9-12 lbs.) or pedreros (10 lbs.) or large sacres (10 pounds), flanked again by a pair of sacres (6 lbs.). The desirability of stone-firing pedreros, as previously explained, is that the balls fragment on impact, creating larger holes in wood planks and more holes in humans. The full cannon, and perhaps the guns immediately flanking were mounted on sliding sledges to absorb recoil. In addition to these five main guns, mounted in the arrumbada, there might be other large and small swivel pieces, and smaller sacres, and further light swivel pieces on the arrumbada. These lighter swivel guns would be used during both the boarding volley and the ensuing melee.

The galeass, however, was the ultimate gun ship of the Mediterranean. While its size made it less maneuverable than the galley and required a much greater rowing crew, it permitted a far heavier armament. Unlike the galley, the galeass had bow and stern superstructures to house artillery. The Neapolitan galleasses of the Spanish Armada had five full cannon, two or three half cannon, eight pedreros, four demiculverins, seven sacres, four half sacres, and about twenty large swivel pieces. All told, one galleass had more guns than five galleys put together. In addition to its offensive arsenal, the galeass had one clear defensive advantage: it had a high freeboard, which made it immune to boarding actions from galleys. The combination of firepower and resistance to boarding allowed six Venetian galleasses at Lepanto to sink approximately seventy Turkish galleys.

The structure of the galley, as we have seen, defines its tactical strengths and weaknesses in individual confrontations. The formation and tactics of galley fleets are a natural outgrowth of these. Galley warfare is, quite literally, a straightforward affair. The emphasis on direct approach with intention of boarding by projecting the spur over an enemy's flank, coupled with the fixed armament on the bow of the ship, are the defining components of galley combat. The stern and flanks are inherently vulnerable, lacking firepower beyond that of individual handheld missile weapons.

For this reason, galley captains always sought to prevent an enemy from gaining their rear. This meant that a strategic retreat was extremely dangerous. To turn around and flee was to deprive one's self of any real defense. Weaker fleets would therefore go to great lengths to avoid coming into range of stronger ones. If two fleets did meet and then withdrawal became desirable, the preferred means was to disengage by moving in reverse. This is a maneuver peculiar to oared vessels. While sailing ships can only move forward, it is possible to row backwards. Even so, the reverse disengagement is slow, and not an effective means of retreat under pursuit. But in can be performed by an entire fleet, which thereby provides mutual support by keeping its guns menacing the enemy. If near a beach, a galley fleet could even back into the shore and moor there, guns facing out, thereby depriving the enemy of the opportunity to encircle.

In order to protect their flanks, galley fleets invariably arrayed for combat in some form of line abreast. In other words, they lined up side-by-side, so that they presented a wall of artillery facing forward, with their vulnerable flanks hidden, except for the outermost ships. Reserve forces would be maintained behind the main line, for reasons that will become clear. The maneuvers of the fleet as a whole would be directed in so far as possible by a commander in a lantern ship, so called because signaling to direct the fleet was performed from the command center at the stern by means of lanterns, as well as flagstaffs, penants, and even trumpets and cannons. Since great advantage accrued to the side that could reach the rear and/or flanks of the enemy, commanders employed variations of two common maneuvers to attain that goal.

The first was envelopment of the flank, either single or double. Single envelopment involves the attacker sending one side of his line out further than the end of the enemy's line, and then encircling that side. If the enemy started to envelop a single flank, the defender would have to counterattack or widen its line to prevent flanking. The latter countermeasure required sufficient numbers to keep the line cohesive. Gian Andrea Doria (in command of the Holy League Right at Lepanto) overreached himself trying to prevent Uluj Ali (in command of the Ottoman Left) from gaining his flank. In so doing, he detached himself from the Christian main line, creating a gap which Uluj Ali penetrated.

To accomplish a double envelopment, the line abreast would assume the shape of a concave crescent, meant to encircle and gain both flanks of an enemy (allowing the attacker to pour ships around the sides of the encircled foe and attack from the rear). This was at the heart of Ali Pasha's plan at the battle of Lepanto.

The second maneuver was penetration of the center, intended to break through the enemy's line abreast and gain the rear of the entire body, or disrupt the defender's line sufficiently (whether by actual penetration or through firepower) to expose the flanks of his ships on either side of the rent to the attacker's reserve forces. This maneuver was central to Don Juan's plan at Lepanto, where he used the superior firepower of his galeasses in the center of the battle to disrupt the Ottoman center.

It may be noted that both of these maneuvers are common to the shock tactics of cavalry (penetration of the center usually being accomplished by heavy cavalry in the form of the "flying wedge"). The speed and maneuverability of galleys made then analogous to cavalry forces, and therefore amenable to command by noble officers with little naval experience (provided a ship's captain could provide the technical skills necessary). Seen in this light, the Spanish system of command, while not ideal, is understandable.

Once the flanks and/or rear of the enemy had been gained, the already described sequence of events would unfold. Ships would close, a boarding volley would be fired, and boarding would take place, with hand to hand combat following. In a large battle, multiple ships could become locked together by a network of spurs, with a sort of floating chaotic infantry battle resulting. Reserve ships, if not employed to exploit openings, might board ships of their own side, to provide reinforcements. At this point, the function of the galley as "floating infantry platform" becomes preeminent, and the value of arms, armor, and skill of the individual soldier should not be underestimated.

