May 2012

# Historical Evolution of Weapons and Armors in India, Persia, and Greece

Gabriel Rene Diaz
*Worcester Polytechnic Institute*

James John McLaughlin
*Worcester Polytechnic Institute*

Laura Elizabeth Hudson
*Worcester Polytechnic Institute*

Noor Mohammad Ali
*Worcester Polytechnic Institute*

# THE INFLUENCE OF WEAPONS AND ARMORS BETWEEN PERSIA, INDIA, AND GREECE DURING THE IRON AGE

An Interactive Qualifying Project Report

submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

By


Noor Ali

Gabriel R. Diaz

James McLaughlin

Laura Murray


Date: May 3, 2012

Submitted to:

Professor Diana A. Lados

Mr. Tom H. Thomsen

# ABSTRACT

Our project focused on the history, military tactics, and weaponry used during the time from 550 BC to 300 BC in which India, Persia, and Greece were in contact with one another due to the wars waged in pursuit of expansion. These three nations all eventually came under Alexander the Great's reign. We examined each nation's weapons, armor, and military strategies that evolved as a result of their warring and competition for power and control of land. This project was supplemented with the creation of a Kopis sword from the Iron Age because it is a Greek sword that heavily influenced other swords used by India and Persia. The sword was built using techniques as close as possible to those of the time period in an effort to immerse ourselves in the culture and experience the craft and methods that were utilized in making weaponry for war. We worked in conjunction with our partner group to update a pre-existing website containing all information on our projects that was originally created by an IQP group from the previous year.

# ACKNOWLEDGMENTS

We would like to express our appreciation to our two advisors, Professor Diana A. Lados and Mr. Tom H. Thomsen, for guiding us throughout our IQP experience and providing insight and help when needed. We would also like to thank Mr. Fay Butler for his valuable time and tutorial that gave us a foundation of metalworking on which we could begin the development of our sword. Without the mentorship, resources, and extensive hours of Mr. Josh Swalec, we would not have been able to perfect our sword to its detailed shape and reproduce a successful rendition of the Kopis to the extent that we did. To him we extend our utmost gratitude. We would also like to sincerely thank Professor Boquan Li for helping us mount, press, and test our metal samples. He spent time teaching us how to use the machinery and how to analyze our samples. Finally, Xiang Chen, a graduate student of Professor Lados', was kind enough to volunteer time in monitoring our casting exercise as well as helping us melt our metal safely. We would like to thank him for putting in long evening hours advising and helping us create our handle successfully. To all those who helped make our project come to a completion, thank you.

# TABLE OF CONTENTS

# AUTHORSHIP

## Noor Ali

- Ancient Persia
- Making of the Kopis (co-written by Laura Murray, Gabe Diaz, and James McLaughlin)
- Conclusion (co-written by Laura Murray)
- Updating the Website (co-written by Laura Murray)
- Material Analysis (co-written by Laura Murray, Gabe Diaz, and James McLaughlin)

## Gabriel R. Diaz

- Ancient India
- History and Properties of the Kopis (co-written by Laura Murray)
- Making of the Kopis (co-written by Laura Murray, Noor Ali, and James McLaughlin)
- Material Analysis (co-written by Laura Murray, Noor Ali, and James McLaughlin)

## James McLaughlin

- Ancient Greece
- Making of the Kopis (co-written by Laura Murray, Gabe Diaz, and Noor Ali)
- Material Analysis (co-written by Laura Murray, Gabe Diaz, and Noor Ali)

## Laura Murray

- Introduction
- History and Properties of the Kopis (co-written by Gabriel Diaz)
- Making of the Kopis (co-written by Noor Ali, Gabe Diaz, and James McLaughlin)
- Conclusion (co-written by Noor Ali)
- Updating the Website (co-written by Noor Ali)
- Material Analysis (co-written by Noor Ali, Gabe Diaz, and James McLaughlin)

# LIST OF FIGURES

# I. INTRODUCTION

The purpose of this project is to study and report on various arms and armors throughout history. Several groups have researched different areas of the world in different time periods, reporting on their style of weapons and armory. An online website has been created where these students post their findings to the public. This particular project will focus on the time period from 550 BC to 300 BC.

This year, the project will be focused mainly on weaponry in different time periods and geographical regions. Throughout history, neighboring civilizations were constantly fighting with one another to gain power. Many disputes for land or other desires were solved through warfare, which meant that soldiers needed a way to fight. Each of the civilizations had specific weapons that they used to defeat their enemy. The project will study the distinctive weapons of specific empires, and how they evolved as alliances changed. The focal point of the weapon study will be on swords, but many weapons will be researched, including knives, bows and arrows, and spears. To compliment the research, each group will forge a weapon used by a studied civilization, keeping forging procedures as close to those in the past as possible.

The project as a whole will focus on several countries within the general area of Europe and Southeast Asia. A specific time period will be explored in each country, including a look at the history, culture, religion, and other aspects. This particular project will focus on the civilizations of Ancient Persia, Greece, and India in the years 550 BC to 300 BC. Each Empire will be examined individually to examine characteristics unique to its culture. Then, the Empires will be studied simultaneously.

History shows that humans are constantly at war, and it is clear that each of these three empires fought amongst themselves. Small civilizations within Ancient India fought against each other constantly. There were many wars in which the Persians fought the Greeks in ancient times. Part of the focus of this project is to examine the history of warfare between these three countries. Because these empires were constantly fighting with each other, they began to influence each other's cultures. Persian weapons were strongly influenced by Greek weapons when the Persian Empire was at war with Greece. We would like to examine the evolution of weapons not only of each country, but how weapons from one country influenced other countries.

Persia, India, and Greece were chosen because of their connections in war. The Greek and Persian Empires both fought and conquered many other empires, and each was a successful civilization. India thrived culturally and spiritually as well. The connection of these three countries culminates with Alexander the Great. A Greek warrior, Alexander the Great became the leader of the Greek Army. He traveled far and wide, conquering many Empires. Within a thirty-year period, he had traveled to Asia to conquer India, and back to Europe to conquer Persia. The research and study of this project will come together with each Empire's conquering by Alexander the Great.

After falling under the rule of the Greeks, India and Persia both adapted Greek characteristics in their weaponry. The practical part of this project will be focused on the study of the Kopis sword. It is a Greek sword that was used for butchering meat and also used as a weapon in the military. The Kopis developed originally from an Ancient Egyptian axe, which later evolved into an Egyptian sword called a Khopesh. This Greek sword was chosen because Persian and Indian swords were influenced by it. We will attempt to make our own Kopis using metalworking techniques used by the Ancient Greeks.

This project's main focus is on the history of India, Persia, and Greece with respect to its military and weapons. Research will cover general history, military history, history of weapons, materials used for weapons, and manufacturing processes for each country within the specific time period. Another group of WPI students is doing a similar study that is also part of this project. This group will research Japan in the 1800s, specifically following the time period of the Samurai warrior. They will cover the spiritual, cultural, and military aspects of the Samurai from their beginning to the time when samurai were no longer considered military leaders. The group will attempt to manufacture a katana. Reports and findings from both groups will be available on a public website through WPI.

## II.A.1 ANCIENT PERSIA

Around 2000 BC, a group of people called the Aryans, originally from present-day Kazakhstan, began to appear along the Fertile Crescent. The word "Aryan" means noble in their language. The Aryans originate from the earlier group of people called the Proto-Indo-Europeans. Indo-Europeans led to the development of various languages including English, Persian, and most other European languages (Burgan 2010). The Aryans, who were nomadic and relied heavily on horses for transportation and warfare, spread out over Central Asia reaching areas like present-day Russia and India. They were the first to introduce and develop war chariots. Around 1500 BC, they settled in areas in present-day Iraq, Syria, and Turkey and took on the cultures of the areas they settled into. Around 1000 BC, the Aryans branched out into two groups that settled in modern-day Western Iran: the Medes and the Persians. Persia is now known as present day Iran. The Medes settled in the north and the Persians settled in the south coming into contact with the original settlers along the Iranian Plateau that included a group called the Elamites, who were the earliest people said to have lived in Persia since 3000 BC and who were very prosperous and had their own cuneiform, which was the first ever writing system developed by the Sumerians who lived in modern day Iraq in a city called Sumer. The Assyrians controlled the Medes and Persians around that time and thus, the Kingdom of Media also fell under Assyrian control. Nomads from the north called the Scythians repeatedly attacked the Assyrians and the Kingdom of Media. They gained control over Media, where the Medes were settled due to their battle strength.

Relationships between the Scythians and the Medes were very good unlike with the Assyrians. The Assyrians forced the Medes to act as their slaves, living in their land, working under them, and paying them tributes or an idea similar to taxes. The Scythians, on the other hand, allowed the Medes to have their own kings and the Medes would have the Scythians teach their youth how to use the bow and arrow. Both groups, therefore, were allies of one another and fought united against the Assyrians. Babylonia rebelled against Assyrian control in 626 BC. Around 636 BC, ten years later, the Babylonians had regained control over their lands and began to invade Assyria. The Medes, Scythians, and the Persians also allied to invade Assyria and fight for control of their territories. In 612 BC, the capital of Assyria called Nineveh was captured and the allied powers began to form their own styles of fighting (Figure 1).

**Figure 1: The Fall of Nineveh.**

The Kingdom of Persis, where the Persians occupied, formed an army they called kara, while the Kingdom of Media, where the Medes occupied, formed an army they called spada. The Medes were the first group around the Iranian Plateau that organized their army into sections. They imitated the Assyrian army, but also included their strength in horseback. They divided the army into spear throwers, archers, and cavalry. The Medes, with their strong organized armies, invaded various lands, including Iraq, Turkey, the present-day Persian speaking areas in Eastern Iran, and then went on to Afghanistan.

Since the Assyrians had previously taken control of the Elamite capital of Susa in 640 BC, the Persians, who were settled in southwestern part of Iran and who were greatly influenced by the Elamites, took control of the second Elamite capital called Anshan. This area and its surroundings were later ruled by the Persian dynasty called the Achaemenid Dynasty founded by Achaemenes around 635 BC. The first king of the Persians was known as Achaemenes who was father of the second king named Teispis. Teispis' grandson, named Cambyses I, allied with the Medes. Around 575 BC, Cambyses I had a son named Cyrus who, according to various sources, had a Mede mother, the daughter of the King of Media at the time (Burgan 2010). Cyrus became referred as the Great due to his unifying powers and just rule.

## II.A.1.1 Cyrus the Great

The Persian Empire was founded by Cyrus the Great in 550 B.C., was one of the largest empires of the ancient world, and was a center for the advancement of governmental practices, laws, and communications (Bramwell 2004). Cyrus the Great is considered the official founder of the Persian Empire because he overtook the Medes' kingdom around 550 BC. Cyrus the Great, also known as Cyrus II, was a great general who unified Persia, conquered many lands, corrected his military weaknesses by successfully observing and learning from his enemies, treating the conquered people well to promote harmony, and introduced structure and organization to his army. He brought many innovations to Persia as a whole and was very influential since he was the acknowledged founder of the Persian Empire.

Cyrus took the throne as a teenager, around 559 BC when he was about 16 years of age. He was a very sharp boy and began his conquests of areas as soon as he took the throne. He united Persis because it was divided into two smaller kingdoms and then went on to declare war with the Kingdom of Media. He gained control around 550 BC when he was only 25 years old.

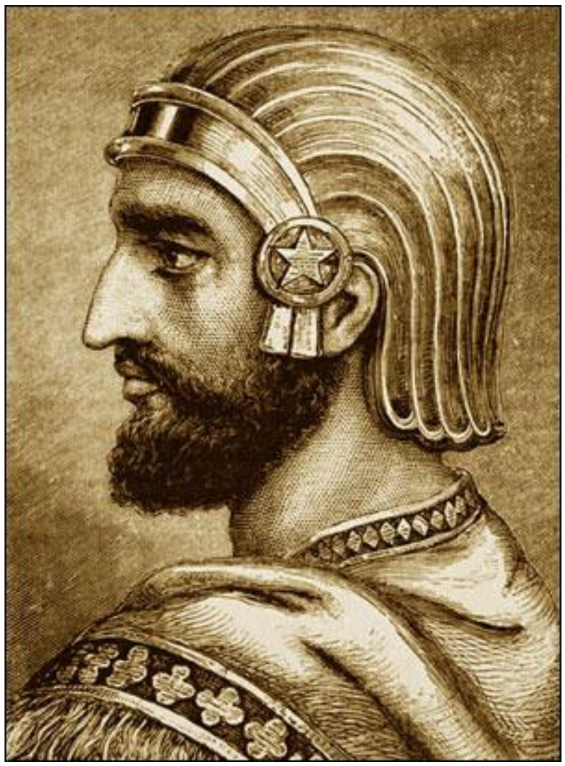


Figure 2: Artistic Portrait of Cyrus the Great.

He successfully united the whole of Persia and called his capital Pasargadae. He was called the Great King and known today as Cyrus the Great (Figure 2). When he came into power and united Persia, he replaced the previous army that was called the kara with a professional army called the 10,000 Immortals (Figure 3).

The 10,000 Immortals were professionally trained men of Persian origin who directly protected the king, while the rest of the army was organized based on roles. Around 600 BC, the Medes had ruled over the Persians, until Cyrus the Great took over them and began the Persian Empire around 550 BC. Cyrus the Great conquered many lands including parts of Egypt, Palestine, Greek colonies in Ionia which is the present-day Asian part of Turkey, and Babylonia (Bramwell 2004).

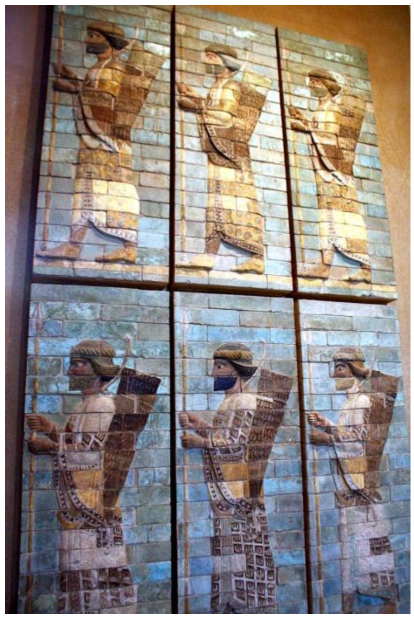


Figure 3: 10,000 Immortals Remnant in Louvre Museum.

Cyrus the Great was a very tolerant ruler and liberated the Jews of Babylonia and allowed them to migrate to Palestine. He modeled his empire after the Assyrian Empire which was established on the banks of the Tigris River in present-day Iraq. Cyrus the Great was killed in battle in 500 BC and followed by the rule of Darius I. By 490 BC, Persia was the largest empire of the ancient world and spanned territories all the way from the Indus River in present-day Pakistan to Asia Minor in an area which is now present-day Turkey and Bulgaria (Bramwell 2004). The Persian Empire consisted of territories such as Iran (present-day Persia), Pakistan, Iraq, Afghanistan, Syria, Turkey, Egypt, and Palestine that lay along the following seas: the Caspian Sea, Red Sea, Black Sea, Arabian Sea, and the Persian Gulf. The Persian Empire's lands were harsh desert-like climates so that Irrigation systems needed to be employed throughout the empire so that fertile lands could flourish and crops could grow.

Cyrus the Great was responsible for conquering most of the lands that would make up the Persian Empire. His conquest of these lands took only thirty years and the king of Lydia named Croesus who was said to be the richest man at that time was taken captive by the Persians after he had attempted to invade Persia. The conquest of Lydia was an important success for the Persians because along with conquering the kingdom of Lydia, they had also taken control of the Greek colonies of Ionia which were under Lydia's control. Athens and Eretria, which were Greek city-states, attempted to aid the Greek colonies of Ionia against the Persians. This interference is what caused the Persian-Greek wars to develop and escalate over the fight for control over territories. The Persians also invaded the kingdom of Babylonia in present-day Iraq where the king, Nabonidus, was already under attack and thus very weak. The Babylonian kingdom spanned land from Iraq all the way to parts of Egypt. Therefore with the conquest of Babylonia, Egyptian territory was also acquired under the control of the Persian Empire.

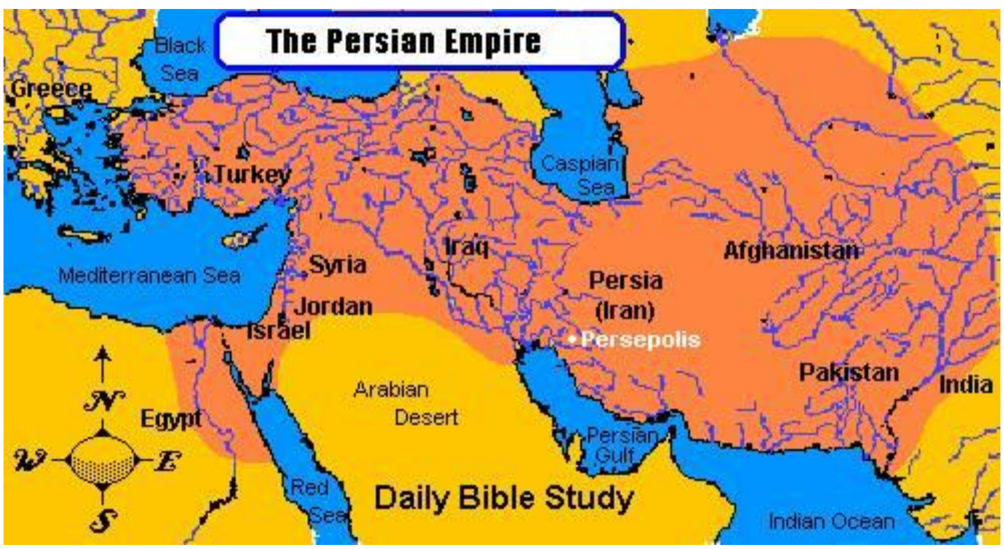



Figure 4: Map of the Persian Empire Due to Cyrus' Conquest.

The acquisition of so much land that were so far apart from one another demanded for an organized governmental system of rule and regulation (Figure 4). Cyrus the Great formed satrapies or provinces that were controlled by satraps or governors of the territory. He died in a battle in 529 BC, whereby his son Cambyses who had helped his father rule the empire by ruling alongside him, took over as successor. Cambyses wanted to rule more parts of Egypt after his father had conquered Babylonia which had already controlled the borders of Egypt. He first built a Persian navy and invaded Egypt in 525 BC, defeating the pharaoh and his army at Memphis successfully acquiring the great Egyptian empire under the Persian Empire's rule.

## II.A.1.2 Darius I

A rebellion had erupted in Persia by a member of the Persian court who was killed by seven noblemen. On his way to put down the rebellion in 522 BC, Cambyses died, leaving one of the seven noblemen to become king. This nobleman was named Darius I and spent the first year of his rule putting down rebellion and gaining the people's trust. His establishment of control and official ascension to his role as king was marked by a memorial carved in a place called Behistun, which is a cliff on a mountain peak. The memorial is now known as the Behistun Inscription (Figure 5) and was a proclamation of Darius I's rights as a ruler and the success he had accomplished based on his ability to keep all the territory under the empire in harmony after a year of rebellion he had attempted to tame.

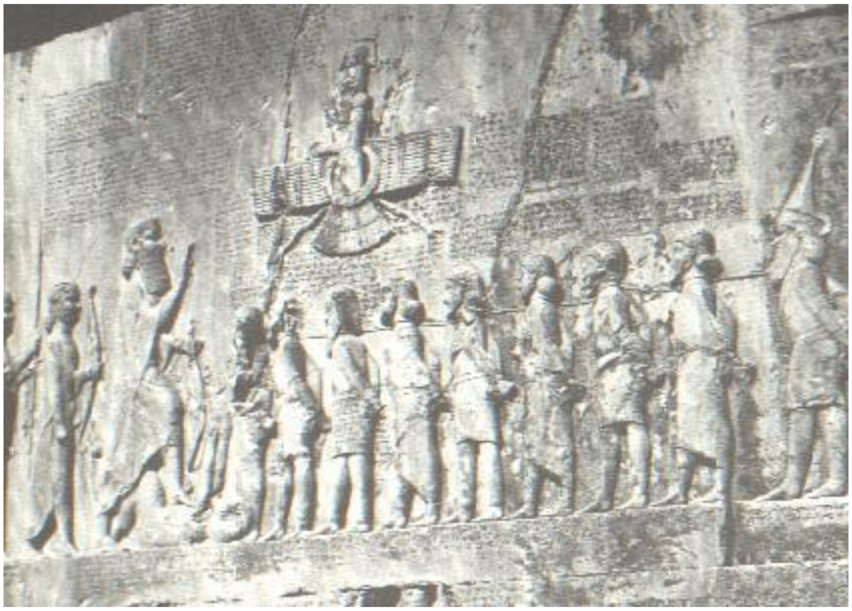


Figure 5: Behistun Inscription of Darius I.

After accomplishing the task of organizing the Persian Empire and stopping any form of rebellion that had occurred, Darius I began his conquests of trying to attain more land under his rule. Since present-day Pakistan was already under Persian rule, he conquered the northwestern part of India and then conquered a country lying on the Balkan peninsula called Thrace, which was in control by the Greeks. He formed an alliance with Macedonia, an ancient kingdom just north of Greece, which enabled him to have closer access to Greece itself. His attack on the Greeks became known as the Persian wars and was ended around 490 BC when Darius I tried attacking the Athenian army at Marathon, which was north of Athens (Bramwell 2004). He was defeated and ended up retreating back to Persia although he still had control over Thrace and the colonies of Ionia that Greece had previously controlled over.

