Trireme – *Teacher Background*

In preparation for teaching this Inquiry Unit, teachers are encouraged to refer to three authors, Murray, Morrison, and Hale. Each of these scholars has spent a significant amount of time researching the Athenian Trireme, and each makes a unique contribution to our overall understanding of the trireme and its importance to ancient Athens. Below are three excerpts from these authors, the combination of which serves as an adequate starting point for understanding the concepts that comprise the foundation of the REACH Trireme Inquiry Unit.

From Murray, William M. *The Age of Titans: The Rise and Fall of the Great Hellenistic Navies.* New York and London: Oxford UP, 2012.

The Athenian "Three" during the Peloponnesian War
Because of its extreme popularity and long period of use, the ship class about which we know the most is the "three," or triple-tier warship. Of all the states who built these vessels, we know the most about the Athenian version used during the fifth and fourth centuries BCE. Our evidence comes from an array of sources, from literary descriptions of fleets in action and depictions of "threes" on pottery, stone, or coins, to foundations for ship-sheds (covered slipways) where the ships were stored, and detailed inventories of state owned property associated with the fleet between 377 and 323/22 BCE.

Much of what we know has been summarized in an excellent book by J. S. Morrison and his colleagues titled *The Athenian Trireme*. I do not mean to imply that all the questions have been answered. Indeed, there is a long history of scholarly interest in solving the so-called "trireme question" and the debate has sometimes become quite heated. Nevertheless, we have reached a point where there is enough agreement on the basic details for us to sketch the physical outlines of the class. To judge from the preserved slipways and known oarcrew (170) the galley was long and narrow – roughly 37 m. x 5 m. (at the outrigger) – with a beam to length ratio of roughly 1:7. A full crew numbered 200 men, and this included 170 oarsmen, a complement of 10 marines (*epibatai*) who were carried on the deck, four archers (*toxitai*), and 16 officers and sailors. Among the officers, there was a trierarch or captain and six petty officers: a helmsman (*kybernetes*), a rowing master or boatswain (*keleustes*), a purser (*pentekontarchos*), a bow officer (prorates), a shipwright (*naupegos*) and a time keeper (*auletes*). The remaining crew members were included under the term "support staff" (*hyperesia*) and must have handled the ship's lines, sails and anchors.

We may learn something of its performance under oar by a number of ancient authors who describe the vessel in action. By far, the best authority is the historian Thucydides, a trireme commander in his own right until he was exiled from Athens in 424 during the war he chronicles. According to his account, an Athenian "three" was able to accelerate quickly, turn sharply, reverse direction smartly, and deliver a ram blow of sufficient strength to shatter steering oars from the rear or splinter an enemy hull. Numerous accounts make it clear that attacks had to be carried out carefully to prevent the ram from becoming entangled or, worse yet, from being carried along in the struck ship and wrenched from the attacker's bow. For this reason, ram strikes were best made from oblique angles to a ship's side or stern in such a way that the target ship's momentum allowed your own ram to safely withdraw from the hole it created. Since groups of warships relied upon one another for protection, "threes" worked well in fast moving squadrons of 10 to 30 ships.

A classic example that demonstrates these characteristics can be found in a speech attributed to the general Phormio by Thucydides (2.89.1-11). At the time of this speech (429), an Athenian squadron of 20 "threes" lay just outside the entrance to the Corinthian Gulf on its north shore. A Peloponnesian fleet of 77 "threes" anchored nearby on the Peloponnesian side of the Gulf.

Now, as for the battle, if I can help it, I shall not fight it in the gulf. I fully realize that lack of sea room is a disadvantage for a small, experienced and fast squadron fighting with a lot of badly managed ships. One cannot sail up in the proper way to make an attack by ramming, unless one has a good long view of the enemy ahead, nor can one back away at the right moment if one is hard pressed oneself; it is impossible also to execute the *diekplous* and anastrophe maneuvers [i.e., to sail through the enemy's line and then wheel back on him] – which are the right tactics for a fleet which has the superior seamanship. Instead of all this, one would be compelled to fight a naval action as though it were a battle on land, and under those circumstances the side with the greater number of ships has the advantage. (Thuc. 2.89.8)

Thucydides felt the Athenians had developed an expert knowledge of naval warfare that stood in contrast to their adversaries' old fashioned tactics. He states this clearly in his description of the sea battle off the Sybota islands (off the mainland opposite the southern end of Corcyra) between the forces of Corinth and Corcyra in 433 (Thuc. 1.49.1-4):

Then, after the signals had been hoisted on both sides, they joined battle. The fighting was of a somewhat old fashioned kind, since they were still behindhand in naval matters, both sides having numbers of hoplites [i.e., heavily armed infantrymen] aboard their ships, together with archers and javelin throwers…. Indeed, it was more like a battle on land than a naval engagement. When the ships came into collision it was difficult for them to break away clear, because of the number engaged and of their close formation. In fact, both sides relied more for victory on their hoplites, who were on the decks and who fought a regular pitched battle while the ships remained motionless. No one attempted the *diekplous* maneuver; in fact, it was a battle where courage and sheer strength played a greater part than scientific methods. Everywhere in the battle confusion reigned, and there was shouting on all sides.