D) ATLANTIC NAVAL WARFARE

Although the galley did see some use in the waters of the Atlantic, conditions were far more severe than those of the gentle Mediterranean. The Atlantic is more prone to rough water, high wind, and an abrupt and deep coastal shelf. These are conditions unfavorable to the frail, lateen rigged, oar powered galley. Rather, Atlantic vessels tended toward deeper keels, sturdier and higher hulls, and most distinctively, reliance upon the powerful square sail. The discovery of the New World, and development of transoceanic trade, further promoted the development of these hardier sailing ships.

The galley had much to recommend it. Its low hull presented less of a target, it was independent of the wind, and its superior maneuverability allowed squadrons to maintain cohesion, facilitating tactical control. Even if a galley couldn't sink a heavier sailing ship, it could avoid or otherwise outmaneuver it, especially in unfavorable wind. Both the French and English used galleys and galeasses in the English channel, and even Sweden (in 1540) and Denmark-Norway (in 1565) used galleys in the Baltic. Up until the 1550's galleys were still favored (although they might fight along huge sailing "great ships"). As the technology of rigging improved over the course of the century, however, the maneuverability of sailing ships steadily increased, making them more effective warships. Eventually the frailer galley could not compete in oceanic waters. By the invasion of the Spanish Armada in 1588, the galley was a minor player in the Atlantic.

In addition to the sheer sturdiness of its thicker hull and greater ability to use a strong wind, the sailing ship had other advantages. Since rowers were dispensed with, the crew was much smaller, allowing longer range (and duration) missions. Some of the earliest sailing warships were derived from Portuguese caravels. These were originally lateen-rigged only, with one to three masts. The Portuguese used these in African exploration and trade. The lateen rigging allowed them to sail close to the wind (at angles of up to 50 degrees), while some square sails were added to allow them to sail with the wind. These were small to medium vessels (20 to 60 tons), but fast and maneuverable. These latter traits led to their use as warships, although they could only carry light guns (seven pound falcons at most).

The real future of sailing warships lay with the more massive vessels, contemporarily referred to as "great ships". The sheer size of these ships allowed storage of much larger amounts of cargo, such as the treasure that Spanish galleons brought from the New World (and plundered by English galleons), or siege provisions (up to and including heavy artillery in quantity), as carried by the Spanish Armada. The same carrying capacity allowed sailing ships to be outfitted with much greater numbers of guns. The relatively wide layout of these ships also allowed guns to be placed on the sides and stern, not just the bow. An additional feature of these larger ships was their multiple decks. While these strengthened the structure, and improved cargo capacity, they also meant that guns could be emplaced at multiple levels on the flanks, provided that gunports with hinged doors were cut into the sides of the hull to admit the barrels of guns below deck. Such gunports probably already existed by the time of the manufacture of the great ship la Louise", built in Normandy in the 1480's, and were clearly in place in "la Cordelière", built in Brittany for use in the French war effort in Italy, which had 16 heavy guns below deck. These early great ships already presage the transition from the "floating infantry platform" of the oared warship to the "floating gun platform" of the sailed warship.

If the galley excelled in maneuverability and amphibious warfare, then the strengths of the sailing ships lay in their increased strength and capacity. That capacity could be used for provisions, which coupled with a lessened crew translated to long range missions; for transport of a siege train or other military provisions; for delivery of a large invasion force; or to carry an extensive armament of artillery which could be aimed in any direction. The latter feature made the gun-armed warship a potent supporting force to infantry battling on a shore by supplying coastal bombardment, as we have previously mentioned occurred at Pinkie, Gravelines, and Nieuwpoort.

The large sailing warships of the late 15th and early 16th centuries were variations on the style of ship called the carrack. The carrack was a large ship (designed to transport cargoes of 300 to 600 tons) with high castles (superstructures) and at least one mast with a square sail. Later carracks usually had three masts, with square sails on the fore and main masts, and a lateen sail on the mizzen mast. This combination, first dated to the 1420's, represents the prototype of the "full-rigged ship".

War carracks could be enormous, and the size of these great ships allowed then to carry an arsenal of guns positioned on multiple decks and in multistory castles through the use of gunports. The early 16th century Swedish "Elefant" for example was 126 feet long and 52 feet tall from the waterline to the top of the forecastle. Its mainmast was 122 feet high with a 99 foot main yard. Another early great ship was the "Michael", built in 1511 for James IV of Scotland. It carried 27 guns, and must have been formidable. Unfortunately it was so huge that Scotland not afford to maintain it, and it was consequently sold to France. We have already mentioned some of France's great ships of the late 15th century, such as the Louise, Charente, and Cordelière, which saw use in the beginning of the Italian wars.

The best studied great ship of the period is the English "Mary Rose", built in 1509 (and refitted in 1527 and 1536), technically a transitional form between the carrack and the later galleon. She capsized and sank for unknown reasons in 1545 during the French invasion attempt (one contentious theory being that she took on water through open gunports). She was raised in 1982 and continues to be studied and restored. The Mary Rose had a keel length of 32 meters, a length at the waterline of 38.5 m, a breadth of 11.7 m, and a draught of 4.6 m. She had four decks, the upper (surface), main (where most of her guns were located), and orlop, and a hold. She had fore- and after castles, which were useful in boarding combat. Records indicate that her normal crew was 200 sailors, 185 soldiers, and 30 gunners. The Mary Rose's guns included a mix of iron breechloaders and bronze muzzleloaders. By 1545 her armament included seven cannon per side on the main deck, three or four per side on the waist of the upper deck, and two per side on the aft castles (aimed forward past the forecastle). There were also many smaller pieces, mostly swivel types. These fired shot of iron, stone, lead, composite lead/iron, and scattershot (such as chopped flint). One light gun was the "murderer", which was hooked over the rail as needed. It was a rectangular muzzleloader, and fired hailshot consisting of small iron cubes. All told, there were 15 bronze and 75 iron guns on board.