Darius I, like Cyrus the Great, who died in 486 BC was a successful and much loved ruler who was very tolerant of the different races, cultures, and religions that were practiced under his rule. Not only had he successfully expanded the Persian Empire more eastward toward India and into southeastern Europe, he also established a system of taxation to generate a constant revenue to help the government with its many expenses. He built two great palaces in capitals he had established called Persepolis and Susa (Figure 6).

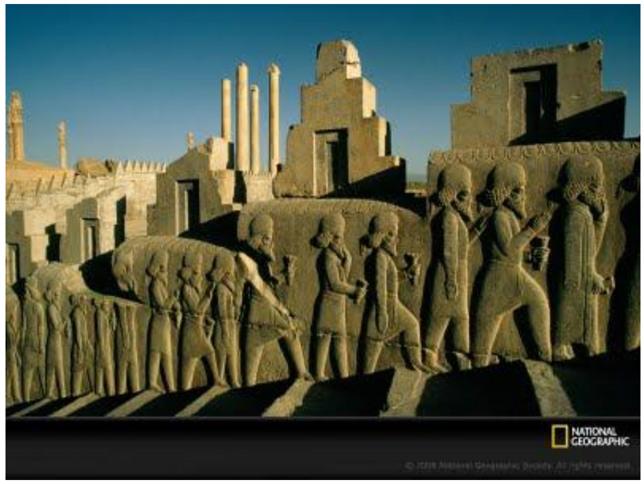



Figure 6: Ancient City of Persepolis in Iran.

He also established the ideology of having a king as the absolute power of the Persian monarch, which was called the "King of the Kings" (Bramwell 2004). Darius I improved the cultural as well as social life within the Persian Empire. His achievements were vastly diverse ranging from better organizing the army to encouraging commerce between nations to help increase the wealth of the Persian Empire. He founded Persepolis as capital in 519 BC. "He introduced a universal system of weights and measures. He also standardized fold and silver coins and started a banking system" (Jestice 2010). However, unlike Cyrus II, Darius I was not as popular due to his fear of betrayal. He appointed close family members to court positions and kept to himself, leading a reserved, introverted life. He did not greatly expand the empire, but mostly maintained it by putting down rebellions by the Babylonians and Greeks. In 518 BC, he also pushed his empire to the east by taking land in India, which extended past the Indus River, to modern day Pakistan providing a rich source of gold for the Persian Empire (Burgan 36).

Darius I's fight against the Greeks in the Battle of Marathon took place a century after the Battle of Thermopylae in 490 BC was the turning point where the Persians realized how ill equipped they were to fight armies as organized and protected as the Greeks. As the Greeks charged at the Persians were their advanced armor and weaponry, the Persians realized they needed heavier armor and more training since they only had no armor and light shields that would do nothing against the Greek weapons. The problem was that metal was expensive and so the Persians decided to pay Greek foot soldiers to fight on their army (Jestice 2010). This strategy worked well until Alexander the Great came into power. Darius I was defeated at the Battle of Marathon, which marked the end of the first Persian invasion of Greece. He attempted to re-attack Greece, but died before then leaving the empire to his son, Xerxes.

## II.A.1.3 Xerxes

Xerxes, Darius I's son, succeeded him and headed into his leadership by first having to put down rebellions by both the Babylonians and the Egyptians. He wanted to get back at the Greeks for killing his father and causing him defeat at the Battle of Marathon. So, he wanted to defeat the Greeks, especially by trying to gain control over both the Aegean Sea and the eastern part of the Mediterranean Sea. In 481 BC, Xerxes, by the aid of his naval fleet and his army, attempted to attack Greece. Although his army outnumbered the Greeks, who consisted of Athens and Sparta long time enemies who united to fight against Persian control, he almost got defeated by the Greeks. Instead, however, he won only due to the last minute strategy employed at the Battle of Thermopylae whereby he used another route to attack the Greeks from both directions (Figure 7). He and his army closed in on the Greeks and defeated them. If it weren't for their quick change of strategy they could have been defeated. They burned the city of Athens, and still the Greeks did not surrender.

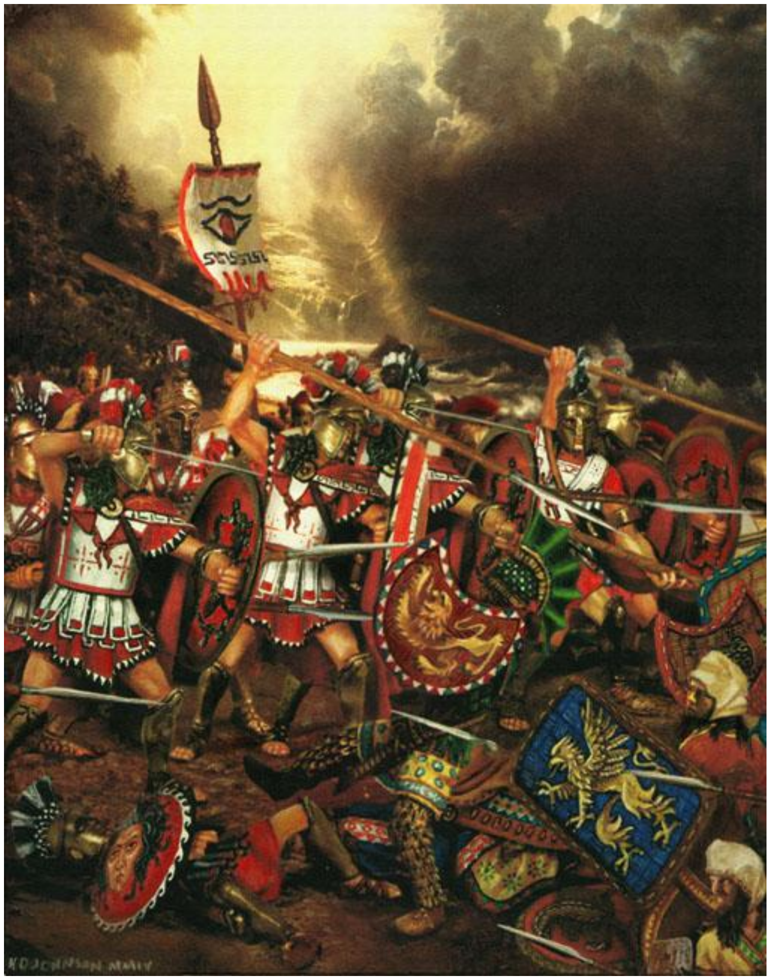


Figure 7: The Battle of Thermopylae.

Confident of his successive victories, he then attempted to attack Greece at the island of Salamis in 465 BC, which became known as the Battle of Salamis. He was defeated due to the training skills the marines lacked such as knowing how to swim. The Persian army retreated and Xerxes discontinued his advances into Greek territory. He was murdered in 465 BC (Bramwell 2004). Ruler after ruler came to power within the Persian Empire only to put down rising rebellions that would be one of the causes of the Persian Empire. The last ruler to come to power in the Achaemenid Empire was Darius III in 336 BC.

## II.A.1.4 Darius III

Philip who was king of Macedonia at the time of Darius III's ascent to power began the Hellenic League, which was the name for the time that he had power over all the Greek city-states and proclaimed himself and his later descendants as rightful leaders of these Greek regions. He planned to invade Persia, but was prevented from doing so because Darius III held the Greek army across the Dardanelles, which is a strait near modern day Turkey connecting the Aegean Sea and the Sea of Marmara. Once Philip's son, Alexander, came into succession things changed dramatically for both the Greeks and the Persians. Alexander was given the title "The Great" due to his strategic military genius and prowess in conquest and management.

At the Battle of Issus, in modern day Syria, that took place in 333 BC Alexander caused Darius III to flea, leaving behind his royal family. After losing the Battle of Issus, Darius III took a long of time and effort to form a strong army to defeat Alexander the Great. They met in a village called Guagamela which is said to be in present day Iraq. The new and improved army of Daruis III comprised of the scythed chariot, better weaponry used by the soldiers, and 15 trained war elephants that were imported from India placed in the front and center of the battlefield used as a scare tactic against the Greeks (Jestice 2010). Even though the Persian army outnumbered the Greeks, they still lost due to Alexander the Great's strategic genius (Tuplin 2010).

Darius III later offered payment to Alexander to get his family back after he fled, but Alexander refused. Alexander the Great continued his entry into Persian territory, taking control of Egypt in 332 BC. 331 BC marks the Battle at Gaugamela where Darius was severely defeated and again decided to flea. Babylonia surrendered to him and he burned the city of Persepolis to the ground in revenge towards Xerxes who had burned Athens to the ground. As he conquered, he continued to pursue Darius until he could get his hands on killing him and finalizing the fall of the Achaemenid Empire.

Figure 8: Portrait of Darius III Fleeing the Battlefield.

One of Darius' generals named Bessos ended up murdering Darius in 330 BC and claiming himself king of Persia. Shortly thereafter, unfortunately for Bessos, he was captured, imprisoned, and then killed by Alexander the Great (Bramwell 2004). The Achaemenid Empire officially collapsed in 330 BC with the death of Darius III. Unfortunately for the Greeks, Alexander the Great died soon after the fall, around 323 BC, leaving the newly acquired territories of the Persian Empire to be distributed among his generals. Alexander the Great's accomplishments lead him into Persia to defeat the Empire city by city.

## II.A.2 Military Tactics

As the Persian Empire expanded and grew more prosperous, so did its culture. Cyrus the Great's initiative to unite the northern and southern halves of modern day Iran lead to the formation of one of the greatest empires (Katouzian 2009). The two most powerful Persian kings and leaders of the Persian Empire were Cyrus the Great and Darius the Great. They were great leaders because they were strategic in their military tactics and were good fighters, unlike kings such as Xerxes I and Darius III.

Trade enabled the acquisition of wealth for Persia as they traded along the Silk Road, which was a road starting from the Mediterranean Sea that continued to China. The irrigation systems built enabled for agriculture to grow. Art and architecture also developed and expensive metals like gold and silver were utilized to make bowls, jewelry, and other ornaments that were used in banquets and parties (Katouzian 2009). An official language for the empire was chosen as Aramaic, a language which first developed in Syria. A new religion developed in Ancient Persia, one called Zoroastrianism, which was based on a prophet called Zoroaster who had influenced the Middle East from around 500 to 650 BC. This became the official religion of the Empire, although people who were conquered under the Empire in different regions of the world and who practiced different religions were also tolerantly allowed within the Empire.

## II.A.2.1 Arms and Armors Used

Traditional Persian warfare consisted of light armor and little face to face combat. The Middle Eastern heat was so intense that it necessitated the need to decrease the amount of armor worn by the soldiers. Metal was also expensive. Soldiers mostly wore tunics, which were loose clothing reaching the knees that were padded with linen as a protective gear against soaring arrows (Jestice 2004). The Persians were mostly armed with spears, arrows, and bows and so they did not need armor as compared to the Greeks who used heavier weaponry like axes and metal swords that would easily severely injure a fighter close by. Soldiers had a shield that was a rectangular sheet, 5 feet in length and was made of sticks that were kept together with animal skin framework. They were used to protect soldiers against arrows. When the archers were attacking an enemy, a line of men who carried these light shields would stand in front of them, while the archers shot from above the shields. They barely protected against heavy weaponry, as expected as seen in Figure 9.

Figure 9: Illustration of Typical Ancient Persian Soldier before Innovations in Armor.

The only well protected soldiers in the army were those who were part of the Royal Guard responsible for protecting the king. This group of soldiers consisted of noblemen because they could afford weaponry and horses (Burgan 2010). They were the most loyal to the king because they were Persian and were not conquered under the Persian army and required to fight for an empire that they fell under. These soldiers were called the 10,000 Immortals (Lendering 2011). They were very well organized and when one was killed, he was immediately replaced by another backup soldier. They wore iron breastplates in addition to their light shields made of sticks and animal skin (Bradford 2001).

### II.A.2.2 Archers

The Persian army was large, but disorganized due to the fact that its fighters were trained in various countries with different fighting techniques (Jestice 2010). All Persian men had to serve in the army and had to provide their own weapons. They were mostly all foot soldiers because it was less expensive to fight on foot than on horseback. The Persians were skilled in archery, while the Egyptians used a lot of spearmen. Palestinians were famous for their slingers (Keegan 1994). The kings of Persia, however, had smaller armies protecting them that were highly skilled, trained, and willing to fight for Persia. The smaller armies were organized and were more loyal to the Persian Empire than were the larger army. This is mostly because the larger armies had soldiers from conquered areas that were forced into the army by the Persians. They did not have any nationalism for an empire that had conquered them and therefore, did not find a motivation to fight well for Persia.

Unlike the Persians, the Greeks were more organized and better face to face fighters. The Greeks believed that fighting needed to happen on the ground using spears, not arrows released from a distance, and that belief allowed them to succeed in battles against the Persians who were not good at close combat fighting. Therefore, the Greeks had good quality protective wear. They were clad in armor that allowed for minimal injury by the Persians' arrows. They also carried shields and wore helmets, covering and protecting as much of their bodies as they could (Bradford 2001). Persia developed adept archers due to their incorporation of archery from the Scythians before them. Around 600 BC, they began to hire Scythian archers to teach Persians how to skillfully master archery.

Persians made their bows and arrows based on the Scythian model, but with slight differences. Scythian arrows were made of reed with tips made of stone and the bows were compound bows because they were made of wood and animal horn that was kept together using animal tendons. Persians however did not use a compound bow, but a simpler bow that was made of wood and a cord to allow flexibility when released the arrow. Spearmen and archers worked hand in hand with one another. The spearmen protected the archers by using the light shields that were made of wood, while the archers shot arrows. These arrows were made of wood and had bronze tips. The bows used evolved to be like the compound bows used by the Scythians because they were much more powerful when releasing arrows. Persian soldiers also sometimes carried daggers and deadly small swords that were called akinakes. Akinakes looked like modern day machetes and had very wide, strong blades.

### II.A.2.3 Cavalry

Cyrus the Great wanted to use more mounted soldiers because he knew how important they were especially since two of his greatest enemies used cavalry or soldiers on horseback. One of his enemies called the Lydians located in Anatolia, which is present day Turkey, used cavalry. At the Battle of Sardis that took place in 547 BC, Cyrus the Great developed a smart strategy in that he placed a line of camels in front of his army which kept the Lydian horses away from the Persian army because horses detest the smell of camels. This forced the Lydian cavalry to fight on foot, easily allowing the Persians to defeat them (Jestice 2010). The second enemy who relied heavily on its cavalry was the Scythians. The Scythians were wandering nomadic tribes that lived around the north of Persia and therefore, had expertise in horseback riding and fighting. Cyrus the Great could not defeat this enemy and ended up dying in battle in 530 BC. Cyrus the Great’s death against the Scythians opened the eyes of the Persian Empire to the importance of integrating trained cavalry into their army. The Persian army was organized in a new fashion. The cavalry flanked both sides of the army in the middle which comprised of archers who attacked first from a distance. Afterwards, the horsemen attacked anyone left standing in the opposing army by throwing javelins, which were light spears thrown by hand.

Due to the fact that the Persian army relied on distance combating in battle, they did not wear armor. Another disadvantage the Persian army had that they tried fixing by incorporating horseman in their army was the fact that the horses they used were very small and only useful in their swiftness. They were not designed to fight in battle and therefore, were easily targeted by the opposing enemy. Cyrus the Great's defeat against the Scythians also made the Persian army realize the importance of high quality weapons and the necessity of protective gear like armor, shields, and helmets. The Scythians, like the Greeks, fought in close combat, while the Persians disliked this approach. The Scythians used a ruthless tactic of cavalry fighting. They were known as "knights" of the ancient world due to the speed and ferocity with which they rode their horses, charging straight towards the Persian army. This tactic greatly intimidated the Persians who stood still shooting arrows, while realizing that the horseman were getting closer and closer. The force of the speed with which the Scythian horsemen rode caused a harder strike and greater impact between the spears they used and the Persian soldiers they targeted.

### II.A.2.4 Chariots

The Greeks fought in close lines that were very tight and allowed for optimum strength. The Persians wanted to find a way to disrupt those orderly lines to allow for their archers to target as many enemy soldiers as they could. As a result, they decided to utilize the scythed chariot, which was an ancient war chariot that had one innovation that set them apart from other armies. The scythed chariot had swords that were connected to the rotating axles of the wheels of the chariot so that when the chariot was driven, the swords poking from either side of the wheels rotated with such speed that any soldier in proximity to the sides of the chariot would get arms, legs, and any other body parts either sliced off or cut deeply enough to cause permanent damage.

Using these scythe chariots, the organization of the army evolved slightly again. Instead of beginning with their archers, the Persian army began with their scythed chariots that drove very swiftly, disrupting the Greek lines of foot soldiers, injuring some, creating chaos, and allowing for an opening for the Persian archers to begin firing away (Bramwell 2004). This tactic that was first employed in 400 BC and although very helpful at first, it grew old once the Greeks found alternate ways to defend against it since they knew when to expect it. The problem the Persian army had was that they only innovated after they came into contact with an opposing enemy and once they employed a new form of tactic like the scythed chariot which proved to be successful, they assumed that sticking with that same tactic would be successful in every battle thereafter. The problem is that other armies will begin to evolve in response to this threat and form stronger armies, develop more clever tactics or more advanced armor and weaponry. For example at the Battle of Issus in 333 BC and the Battle of Guagamela in 331 BC, the Persians were defeated by the Greeks because Alexander the Great was a powerful leader who taught his army to fight as a group. So when the chariots attempted to drive through the tight line of soldiers, expecting it, they moved aside in a timely fashion to avoid the chariot. Thus, fewer injuries developed and the Persian archers were not allowed as successful openings as the chariot would have previously allowed for.

## II.A.2.5 War Fleets

Darius I developed a navy or enormous fleet for sea warfare. The Phoenicians were adept naval warriors and were accustomed to sea warfare mainly because of their geographical location near the Mediterranean Sea. However, once Persia conquered them in 539 BC, they divided Phoenician territory into vassal kingdoms. The Persians adopted Greek war ships called triremes and biremes. Triremes were long narrow ships that supported three levels of rowers that had a long oar for steering at the back end and a ram, which is an iron beam at the front of the ship. A bireme, on the other hand, is the same as a trireme except it supported two levels of rowers, which are about 200 men as opposed to 300 men found in the triremes. The vessels had a ram at the front because it was used to stab into an enemy ship, attacking it and then successfully destroying parts of it. Marine soldiers were stationed in the vessels by lying down on the deck and once the vessel had attacked the enemy ship, they would fight face to face combat. Marines used small shields, axes as weapons for face to face combat, and arrows for farther distance fighting across ships.

Unlike the Persian army on land, the Persian navy on sea was much stronger and more trained. The rowers were usually Phoenicians or Egyptians, while the marine soldiers were Persians who underwent thorough and intense training as ordered by the Persian king who not only monitored the training, but also paid for the fleet. Therefore, the Persian navy was well funded and could therefore afford expensive and high quality armor and weaponry made of metal. This was largely due to the fact that the Persian king supplied the tools necessary unlike the Persian foot soldiers who had to supply themselves with weaponry and armor. The Persian fleet was successful against Greek rebels who were put down in 494 BC at the battle at Miletus, which was a sea battle in Anatolia, which is modern day Turkey (Souza 2008).

The main reasons for defeat of the Persian Empire by the Greeks even when they had developed a strong fleet was due to the fact that the Persians were not accustomed to Greek waters and they did not have as strong armor as the Greeks had. Another disadvantage the

Persians had was the fact that they could not swim. At the battle of Salamis, which took place at the waters between Athens and the island of Salamis, the Greeks defeated the Persians because due to their knowledge of the waters surrounding them, they decoyed the Persian fleet into a narrow channel that trapped them. The Greeks attacked them mercilessly and the Persians had no way of escaping since they could not swim. The battle of Salamis in 480 BC marked the nearing end of the Persian Empire. Alexander the Great finished off the last remaining hopes the Persians had of maintaining control over the territories they possessed (Ancient History Encyclopedia 2011). The Achaemenid or Persian Empire was successfully defeated in 334 BC when Darius III died at the hands of Alexander the Great. The lands the Persian Empire had conquered and maintained were now under Greek control.

## II.B.1 Ancient Greece

The Persian Achaemenid Empire took place from the year 700 B.C. to 331 B.C., two main time periods in Greece took place during this span. The first was the Archaic period, which lasted from 750 B.C. to 480 B.C. It was a time of revival and advancement in several fields, such as politics, culture, and art. The following period lasted from 480 B.C. to 323 B.C. and is known as Classical Greece. In this period there was a massive cultural boom, inward city-state fighting, major clashes with Persia, and the death and reign of Alexander the Great. This time frame is when ancient Greece emerged from the Dark Ages (1100 B.C. to 750 B.C.) and made their famous historic advancements.

### II.B.1.1 Archaic Period

Figure 10: Hoplite Soldiers and Armor.