The main purpose of the castles of war carracks (or later, galleons) during combat was to provide the crew with a position to gather for counterattack if boarded. In this case, the castles served much the same function as their namesake: to provide a fortress from attackers. For most of the century, even in Atlantic waters, boarding tactics prevailed. Freed from the mass limitations of galleys and galleasses, sailing ships could take full advantage of the anti-boarding benefits of high bulwarks. Preceding and continuing throughout boarding the crews would exchange artillery fire using their broadside guns (including the swivel guns and murderers), and small arms fire (arrows and musket and arquebus shot).

Finally the two ships would close (using hooks, not spurs as in galley warfare). Commonly, incendiary devices would be used. These could serve as an aid to boarding, as the Spanish bomba, a roman candle like affair. It was a tube packed with alternating incendiary and explosive shrapnel charges on the end of a long pole. The bomba was used to spray shrapnel and fire on the enemy crew to allow the attackers to board. Other incendiaries were used with the aim of setting the trapped ship and crew on fire, such as the English "balls of wildfire" or "arrows of wildfire" or the Spanish alcancia. The latter was a ceramic pot full of gunpowder, spirits, and resin, with lit fuses tied around it, essentially a napalm grenade.

Once grappling hooks had been secured, and the two ships locked, the business of boarding (under incendiary and other missile fire) began. The extensive arsenal of pole arms carried on board the Mary Rose reflects the goal of boarding and engaging in hand to hand combat. The tactic of naval combat by the use of bombardment at range developed only late in the century (arguably, at the battle off Gravelines in 1588).

For most of the century, even though the sailing warship was heavily armed, its broadside guns were apparently used primarily to fire upon ships attempting to close and board. The chief offensive guns were, as on galleys, the bow guns. One significant advantage that sailing ships had with respect to their guns, however, was the room to mount them on carriages. The use of naval gun carriages (as opposed to sledges) meant that guns could traverse (aim left to right) as well as adjust elevation.

Broadly speaking, these carriages fall into two types. One such type is the long-tailed variety, possessing two large wheels, essentially the same as that which was used on land throughout the century. The second, known as the "truck carriage", is short, stout, and has four small wheels. The truck carriage had been used by the English and Portuguese since the middle of the century (it was in use on the Mary Rose at the time of her sinking), and offered a substantial advantage over the long tailed variety. The advantage was simply that of its compactness. The smaller wheels on the truck carriage meant that the gun could be wheeled further out the gunport, freeing up space inside the ship. Far more importantly, though, was the lack of the long tail. The tails of carriages could be long enough to hinder wheeling the guns back into the ship. If the guns were breechloaders, this was not much of an issue. However, iron breechloading guns were severely limited in the weight of ball they could fire. Bronze muzzleloaders could fire 60 pound balls, which were able to pierce hulls. In order to reload these on ship, the barrels needed to be run back through the gunport, and this was where the long tailed carriage became an enormous hindrance. If the tail was too long, the only way to reload a muzzleloading gun would be to lower a gunner down the side of the ship, or for guns on the main deck, to shimmy down the barrel. This enormous disadvantage is regarded as among the chief reasons for the English defeat of the Spanish Armada. Archeological evidence indicates that the Spanish were unable to reload their large guns during the battle off Gravelines, almost certainly because they clearly had mounted these guns on cumbersome long tailed carriages. The English, as we have seen, had been using the truck carriage since at least 1545, and were able to run back their guns easily, allowing them to fire repeatedly against the Spanish.

Perhaps the main reason why forward fire was favored for most of the century was the poor maneuverability of most sailing ships of the time. Against thick hulls, many shots were required to sink an enemy, and this was a difficult proposition with the predominance of sailing ships. While the forward guns, which were in the minority, were feasible offensive weapons, the guns on the broadside seem to have been intended to repel boarding attempts, as those in the stern were intended to cover a retreat. Massed broadside cannonade at a distance is very rarely heard of before the 17th century. Rather, the gun-armed sailing warship through most of the century can be seen as partaking of the offensive boarding tactics of the galley (with technical advantages of gunnery, though lessened maneuverability), while possessing some of the defensive advantages of the galeass (although capable of greater speed).

With respect to the command of fleets of sailing warships, up until 1530 an unstructured melee seems to have prevailed. For the most part, ships would pick out opponents of similar size to themselves, and while firing small missiles and bow guns, would try to grapple and board. Some sophistication of command emerged in 1530, with the publication of *Espejo de Navagantes* (Mariners' Mirror) by Alfonso de Chaves, lecturer at the nautical school at Seville, written for Charles V. It is probable that a copy was given to Henry VIII in 1543 during an alliance of the Empire and England against France, and influenced English naval tactics.

Chaves demanded order of sailing ships, as was the case of galley fleets. He recommended that sailing fleets be comprised of two types of ships, large ones with light artillery for boarding and small ones with heavy artillery to harass the enemy at a distance. In his scheme, the fleet should try to get windward (upwind) of the enemy and then form up. The standard formation is at least a vanguard of ships line abreast (i.e. side-by-side); he advised against arraying line ahead (single file) since then only the front ship could fight (revealing the contemporary bias against using broadside guns offensively). A detached squadron of reinforcements should stay on one flank. Other configurations he recommended were to meet a single line abreast with the same, with one's strongest ships in the center; or meeting an enemy disposed in a wedge by forming a "V" so as to entrap them.

The *Espejo de Navagantes* emphasizes the goal of boarding, and includes some specific details. Heavy guns should be fired first during closing, for psychological effect, then light guns at boarding distance to clear the deck. This accomplished, grappling and boarding begins. Part of the boarding company is to be responsible for damaging the enemy's rigging (in case the boarding party must flee). Once engaged, the ship's boats should circle the enemy and board wherever is clear, or alternately damage the enemy's rudder.

Chaves also advises that the flagship should avoid engagement unless it is critical. Rather, the admiral should stay aloof, observing and directing the combat. Among his responsibilities is directing the detached squadron to fill gaps in his defense.

It appears that the idea of sailing ships being disposed in, and fighting in, formations (as opposed to one-on-one melee) was a novel one to his contemporaries. Equally revolutionary is the concept of an admiral directing combat without engaging in it. While the emphasis on boarding in the age of artillery may seem antiquated, Chaves' insistence on order of disposition, and maintenance of command structure, is forward-looking, and mirrors the evolution of warfare on land.

The technological innovation that brought the gun-armed sailing warship into its own was not one of artillery, but rather one of sails and rigging. The greatest shortcoming of war carracks (aside, perhaps, from the dependence on wind common to all sailing ships) was their poor maneuverability. With the advent of the "full-rigged ship", maneuverability improved to the point that captains could both maintain cohesive formations (allowing admirals to exercise better tactical control), and, critically, employ their artillery to full effect.

The essence of the full-rigged ship is the combination of multiple square and lateen sails with sophisticated rigging. Such a ship can derive great speed from the wind, make controlled adjustments, and also be capable of sailing close to the wind. These advantages allowed ships to get close to lee (downwind) coasts, to gain a windward position of an enemy, and maneuver by tacking. While the combination had been employed since the fifteenth century, it was steadily refined. By the end of the 16th century the usual arrangement was ten sails: three square on both the foremast and mainmast, a lateen and square sail on the mizzenmast, and two square sails on the bowsprit. Sometimes more sails would be added on a fourth (bonaventure) mast. These new full-rigged ships also possessed the maneuverability to use their broadside guns offensively. These ships remained at the mercy of the wind, but to a lesser degree than their predecessors. And in the case of a completely calm wind, the option remained for the crew to use the ship's boats to tow the ship by rowing.

Modifications to the structure of the ship itself accompanied developments in rigging to improve maneuverability. Decreasing the superstructures (which helped lower wind resistance) and increasing the length to breadth ratio (which decreased drag below water) led to the development of the galleon. The earliest forms of galleons may date as early as the 1520's, among the Italians or Spanish. The classic form of the galleon was a narrow ship (length to width of about 3.5 to 1), with two full decks for artillery, and a half-, quarter-, and poop deck aft of the main mast (some of which carried guns). The forecastle (if even present) was always lower than the aft castle (which was the main refuge if boarded), imparting a characteristic lowslung crescent profile. The galleon was a faster, better sailing warship and a more stable gun platform than the great ships that preceded it.

The ultimate evolution of the form in the 16th century was the English race-built galleon. Credit for their design is given to John Hawkins, who was a New World trader (in defiance of Philip II's monopoly) and trader in African slaves, and Treasurer of the English Royal Navy from 1578. As English ships came in for maintenance, he modified them to improve their speed and maneuverability, traits he found to be of great advantage against the Spanish as a privateer on the Spanish Main. He also increased their armament of heavy guns (which were able to destroy hulls as well as men) and decreased the number of lighter antipersonnel pieces. From this time onward, the English fleet is designed for close range broadside cannonade, and boarding is abandoned. The advantage of mobility allowed them to stay out of the Spanish Armada's boarding range at the battles off Plymouth and Gravelines while delivering broadside fire. The design characteristics of the race-built galleons included an even greater length in relation to width, sharper underwater lines, a more efficient sail plan (designed to reduce billowing, and allow closer travel to the wind), reduced castles (the stern castle was trimmed to a sloping half- and quarter-deck, while the forecastle was a simple deckhouse), and of course, the aforementioned artillery.

These included chiefly demicannon (which fired 32 pound iron shot) and cannon perrier (pedreros, which fired 24 pound stone shot), which could pierce hulls, and 17 pound culverin and nine pound demiculverin, with ranges up to a mile. The English warships carried 10% of their weight as artillery, vis-a-vis only 4% for most Spanish galleons. English shot also included a variety of missiles intended to cripple sails and rigging, such as stone shards, chains, bars, and more bizarre projectiles, such as balls chained to each other, and balls that had spring-loaded spikes or blades attached to them for cutting sails.

With the new maneuverability, commanders were better able to maintain their fleets in ordered formations. Some of these formations were meant to provide mutual support in either offensive or defensive situations. The Danish and Swedish navies employed characteristic three-ship groups (one large, two small) in the Nordic War of 1563-1570. These units were assembled into multiunit arrays, as the Danish offensive wedge, the Swedish two-rank offensive line abreast, or defensively in a line ahead (meant to minimize the profile of the fleet). The initial formation of the Spanish Armada was a convex crescent, almost certainly inspired by the concave crescent employed at the battle of Lepanto. Strong warships were placed throughout, in positions that were believed to be able to defend any part of the crescent. This formation was quickly found to be wanting; the Armada was reconfigured after the battle off Plymouth, with its weak ships in the center, and warships in a vanguard and rearguard.

One of the most impressive benefits to come from the combination of mobility and heavy armament was the development of maneuvers to offer continuous broadside fire. This development represented the naval equivalent of the infantryman's volley fire, or countermarch. The use of broadside guns by multiple ships in conjunction required a line ahead (single file) formation. The English are regarded as the first to effectively employ the line ahead offensively.