The Archaic period was when the Greeks started to gather into settlements, which eventually developed into the independent city-states, or polises. These polises often traded among each other and maintained general close interactions. More often than not they would cooperate with other city-states so they could protect themselves and take over their enemy city-states. At this point, government was run either by an oligarchy or a tyranny. The oligarchy was made up from the richest citizens of the polis and held the power usually possessed by kings. The tyrannies would usually overthrow these governing bodies with support from the people. These were always unstable and lost support from the people. Each tyranny reign would only last for a short amount of time before being overthrown, but this was the predominant form of rule throughout Greece. As populations expanded, they needed to take over new lands for their people to inhabit. There were hundreds of different military campaigns, consuming a great deal of resources, but resulting with one of the greatest returns from war in the ancient world. Each expedition was commanded by a single person who had orders to establish a walled city with houses, shrines, and farmland. The city-states would chose the settlement land based on the guidance of their god Apollo at Delphi. These settlements would often become additional independent polises that would be found from North Africa to Spain and to Asia Minor. The Greek armies usually did not need to fight at this time because of the openness of other countries to Greek settlement; they came by sea resulting in the avoidance of traveling through populated territory; and they usually chose lands uninhabited by the local country.

Most of these new colonies were the result of the cooperation between the two leading city-state sea powers, Chalcis and Eretria. Envy drove the Chalcidians into hostility toward their ally, resulting in the Lelantine War. Each side gathered their own allies, eventually leading to a war that spread across the Greek world. Their government bodies agreed on forbidding the use of long range weapons in their war, so that the battles were fought with swords and spears. Eventually Eretria did lose the war and its empire. During the confusion caused by the war, the polis, Sparta invaded the not yet united Messenians for their fertile land. After four years, the Messenians were pushed out of their villages, forced to swear an oath not to revolt, and had to pay a tribute of half their crops. Eventually there was a conflict between Sparta and yet another polis called Argos for control of the land called the Peloponnesus. The king of Argos, King Pheidon, devised a new type of strategy that required a new type of soldier. This was a formation called the phalanx, which used heavily armored militia called hoplites. King Pheidon used this tactic to defeat Sparta at the battle of Hysiae. This tactic was then used by many other polises, and was perfected by the Spartans.  Sparta then became a leading power and had an established government. It was ruled by two kings along with a council made up of twenty-eight elders. It even had a specific hoplite class, which were full time soldiers given land and servants called helots. In other city-states, hoplites were ignored in times of peace, which means they had to use force if the governing body would not grant them democratic freedoms. This often led to putting a tyrant in place, chose by the hoplites. This led to an early form of democracy, at least for the hoplites.

The Persian king Darius wished to put an end to Scythian disruptions to his empire, so he set a military expedition to destroy them. To do this he had to cross a body of water called the Bosporos and commanded the Ionians under his rule to guard the constructed bridge across.  On his way back from his failed campaign, he grew distrustful of the tyrants in charge of Ionia. Deciding to act before the Persians do, the Ionian tyrants started to rebel against Darius. They sent out pleas for assistance from other polises. The major force that helped was that from the Athenians. They sent twenty ships and helped burn down the capital of Lydia, Sardis in 498B.C.

The Ionians were eventually defeated at the naval battle of Lade in 494 B.C. They took control back and reestablished stability by implementing democracy, establishing courts, and redistributing the tax burden. Darius wanted revenge for the burning of Sardis, so he moved his conquest towards Greece in 490 B.C. His army landed at Marathon and was met with a surprise attack by ten-thousand Athenian hoplites and one-thousand Plataean hoplites. After eight days of fighting, the Persians decided to retreat, with half the Greek army still in pursuit. The Athenians lost about two-hundred men to the Persians six-thousand five-hundred. This battle demonstrated the effectiveness of the hoplite phalanx against the Persians, but also the weakness of the Athenian navy. To correct this, the successor to the king demanded that two-hundred triremes, a Greek war boat that would ram into other ships, be made with the profits from a newly discovered silver vein.

Ten years later, Darius's son Xerxes led a carefully planned campaign against Greece as vengeance for defeating his father. He secured lands surrounding Greece, built roads, dug canals, had his navy up to date by using the trireme ships, and gathered a massive army. An attempt to unite the city-states to defend Greece from Persia was ignored for the most part. The major powers were Sparta and Athens, who each had some allies as well. In 480 B.C. Xerxes forces landed and had begun the invasion. First they had to make it past Thermopylae, where King Leonidas made his famous stand with three-hundred Spartan Hoplites and seven-hundred Thespians. They had to hold the Persian army back while the Athenians and their allies fought the Persians in the naval battle at Artemisium. The Persians had a stalemate in their naval battle, but made it past the Spartans and ransacked Athens. The second in command of the naval forces, Themistocles, destroyed Xerxes navy with a retreat and surprise attack. Xerxes then left back for Persia out of fear of having an escape route cut off, and in his stead left his general Mardonious.

In 470 B.C. the Persian army was defeated at Plataea by the Greek alliance under the regent Spartan general Pausanius.

## II.B.1.2 Start of the Classical Period


Figure 11: Map of Locations of Peloponnesian War.

This marked the end of the Archaic Period and starts the Classical period. Athens establishes the Delian League, which was a naval defensive alliance against any future Persian invasion. This gave Athens the largest and greatest navy in the Aegean Sea. The Athenian general, Pericles, wanted to use this power to eliminate any other opposing naval powers, to create an alliance on land similar to Sparta's and to liberate Egypt from Persia. However, all of these goals were too substantial to accomplish. Failing at completing these objectives, a thirty year truce was made between Sparta and Athens and was open to be acknowledged by other city-states who wished to chose one or the others side. The Athenians yet again made three mistakes that would cause another, much larger war. They essentially blockaded the polis, Megara, they attacked the city, Potidaea, for not taking down their costal city wall, and finally they aided the island of Corcyra in their conflict with Corinth. Sparta and its allies met to discuss waging war on Athens for breaking the truce. To create a balance in power, Sparta established the Peloponnesian League, which mainly consisted of polises from the Peloponnesus. They then launched the start of the Peloponnesian War with an assault on the Athenian peninsula, Attica. This war would last from 431B.C. to 404B.C. Athens had a powerful navy, where Sparta had a powerful land force. At some point, this war had involved almost every other Greek city-state as well. Pericles restrained from meeting Sparta in open battle and instead opting for attacking the coasts to demoralize the Peloponnesian League. In the year 430, after Sparta had spent forty days in Attica, Athens was hit by a plague that wiped out thousands of people. This resulted in Pericles death and a loss of one-quarter of the Athenian troops. Two years later, one of Athens' allies, Mytilene, revolted. Pericles successor, Cleon, used their powerful navy's triremes to take control and then claimed all of its lands and possessions for Athenian settlers. Many Greek cities were divided between support for Athens and support for Sparta. One of Athens, strongest naval powers, Corcyra, dealt with a large amount of mayhem and divisions. The war then seemed to shift in favor of Athens when one of its finest generals, Demosthenes, trapped a large group of Spartan soldiers on the island of Sphacteria. However, Sparta was able to float and swim supplies to the island to sustain the troops. Leon and Demosthenes amassed an army to defeat the Spartans at Sphacteria. The Athenian hoplites would be outmatched by the Spartan's hoplites, though the Athenian's ranged soldiers, the peltasts and archers, were able to subdue them. The Spartan soldiers surrendered when they were given the chance and were used as deterrent for Sparta's continued invasion of Attica. Sparta turned to a major figure and skilled soldier, Brasidas, to convince Athenian cities to revolt. One of the cities he convinced was Amphipolis, which was the location of the battle which ended in the death of Cleon and Brasidas. In 421B.C. a treaty was made between Sparta and Athens, called the Peace of Nicias, which should have sustained fifty years of amity. It was ended in 418 B.C. by the efforts of a new Athenian political figure, Alcibiades, to make a new defensive alliance. After the treaty, Athens and Sparta both made efforts to get polises that did not accept the terms back into their alliances. Sparta, led by king Agis, battled Argos twice and won both battles, resulting in a fifty year treaty between them and their old ally who helped Argos, Mantinea, rejoined their alliance. Athens was convinced by Alcibiades to force Syracuse and the rest of Sicily into the Athenian empire, believing that otherwise they would aid Sparta and that their wealth could sustain Athens' navy. He was accused of destroying sacred artifacts before leaving, so in an attempt to escape trial he defected to Sparta and informed them of Athens' takeover of Sicily. In response Sparta sent an expert on warfare to aid them, Gylippus. During their Syracuse invasion, Athens also attacked Amphipolis and the coasts of Laconia. Sparta took this as an official break in the treaty and invaded Attica again in 413. King Agis constructed a fort in Attica at Decelea to maintain troops and keep the Athenians inside their city. With the help from their Spartan expert, Syracuse was able to defeat and drive out Athens, resulting in a serious loss for them. Athens eventually won a decisive naval victory in 406 at Mytilene, losing only 25 ships compared to the Peloponnesians losses of over 70 ships. Sparta was able to gain funds for the war from a friendship between their admiral-in-chief, Lysander, and the Persian prince, Cyrus the Younger. Lysander stationed his fleet at the Hellespont, which threatened Athens' grain supply. Athens responded by sending their whole fleet, however Lysander refused to leave the harbor. Athens took this as cowardice, so on the fifth day they beached their ships to gather supplies. At this point Lysander chose to attack while they were vulnerable and won the battle. As a result, Athens lost the Peloponnesian War and was almost entirely demilitarized and had an anti-democratic government put in place.

Sparta became the dominant polis in Greece, but slowly lost its hold because of a lack in unity and political skill. Some of the tyrants that the Spartans attempted to put in charge of certain city states conspired with the Persian, Cyrus, to overthrow his brother, King Artaxerxes. This was in exchange for help from Persia in controlling the polises without giving up control of Iona, which was in the terms for having help from the current Persian ruler. King Artaxerxes sent gifts of gold to Sparta's now many enemy city-states, formed the League of Corinth against Sparta. It was around this time that the peltast soldier began to be seen as an answer to defeat hoplite warfare. Ultimately Sparta was forced by Persia to sign a peace treaty in 387 B.C., which resulted in the transfer of Ionia to Persian rule and all polises to become autonomous. They broke the treaty and continued an ongoing battle with Thebes, in which they were defeated. The decline of Sparta resulted in there being no one ultimate power in Greece, meaning the individual polises were now autonomous and free.

This place was eventually filled by the Macedonians lead by Philip II after a victory at Chaeronea against Athens in 338 B.C. When Philip II was put on the throne for Macedonia, he received a land that was threatened by inward and outward fighting. Through the use of his great military tactics, inventions, and diplomacy, he was able to make Macedonia a powerful and respected nation. He was one of the first people to implement siege weapons and the use of the oxybeles catapult. Some of the siege tactics used were siege towers, tunnels, and incendiaries. Philip II also redesigned his phalanx formation by having his men use smaller shields and a much longer spear called the sarissa. Philip II was assassinated in 336 B.C. while attending his daughter's wedding. With his death, his son, Alexander, was the definite heir to the throne.

## II.B.1.3 Alexander the Great

Figure 12: Painting of Fictional Alexander the Great

From a young age, Alexander was trained to be a worthy successor to his father. He received a great education and was even tutored by Aristotle. It was under his tutelage that he formed a love for Greek culture and the *Illiad*'s warrior code of honor, which inspired him to not only be very intelligent, but a great fighter. When his father died, he had more than enough experience to assume his role, despite his young age of 20. At the age of 14 he was left as regent while Philip II was away at war, he lead his own military campaign at 16, and was commander of the companion cavalry for two years. The Greek League did not acknowledge him as king, so he marched to Thebes and was made general with unlimited power. After leaving, the Greeks renounced their oaths, which Alexander responded to by decimating Thebes. This sent a message to the city-states, allowing Alexander to march on Persia without worry about local rebellions. Alexander started his campaign against Persia in 334 B.C. with the battle at the Granicus River. The Persians, lead by Darius III, wished to meet Alexander at the river and kill him, avoiding the use of the risky scorched earth strategy proposed by Memnon of Rhodes. Alexander had 30,000 foot soldiers and 5,000 cavalry and the Persians had 20,000 calvary and 20,000 armored Greek mercenaries. Alexander ordered an immediate attack on the Persians, which allowed them no time to implement their mercenaries. Through his tactics and skills in the battlefield, only 2,000 prisoners remained left of the Persian army while he lost just above 100 men. After this battle, many cities ceded to him, and the ones who did not were defeated. The city of Tyre, located on an island, supported a solid defense against Alexander's advancement through the use of ingenious weapons and defenses. Alexander's cunning and determination were still too great for them, resulting in every man in the city being killed and the women and children being sold into slavery. Alexander eventually went on to defeat Darius III at the battle of Gaugamela with expert cavalry movements and specifically designated troops that could dispatch Persian chariots. Darius III was able to escape from this battle due to a misunderstanding about the Macedonian phalanx being in danger and Alexander attempting to rescue his men. Darius was later killed by his own men. From 330 to 327 B.C. Alexander conquered the Iranian plateau and shifted much of his attention to integrating Greek and Persian cultures in an attempt to be a united kingdom instead of a conquered land. Prior to this he had made some wise efforts to put Persians in charge as satraps (a name for governors of provinces in ancient Persia) in places like Egypt and Babylon. He encouraged education of Persians in Greek speech and Macedonian arms, encouraged Macedonians to marry Persians, placed Persians into trusted positions, and he even adopted the act of proskynesis (the Persian act of bowing and touching foreheads as a salute to the king). In 326 Alexander arrived at the border of India at the bank of the Hydaspes River. On the opposite bank he was met by the Indian king, Porus, who had light infantry, cavalry, chariots, and war elephants under his command. Alexander fooled Porus into thinking that he would wait for the river depth to lessen by setting up what looked like a very settled encampment. When a thunderstorm hit, he moved his men, whose noise was covered by the thunder, across the river and had a detachment flank the Indians further down the river. Using even more flanking maneuvers, he was able to confuse and clump Porus's forces together. This resulted in their own elephants trampling them. At the end of the battle, two-thirds of the enemy army was killed or captured. Porus was among the captured and was asked by Alexander how he wanted to be treated. Porus responded "like a king", to which Alexander responded by making him satrap of India. Reluctantly listening to his men, Alexander did not press on through India, but decided to made a difficult trek through the Gedrosian desert to make it back to Susa. On his return in 324 B.C., he was greeted by the men he put in power abusing their privileges as they thought Alexander was lost to the desert. He punished these men, replaced them, and reorganized the empire. In 323 B.C. he caught a fever in Babylon and died with no adult heir. This resulted in the end of Greece expansion and lead into a great decline as his followers fought for rule.

## II.B.2 Military Tactics, Arms, and Armor

The military tactics of ancient Greece remained the same for 300 years once it entered the Archaic Period. During this time there was mostly fighting among the city-states, who would all abide by similar rules for combat, resulting in the lack of a need to change their warfare. It was not till the end of this age, during the battles with Persia, did Greece really start changing tactics and armor. Interestingly, there is a great deal of variety among artifacts due to regionalism among the polises. Each one had a unique culture and therefore different versions of the hoplite armor. Even naval battle did not see a change until the Peloponnesian Wars. The most drastic change in warfare was brought about during the Classical Period by Philip II's noticeable introduction of siege tactics as a major tool and Alexander's new tactics and changes to arms and armor.

## II.B.2.1 Hoplites

The hoplite was a heavily armored unit that was equipped with a bronze helmet, corslet, greaves, and large circular shield, called the hoplon, which weighed twelve to fifteen pounds alone. They were typically had a height of 5’2” to 5’4” and mainly wielded a spear with a backup sword called a xiphos, used if the spear had to be discarded. The gear all together, called the panoply, weighed a massive 50 to 60 pounds. In order for the hoplite to be at its greatest potential, it would have to be used within the phalanx. This strategy involved having a row of hoplites that would protect the man on their left with their shield, which eliminated the weakness of other shields which could only protect one side. Behind were several other rows of hoplites that would push forward to disrupt the enemy formation. There were breaks in the lines at certain points so that the normal foot soldiers could advance; these same soldiers also defended the right most hoplite. The men would march to a piper and were ordered through the use of a trumpet, or similar device. This was the major and most influential form of fighting throughout the Archaic Period and the beginning of the Classical Period. Many hoplites would work as mercenaries for other city-states and powers. In fact, during the battles against Alexander the Great, the largest portion of Persia’s heavy troops were Greek mercenaries. Compared to the hoplite, Persian troops were wearing next to nothing in protective gear. Because of their strong armor and hoplon, the Greeks were among the greatest melee fighters during this time period.

### II.B.2.1.a Hoplite Armor

Even though many of the city-states had their own styles and variations of hoplite armor, the majority used the same bronze plate-corslet. This original corslet was designed so well that it stayed in use for about two-hundred years, eventually undergoing changes just before the wars with Persia. It was made up of two basic pieces, a back and breast plate which curved out ward at the bottom, giving a bell shape to the armor. Eventually, the armor's fault of being too heavy was addressed by the combination of plate, scale, and linen armor. Not much of this armor has been found in terms of actual artifacts, historians base most knowledge of it from monuments and paintings. It consisted of two large shoulder-pieces, called epomides, that were attached at the back and fastened over to the chest. It is hard to tell what parts of the body of the armor was metal or leather. It was most likely leather with bronze plates attached and metal scales down the sides. Some variations have the metal scale armor along the front as well. Towards the bottom of the corslet was a skirt like area formed by leather flaps called pteruges. With the lightened armor, the hoplites could actually run in battle, which is seen in pictures of battles and remembered when the Athenian hoplites ran at Persian archers to avoid their arrows and close the distance before they could volley more shots. Another variation, not used as much, developed around this time was similar to the original plate corslet, but was carefully shaped to fit the wearer and was decorated with the main muscles in the torso. This type of armor is seen worn by Alexander's Macedonian cavalry.

Figure 13: "Bell" Corslet used by Greeks before the wars with Persia.

The hoplite hoplon was the most important part of his panoply, it gave him the greatest amount of protection and without it, the phalanx would not work. Of the hoplite’s equipment, this was the least changed throughout time. Hoplon shields were still in use even when Philip II invaded Olynthus in 348. The shield protected the hoplite from his chin down too his knee, having a usual diameter of three feet. The shield was round and slightly concave in shape except for the rim. The hoplon was made from wood and reinforced with bronze. The rim was faced with bronze and sometimes the entire shield was also faced in bronze. Similar round shields have existed for a while and across other cultures. The Greeks made a design change to how the shield was held that made the hoplon better than these shields. On the inside of the shield was a bronze strip the bowed outward called the porpax, which the hoplite’s arm would go through up to the elbow. The hand of this arm could then grip a leather handle called the antilabe. This design gave the soldier several advantages to other shields; it lessened the amount of effort to hold the heavy shield, it allowed him to hold another weapon and keep the hoplon if he released the antilabe, and it generally gave him better control of it. On the front of the shield would be some sort of blazon that would differentiate an individual hoplite from others, usually it was of some sort of animal. These blazons would be painted on a bronze faced shield or detailed in bronze and fastened on to the bare wood. With the spread of democracy, the hoplites would have the blazon of their city, which was usually a letter, though some had images like a club or trident. One major advancement with this shield was the addition of a long antilabe, which ran along the inside of the whole shield on a series of tassel covered studs. This allowed for making another handle if the antilabe broke.

Figure 14: Round, Slightly Concave Hoplon Shield

Helmets were probably the most varied form of armor among the Greeks, due to the regionalism of different city-states and attempts to correct flaws with other helmets. They were usually constructed of bronze and possessed some sort of crest. The Corinthian was the most common form of helmet and stayed in use for the better part of the Archaic period, undergoing many variations and inspiring other types such as the Chalcidian, which used softer contours and had an opening at the ears for hearing. The main feature of these helmets is the impressive work of the smith to beat out the entire helmet from one sheet of bronze. The helmet usually had a T shape for the eyes and mouth and often had a nose-guard. This innovation was so great that similar design types could be seen 2,000 years later in Italian armor. Another common type was called the Illyrian, which was open-faced, had cheek pieces coming down from the top, and a low neck-guard. It was made from two pieces, but the crest was placed over the location of the joint to strengthen the weak point. There are also many other variations in addition to these. By the end of the sixth century, the Corinthian became much more developed, taking from different variations made to make a new standard of helm. Eventually the Corinthian gave way to a new helmet, the Attic, at the beginning of the fifth century. This helmet was vastly different, continuing the trend towards lighter armor. It was open faced, did not protect the face, cheeks, or ears; though some variation do have hinged cheek guards.

Figure 15: Illyrian Helmet.

Figure 16: Chalcidian Helmet.

Figure 17: Corinthian Helmet.

Figure 18: Thracian Helmet

The final piece of major armor worn was the greave, which ran from the top of the kneecap to the instep. This was made out of bronze with a fabric lining and formed to fit the leg. The greatest advancements in the greave had to do with the continued perfection of forming it to the soldier's leg and thinning out the metal so that eventually the greave could simply snap on to the wearer. The only noticeable difference between sixth and fifth century greaves were design patterns. In addition to the key parts of the panoply, hoplites had optional pieces or armor they would wear, such as ankle-guards, a rerebrace on the right arm, thigh-guards, and rarely vambraces. Most hoplites did not try to get all these optional pieces, especially when attitudes shifted towards a desire for mobility.

### II.B.2.1.b Hoplite Weaponry

The primary weapon of the hoplite was the thrusting spear. It consisted of a wooden shaft around 6 ft., a 1 ft. leaf-shaped iron spear head, and a 2 inch spear-butt made of bronze. The spear-butt was an important counterbalance that was cast from a four-sided mold and often was decorated. At the beginning of the Archaic period many hoplites would carry three spears and use one as a javelin. This was realized to be cumbersome, so hoplites switched to using one spear towards the late fifth centuary. The spear would be held overhand and then thrusted at the enemy.