Perhaps the earliest example of a form of line ahead continuous naval fire was the English response to a Spanish invasion of Ireland in 1579. The Spanish built a coastal earthwork fortification at Smerwick Bay, which was attacked by six English ships under Sir William Wynter. Three of them had keels too deep to enter the shallow bay. The other three advanced in a line ahead, and proceeded to bombard the fort in turn, first with their bow guns, then a broadside as they turned, and with stern guns as they retired. Each ship reloaded as it retired, and looped back to repeat the cycle, resulting in a continuous bombardment.

At the battle off Plymouth in 1588 the English galleons employed a maneuver which allowed a much greater concentration of continuous fire, using a line ahead. As nearly as can be reconstructed, it seems that the English formed in a line ahead (as the Spanish put it, "en ala", in file), with the flagship leading and vice-flagship trailing, at the rear of the crescent formation of their Spanish. The English then traversed the width of the crescent, with each ship firing broadside volleys as they passed across the line of the Armada, first at the Spanish vanguard, and then at the rearguard, each ship successively discharging its guns as they passed. Once the last ship (the vice-flagship) had fired, each ship rotated to turn its other broadside toward the Spanish, and zigzagged back, repeating the process (with the vice-flagship now leading, and flagship trailing the line ahead).

The most decisive battle of the English against the Spanish Armada was that off Gravelines. Records do not tell us any details of maneuvers, but it is clear that the English used their maneuverability to stay just out of range of Spanish boarding attempts, while remaining close enough that their heavy guns could do enormous structural damage to the Armada. As we have already seen, the English truck carriage was the other component of English technological superiority, as the Spanish could not run back their long-tailed carriages to reload during the battle.

A final tactic of naval warfare, which helped seal the destruction of the Armada, must be mentioned. As the battered Armada lay at anchor off Calais, the English dispatched eight fireships. These are the same manner of explosive and shrapnel laden vessels as were used to break the blockade bridge at Antwerp. The Spanish well knew that the architect of the originals, Federigo Giambelli, had moved to London. Remembering the horrible slaughter of Spanish soldiers from the explosion of just one of these so-called "hellburners", the Spanish cut anchor and fled. Without anchors, structurally unsound and ill-provisioned, much of the Armada was lost at sea, or wrecked on coastlines of Ireland, Scotland, or Norway.

The battle of the Spanish Armada, toward the end of the 16th century, in some ways can be seen to mark the passing of an older style of naval warfare, embodied by the Spanish fleet. The Armada, while admittedly not intended to seek battle, was prepared to do so in a fashion patterned after traditional, galley inspired methods: fire once, close, grapple, and board. The English fleet presages the tactics that characterize naval warfare in centuries following: the continuous use of well-ordered massive broadside volleys of heavy artillery, maintained through the use of speed and maneuverability. Such tactics clearly delineate the transition from the ship as infantry platform to the ship as gun platform.   This is the mechanism which was to lead to eventual English naval supremacy, and through which the control of oceanic trade routes, and global European empires, were established and contested.

EPILOGUE: TOWARD THE 17TH CENTURY

From a purely tactical viewpoint, certain trends can be observed as the promise of the new military science bore fruit. With the recognition of the efficacy of projectile weapons, especially with the training pioneered by the Nassaus to maximize rate of fire, shot came to dominate the field. Pike did not vanish immediately, remaining necessary to guard against cavalry. But whereas once shot was seen as necessary to protect pike, the obverse was now the guiding principle. The ratio of pike to shot in the Italian Wars was approximately 3:1; by the mid 17th century, the ratio was closer to 1:3. With the invention of the bayonet, riflemen could hold off cavalry, and we hear (outside the peasant uprisings of the French Revolution) little more of the pike.

Similarly, as we have noted, the supremacy of the pistol spelled the end of the lance. The lancer was replaced by the mounted pistoleer with his cavalry saber. The characteristic armor of the heavy cavalry grew thicker through the century, to resist the power of ignoble small arms. As has always been the case, arms and armor competed for the upper hand, and the armor-piercing musket proliferated. Eventually the weight of armor became a pointless encumbrance. As it did, the raison d'etre of the musket vanished. By the 18th century, the "musket" was no heavier than the arquebus of the 16th, and the forked rest forgotten.

Training, undeniably vital to the efficient usage of (by modern standards) intrinsically inefficient arms, grew in its complexity and extent. As more complicated maneuvers were developed, the size of battalions shrank. The pike phalanx numbering thousands of men, the backbone of the 16th century field army, was replaced with more tractable companies of perhaps a hundred or so. The highly evolved drills pioneered by the Dutch were executed in the milieu of their characteristic checkerboard disposition of forces, with mutually supporting fire and rapid maneuverability and tactical fluidity.

The initial success of field and siege artillery, so conspicuous in the French invasion of Naples, spurred the science of fortification. By the middle of the 16th century fortification had become so resistant to artillery that field battles became the exception. As in the middle ages, fortified places, whether cities or castles, became the dominant factor in control of the country.   The spade and the gun became the dominant weapons of war. The combination of overwhelming expense and logistical complexity can be regarded as largely responsible for the drawn-out nature of war in the end of the century and beyond. While open battles were not unknown, conflicts such as the French Wars of Religion were characterized by protracted sieges (as of Rouen, Paris, Orleans, and La Rochelle), while the Eighty Years War of Dutch Independence was, on the whole, a series of expensive, tedious sieges in difficult water-logged terrain.

This siege-dominated mode of warfare required progressively greater provision of artillery, with all its attendant expense of teamsters, pioneers, craftsmen, and so on. Moreover, the effective use of field forces demanded extensive training, and therefore skilled professionals to provide that training, i.e. a standing army with a command corps. Thus the progressive militarization of the state required funds, and manpower, on a grand scale.

The acquisition of military power through funds, and of funds (in the form of enforced collection of taxes, duties, or tribute) through military power, simultaneously demanded and contributed to the centralization of political power. The process was hardly a smooth one, as many battles and even wars in the 16th century ended without resolution due to scarcity of funds, even bankruptcies of state. In the 17th century, however, following the Thirty Years War, the foundations of permanent standing armies with clear command structures, at the disposition of the monarchs or governing bodies of states were laid. This both discouraged internal rebellion (either by the populace or the nobles) and further improved the efficiency of the fiscal collection process, providing even greater opportunity for the maintenance of military power, and thus of consolidation of control of the state.

Simultaneously, the advantage of the besieged over the besieger made territorial gains (except abroad, as in the colonies in the New World and the East) prohibitively expensive, fixing European national borders to an unusual degree. The development of fast, maneuverable warships, capable of transoceanic voyages, with large cargo capacities and heavy armaments carried European disputes abroad. Thus it could likely be more profitable to fight battles over foreign colonies, goods, and trade routes, than to attempt wars of conquest within Europe.

The revolution of military science may be seen as necessitating an efficiency and efficacy of force that only a strong national power could maintain. Once in place, that same force served to protect the interests of, and maintain, the head of that state—thereby ensuring the place of the national army, and navy, as permanent fixtures of the political landscape.

TIMELINE OF REFERENCED BATTLES:

For sources on political background and details of events of individual battles, see the section, “Further Reading”.

<u>The Italian (Habsburg-Valois) Wars</u>
Fornovo 1495
Cerignola 1503
Ravenna 1512
Marignano 1515
Bicocca 1522
Pavia 1525
Ceresole 1544
Siege of Montalcino 1553

<u>Mediterranean Conflict with the Ottomans</u>
Jiddah 1517
Prevesa 1538
Lepanto 1571

<u>The French Wars of Religion</u>
Dreux 1562
Siege of La Rochelle 1573
Riberac 1584
Coutras 1587
Ivry 1590

<u>The Dutch War of Independence</u>
Siege of Antwerp 1584
Nieuwpoort 1600

<u>The Spanish Armada</u>
Battle off Plymouth 1588
Battle off Gravelines 1588

GLOSSARY

arquebus long firearm, lighter than the musket
arriére-coin return, or extension, off the side of a trench, to be manned by soldiers in case the trench is gained by the enemy
barbican outer defense, e.g. a wall or double tower of a gate
bastion an outcropping, as a tower or angle, built at the corners of (and integral with) the curtain/ramparts of a fortified place
battered sloping, as the base of a wall to provide extra strength
blockade-bridge bridge, usually floating, intended to close off a waterway so as to prevent relief of a besieged place
bombard class of early artillery, distinguished by increased thickness of walls of the powder chamber relative to that of the bore
bore inner diameter of a gun
breach hole created in the outer defenses of a structure
breech back end of a gun (which must be sealed during firing)
caliber diameter of bore or shot expressed as a decimal of an inch (e.g. ".54 caliber" shot is 0.54 inch in diameter); also used to express length of a gun relative to its bore (e.g. a 12 foot gun with a six inch bore is 24 calibers long)
cannon specific class of artillery pieces, approximately 18 calibers in length, with relatively thin walls
caracole pistol-armed cavalry maneuver associated with reiters, in which the front rank of a squadron advances, fires, and retires to the left to reload, as the next rank performs the same maneuver so as to maintain continuous fire; also called "limaçon"
carrack type of mainly square-sailed ship with high superstructures, predecessor of galleon
casemate gunchamber, i.e. outbuilding with gunports placed inside a ditch**;** also called "caponato"
cavalier elevated artillery platform atop bastions
circumvallation siege line to provide opposition to the besieged
cock of the lock of a gun, the part that holds the pyrite, flint, or lit slowmatch
contraforti earth piled against a wall to reinforce
contravallation siege line to provide opposition to relieving forces
countermarch infantry maneuver to provide constant fire, in which front rank fires then retires to rear and reloads while next rank advances to fire
countermine a mine dug by the besieged to meet and disable the besieger's mine
counterscarp outer wall of ditch
covered way see "via coperta"
corning method of preparing gunpowder in defined grain size, to control burn rate
culverin specific class of artillery pieces, approximately 36 calibers in length, with relatively thick walls
curtain section of wall or rampart between bastions
dog lock late 16th century form of firelock
enfilade fire on the flank or diagonal of an enemy
face of an angle bastion, the distal walls, which meet at the salient and point outward
fascina bundle of sticks, used to provide structural strength to earthworks
firelock any firearm ignition mechanism that strikes a flint against steel
flank 1) generally, the side, as of a body of troops; 2) of an angle bastion, the wall adjacent to the curtain
flintlock specific form of firelock, probably early 17th century
gabion wicker basket filled with earth; modular component of fortifications, used to provide cover
galleass high-hulled, large ship powered by both oar and sail
galleon slender, full-rigged sailing ship with low superstructure
galley shallow drafted, low-hulled narrow oar-propelled ship with auxiliary lateen sails
gallon 128 fluid ounces; approximately 3.8 liters
gauge 1) of metal, thickness (as fractions of an inch); 2) of shot, weight (as number of balls per pound)
glacis slope of earth leading up to ditch; conceals the via coperta
grati screens of woven sticks, to provide concealment
gunport openings in a wall, hull, etc. to admit the muzzle of a gun; includes "hinged", usually a watertight door in the hull of a ship for below-deck guns; "keyhole", a small hole to allow a single line of fire, with vertical slit for aiming; and "letterbox", a horizontal slit to allow traversing
line abreast side-by-side line of ships, i.e. single rank
line ahead bow-to-stern line of ships, i.e. single file