In the event that the spear was broken or lost, the hoplite had to quickly switch to a small sword called the xiphos. This most likely evolved from the very widely used Griffzungenschert. It had a thick hilt and leaf-shaped blade. The xiphos was originally constructed from bronze, but changed over to iron with the change in age. It was worn high up with a strap, under the left arm in a sheath for quick access. This weapon persisted through much of the sixth century, but eventually was overshadowed by the kopis. This was a short, single-edged sword with a slight curve. The back of the sword and the cutting edge were both convex, giving the sword an appropriate weight towards the tip. The hilt had a hand-guard and curved around the hand. It was specifically designed as a cutting weapon that would be drawn back behind the left shoulder and swung downwards. The 300 Spartans at Thermopylae had to fall back on this weapon towards the end of the battle.

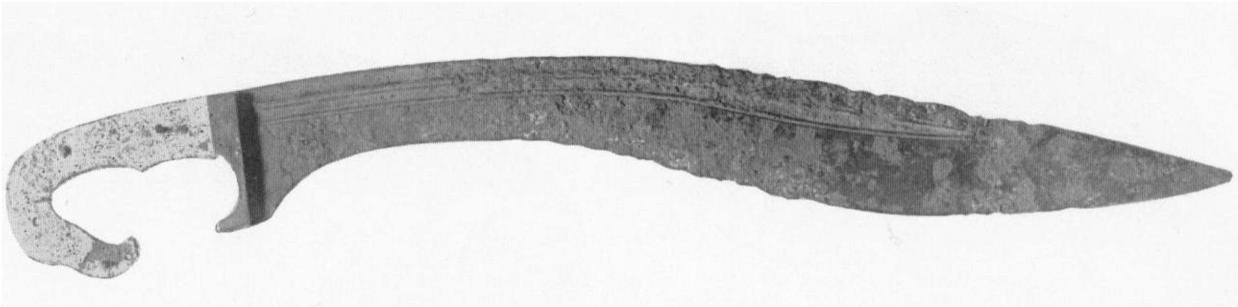


Figure 19: Short, Single Edged Kopis Sword Used by Greeks.

## II.B.2.2 Light-Armed Troops

Greek light-armed troops did play an important role in battles, but not until the classical period. During the fights between city-states, the cavalry and troops launching projectiles could not do significant damage to hoplites. During the Persian wars, they were discouraged from fighting because cavalry and archery were what the Persians excelled at and challenging them on this front would be unwise. They were probably as abundant as hoplites in battles, but were rarely used effectively. In the seventh century, the main support troops were called the gumnetes, or the “naked men”, wore light armor and would hurl javelins and stones at the enemy. Later into the fifth century, more of an emphasis was placed on these types of troops. The peltastes were men who throw javelins and possessed a shield called the pelta. This was a small light shield made of wicker and animal skin, with different variations in size and shape. The javelin had a small iron tip and a throwing-loop near the center of the shaft, which increased the distance it could be thrown. Archers were not abundant in the Archaic Period of Greece, with the exception being Crete; and it was actually seen as foreign and effeminate. Most archers used before the fifth century were Cretan or Scythian mercenaries. After this point, Athens starts to train these soldiers and uses them in the Peloponnesian War, which inspires others, like Sparta, to also use these soldiers. One other light-armed troop was the slinger who, like the archer, did not get much attention among the different polises. They really came into use during the Classical period, mostly by the Rhodians who would hire themselves as mercenaries. The sling was made from a similar material as bows, out of dried gut or sinew. For projectiles they would hurl stones or, during the Classical period, lead bullets. Cavalry was another field where only certain Greek polises specialized. The men who generally were called cavalry, merely rode their horse to the battle, then joined a phalanx. No great use of cavalry was seen until the times of Alexander the Great. When these light-armed troops lost their weapon or depleted their ammo, they had to fall back to another weapon. This weapon was not very standardized; in fact they usually possessed the same secondary weapons of the hoplite. There are some accounts of men wielding axes, called sagaris, large iron swords, and even tridents.

### II.B.2.3 War Fleets

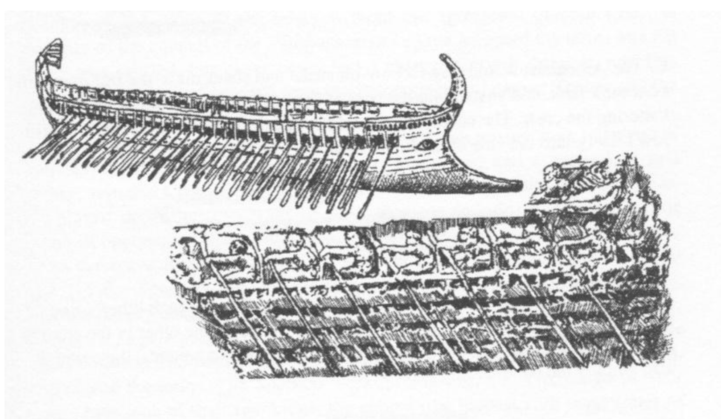


Figure 20: Trireme War Fleet.

Early naval battles were much like land battles. The ships would have fighting-decks, where hoplites and light-armed troops would battle other men when ships collided. The combat was similar too, with hoplites fighting and the light-armed forces lending support. The main ship used was called the trireme, not much is known about it except that it was stouter and harder to maneuver than the Persian ships and possessed a bronze point on the bow. After the battle at

Marathon in 490 B.C. Athens realized its naval weakness and, thanks to the discovery of a silver vein, purchased a large fleet of triremes. They turned into a naval superpower at the start of the Peloponnesian War, making their navy their strong point to Sparta's land forces. Athens developed complex and demanding tactics that only people of their skill could perform. Some tactics included rowing straight at the enemy, only to veer off at the last second to destroy the enemy ships oars. They could also quickly maneuver behind the other ship or to its side to ram and tip it.

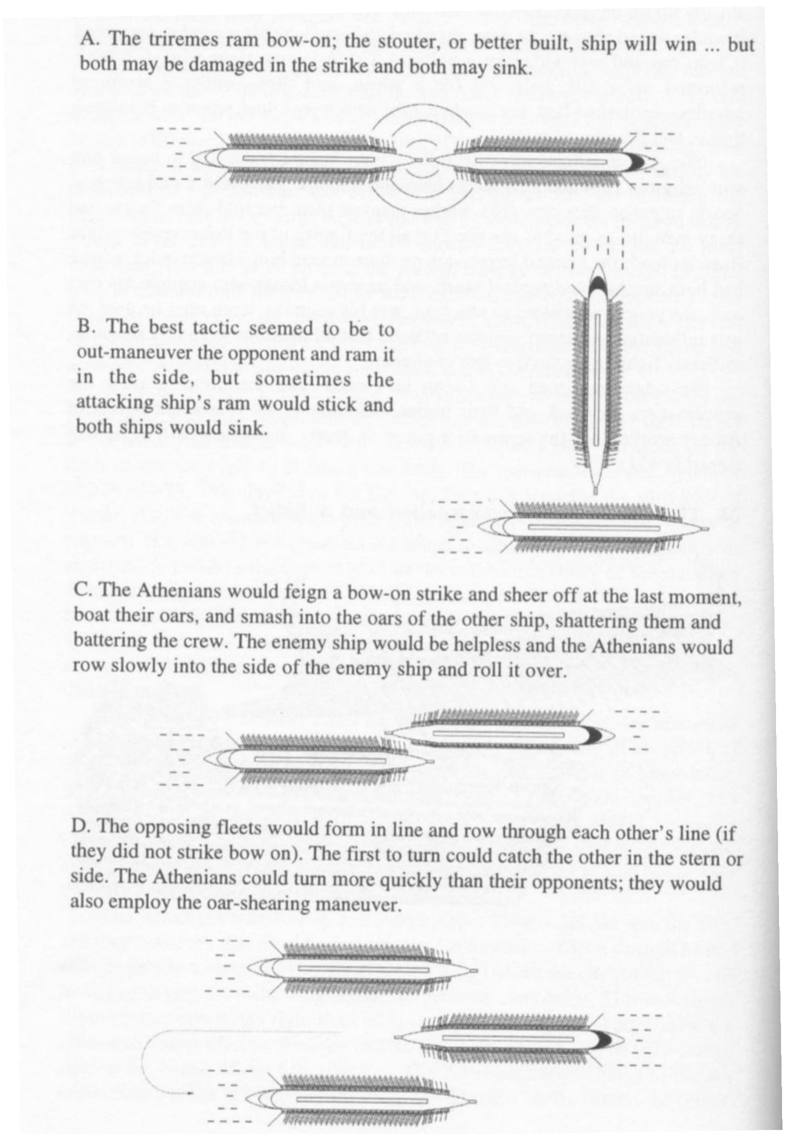



Figure 21: Trireme Tactics Utilized in Battle.

## II.B.2.4 Macedonian Weaponry and Tactics

The time of Macedonian expansion coincided with new military inventions and tactics the revolutionized warfare. One of these major advancements was the invention of siege warfare of which Dionysius I of Syracuse was a major pioneer along with the Macedonian king, Philip II. Around this time catapults, meaning shield-piercers, started to emerge. One of these was called the gastraphetes, which was a compound bow on its side that could be braced with the stomach while two hands draw back the string, resulting in a much more powerful projectile. This type of device would eventually evolve into a stone launching catapult used during Alexander's time. There was also the invention of siege towers, which were six stories tall and possessed catapults and battering rams. There was a short treatise called Siegecraft written by Aeneas the Tactician which goes over several ways to defend against these new tactics and weapons. Some things it addresses is how to deal with battering rams, tunneling, fire attacks, and the use of smoke for cover. Heavy use of siege tactics can be seen when Alexander took the island city, Tyre. Alexander constructed a mole across to the island and tied triremes together with attached catapults. The Tyrians counter-siege tools were the use of superheated sand, nets, and a variety of other effective mechanisms. Alexander the Great's victories were more dependent on his strategies than on his arms and armor, but he did make several drastic changes in these fields when compared to Greek armament. His own version of the phalanx no longer relied on the hoplite, but on a spear called the sarissa. It is debated on how long the spear was, one source says 18 ft. another says 21 ft., both could be correct for the times they were written, but the main point is that they were very large in length. Each row of men stood 3 ft. apart, and the first five rows of sarissae would be projected in front of the phalanx. They other men behind the first five rows would offer their weight and could use their sarissae over their heads to protect the men from projectiles. They did not wear corslets like their hoplite counterparts, but did possess greaves, a 2 ft. diameter shield, and wore a Thracian helmet with a high crown and flowing crest. The Thracian came about after the Persian Wars and was characterized by a combined forehead-guard and visor that juts forward. The center force of the army containing these troops were called the Foot-Companions. One of the most important parts of Alexander's army was his Companion cavalry, which he rode with. This was a small, 2,000 man force of heavy cavalry. For armor they wore a metal corslet, the close fitting corslet described earlier, and a Thracian helmet. For arms they wielded a spear called the xyston and the kopis sword, which was a great cavalry sword because of its downward strike. This sword actually saved Alexander's life when his body-guard used it to stop an attacker at Granicus. His cavalry also consisted of a large light cavalry and Macedonian lancers called the Sarissophoroi. The typical military formation would place the cavalry on the ends of the lines of troops and filling the spaces between them and the Foot-Companions would be a similar sarissa soldier called the hypaspists. For his missile-troops he used the standard Cretan archers, Thracian peltasts, and slingers.

# II.C.1 ANCIENT INDIA

Due to the lack of record of ancient India pre-Aryan invasion, the time period studied starts when the Aryans invaded India and took over one of the most important civilization in the Indian region, the Indus Valley Civilization.

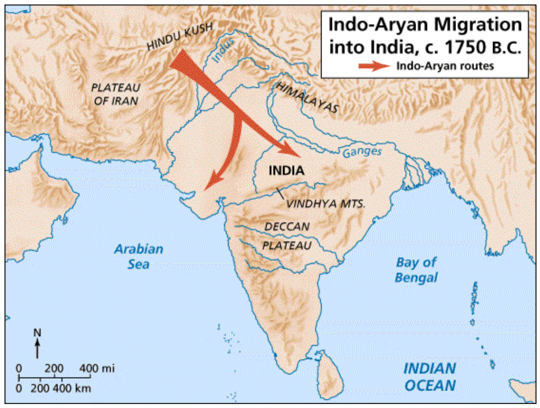



Figure 22: Route of the Aryan Invasion into India.

The Aryans invaded India in waves, instead of in one large group, starting at around 1700 BC. (Dupuy 1970) They pushed most of the tribal and local groups such as the Dravidians towards the South. The Dravidians were the tribe who created the Indus Valley Civilization, one of the world's earliest civilizations, which spans the area that is now the Northwestern section of India, and parts of Pakistan. The Indus Civilization was centered on the Indus River. It was their source of water and fish, their main food. The river also gave the inhabitants of the valley a source of transportation and trade, especially with Mesopotamia. The Indus Civilization, though large, would not accept any new innovations that foreign civilizations had created such as canals. This led to the demise of the civilization. (Kosambi 1965) When trouble had occurred in the Indus River either by nature or by invaders breaking dams and such, the inhabitants of the Indus Valley could not sustain themselves in the area due to the difficulty of obtaining food and water.

At the start of the decline of the Indus Valley Civilization, its inhabitants started to move away from the North and settle in different areas of India. After the Aryans invaded, they fought battles among themselves and with some of the local groups as well for bovine between the years 1500-1000 BC. (Dupuy 1970) The Aryans wanted to impose their culture and language onto others, but also assimilate with the culture of the local groups and tribes as well. Most of the Aryans settled in India and became farmers.

## II.C.1.1 EPIC INDIA

The Epic India period spanned from around 1000 BC to the formation of the Mauryan Empire in 322 BC. Mongoloid invaders briefly raided into India, but the Indian tribes were able to push them out with their military forces. (Dupuy 1970) Around 600 BC, the local groups and tribes grew into kingdoms. Many small kingdoms were being created throughout India. There were believed to be sixteen main kingdoms called Mahajanapadas. Many internal wars broke out in India between the kingdoms. There were two powerful monarch kingdoms during the Sixteen Mahajanapadas, and each was important to India’s history. The first was Kosala, located in the Northwest. Kosala became a leading power in Northern India. The second was Magadha, which was located in the Southeast. Magadha wanted to expand all around India, but this did not happen until after the Persians, and later Alexander the Great, invaded India.

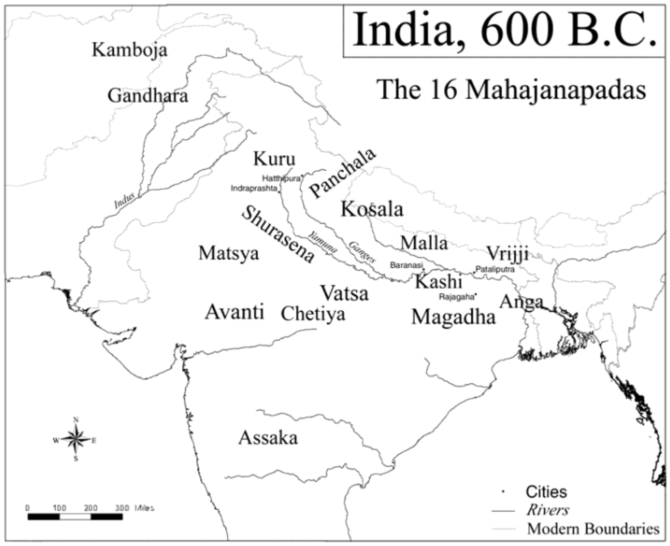



Figure 23: Map of the Sixteen Mahajanapadas.

Between 537 and 530 BC, the Persians, under the leadership of Cyrus reached the Indus River in the Northwestern part of India and conquered most of the western side of the river. Cyrus died in battle while he was campaigning north of India. Darius, who took leadership ten years later after Cambyses, annexed the west bank of the Indus River, and was able to conquer parts of the Punjab region, which was east of the river. Persia had control over these lands until the beginning of the fourth century BC.

Around 327 BC, Alexander the Great reached India. He had forced his way from the North, through the Kabul Valley to the Indus River. There, the King of Taxala who was at war with Porus and was in need of a strong ally, gratefully welcomed Alexander. Alexander used this as an excuse to get further into India. He fought with soldiers from Taxala against Porus and cunningly won the war. Alexander wanted to keep moving forward and take all of India, especially the lands of Magadha. However, his soldiers were exhausted and demanded to return home. Alexander gave in and started heading back.

## II.C.1.2 The Maurya Empire

Wars between Indian kingdoms never stopped, even when the Persians and Alexander were invading India. Magadha was able to take over Kosala in 490 BC after winning many successful battles. In 470 BC, Magadha had expanded greatly. (Dupuy 1970) The had a rich deposit of minerals, and the kingdom became so powerful that there were "no significant military rivals left**.**" (Kosambi 1965) In 322 BC, Chandragupta, an exiled general, was able to overthrow the previous ruler of Magadha and he expanded westward. The kingdom soon became an empire known as the Maurya Empire. Up until the reign of Asoko from 274 to 232 BC, the Maurya Empire was strong and expanding. After Asoko, the later rulers "lacked the zeal, energy, and organizing ability of the first three" (Dupuy 1970) which caused the decline of the empire up until 180 BC when the empire disappeared completely.

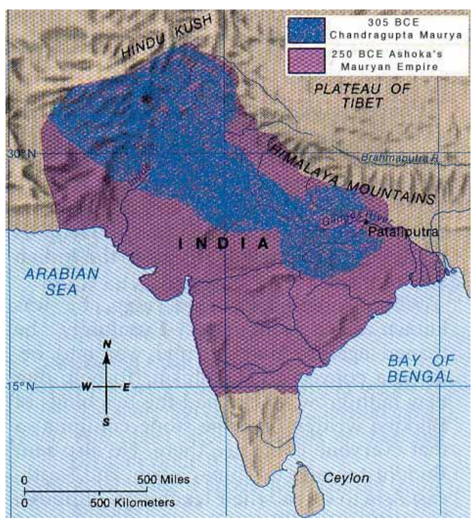



Figure 24: Map of Maurya Empire Land.

## II.C.1.3 Beginning of the Iron Age

There is evidence that there was no Bronze Age in India. India moved right from the Copper Age to Iron Age. This does not mean that India did not use bronze. It just means that

India did not have a period in which bronze was primary material used. The reason for this was iron was introduced to India early, so iron became a better material to use because of the better economic proposition. (Kosambi 1963) Archeologist has found in their excavations iron objects with copper objects together in the same site. (Singh 1990) There has always been an abundant amount of iron ores in India, but their learning process of how to smelt and forge the material into something useful is much more skeptical. There were some archeologists such as Sir Mortimer Wheeler, Director-General of the Archeological Survey of India in the mid 1940s, who believed that the Indians learned about iron from the Achaemenid conquest. (Kosambi 1963) Today it is thought that iron was starting to be used in India around 1000 BC.  This year also marks the beginning of a period called the Epic Period. (Singh 1990) Vere Gordon Childe, an Australian archeologist of the early 1900s, wrote that the Hittite people and their king at this time, King Hattusilis, knew how to produce iron. It was through the mercenaries who worked for the Hittites by supplying them with the iron who "learned and spread the art of their manufacture" (Singh 1990) and possible brought it to India.

## II.C.1.4 WOOTZ AND DAMASCUS STEEL

During the Iron Age and after, Indian blacksmiths made what is called Wootz Steel. The Wootz process was invented around the $6^{th}$ or early $5^{th}$ century BC. (Singh 1990) Wootz steel is said to contain very high carbon (1.5%-2%). (Srinivasan and Ranganathan 1997) It is also found to have superplastic properties when heated. Superplastic is the ability of a material to "undergo extensive tensile plastic deformation under specific temperature and load conditions without the formation of a neck prior to failure." (aluminium.matter.org.uk) The Wootz steel would still remain strong and ductile in room temperature. (Srinivasan and Ranganathan 1997)

In ancient literacy, it is said that during Alexander's conquests in 326 BC, he has been presented with "100 talents of Indian steel" which were the Wootz steel. (Srinivasan and Ranganathan 1997) It was through Alexander that Wootz steel was found to be of great quality, and it was used to make the famous Damascus Steel. Colonel N. Belaiew says that the best Damascus steel contains 1.49% carbon, .08% manganese, .005% silicon, .05% sulfur, and .1% of phosphorus. (Richardson 1934) Belaiew describes the way Damascus steel was made here:

> *"The charge, consisting of black magnetite ore, bamboo-charcoal and the green leaves of certain carbonaceous plants, was sealed in a crucible made from native clay. Several of these would be set in the hearth which was then filled with charcoal and the furnace lighted. Gradually raising the temperature to a point where the charge became molten (approximately 3000ºF), an iron-carbon alloy was thrown out of solution and solidified in mass at the bottom of the crucible. This metallic button or mass, mechanically separated from its slag, was then alternately melted and cooled again four or five times - each complete operating cycle requiring a day. Then in round cakes about five inches in diameter and one-half inch thick, each of which weighed approximately two pounds, the metal was carried overland by cara-van to the arms-making centers of western Asia; or if for export, to the various shipping points. A long normalizing treatment preceded the forging operation which was done with great care, flowing the metal in two or more directions with light blows of the hammer. After prolonged annealing the blades were quenched and drawn to the desired hardness, then polished and etched. This last operation brought to the surface the damask inherent in the steel; and its pattern and background color determined the quality."* (Richardson 1934)

Wootz ingots, molded blocks were exported from India for use in Damascus steel all across Asia and Europe. The ingot has been exported for thousands of years. Wootz steel was still being studied in the 1900s. (Srinivasan and Ranganathan 1997)

## II.C.2.1 WAR ELEPHANTS AND CHARIOTS

Before the Aryans invaded India, Indian armies were mostly made up of footmen, primarily armed with bows. They sometimes used slings and javelins as well for range attacks. In close combats, they used swords, axes, and spears. Tamed elephants were used for war. War elephants had been in use since around 1800 BC but they were not that heavily armored until the Maurya Empire.