matchlock firearm ignition mechanism using a smoldering length of slowmatch
mine tunnel, usually dug under a wall to facilitate the making of a breach, as with explosives
mortar type of gun used to lob projectiles at high trajectories
musket long firearm, heavier than an arquebus, with larger shot at powder charge; requires a forked rest
muzzle the distal, open end of a gun; opposite the breech
orrechione curved projections on an angle bastion at the intersection of the face and flank; provides cover for flank guns
parapet a vertical projection on the perimeter of a rampart, trench, etc., to provide cover and concealment
pedrero gun designed to fire stone projectiles
petard bell-shaped explosive device to direct force of explosion; used to break through gates, doors, etc.
puntone pyramidal scarp at the foot of the salient of an angle bastion
rampart extremely thick fortified wall, with broad top, usually with a parapet
ravelin outbuilding, typically chevron shaped, constructed beyond the ditch
reiter pistol-armed cavalry; usually refers specifically to Germans
retirata a retrenchment creating a concave rampart within the original, breached rampart; also called "double Pisan rampart"
retrenchment any fortification built proximal of a breached area, to close off the breach
rifling gently spiraling grooves cut into the bore of a gun to provide spin to the shot
salient of an angle bastion, the angle formed by the intersection of the faces
sap head of a trench used to approach a place; as a verb, to try to create a breech by excavation
scarp the inner face of the ditch
serpentine 1) finely ground (as opposed to corned) gunpowder; 2) the simplest form of lock, an S-shaped bar that is integral with both the trigger and cock of a gun
siege lines continuous barricades around a besieged place; comprise lines of circumvallation and contravallation
stipa brushwood; used to provide structural support to earthworks, and create obstacles, as by filling a ditch
smoothbore literally, having a smooth bore, i.e. lacking rifling
swivel gun large antipersonnel gun mounted on a swiveling base
terreplein space atop a rampart behind the parapet, i.e. the walkway and artillery platform
trace italienne "Italian footprint", distinctive outline of angle-bastioned fortifications of the new Italian school
trunnion lugs on artillery which engage the carriage to provide pivot points for elevation
via coperta "covered way"; shelf above counterscarp of ditch, covered by glacis; meant to serve as cover, as for snipers
wheelock firearm ignition mechanism in which a serrated wheel is made to spin against a lump of pyrite

TABLE 1: ARTILLERY OF THE 16TH CENTURY

Note: all values are approximate; see text for further details.

HOLY ROMAN EMPIRE (UNDER MAXIMILIAN)	CLASS	NAME	GUN WEIGHT (LB'S x 1000)	SHOT WEIGHT (LB'S)
	Heavy (Siege):	Hauptsbüchse	up to 30	over 100
		Scharfmetze	10	110
		Basilicus	7.5	77
		Nachtigall	6	55
		Singer	4	22
	Medium Artillery (mobile field pieces)	large Kartaune	3	18
		small Kartaune	2.5	11
		Rothschlange	5	
		Demirothschlange	2	8
		Sau	2	22
	Light (anti-personnel)	Falkaune	2.5	5.5
		Falkonet	1.5	2
		Scharffetinnle	3	0.5
EMPIRE (UNDER CHARLES V)		Cannon Royale	6.4	40
		Medium Piece	5	25
		Culverin	3	12
		Demiculverin	2.7	6
		Saker	2.7	6.5
		Falconet	1.7	3
		Mortar	5.7	100

FRANCE (UNDER HENRI II)	CLASS	NAME	GUN WEIGHT	SHOT WEIGHT	POWDER WEIGHT	LENGTH
	Heavy	Cannon	10.4	42	26	10'6"
		Great Culverin	8.5	20	21	11'
	Medium	Bastarde	5.7	9	15.5	11'
		Moyenne	2.9	2.5	6.5	8'6"
	Light	Faucon		1.3		7'6"
		Fauconneau		1		7'

SPAIN (UNDER PHILIP II)	TYPE	NAME	SHOT
	Cañones (up to 25 calibers)	Cañon de batir	40-50 (iron)
		Cañon	28-35
		Medio Cañon	15-27
		Tercio Cañon	10-14
		Quarto Cañon	9-12
		Cañoncete	10
	Pedreros	Cañon Pedrero	12-20 (stone)
		Medio Cañon Pedrero	10-12
		other pedreros	4-12
	Culebrinas (30 or more calibers)	Culebrina	16-21 (iron)
		Media Culebrina	7-14
		Sacre	5-8
		Medio Sacre	3-4
	Light Culebrinas (often swivel pieces)	Falconete	2-4
		Media Falconete	1
		Falcon	1-3
	Antipersonnel	Falcon Pedrero	3-6 (stone)
		Esmeril Doble	12 oz. (iron or lead)
		Esmeril	6-8 oz. (iron or lead)

ENGLISH (UNDER HENRY VIII)	TYPE	NAME	GUN WEIGHT	SHOT WEIGHT	LENGTH
	Cannon	Basilisk	12	90	10’
		Double Courtant	7.3	80	
		Cannon Royal Curtowe	8	60	8’6”-12’
		Cannon	7	50	13’
		Cannon Serpentine	6	42	12’
		Bastard Cannon	4.5	42	10’
		Demicannon	4	24-36	11’
		Quarter Cannon	2	12	7’
	Culverins	Culverin Royal	7	32	16’
		Culverin	4-4.8	15-19	11’
		Demiculverin	3-3.4	10	8’6”
		Culverin Bastard	2.3-3	12	8’6”
		Saker	1.5	5.5-9	7’
		Passe Volant	3	6	10’
		Minion, Demisaker	1	4.5-6	6’6”-8’
		Falcon	0.8	3	6’-7’
		Falconet	0.5	1-2	9’
		Serpentine	0.25-0.4	0.5	3’
		Robinet	0.2	1	
		Esmeril, Rabinet	0.2	0.3	2’6”
	Pedreros	Pedrero (Medium)	3	30	9’
		Cannon Perrier	3	24.5	
	Mortars	Mortar (Heavy)	10	200	6’
		Mortar (Medium)	1.5	30	2’

FURTHER READING

Probably the most "reader friendly" work is Thomas Arnold's recently published The Renaissance at War. It is very well illustrated and contains much valuable information, and would serve as a good introduction to the topic, although it is written for the layman.

If you are seriously interested in 16th century military science and history there are two books that I can not recommend highly enough. The first is Sir Charles W. Oman's A History of the Art of War in the Sixteenth Century. This book is absolutely indispensable to any study of military history or science of the period. It contains an overview of the political background and breakdown of the actions, with maps where possible, of every significant battle of the century in western and eastern Europe, and summations of the tactical lessons thereof.

The second book, which is an analysis of 16th century military science on land (field and siege) as a whole, and benefits from more modern scholarship, is David Eltis' aptly named The Military Revolution in Sixteenth-Century Europe. This work, while relatively brief, is definitely denser reading than Arnold's work, and is written for an academic community. It remains, to my mind, the single best work for providing an overview of 16th century military science. I would recommend reading Eltis to provide an overview, and Oman for illustrative specifics.

Moving on to specific topics, for the topic of gunpowder weaponry in particular, Hall's work Weapons and Warfare in Renaissance Europe: Gunpowder, Technology, and Tactics is extremely detailed and enjoyable reading, although the title is more all-encompassing than the contents merit. The book is specifically on the use of gunpowder weapons on land. A good brief overview of period gunnery can also be found in the opening chapters of Simon Pepper and Nicholas Adams' Firearms & Fortifications: Military Architecture and Siege Warfare in Sixteenth-Century Siena. Revealing hard data on the capacities of period firearms can be found in Peter Krenn's article "Test-Firing Selected 16th to 18th C. Weapons".

For the topic of fortifications and gunnery as applied to siege warfare, the aforementioned work by Pepper and Adams is an excellent analysis of the topic in a single historical context, while the topic is covered in much broader scope in Christopher Duffy's Siege Warfare: The Fortress in the Early Modern World 1494-1660.

What has been written on the topic of cavalry is limited and fairly scattered. Some discussion in Eltis is useful, as well as a number of other works cited here. While slightly post-period, John Cruso's Military Instructions for the Cavallrie is of interest (and available through a quality library), and may fairly reflect Dutch practice at the end of the century. Sydney Anglo's The Martial Arts of Renaissance Europe, ch. VII-IX contains a fair deal of information on actual mounted combat technique, both in the lists and in war, as well as equipment, derived from period manuals.

For discussions of logistics, and the composition of armies of the period, John Hale's War and Society in Renaissance Europe 1450-1620 provides a general analysis, while specific cases are examined in much greater detail in Geoffrey Parker's The Army of Flanders and the Spanish Road 1567-1659 and James Wood's The King's Army: Warfare, Soldiers, and Society During the Wars of Religion in France, 1562-1576.

Additional information on the makeup of armies, and on their arms, armor, and appearances, which may be of particular interest to recreationists and wargamers, may be found in George Gush's Renaissance Armies, 1480-1650 and Ian Heath's Armies of the Sixteenth Century: The Armies of England, Scotland, Ireland, the United Provinces, and the Spanish Netherlands 1487-1609. Various publications by Osprey Publishing (including Douglas Miller's The Landsknechts) will likewise be of interest.

For a general summary of naval warfare of the period as a whole, see John Francis Guilmartin's Galleons and Galleys and Jan Glete's Warfare at Sea 1500-1650: Maritime Conflicts and the Transformation of Europe. For Mediterranean warfare in particular, Guilmartin's Gunpowder and Galleys: Changing Technology and Mediterranean Warfare at Sea in the 16th Century remains the classic. For the Spanish Armada, the generally acknowledged single best text is Colin Martin and Geoffrey Parker's The Spanish Armada. The extensive website of the Mary Rose Trust contains a wealth of information on Tudor naval warfare.

Finally, for details of battles referenced in this paper, Oman remains the best single comprehensive source. For specific battles, Osprey's publications are particularly detailed (those used in researching the present work are Angus Konstam's Pavia 1525 : The Climax of the Italian Wars and David Nicolle's Fornovo 1495 : France's Bloody Fighting Retreat). Hall includes a clear discussion of the battle of Ravenna, and Wood covers the battle of Dreux and siege of La Rochelle in 1573 at length. The siege of Montalcino is related in exquisite detail by Pepper and Adams. The battles of Jiddah, Prevesa, and Lepanto are covered in the greatest detail by Guilmartin. Blaise de Monluc's memoirs (translated into English as The Habsburg-Valois Wars and the French Wars of Religion) contain valuable first hand accounts of the battle of Ceresole and of the sieges of Siena and Thionville; it remains a smashing good read, to boot.

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