When the Aryans invaded India, they used chariots to get around from place to place. These chariots were much bulkier and larger than the sleek Greek chariots most people visualize. Typically, two men would be driving the chariot with an archer in the back. Some chariots were able to hold more men. These were the chariots that Indian tribes adapted into their military system and used extensively in battle. The Persian invasion of India also made an impact on their warfare tactics. From the Persians, the Indian kingdoms developed their own cavalry, men that fought on horseback but because horses were hard to come by in India, they used the best horses for their chariots instead.

During the reign of the Maurya Empire according to recovered report fragments, there were 600,000 infantry, 30,000 cavalry, and 9,000 elephants used for their campaigns. (Dupuy 1970) The Maurya Empire did not use chariots in warfare as extensively as the kingdoms before. This is probably due to the fact that chariots were a poor military tactic against Alexander the Great. The use of elephants also started to decline because of their unreliability and the dangers they imposed onto friendly allies. When they were used, they were heavily armored, and fitted with a caste that could hold archers and javelin throwers. With diminishing use of the chariots and elephants, there were many different military formations set up with and without them.

## II.C.3 ARMS AND ARMOR USED DURING TIME PERIOD

Most of what is known about the time of the Indus Valley Civilization was studied from archeological findings. Their favorite weapon was the bow and arrow. The arrowheads were made of copper, and were 1.9 inches in length, .64 inches in breadth, and .07 inches in thickness. (Singh 1990) Another very common weapon was the sling. The way they used the sling is either overhand like bowling a cricket ball or underhand like pitching in softball. When not using small stones in the slings, they use pellets made of baked clay. Most of these pellets weighed either 6 ounces or 12 ounces. They were hand shaped and then baked. The people of the Indus Valley also had spears with thin leaf-shaped spearheads.  Other common weapons were short swords, daggers, and axes, all made of copper. Armor used in this time cannot be confirmed, but there were findings of pictographs of men carrying shields.

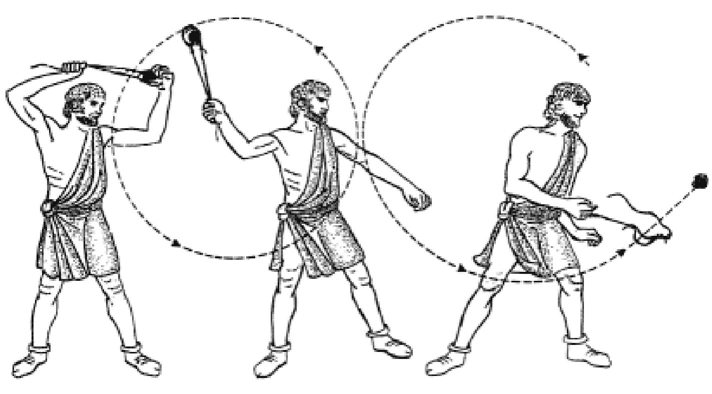


Figure 25: Underhand Slinging Method.

## II.C.3.1 ARYAN

The Aryans' primary weapon was also the bow and arrow when they invaded India. These were composite bows, which were short and stiff with a curved shape. They were made from horn and sinew. The string was made of cowhide. (Singh 1990) The Aryans used spears, axes, short swords and lances as well. These were made of iron. (Singh 1990) The Aryans wore armor, but the material of the armor is uncertain. However, many think that it was a mixture of leather reinforced with metal. (Singh 1990) Aryan warriors wore helmets as well.

## II.C.3.2 EPIC INDIA

During the Epic India, iron was being used in their weapons. Their primary weapon was still the bow and arrow. Some bows are made from horn, like the Aryan's, but others were made from bamboo. They were between four and five feet in length. (Dupuy 1970) The bowstring was made from cowhide. The arrows were made from a reed, cane, or bamboo as well. They were two to three feet long and tipped with metal. It is unclear as to whether or not the metal used to tip the bows was iron because no artifacts have been found to prove this. (Singh 1990) In Vedic literature however, the author wrote that they did. The bow can shoot an arrow from 100 to120 yards away.

Spears and javelins were just as common as the bow and arrow. They were made of iron and sometimes oiled for smoothness. (Singh 1990) They were flung at the enemy from the warriors in the back of their chariots. Men on horseback would use the spear for thrusting. Warriors used broad and short swords made of iron. The sheath was made from the skin of tigers, goats, or cows. (Singh 1990) Like the spears, swords were just as often being hurled at the enemy during close combat. The same method was used for their knives and daggers.

All warriors used shields and chain armor. Archers used arm-guards and finger protectors to keep from getting hurt due to the friction of the released bowstring. (Singh 1990) Those of high social rank were able to design their armor with precious metals and use gold and silver instead of the usual iron or copper for the making of their armor and shields. Tiger skin was sometimes used as extra protection for the warriors.

# III. HISTORY AND PROPERTIES OF THE KOPIS

## III.A. Evolution of the Kopis

The Kopis is a Greek sword that was used mainly for chopping meat, but it was also used as a battle weapon. It is a one handed sword with a curved handle for gripping, and it was commonly made out of iron or steel. (Bakhuizen 1977) The blade is distinctively shaped, curving outwardly from the handle and inwardly to a point at the end. Persian and Indian armies created their own versions of the Kopis after being invaded by the Greeks.

Figure 26: Picture of a Kopis.

The Kopis was designed so as to be able to cut with the inner curve rather than the outer curve. The soldier using this sword used what is called a “drawing cut”, where the sword was drawn from the side and used in one motion. It is also suggested that the shape allowed for the point of the sword to be used to cut as well. These were techniques were influenced by Egyptian swords. (Burton 1884)

In ancient times, swords such as the Kopis were manufactured using a wide variety of techniques. One way was casting, in which metal was melted and poured into a mold to achieve the desired shape. Another way was simply heat treating and shaping the metal, making it hot and then pounding it with a hammer into the desired shape. Special techniques were used to strengthen and perfect the appearance of the sword, such as case hardening and polishing. As the blades were typically made of iron, case hardening gave the sword a stronger outer layer made of steel.

**Kopis Dimensions (romanarmy.com 2009)**

| | |
|---|---|
| Length excluding handle | 56 cm |
| Length of curved back part | 15.5 cm |
| Max width of blade | 5 cm |
| Min width of blade (near tip) | .5 cm |
| Mid Rib from bottom edge (rib running down center of blade) | 2 cm |
| Mid Rib from top edge | 3 cm |
| Thickness of blade (closest to handle) | .5 cm |
| Thickness of blade (closest to tip) | .2 cm |
| Handle length | 12.5 cm |
| Handle width | 7 cm |
| Gap in handle length | 9 cm |
| Gap in handle width | 3 cm |
| Grip part of the handle length | 10 cm |
| Grip part of the handle max width | 3 cm |
| Grip part of the handle min width | 2 cm |
| Thickness of handle (max by blade) | 2 cm |
| Thickness of handle (min at end) | 1.5 cm |

The Kopis is one of many swords in a long line of similar weapons that were developed by improving upon and altering its predecessor. The evolution begins with the Pole Axe, which originated in Canaan as a war weapon. The Pole Axe then evolved into the Egyptian Khopesh, followed by the Kopis. (McIntee 2009)

## III.A.1. India

The Kopis is thought to have influenced the design of many other swords.


Figure 27: Design Influence of the Greek Kopis.

One such sword is the Sousson Pata of Northern India, which was developed around the year 12. The Sousson Pata is characterized by a downward curving blade, very much like the Turkish Yataghan, which is also influenced by the Kopis. (Oriental-Arms Ltd. 2001)

The Sousson Pata was later involved into the Khukuri, or Kukri sword of India. (Yannis 2005) The Kukri is a medium length knife with a curved blade. It was used by the Ghurka soldiers of Nepal, and it was designed to function as the extension of an arm which the soldier would use in battle as a last resort. (Khukuri House 2011) Though the origin of the Kukri is not certain, it is believed that its shape may have been influenced by the Kopis.

## III.A.2. Europe

The Kopis is also thought to have influenced the development of some early European weapons.

Figure 28: Similar Weapon Style to the Kopis.

It is suggested that the Kopis may have evolved into the Seaxe weapon, which then influenced the Viking sword. The Seaxe, used by Anglo-Saxon warriors, was a small single bladed knife that could be used as a tool or, much like the Indian Kukri, a weapon of last resort. (McCullough 2007) The single edged Viking sword was used by Norwegians up until the 9$^{th}$ and 10$^{th}$ centuries. The spine up the back of the blade made it stiff, and the sword was easily handled and good for cutting. (Johnsson 2007)

## III.A.3. The Khopesh

The unique design of the Egyptian Khopesh was most likely the model that was used by the Greeks to form the Kopis Sword. The Khopesh was a sickle shaped sword used by the ancient Egyptians. This sword was adapted from a similar weapon originating in Canaan, which was widely used as a type of war axe. The Egyptians shortened the handle so that the sword could be used single handedly. Over time, the curvature of the blade was also lessened. The khopesh consisted of a bone hilt with a blade made out of metals such as bronze and copper, and it was usually cast in a mold rather than forged. (McIntee 2009)

Figure 29: Picture of a Khopesh.

The Khopesh was designed to use with one hand while the other handed was holding a defensive shield. The blade was thick due to the mold casting, but the metal was soft so the weapon was not ideal for blocking. Because the blade was curved, it applied much greater pressure to its target than a straight edged blade. The weapon was most commonly used by implementing large swipes from side to side or up and down, and thrusting forward, as the tip of the sword was weighted. The hooked shape was also advantageous as it could be used to hook another weapon and deflect it.

## III.B. Project Considerations

Depending on the era in which we studied, Greek swords were either made from bronze (3200 BC to 600 BC) or iron/steel (1200 BC to 400 AD). Bronze swords were typically made using a casting process while iron/steel swords on the other hand were mostly forged.

For the blade, wrought iron is the best possible material for us to use, as it is the closest to that used by the Ancient Greeks. To make wrought iron the blacksmith must heat the iron ores and then "wrought," or work it to get the impurities out through pounding it with a hammer. This process is continually repeated until the blacksmith finds the iron usable. This also makes the iron more malleable because it can be worked under more heat, and the more malleable the iron is, the easier it is to forge.

The reason why we are not using wrought iron is because wrought iron is expensive. It is seen as an out-of-date material. Other materials seem better qualified for modern-day uses, and this is evident because of how cheap they are compared to wrought iron. For this reason, wrought iron is also limited in its availability. It is now seen as a specialty material for blacksmiths and art. Wrought iron is sometimes used to restore historical ironwork as well. (Canaandoors 2011) We did find a company that buys and sells wrought iron, but they reside in the United Kingdom, and their cost exceeds our budget.

Figure 30: Modern Method of Reusing Wrought Iron.

The popular cast iron is abundant, but it is a material we cannot use for forging. Cast iron is made by melting iron ores and then pouring the molten material into molds. The high amount of carbon in cast iron (1-3%), which makes the iron harder and stronger, but also makes it brittle and causes it to rust faster. Cast iron was not possible to make during the Iron Age in Ancient Greece because of the extremely high melting temperature needed to melt iron. Such a blast furnace did not exist yet. (Singh 1990)

After careful consideration, the most probable material choice is steel. Steel comes in many types of iron alloys consisting different amount of iron, carbon, and other elements such as silicon. Unlike the other project group, we are not looking for high carbon steel such as alloy 1075 or 5160. High carbon steel has from .3-1.7% carbon, much less than cast iron. This amount of carbon does make the blade stronger but unlike cast iron it will not be as brittle. The reason why we are not going to use high carbon steel is still because of the high carbon contained in the material. We want to try and use a material that has similar properties to those of wrought iron, so we looked at mild steel and low carbon steel, each having a low enough carbon content in which we could work with. Because of the availability of low carbon steel on a trusted site, we decided to get the low carbon steel for our project.

We did not have as much of a hard time choosing a type of bronze since we were just looking for a type that did not have any newly added elements like silicon. We also wanted to make sure that there was nothing in this bronze that would be hazardous to our health. Some types of bronze contain zinc, which can be dangerous if inhaled when melting the bronze.

For the purpose of this project, a few changes were made due to some procedures being impractical. Since iron is not a popular material to work with in the present day, it is difficult to find reasonably priced iron in large quantities to work with, so the blade for this Kopis will be made out of a low carbon steel material. Because of this alteration, there will be no need to implement the practice of case hardening, but the procedure will be recognized and discussed because it was greatly important in sword making during the observed time period. Although swords were made a variety of ways, the construction of a single sword was typically done using a single procedure. Our sword will be made using two procedures in an attempt to gain experience using as many techniques similar to those from the time period as possible. The blade will be heat treated and shaped with a hammer. The handle will be cast in a mold made out of a sand mixture. Similarly, our sword will be made out of two materials, steel and bronze, so that we learn about and gain experience working with two different metals.

# III.C. Material Properties

## III.C.1. Deformation, Stress, and Strain

When a material is stretched, it usually deforms. There are two types of deformation that can occur: elastic and plastic deformation. The first to occur is elastic deformation, which is not permanent. After a material has been elastically deformed by an applied force, it will go back to its original shape once the force is lifted. Once a material has reached its yield strength, plastic deformation begins to occur, which is permanent deformation. At this point, a material will become steadily more deformed as a force is applied until the material finally fractures. (Groover 2006)

Stress and strain are two measures of a material that are independent of its shape and size. Stress measures the force per unit area applied, and strain measures the displacement that is caused. (Callister 2007) A stress vs. strain curve can be plotted to examine the relationship between them and the impact of the deformation of the material. Elastic deformation has a linear relationship between stress and strain, and the slope of this relationship is the Elastic Modulus. Materials with higher elastic moduli experience less irreversible deformation. The Tensile Strength is the point in the process where the stress on the material is at a maximum. After this point, the stress decreases as the strain increases until the material fractures. (Callister 2007)

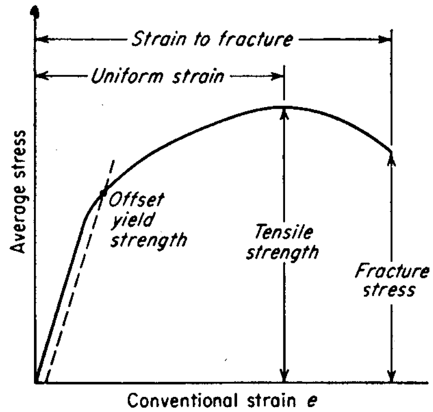



Figure 31: Stress-Strain Graph.

## III.C.2. Ductility and Toughness

Ductility is a measure of how much plastic deformation has occurred in a material at its fracture. If a material experiences very little or no plastic deformation before it fractures, it is considered brittle. A material is considered more ductile if it experiences more plastic deformation before it breaks. (Callister 2007) A ductile material is desirable for this project because the blade needs to be able to experience plastic deformation upon reshaping without breaking. Ductility can be measured in two ways: percent elongation, which is a measure of how much longer the material becomes before it breaks, or percent reduction in area, which is a measure of how much smaller the cross sectional area of a material becomes before it fractures. (Callister 2007)

Toughness is a measure of the amount of energy absorbed by a material up to its fracture point, or the amount of energy required to break a particular material. Toughness can be measured by conducting a stress strain test; it is the area under the curve in units of energy per unit volume. (Callister 2007) Usually ductile materials tend to be tougher because they allow for more plastic deformation before fracture, thus not breaking as easily as brittle materials. Therefore it requires more energy to break a ductile material. The figure below shows relative toughness for different materials. Metals tend to be the toughest of materials because they have a moderate modulus of elasticity, yet they can bear a great amount of plastic deformation because of their ductility.

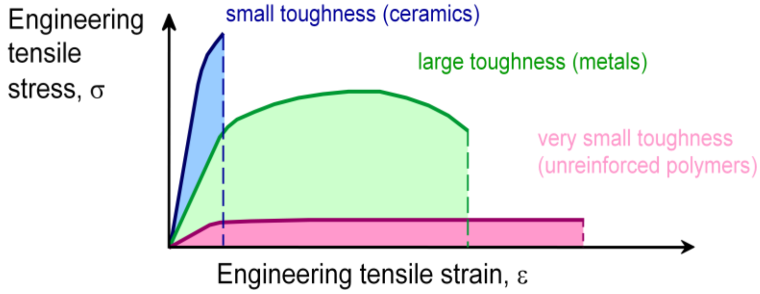



Figure 32: Engineering Stress-Strain Graph.

## III.C.3. Iron

Iron has a moderately large modulus of elasticity and exhibits ductile properties, so it is easy to mold and shape iron without breaking it. It exhibits primarily metallic bonding, in which the iron cation cores remain stationary in a crystal structure while the negatively charged electrons move freely between them.

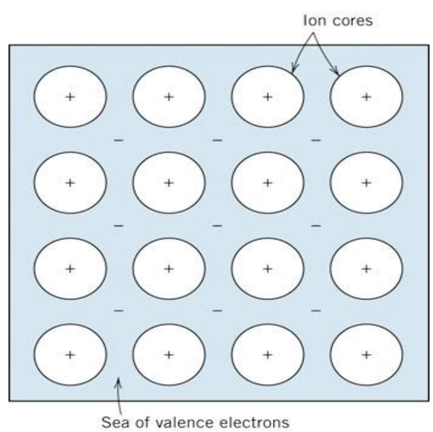



Figure 33: Metallic Bonding.

Iron, like all metals, is a crystalline structure. Its atoms are arranged in a unit cell, which is the smallest repeating unit of the entire structure. In a pure metal structure, all of the atoms are the same, so all of the ionic radii are the same. This makes it easy to calculate properties of the metal such as atomic packing factor (APF) and theoretical density. Iron is a polymorphous atom, which means that its crystal structure changes when it reaches a certain temperature. At room temperature, Iron has a Body Centered Cubic (BCC) crystal structure. (Groover 2006)

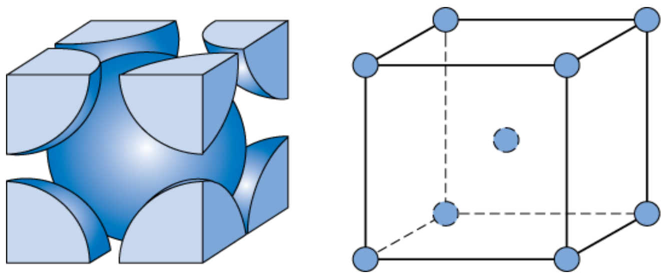


Figure 34: Body Centered Cubic Crystal Structure.

The BCC structure has 1 atom in the center, and 8 atoms in the corners. Atoms touch each other along the cube diagonals. When iron reaches above 912$^{o}$C, its structure changes into a Face Centered Cubic (FCC) crystal structure. (Groover 2006)

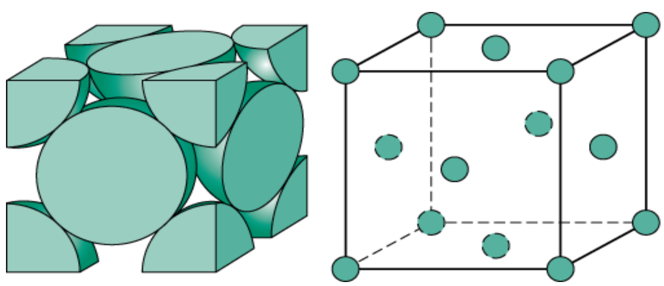


Figure 35: Face Centered Cubic Crystal Structure.

The FCC structure has 1 atom on each face of the cube and 8 atoms in the corners. Atoms touch each other along the face diagonals. Therefore, iron becomes denser when it is heated to higher temperatures.

## III.C.4. Metal Alloys

In and around 500 BC, the Greeks made their swords out of any iron that they could find. Most metal found on the planet is filled with impurities. It is very likely, therefore, that the iron they used contained impurities, implying that many swords were made out of metal alloys. An alloy is a metal in which impurities have been intentionally added to create desired characteristics of a material. Steel and bronze are both examples of metal alloys infused with such impurities. These impurities are all examples of point defects in metal. (Groover 2006) Depending on the radius of the atom and the electronegativities relative to iron, these atoms will either be substitutional or interstitial atoms.

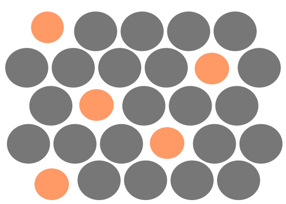


Figure 36: Substitutional Atoms.

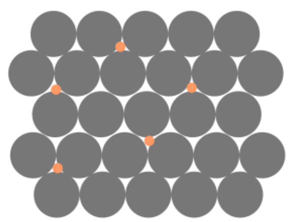


Figure 37: Interstitial Atoms

Larger atoms tend to take the place of the iron atoms, becoming substitutions. Smaller atoms fit into the spaces between the iron atoms, becoming interstitial. The presence of these impurities is very useful for strengthening purposes. Metals are not defect free, they have dislocations, and planes of atoms slip past each other. With substitutions present, the lattice of the entire structure becomes distorted, and the atomic layers are less likely to slip past each other because they are no longer smooth. (Groover 2006)

*Steel*

Steel is an iron alloy containing carbon and very small amounts of other impurities. Steel tends to have less than 1%wt carbon, but the percentage of carbon can vary depending on the type of steel. The type of steel used for this project is a low carbon steel, which generally contains about 0.25%wt carbon. (Callister 2007) This type of steal is fairly inexpensive, and it exhibits high ductility and toughness which is desired for shaping into a blade without fracturing. Low-carbon steel responds more favorably to cold work and lower temperatures, so it will not have to be heated as much in order to reshape.

Steel assumes the crystal structure of iron, as it is a mainly iron alloy. The carbon atoms are much smaller than the iron atoms, and so they fit into the small interstitial spaces between the iron atoms, and they have little effect on the basic structure of the unit cell. (Groover 2006)

*Bronze*

Bronze is a copper alloy that includes several other elements such as tin, aluminum, silicon, and nickel. Bronze alloys tend to be very resistant to corrosion. (Callister 2007) Since this alloy is one that incorporates other metals as well as copper, the atomic radii of each of these metals is fairly similar. Therefore, the impurities do not fit into the interstitial spaces between copper atoms, so they become substitutional impurities, displacing the copper in the crystal structure. (Callister 2007) Bronze also tends to have a much lower melting point than steel. It is therefore desirable for the casting portion of this experiment as it will be easier to melt down into molten metal.

## III.D. Treatment Techniques

## III.D.1. Heat Treating

Metals can be strengthened by different types of heat treatment. After heat treatment, the metal atoms will diffuse into the structure, creating identical dislocations from either side that eventually cancel each other out. This process is called dislocation by annihilation. (Groover 2006)

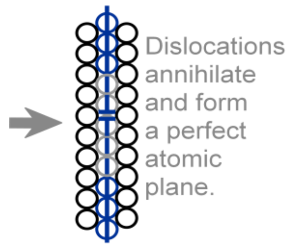



Figure 38: Dislocation by Annihilation.

Grain crystals then reform, gradually increasing in size as time passes. This gets rid of any large dislocations or other imperfections. One way to heat treat a metal is called annealing. This is a process where the material is heated above the recrystalization temperature, and then cooled slowly. (Groover 2006)

## III.D.2. Case Hardening

Another method used to strengthen the Kopis is called case hardening. Carbon atoms are added to the outer layer of the metal, creating an outer casing of steel on the sword. Carbon enters the iron metal through a process called diffusion. Diffusion is the transport of material on an atomic level. Diffusion in solids can be interstitial or it can be due to some number of vacancies in the material. (Groover 2006) Because carbon has a much smaller atomic radius than iron, it diffuses interstitially, moving between the iron atoms in the crystal.

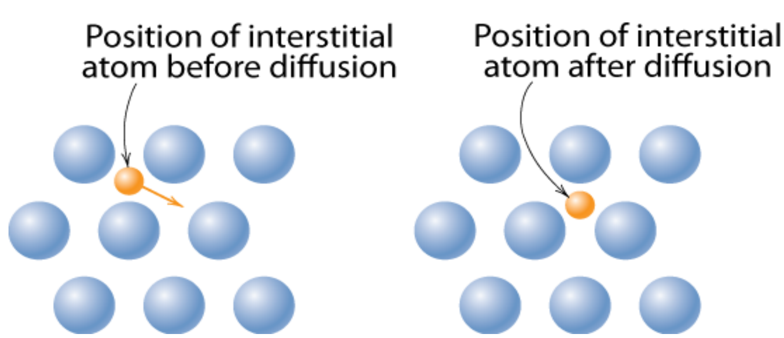



Figure 39: Position of Interstitial during diffusion.

The atoms diffusing, in this case carbon, always move from an area of higher concentration to an area of lower concentration. (Groover 2006) Therefore, to form the outer layer of steel, the iron is placed in kasenit, which is rich in carbon. The carbon is of high concentration on the outside of the sword, and very low concentration on the inside of the sword, so it travels through the outer layer towards the middle. The amount of carbon diffusing, or the flow rate, is regarded as the Flux. It measures how much carbon is diffusing per unit area per unit time. (Groover 2006) The flow rate is dependent on the concentration gradient, which is the change in concentration per unit distance, as described in the following equation:

$$J = -D\frac{dC}{dx} \cong -D\frac{C_2 - C_1}{x_2 - x_1}$$

The variable $x$ is the position in the material, so the change in $x$ represents the thickness of the layer of steel desired on the sword. $D$ is the diffusion coefficient. If the flow rate is known and there is a desired thickness to be achieved, then $D$ can be calculated and its value can be substituted into the following equation:

$$D = D_o \exp\left(-\frac{Q_d}{RT}\right)$$

$D$ = diffusion coefficient [$m^2$/s]
$D_o$ = pre-exponential [$m^2$/s]
$Q_d$ = activation energy [J/mol or eV/atom]
$R$ = gas constant [8.314 J/mol-K]
$T$ = absolute temperature [K]

Figure 40: Diffusion Coefficient Equation.

From this equation it is possible to calculate the temperature needed to heat the iron to achieve the desired thickness. Case hardening is a procedure that will not be attempted in this experiment.

## III.D.3. Casting

Casting is a process in which molten metal is poured into a mold cavity of the desired shape so that when the metal cools, it solidifies into that shape. (Callister 2007) Casting is useful when the desired shape is complicated or too intricate to shape by hand or machine. There are many types of casting, and several of them will be focused on for this experiment. Sand casting, in which the mold is made of sand, will be attempted as it is close to some of the clay mixtures that were used in ancient times as a mold.  Lost foam casting will also be utilized. This can be coupled with sand casting as it uses a polystyrene foam mold that can be packed into the sand. The metal poured into the mold will vaporize and replace the polystyrene.

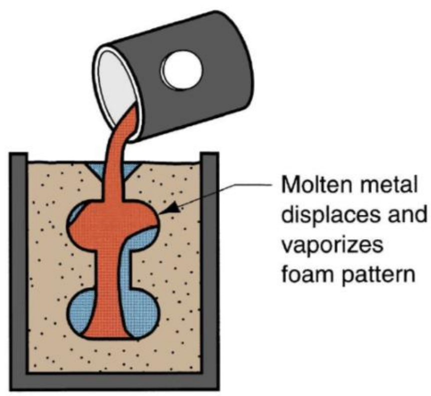



Figure 41: Casting Method.

The idea of this expendable pattern is called investment casting. (Callister 2007) This form of casting is efficient and takes a relatively short amount of time.

# IV. MAKING OF THE KOPIS

## IV.A Chemical Properties of Metals/Phase Diagram

### IV.A.1. 1018 Carbon Steel

The 1018 carbon steel is a very low carbon steel. Its compositions typically range from 0.14-0.2% carbon, 0.6-0.9% manganese, up to 0.04% phosphorus, and up to 0.05% sulfur. This alloy is easy to obtain, and it is very easy to shape due to its high manganese content. This particular steel is able to be forged in the range of 1825-2300ºF. Below is a phase diagram of temperature verses percentage of carbon that depicts different phases of low carbon steels.

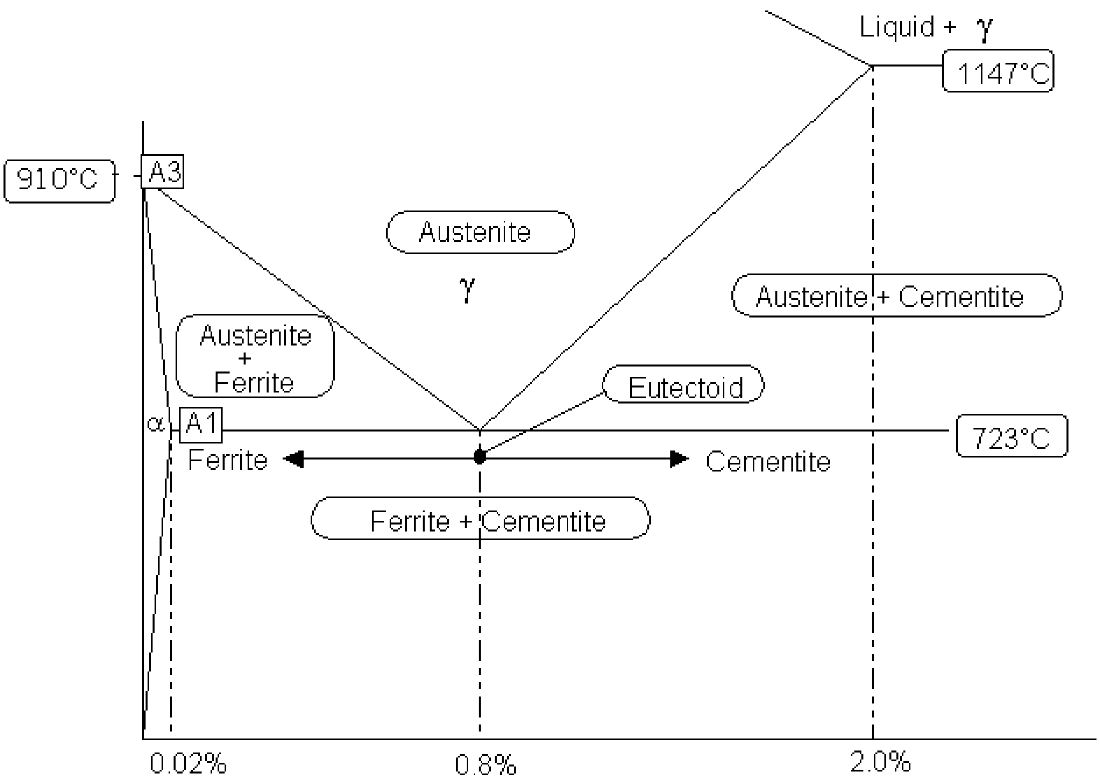



Figure 42: Phase Diagram of T vs. % Carbon in 1018 Steel.

## IV.A.2. Everdur Bronze

Everdur bronze is a type of silicon bronze. Its composition is approximately 95% copper, 4% silicon, and 1% manganese. This type of bronze is low in lead content, and it can be melted down numerous times without causing changes in its composition. For this reason, it is ideal for the inexperienced to use this metal. Its melting temperature ranges from 1850-2150$^{o}$F. Below is a phase diagram of temperature verses weight percent and/or atomic percent of silicon that displays the different phases found in silicon bronze.

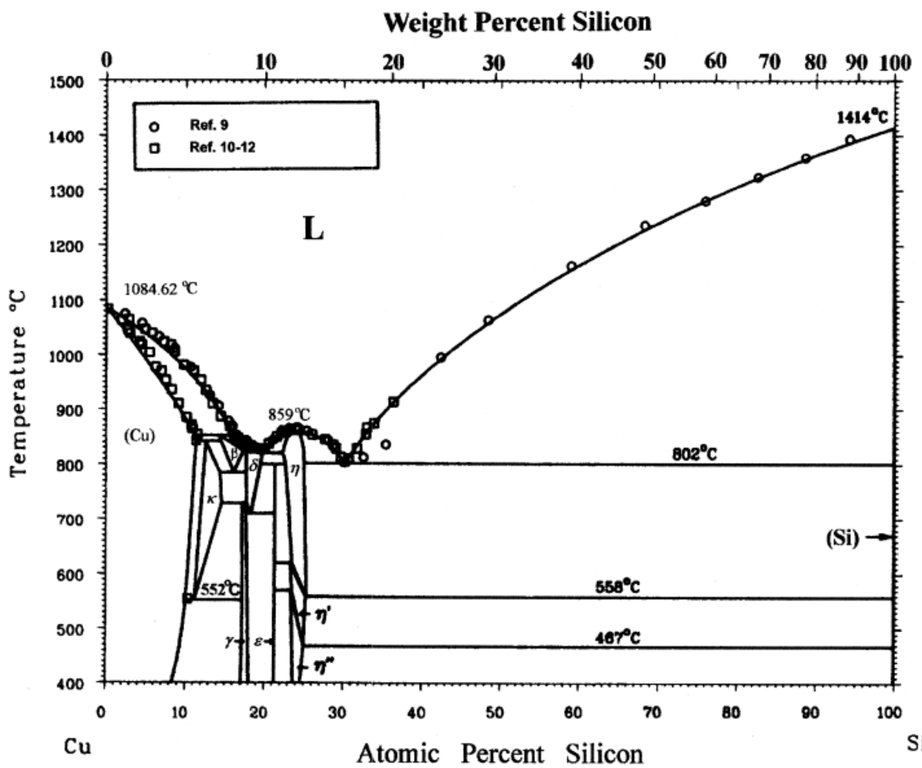



Figure 43: Phase Diagram of T vs. Weight %of Silicon in Everdur Bronze.

## IV.A.3. Cast Aluminum Alloy 319

This aluminum alloy is a common alloy that is easily obtained and easy to melt. Its composition ranges from 5.5-6.5% silicon and 3-4% copper. Small amounts of zinc, magnesium, nickel, and other metals may also be present. This alloy is gray/silver in color and it has a melting range of 1050-1220ºF. Below is a phase diagram of temperature versus mass percentage of copper in an aluminum alloy. The diagram is calculated with 5% silicon by mass.

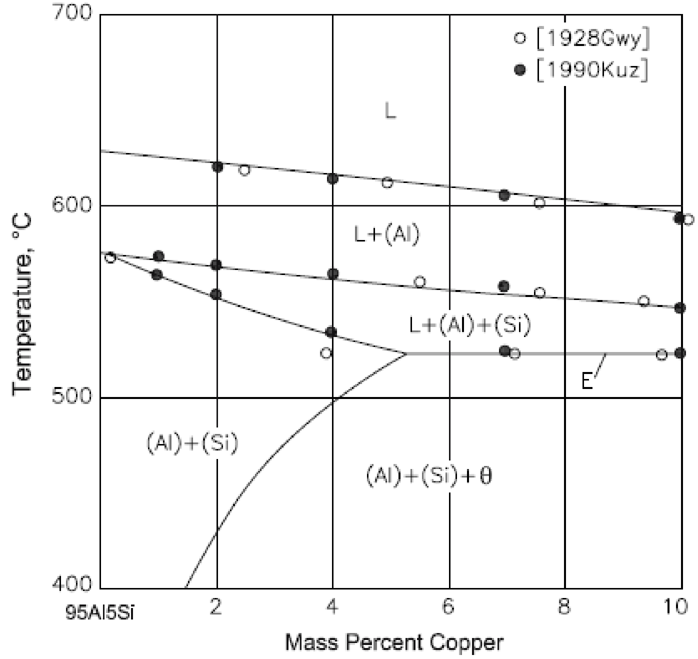
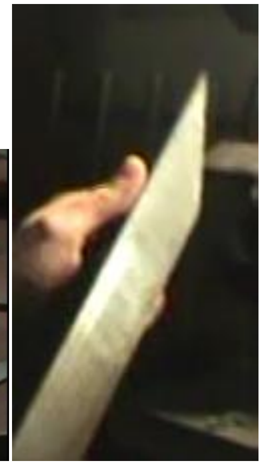



Figure 44: Phase Diagram of T vs. Mass %of Copper in Aluminum Alloy.

## IV.B Procedure with Integrated Pictures

## IV.B.1. Forming the Blade

A 6 foot long rod of low carbon mild steel was cut into three equal pieces to allow for multiple blades in the event of an error. The rod was cut at an angle so that each piece had a point on one end to serve as the point of the blade.

A large scale drawing of the Kopis was created to serve as a plan, depicting specific shape and dimensions, as shown in Figure 45.

Figure 45: Drawing of Sword.

The dimensions were used as a guideline, but they were approximated because it is almost impossible to shape a sword free-hand into the exact dimensions. Each cut piece of metal was filed at the point in order to smooth out the rough edges left behind by the rough cutting.

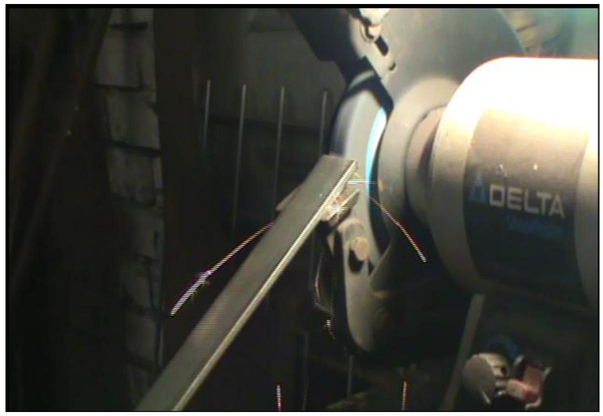



Figure 46: Filing down the edges of a cut metal piece.

The piece of steel was placed into a coal fire and left to heat. Once the metal was bright yellow, it was taken out and placed on an anvil to be shaped with a hammer. The metal was hammered and shaped until it turned bright red, and then it was placed in the fire again.

Figure 47: Hot Metal Being Hammered into a Sword Shape.

The blade was flattened by tapping the metal with a small hammer and then hit in the same spot forcefully and repeatedly with a large hammer. The metal was then hammered with a one handed medium sized hammer for shaping.

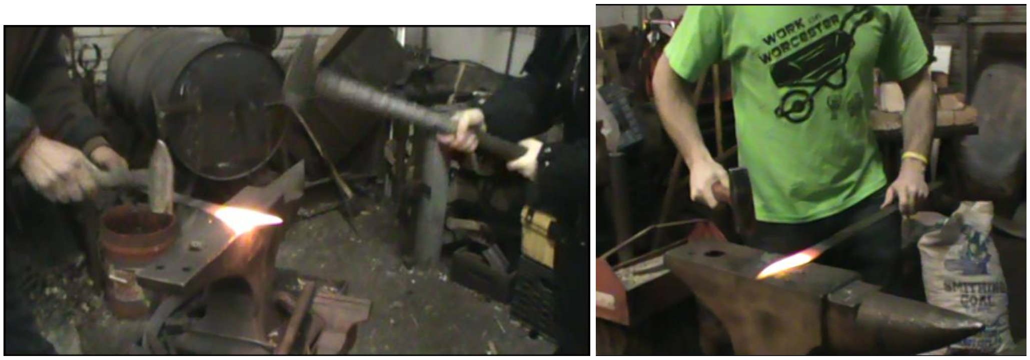


Figure 48: Sword Taking Shape.

The steel was hammered in the center of the bar in order to flatten it.  To achieve the big curve, the steel was hammered along its edge to spread out only on one side.  The rod was then turned and balanced on its edge and hammered along the curve to straighten out the back of the blade.

Figure 49: Edge of the Sword to Show Dimensions.

A routine of heating and hammering the metal was repeated until the desired shape was achieved.

## IV.B.2. Hypothetical Case Hardening Procedure

Once the desired shape was made, the blade underwent case hardening.  The metal was heated until it was white hot, and then dipped into Kasenit powder, a special compound used for case hardening.  The kasenit powder cooled the outer surface of the metal.  Once it was coated in powder, the metal was again heated until it was white hot, and quenched in water.

# IV.B.3. Forming the Handle

A duplicate of the desired handle was formed into a polystyrene pattern. A large block of polystyrene was cut down into a general shape with a knife. The specific shape and details were achieved by sanding the resulting block of polystyrene with sandpaper. However, after successfully casting a handle in its entirety for practice, we had to decide a way to make the polystyrene handle in two pieces that after casting could be put together over a protruding end of a sword so that it could be fastened properly. Figure 50 shows the original shape of the handle using the polystyrene material that was originally used as a practice run.


Figure 50: Handles Carved out of Polystyrene (Practice Run).

Figure 51 shows the handle made out of polystyrene with the two halves that were used to make the actual handle.

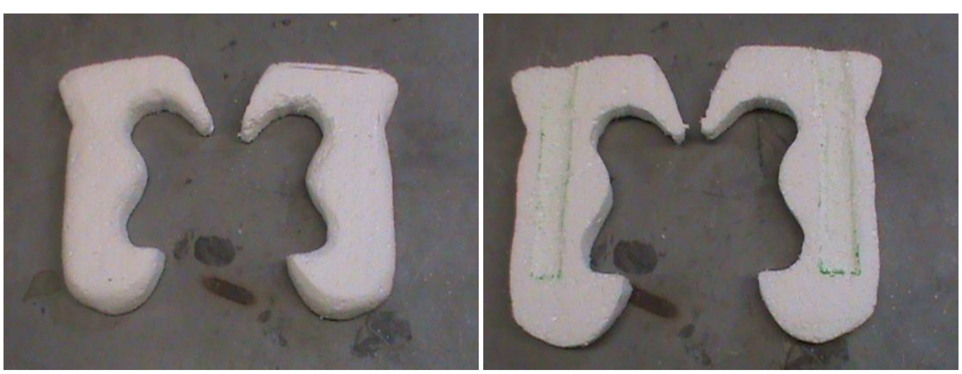


Figure 51: Two Halves of Handles Carved out of Polystyrene.

Originally, we had decided to use bronze for our handle because that was the typical metal used in that time period that we studied. However, once we bought the bronze which was called Everdur Alloy C873 from the same company that we purchased the casting materials from, we tried to melt it. Its melting point is about 1260°C. Once we tried to melt it with help from Xiang Chen, we realized that the metal was not melting and was turning into a crumbly, sandy type material. We assume it is a result of not being able to have a furnace that could heat far enough to melt it efficiently, even though the furnace's maximum temperature capacity was around the melting point of the bronze. Thus, we also think it might be due to poor quality of the bronze. Due to complications with melting the bronze, we decided to use aluminum to cast the handle with. We used aluminum alloy 319 and followed the casting procedure as we will describe. We purchased our casting materials from Lost and Foundry in Spokane, WA and followed their casting procedure on their website which was published in 2008. Our casting procedure, therefore, will be very close to what they have written. Figure 52 shows an image of the bronze metal after being placed inside the crucible located in the furnace that holds the melting metal. As seen, the bronze does not look like metal, but clay. It also shows when the bronze was melted and how the metal did not look like liquid, but looked like little clumps of dust.

Figure 52: Bronze Pieces Placed Inside Crucible within Furnace (Before and After).

A polystyrene pattern of the desired handle was placed into the bottom half of a wooden box and dusted with parting dust, which is a material that is used to repel moisture. Parting dust was used as a substitute for a refractory compound spray. Figure 53 shows the image of the handle in the wooden box with the parting dust placed over it. The images were of the practice run handle since it was documented fully.

Figure 53: Practice Handle with Parting Dust over it in the Casting Box.

Special casting sand that had been sifted through a sieve was used to create a thin layer over the pattern. The wooden box was then filled to the top with non-sifted sand that was free of lumps. Using a blunt wooden paddle, the sand was packed down hard. The box was then filled with sand again to about two inches above the top. The sand was then packed down hard again, and the excess was scraped off to create a level surface. Figure 54 shows the sand being sifting and packed into the box.

Figure 54: Sand Sifted on Top of Handle and Packed into Casting Box.

A temporary bottom was placed on top of the sand surface and the box was inverted. The top half of the box was attached. A shallow circle was imprinted in the sand using a hollow hole cutter, and an X was marked on the other side as an escape hole for the molten metal as shown in Figure 55.

Figure 55: Circle and X Markings with Handle in Sand.

Once these two imprints were made, the steps related to filling the box with sand was repeated for the top half of the box. The two halves of the box were then taken apart to reveal the pattern on the inside with the top half of the box having the imprinted circle and X. A small tunnel was dug in the bottom half of the box leading from the entry hole to the escape hole, with a path in the middle leading to the polystyrene mold. The large entry hole and the small escape hole were drilled all the way through the sand in the top half of the box to reach the tunnel. All rough edges created by digging in the sand were smoothed out with a spoon. Figure 56 shows half of the box with the hole for pouring placed into it.

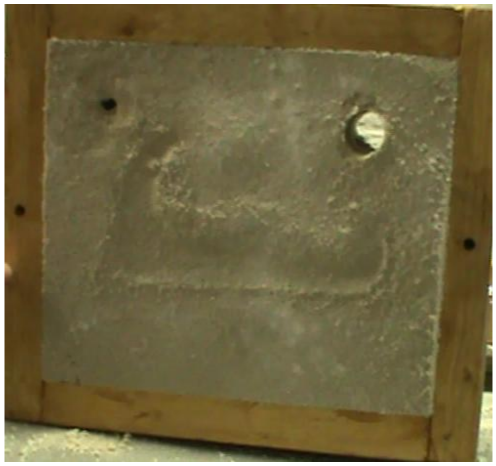


Figure 56: Larger Hole for Pouring Metal.

The two halves of the box were put back together with the holes on top. Molten aluminum was poured in small increments into the large entry hole, which took the place of the polystyrene. The metal was poured into the entry hole until it could be seen coming out of the escape hole. Figure 57 shows the melted aluminum metal and the after it was poured into the casting box.

Figure 57: Melted Aluminum and Being Poured into Casting Box.

The entire setup was left standing to cool for awhile and then it was disassembled and cleaned. The resulting handle was freed from the sand with tongs.  The excess aluminum formed by the shape of the tunnel and the holes was separated from the actual desired handle with a hammer.

The casting procedure was carried out at first using one polystyrene mold of the kopis handle.  The purpose of the first trial was to familiarize ourselves with the process and to make sure there were no problems with the particular materials or procedures used.  The second time the procedure was attempted, it was done twice in order to create two sides of the handle separately.  A polystyrene handle was formed and cut down the middle to form two halves.  On the flat side of each half, an indent was made to accommodate the end of the blade intruding into the handle. Figure 58 shows the final handle product after the practice run on the left and the final handle product for the actual run with the resulting two halves on the right.

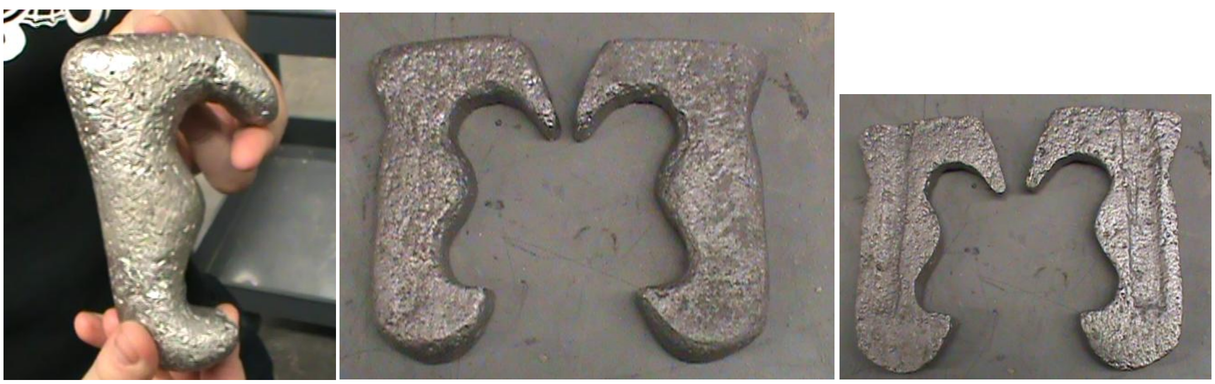


Figure 58: (Left) Finished Practice Run Handle, (Right) Finished 2 Halves of Final Actual Handle.

Figure 59: Finished Handle on Sword.

The end of the sword was cut down with a saw so it was thin enough to fit within the handle. A grinder was then used to make the inserts in the handle fit closely with the hilt. After that, the measurements for creating holes in the sword and in the handle pieces were taken. Using the drill press, three holes were made in each piece so they would line up perfectly. Rivets were obtained and cut down to fit through the hole. To make the other side of the rivet, the piece of nail sticking out needed to be hammered. The edges were then heated and hammered the handle and sword together.

## IV.C. Material Analysis

## IV.C.1. Procedure

Samples of each type of our metal were collected for material analysis. The samples included bronze before melting, aluminum after melting, steel before forging and steel after forging. We attempted a material analysis on bronze even though we did not use it in our sword because we wanted to see the properties and if that affected its inability to melt properly. Each sample was mounted, polished, for viewing under an optical microscope and to undergo hardness testing. The steel samples were etched in order to see the different phases on the surface.

## IV.C.1.1. Mounting

Samples were mounted using a compression method. A release gel was applied to the platform surfaces of the mounting machine with a Q-tip. The metal was placed on the bottom platform with the side to be viewed facing down. The platform was then lowered into the cylinder shaped chamber in the machine and a pellet of mounting compound was placed in the chamber on top of the metal sample. The machine was then closed and turned on to begin the process. The sample was then preheated, heated for one minute, and cooled down for four minutes. The bottom platform was then lowered to relieve pressure, and raised to open. The machine was then cleaned, and the process was repeated for each metal sample.

## IV.C.1.2. Polishing

All samples were placed in a template at once and tightened into place with an allen wrench. The template was then placed onto an automatic polishing machine with all samples facing down. A circular piece of 120 grade sandpaper was fastened face up onto the platform of the machine. The machine was turned on, and water was poured onto the sandpaper which rotated as the template was lowered, scratching the surface of the samples. The samples were polished with 120, 400, and 600 grade sandpaper, each for about two to four minutes.

Each sample with the exception of aluminum was placed into an individual clamp and all clamps were placed on a white cloth inside a fine polishing machine. An oil based lubricant was added to the cloth, and the machine was turned on, spinning while the samples were placed face down and left to move freely on the cloth. The samples were left in the machine for six hours and were then taken out and washed with acetone.

The aluminum was polished differently. A polishing solution was applied to a circular polishing apparatus, which was then turned on so that it rotated counterclockwise with adjustable speed. The mount was placed sample side down on the apparatus and was hand-held in place against the rotating motion until the sample was free of scratches. It was then moved to another apparatus of a finer grade and the process was repeated. After washing the mount with acetone, a blue liquid polishing agent was applied to a stationary velvety surface. The mount was gently dragged across the surface sample side down by hand. The mount was then washed with acetone and capped to avoid scratching.

## IV.C.1.3. Etching

Once the samples were mounted and polished, etching was done on the steel samples in order for the metal phases to be seen more clearly. Aluminum didn’t need etching. The bronze sample was not etched either because of its difficulty in polishing since the quality was poor and the metal had many scratches. We used the solution Nital for etching which consisted of about 100 ml of ethanol and 1 to 10 ml of nitric acid since it is good for low carbon 1018 steel, which we used to make the blade. It is important to not exceed 10% or 10 ml of nitric acid because the solution is explosive. We etched both the before and after samples of the 1018 steel. After drying the sample and looking under the microscope we had good results. The images obtained after looking at the samples in an optical viewing microscope are shown below.

### IV.C.1.4. Optical Analysis

For the before steel sample that was not forged or hammered, a picture was taken, as shown in Figure 60, with a 10 µm scale and at 100X magnification. The grains are cubic shaped and not elongated. Figure 61 shows the same sample taken at a scale of 50 µm at 20X magnification. Referring back to the phase diagram in Figure 42, and examining the carbon content, one can see that where the metal is heated to a high enough temperature, it transforms into the austenite, ferrite phase. When cooled from this temperature, grains as seen in Figure 60 form; they are called proeutectoid ferrite. The other phase in the microstructure represents the pearlite, which consist of both soft and ductile ferrite and hard and brittle cementite. This metal was very ductile, containing large amounts of ferrite.

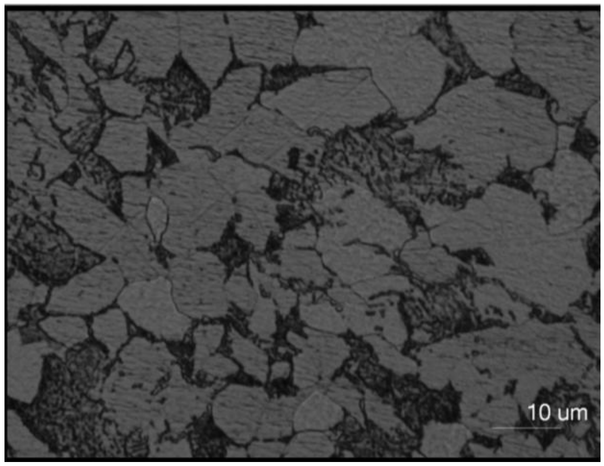



Figure 60: Steel 1018 Sample of Blade at Scale 10 µm and at 100X Magnification (before hammering).

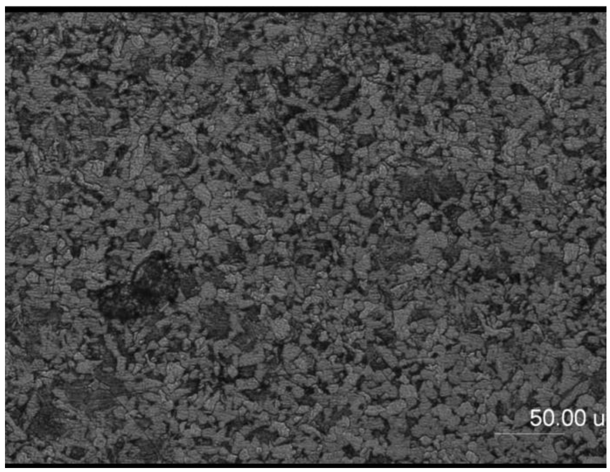



Figure 61: Steel 1018 Sample of Blade at Scale 50 µm and at 20X Magnification (before hammering).

After the steel sample was heated and hammered, however, the grains in the material deformed and became elongated with the tension applied to the metal as seen in Figure 62 with a scale of 10 µm at a magnification of 100X. This elongation occurred because we were hammering out the blade into a thinner sheet of metal as opposed to the thick block we had bought. Figure 63 shows the same sample taken with a scale of 50 µm and at a magnification of 20X.

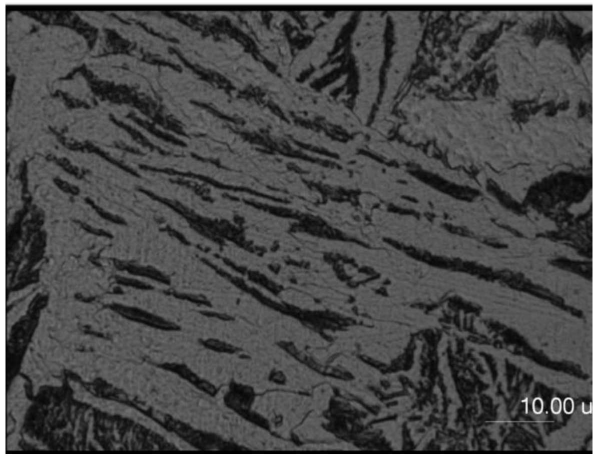



Figure 62: Steel 1018 Sample (Forged and Hammered) of Blade at Scale 10 µm and at 100X Magnification (after hammering).

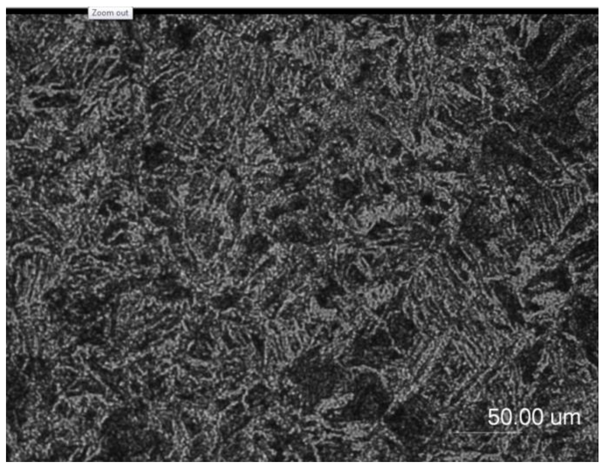



Figure 63: Steel 1018 Sample (Forged and Hammered) of Blade at Scale 50 µm and at 20X Magnification (after hammering).

Images were also taken of the 319 cast aluminum alloy sample after it was melted to see how the properties. It was assumed that since melting doesn't change the metal properties, there wouldn't much of a difference in the grains. Figure 64 shows the image taken of the aluminum sample with a 10 µm scale and at 100X Magnification. Figure 65 shows the same sample but with a scale of 50 µm and at a 20X Magnification.

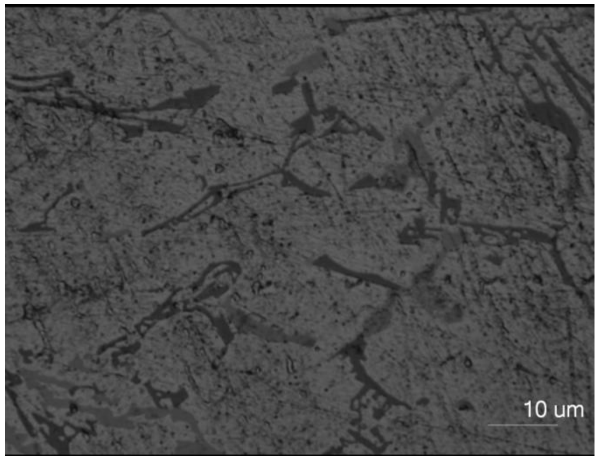



Figure 64: Aluminum Sample Microstructure with Scale 10 µm and at 100X Magnification.

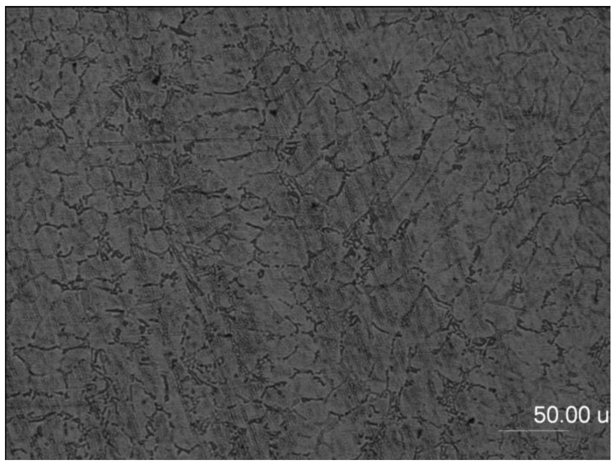



Figure 65: Aluminum Sample Microstructure with Scale 50 µm and at 20X Magnification

Lastly, images were taken of the bronze sample even though it was not actually used it. Since we had metal available we wanted to look at the properties of the metal in order to understand why the casting of the bronze did not work successfully. Bronze was also a commonly used metal during the time period under study, so examination of the material holds relevance in that respect as well. Figure 66 shows the same sample but with a scale of 50 µm and at a 20X Magnification.

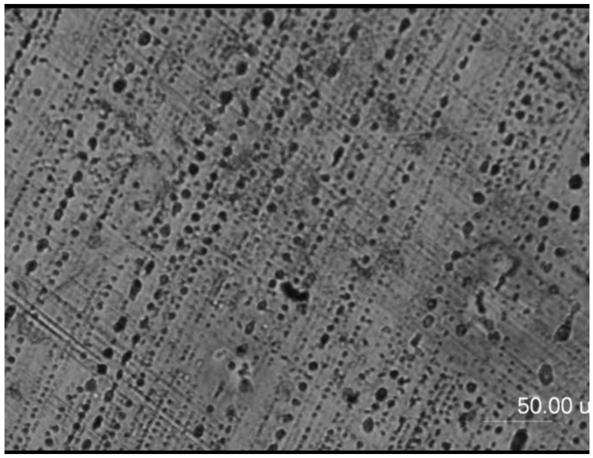



Figure 66: Bronze Sample Microstructure with Scale 50 μm and at 20X Magnification.

## IV.C.1.5. Hardness Testing

Hardness testing was performed using the Analogic Measuremeter II with the C-scale brale penetrator. The Rockwell Hardness test was the main hardness test that was used. As a load is applied to the metal sample, the Rockwell Hardness test measures the net increase in depth of impression. The higher the measured value that results from the test means that the harder the material is because it takes a heavier load to imprint a certain depth in the material. The Rockwell Hardness test does not have any units associated with its measured values. Hardness is a measure of how much resistance an object has to prevent penetration, scratching, or other aesthetic destruction. An indenter, which can either be a steel ball or a cone called a Brale, is a type of load that is applied to the metal samples that will undergo Rockwell Hardness testing. First a small load of about 10 kg is applied to the sample so that initial penetration occurs which holds the indenter in place. The scale is then zeroed or calibrated and a new load of a specific mass, such as 150 kilogram in this case, is applied and then once it is removed, the hardness measurement is read. The Rockwell Hardness test used for the steel samples utilizes a 120° diamond cone called the Brale, which can carry up to a 150 kilogram major load. The hardness test will thus be read on a “C” scale. The Rockwell Hardness test performed for the Bronze and

Aluminum samples uses a 1/16 inch diameter steel ball penetrator and allows up to 100 kilograms of major load to be applied. The hardness test in this case is read on the “B” scale. The indentation caused by the minor load is subtracted from the indentation caused by the major load which gives the Rockwell hardness measurement. 8 hardness measurements were taken of each metal sample and averaged as shown in Table 1.

Table 1: Rockwell Hardness Testing Measurements

| **Metal Sample** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **Average** |
|---|---|---|---|---|---|---|---|---|---|
| Before Steel (HRC) | 6.9 | 9.9 | 8.4 | 7.8 | 10.3 | 6.9 | 8.1 | 5.8 | 8.0 |
| After Steel (HRC) | 2.6 | 1.0 | 2.6 | 2.8 | 1.9 | 4.8 | 1.4 | 2.5 | 2.5 |
| Aluminum (HRB) | 31.7 | 35.3 | 32.9 | 29.8 | 32.2 | 32.6 | 31.6 | 31.4 | 32.2 |
| Bronze (HRB) | 2.9 | 7.8 | 17.9 | 24.5 | 9.3 | 11.8 | 5.3 | 22.4 | 12.7 |

The before steel sample is how the steel was purchased, without any forging or hammering being done to it. The average hardness measurement was 8.0. The after steel sample that was the steel after forging and hammering and was similar to the finished steel of the blade had a hardness measurement of 2.5, significantly lower than the before steel. This means that the before steel was much harder than the after steel since the hardness measurement was higher and measures the resistance of the metal to any penetration. This makes sense because the steel before was much stronger than the steel after forging and hammering. This can also be evidenced by Figures 60 and 61 for the before steel samples and Figures 62 and 63 for the after steel samples taken under the optical density testing. Figures 60 and 61 show how the grains of the before steel sample looked like. After hammering and forging, the steel sample microscope images, as seen in Figures 62 and 63, had grains that were elongated. This is due to the stress that was put on the metal which enabled the metal to thin out. Its thinning out made it more fragile and less hard as evidenced by the hardness measurement of 2.5 compared to what it was before, which was 8.0.

For the aluminum samples, the hardness measurement came out to be averaged around 32.2. The aluminum samples were not as hard as the steel samples, however, because two different scales were used in measuring them. It must be remembered that the steel samples used the “C” scale because they are much stronger metals and thus the resulting measured values cannot be compared to those of the aluminum and bronze measured values since they utilized a Rockwell hardness test with the “B” scale meant for use for softer metals. As can be seen in Figure 67, the bronze sample measurements were greatly varied. However, it was noticed that hardness measurements taken on one side of the bronze had all higher numbers, while the other side of the bronze had all lower numbers. The reason to this is not clear, but is assumed to be because of inefficient mounting. This shows that the bronze was indeed bad quality because the properties were not the same across the whole metal. The average value obtained was 12.7.

# V. CONCLUSION

The purpose of this project was to study and report on various arms and armors throughout history. We focused on the time period from 550 BC to 300 BC in three nations: Persia, Greece, and India and examined how Alexander the Great's conquer of India and Persia allowed Greece to act as the main influence in causing the evolution of the weaponry, armor, and military tactics that were used by India and Greece.

Because Persia and India were in constant fighting with Greece, they experienced both advantages and disadvantages in their proximity. Greece was highly advanced in weaponry and military tactics due to their strong and zealous rulers. They constantly changed their tactics so that they surprised their enemies and did not allow for defeat. Persia, especially, utilized techniques learned from Greece since they were the primary enemy that was a challenge for Greece. However, they were unsuccessful because they did not diversify their tactics and emulated those tactics of Greece that had already been discarded and renewed for efficiency.

After extensive research, it was concluded that Persia and India were greatly influenced by Greece. We illustrated this conclusion by using the Kopis sword as our example for the hands-on portion of the project because this weapon influenced the development of a specific sword that was found in both Persian and Indian culture. We also found out that weapons were fashioned in a variety of ways during the Iron Age. A few procedures were attempted in order to study the difference in these separate techniques. The hands-on approach to our project nicely complimented our research by not only allowing us to understand the time period better, but to enhance the understanding of the theory by engaging in the practice of making weaponry.

# VI. APPENDIX: UPDATING THE WEBSITE

Last year's IQP groups had created a website that contained all the information relating to the historical evolution of materials in arms and armors project advised by both Professor Diana A. Lados and Mr. Tom H. Thomsen. For this year's IQP project, we and another group explored different time periods and nations, but both built swords of a particular culture that we studied. None of our group members have knowledge of computer science to be able to update the IQP website with our project additions. Therefore, Michal Talmor of our partner group was kind enough to add our additions to the website. She was primarily responsible for the editing and finalization of the IQP website of this current academic year.

Our additions to the website consisted of two main aspects: the procedure of the kopis sword with images for easy visualization and a summary table of each nation's weaponry, armor, and military tactics. We also added a map of the Africa, Europe, and Asia that pinpointed the three nations that we studied: Persia, Greece, and India so that when the nation was clicked on, the website would be redirected to a summary table that we created as mentioned previously. Figure 67 is an example of the summary table for Persia that was put on the website.

## ANCIENT PERSIA IRON AGE 550-300 BC

### SHIELD

**Original Image:**

http://www.parstimes.com/library/brief_history_of_persian_empire.html

Soldiers had a shield that was a rectangular sheet, 5 feet in length and was made of sticks that were kept together with animal skin framework. They were used to protect soldiers against arrows. When the archers were attacking an enemy, a line of men who carried these light shields would stand in front of them, while the archers shot from above the shields. They barely protected against heavy weaponry.

### ARCHERY

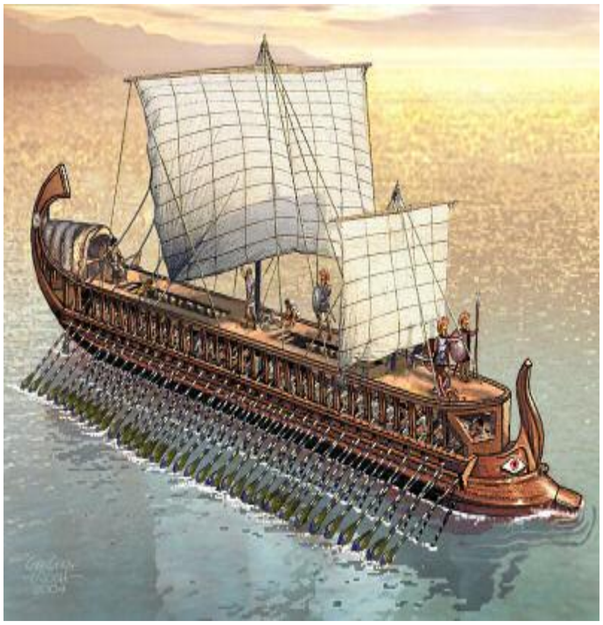
Persian Archers with Recurve Bows (500 BC)

**Original Image:**

http://www.historyforkids.org/learn/economy/bo

Around 600 BC, Persians began to hire Scythian archers to teach them how to skillfully master archery. They made their bows and arrows based on the Scythian model, but with slight differences. The Persians did not use a compound bow like the Scythians, but a simpler bow that was made of wood and a cord to allow flexibility when released the arrow. These arrows had bronze tips. The bows used evolved to be like the compound bows used by the Scythians because they were much more powerful when releasing arrows.

| | |
|---|---|
| w.htm | |
| **CAVALRY** | |
| <br>**Original Image:**<br>http://forums.taleworlds.com/index.php?topic=163533.1170 | Cyrus the Great wanted to use more mounted soldiers because he knew how important they were especially since two of his greatest enemies used cavalry or soldiers on horseback. The Persian army was organized in a new fashion. The cavalry flanked both sides of the army in the middle which comprised of archers who attacked first from a distance. Afterwards, the horsemen attacked anyone left standing in the opposing army by throwing javelins, which were light spears thrown by hand. |
| **CHARIOTS** | |
| <br>**Original Image:**<br>http://aryamehr11.multiply.com/journal?&page_start=200&show_interstitial=1&u=%2Fjournal | The Persians wanted to find a way to disrupt the Greek orderly lines to allow for their archers to target as many enemy soldiers as they could. As a result, they decided to utilize the scythed chariot, which was an ancient war chariot that had one innovation that set them apart from other armies. The scythed chariot had swords that were connected to the rotating axles of the wheels of the chariot so that when the chariot was driven, the swords poking from either side of the wheels rotated with such speed that any soldier in proximity to the sides of the chariot would get arms, legs, and any other body parts either sliced off or cut deeply enough to cause permanent damage. |
| **WAR FLEETS** | |

| | |
|---|---|
| <br>**Original Image:**<br>http://www.stephenhicks.org/tag/trireme/ | The Persians adopted Greek war ships called triremes and biremes. Triremes were long narrow ships that supported three levels of rowers that had a long oar for steering at the back end and a ram, which is an iron beam at the front of the ship. A bireme, on the other hand, is the same as a trireme except it supported two levels of rowers, which are about 200 men as opposed to 300 men found in the triremes. The vessels had a ram at the front because it was used to stab into an enemy ship, attacking it and then successfully destroying parts of it. |

**"Figure 67: Example Table of Website"**

The final paper was made public by adding it to the website for accessibility by any interested party in our finalized product.

# VII. WORKS CITED


Ali, Daud. *Passport to the Past: Ancient India.* New York: The Rosen Publishing Group Inc., 2009.

"Ancient Warfare". *Wikipedia*. Web. 15 Sept. 2011. <http://en.wikipedia.org/wiki/Ancient_warfare#Persia>.

"The Ancient Warfare, Weapons and Military of India." AncientMilitary.com. 2010. Web. 19. Sept. 2011. <http://www.ancientmilitary.com/ancient-india-military.htm>.

"ArchaicPeriod – Ancient Greek History". *Ancient Greece*. Web. 9 Oct 2011. <http://www.ancientgreece.com/s/ArchaicPeriod/>.

Bakhuizen, S. C. "Greek Steel." *World Archaeology*. Vol 9, No. 2. Architecture and Archaeology. 1977. pp. 220-234.

Berrigan, Joseph. "Prelude to the Persian Wars." Jan, 2011. Web. 15 Sept. 2011. <http://joseph_berrigan.tripod.com/ancientbabylon/id25.html>.

Berrigan, Joseph. "Alexander and Persia." Jan, 2011. Web. 12 Sept. 2011. <http://joseph_berrigan.tripod.com/ancientbabylon/id31.html>.

Bradford, Alfred S. *With Arrow, Sword, and Spear: A History of Warfare in the Ancient World*. Westport, Connecticut: Praeger Publishers, 2001.

Bramwell, Neil D. *Civilizations of the Ancient World: Ancient Persia*. New Jersey: Enslow Publishers, Inc., 2004.

Burgan, Michael. *Great Empires of the Past: Empires of Ancient Persia*. New York: Chelsea House, 2010.

Burton, Richard. *The Book of the Sword*. London, Chatto and Windus, 1884.

Callister Jr., William D. *Materials Science and Engineering An Introduction*: *7th Edition*. John Wiley & Sons. New York, NY, 2007.

Canaandoors. "Wrought Iron vs Mild Steel & Cast Iron-Document Transcript." Web. 14 Oct 2011. <http://www.slideshare.net/canaandoors/wrought-iron-vs-mild-steel-cast-iron>.

Cowen, Richard. "Exploiting the Earth." John Hopkins University Press. Web. 14 Nov 2011. <http://mygeologypage.ucdavis.edu/cowen/~gel115/warning.html >.

Curtis, Vesta Sarkhosh and Stewart, Sarah. *Birth of the Persian Empire*. London: I.B. Tauris, 2005.

Dalal, Anita. *Ancient India: Archaeology Unlocks the Secrets of India's Past.* Washington, D.C.: National Geographic Society, 2007.

Dixie Gun Works Inc. *MA0600 Kasenit*. 2003. Web. 11 Nov 2011. <http://www.dixiegunworks.com/product_info.php?products_id=6465>.

Drury, Mark. "The Early Achaemenid Persian Army: Arms and Equipment." *Achaemenid Persia: A History Resource*. Web. 10. Sept. 2011. <http://members.ozemail.com.au/~ancientpersia/org_frm.html>.

Dupuy, Ernest. *The Harper Encyclopedia of Military History*. Harper & Row, Publishers, 1970.

Edmiston, Rodford. "The Joy of High Tech." 2007. Web. 12 Dec 2011. <http://www.dcr.net/~stickmak/JOHT/joht31ironage.htm>.

Gabriel, Richard A. *The Culture of War: Invention and Early Development.* New York: Greenwood Press, 1990.

Gill, N.S. *An Introduction to Ancient Persia and the Persian Empire*. Web. 14 Sept. 2011. <http://ancienthistory.about.com/cs/persianempir1/a/aa032800a.htm>.

Gorkhali. "Military History of Ancient India." *All Empires: Online History Community*. 10 Feb. 2002. Web. 14 Sept. 2011. <http://allempires.com/article/index.php?q=military_ancient_india>.

"Greco-Persian Wars". *Wikipedia.* Web. 15 Sept. 2011. <http://en.wikipedia.org/wiki/Greco-Persian_Wars>.

Groover, Mikell. *Fundamentals of Modern Manufacturing: Materials, Processes, and Systems:* 3rd Edition. Wiley, 2006.

Haskins, John F. "Northern Origins of "Sasanian Metalwork". *Artibus Asiae, Vol 15, No 4*. Artibus Asiae Publishers, 1952. Web. 26 Sept 2011. <http://www.jstor.org/stable/pdfplus/3248818.pdf?acceptTC=true&>.

"History of Greece: Classical Greece". *Ancient Greece*. Web. 10 Sept 2011. <http://www.ancientgreece.org/history/classical.html>.

"How to Make a Sword – A Beginner's 10 Step Guide". Web. 25 Sept. 2011. <http://www.sword-manufacturers-guide.com/how-to-make-a-sword.html>.

"Immortals (Persian Empire)". *Wikipedia*. Web. 15 Sept. 2011. <http://en.wikipedia.org/wiki/Persian_Immortals>.

Jackson, A.V. Williams. "XIV: The Persian Dominions in Northern India Down to the Time of Alexander's Invasion." *The Cambridge History of India-I-Ancient India*. Third Millennium Library. Web. 15 Sept. 2011. <http://www.third-millennium-library.com/readinghall/UniversalHistory/INDIA/Cambridge/I/CHAPTER_XIV.html>.

Jestice, Phyllis G. *Ancient Persian Warfare*. New York: GS Learning Library, 2010.

Johnsson, Peter. “The Berserkr”. *Albion Swords: History in Your Hand*, 2007. Web. 27 Dec 2011. <http://www.albion-swords.com/swords/albion/nextgen/sword-viking-berserkr.htm>.

Katouzian, Homa. *The Persians: Ancient, Mediaeval, and Modern Iran.* New Haven: Yale University Press, 2009.

Keegan, John. *A History of Warfare*. New York: Knopf, 1994.

Kosambi, D.D.. “The Beginning of the Iron Age in India.” *Journal of the Economic and Social History of the Orient*. Vol 6, No 3. Brill, 1963. pg. 309-318

Kosambi, D.D. *The Cultural and Civilization of Ancient India in Historical Outline*. Routledge: Kegan & Paul, 1965.

Koster, Daniel and Slade, Benamin. *Himalayan Imports: Hand-Forged Khukuris by the Finest Craftsmen in Nepal*. Reno, NV: Himalayan Imports, 2010. Web. Sept 24, 2011. <http://www.himalayan-imports.com/khukuri-history.html>.

KRD. Web Forum Comment “Early Greek Kopis Reconstruction-Dimension.” *Romanarmy.com*. Web. 10 Nov 2011. <http://www.romanarmytalk.com/rat.html?func=view&catid=63&id=244096&view=entrypage>.

"Kukri History: Origin of Gurkha Knife/kukri." *Khukuri House Thamel Pvt Ltd*. Web. 28 Dec. 2011. <http://www.khukuriblades.com/kukri_history/>.

Lamberg-Karlovsky, C. C. “Archeology and Metallurgical Technology in Prehistoric Afghanistan, India, and Pakistan”. American Anthropologist, News Series. Vol 69. No. 2. 1967. Pg. 145-162

Lambert, Tim. “A Brief History of India.” *A World History Encyclopedia*. Web. 2 Oct 2011. <http://www.localhistories.org/india.html>.

Lendering, Jona. “Immortals.” *Livius: Articles on Ancient History*. Ed. Jona Lendering. 1995-2011. Web. 7 Sept 2011. <http://www.livius.org/ia-in/immortals/immortals.html>.

Londhe, Sushama. “War in Ancient India.” *HinduWisdom.* Web. 19 Sept 2011. <http://www.bibliotecapleyades.net/vimanas/esp_vimanas_11a.htm>.

McCullough, Joseph Allen. “The Anglo Saxon Warrior: The Weapons and Armour of the Early English Warrior”. *Suite 101*, 5 April 2007. Web. 27 December 2011. < http://joseph-allen-mccullough.suite101.com/the-anglosaxon-warrior-a18095>.

Mattusch, Carol. “Bronze and Ironworking in the Area of the Athenian Agora.” *Hesperia: The Journal of the American School of Classical Studies at Athens*. Vol 46, No 4. 1977. pg. 340-379.

McIntee, David. “Khopesh, Sword of Ancient Egypt”. *Suite 101*, 13 July 2009. Web. 25 December 2011. < http://david-mcintee.suite101.com/khopesh-sword-of-ancient-egypt-a132506>.

Perrett, Roy. “History, Time, and Knowledge in Ancient India.” *History and Theory*. Vol 38, No. 3. Blackwell Publishing, 1999. pg. 307-321.

“Persia.” *Ancient Encyclopedia History*. Web. 12 Sept. 2011. <http://www.ancient.eu.com/Persia/>.

Prakash, B. “Metallurgy of Iron and Steel Making and Blacksmith in Ancient India.” *Indian Journal of History of Science.* Vol 26, No. 4. 1991. Pg. 351-371.

Richardson, Harry. “Iron, Prehistoric, and Ancient.” *American Journal of Archeology*. Vol 38, No 4. Archeological Institute of America, 1934. pg 555-583.

Shrivastva, Rina. “Smelting Furnaces in Ancient India. *Indian Journal of History of Science*. Vol 34, No. 1. 1999. pg 33-46

Siegel, Janice. “Dr. J’s Illustrated Persian Wars.” *Dr. J’s Illustrated Guide to the Classical World*. 2 Aug. 2005. Web. 20. Sept. 2011. <http://people.hsc.edu/drjclassics/lectures/history/PersianWars/persianwars.shtm.>

Singh, Sarva. *Ancient Indian Warfare: With Special Reference to the Vedic Period.* Motilal Banarsidass Pub, 1990.

Snodgrass, A.M. *Arms and Armour of the Greeks.* Ithica, New York: Cornell University Press, 1967.

Souza, Philip de, ed. *The Ancient World at War.* New York: Thames & Hudson Ltd, 2008.

“Superplastic Definition.” alumatter. Web. 10/12/11. <http://aluminium.matter.org.uk/content/html/eng/default.asp?catid=208&pageid=2144416604>.

“Sparabara”. *Wikipedia*. Web. 15 Sept. 2011. <http://en.wikipedia.org/wiki/Sparabara>.

Srinivasan, Sharada and Ranganathan, Srinivasa. "Wootz steel: an advanced material of the ancient world." Jamshedpur: Indian Institute of Metals & Tata Steel, 1997. Web. 10 Oct 2011 <http://materials.iisc.ernet.in/~wootz/heritage/WOOTZ.htm>.

“The Ancient Persian Empire”. *The Ancient Web.* Web. 17 Sept. 2011. http://ancientweb.org/explore/country/Persia

Tuplin, Christopher. “All the King’s Horse: In Search of Achaemenid Persia Cavalry.” *New Perspectives on Ancient Warfare.* Ed. Garrett G. Fagan and Matthew Trundle. Boston, MA: Brill Academic Publishers, 2010. (101-182). 14 Sept 2011.

“Very Fine Damascus Sousson Pata Sword – India- 7704”. *Oriental-Arms Ltd.*, 2001. Web. 27 Dec 2011. <http://www.oriental-arms.com/item.php?id=1734>.

Yannis. Web log comment. “Ethnographic Arms & Armour Forum.” *Jelsoft Enterprises Ltd.*, 22 Mar. 2005. Web. 25 Dec. 2011. <http://www.vikingsword.com/vb/showthread.php?t=498>.

## VIII. FIGURE REFERENCES


Figure 1: http://joseph_berrigan.tripod.com/ancientbabylon/id31.html
Figure 2: http://www.iranchamber.com/history/cyrus/cyrus.php
Figure 3: http://taghribnews.ir/vglivzap.t1aywtckqltl9.2kipt.x.html#8
Figure 4: http://www.farsinet.com/iranbibl
Figure 5: http://visopsys.org/andy/essays/darius-bisitun.html
Figure 6: http://science.nationalgeographic.com/science/archaeology/photos/lost-cities/#/lost-city-persepolis-iran_24727_600x450.jpg
Figure 7: http://www.howarddavidjohnson.com/spartans.htm
Figure 8: Gombrich, E.H. Translated by Caroline Mustill. *A Little History of the World*. Boston: Yale University Press Publications, 2005.
Figure 9: http://www.parstimes.com/library/brief_history_of_persian_empire.html
Figure 10: http://edsitement.neh.gov/edsitement's-persian-wars-resource-pages
Figure 11: http://library.thinkquest.org/17709/wars/peloponn.htm
Figure 12: http://www.bbc.co.uk/history/ancient/romans/pompeii_art_gallery_07.shtml
Figure 13: Snodgrass pic 17
Figure 14: Snodgrass pic 18 & 19
Figure 15: Snodgrass pic 23
Figure 16: Snodgrass pic 24
Figure 17: Snodgrass pic 20
Figure 18: Snodgrass pic 53
Figure 19: Snodgrass pic 50
Figure 20: Bradford pic 23
Figure 21: Bradford pic 24
Figure 22: http://ccmarie96.edu.glogster.com/aryans-arrive-in-india/
Figure 23: http://radhikaranjanmarxist.blogspot.com/2010_09_01_archive.html
Figure 24: http://worldcoincatalog.com/AC/C3/India/MauryanEmpire/MauryaEmpire.htm
Figure 25: http://www.rapturenotes.com/slingsandstones.html
Figure 26: http://www.swordhistory.info/?p=78
Figure 27: http://www.vikingsword.com/vb/showthread.php?t=498
Figure 28: http://www.myarmoury.com/talk/viewtopic.php?t=2729
Figure 29: http://www.myarmoury.com/talk/viewtopic.php?t=9497
Figure 30: http://www.realwroughtiron.com/
Figure 31: http://www.keytometals.com/Article107.htm
Figure 32: Groover, Mikell. Fundamentals of Modern Manufacturing: Materials, Processes, and Systems: 3rd Edition. Wiley, 2006.
Figure 33: Groover, Mikell. Fundamentals of Modern Manufacturing
Figure 34: Groover, Mikell. Fundamentals of Modern Manufacturing
Figure 35: Groover, Mikell. Fundamentals of Modern Manufacturing
Figure 36: Groover, Mikell. Fundamentals of Modern Manufacturing
Figure 37: Groover, Mikell. Fundamentals of Modern Manufacturing
Figure 38: Groover, Mikell. Fundamentals of Modern Manufacturing
Figure 39: Groover, Mikell. Fundamentals of Modern Manufacturing
Figure 40: Groover, Mikell. Fundamentals of Modern Manufacturing
Figure 41: Groover, Mikell. Fundamentals of Modern Manufacturing

Figure 42: http://www.gowelding.com/met/carbon.htm
Figure 43: http://144.206.159.178/ft/537/20481/369686.pdf
Figure 44: http://www.springerlink.com/content/58k030868503214p/fulltext.pdf