Both accounts tend to reinforce the same impression. The principle maneuvers are described by terms like diekplous and anastrophe, (sailing through the enemy line and turning back to attack the enemy in the rear), periplous (sailing around the enemy's wings) and a defensive tactic called the kyklos where ships form a circle, bows outward, and at a signal sprint forward to attack the enemy. Although scholars may debate the precise definitions of these maneuvers, the general impression remains the same: Athenian "threes" were formidable weapons when they fought together in squadrons and had adequate sea room to maneuver. At the close of the first 10 years of the Peloponnesian War, the Athenians and Spartans agreed to make peace, largely on the status quo. The Athenians had demonstrated repeatedly that they were virtually unbeatable at sea, if the fight involved maneuver-and-ram warfare.

Frontal Ramming as a Battle Tactic

Frontal ramming, or the deliberate head-on collision between two warships, is a well attested maneuver practiced by fleets and individual warships as early as the fifth century BCE. During the generation following Alexander the Great, and then frequently thereafter, we find this maneuver used at the start of many pitched naval battles. So long as fleets were composed of warships that were roughly the same size and mass, no commander could be sure his vessel would survive a head-on collision with the enemy and the *antiproiros* or "prow-opposed" maneuver was used as a defensive stance. Ships would adopt this position, for example, when they found themselves overtaken by faster pursuers. We might assume that this defensive maneuver dates back to the beginnings of ramming warfare, although our first clear reference to it as a battle tactic does not occur until the invasion of Xerxes in 480, when Herodotus describes the Greek fleet in this posture at Artemision.

During the course of the fifth century, the Athenians developed and refined their ability to initiate offensive attacks from a prow-opposed position. This unexpected action clearly intimidated their enemies; so much so, that in 425 when the Athenians charged the prows of the Spartan fleet at Pylos, arrayed in the standard prow-opposed defensive position, the Spartans flinched first and fled. Thucydides does not provide the details of this encounter, but presumably the Spartans so feared the Athenian ability to accelerate and maneuver out of this prow-opposed formation that they withdrew rather than wait to receive the attacks of the enemy on their flanks and sterns (Thuc. 7.36.3-4)

Until advances in technology allowed for the manufacture of bronze rams that would routinely withstand the force of a head-on collision between warships, intentional prow-to-prow ramming strikes were reserved for extreme situations or were limited to attacks on the forward lateral ends of the outriggers, the catheads (*epotides*), which were strengthened for this purpose. These collisions, when carried out in a deliberate, purposeful manner could be quite violent. In a battle off Naulochus in 36, Agrippa struck the enemy flagship with a prow-to-prow strike and the force ejected men from the enemy deck towers into the sea (App. BC 5.11.107). In 306, off Cyprian Salamis, we are told that deck soldiers crouched down just before the collision, presumably to hold on for dear life (Diod. 20.51.2). The sounds of bow hitting bow were so loud that they drowned out the commands of the combatants. The jolt was likened to the force of a 55.5 meter-long battering ram striking a stone city wall (Diod. 20.95.1). The considerable forces generated by such collisions would cause all but the most solid of rams to fail unless they were made with great care. This is because the process of bronze casting leaves weak spots and cracks when gas bubbles are not released from the melt and the metal is allowed to cool and thus shrink too rapidly. It is likely that the first step involved strengthening the timbers forming the ends of the outriggers. This beefed up bow structure then became a weapon in its own right for those wishing to attack from a prow-opposed stance.

The sheer audacity involved in carrying out the threat to attack an enemy's prow lies behind the advice given to Syracusans by Hermocrates in 413 (Thuc. 7.21.3): "What daring people like the Athenians find most awkward is to be confronted with equal daring on the other side; Athens, sometimes without any real superiority in strength, was in the habit of terrorizing her neighbors by the very audacity of her attacks; the same method might now be used by Syracuse against Athens." The rules of engagement were about to change.

From: Morrison, J.S., J. F. Coates, and N. B. Rankov. *The Athenian Trireme: The History and Reconstruction of an Ancient Greek Warship.* Cambridge: Cambridge University Press, 2000.

(Anglican spellings from the original text have been Americanized here)

The Greeks called the standard warship of the classical period a *trieres*. The Romans called it a *triremis*, and English scholars have traditionally followed the Romans and called it a trireme. But since the Greek ship is the theme of this book we shall use the term 'trieres' (plural 'triereis') throughout, except when we are speaking of the Roman vessel.

At the outset a number of questions require to be answered. Why is the trieres important? Why did a book need to be written on the subject? Why should the book have been followed up by the design and making of a full-scale ship? And, finally, why was the definitive book not written, and a satisfactory ship built, long ago, since the evidence has been available for a good many years?

The importance of the trieres

Oared warships, of which the trieres is the most famous, lie at the heart of the Greek, Hellenistic and Roman story as it unfolds from Homer to Constantine. In the seventh and sixth centuries BC, oared galleys took Greek colonists from their mother cities to all parts of the Mediterranean and the Black Sea. In 480 BC a great Persian armada was defeated by a much smaller Greek fleet in the narrow waters between Attica and the island of Salamis. Athens' ensuing maritime supremacy was founded on the crucial role which she played in the famous victory. The skilled use of the trieres enabled her to win, and for some decades to keep, the hegemony over some, at least, of her former Greek allies. In the fourth century larger oared ships – 'fours', 'fives', and 'sixes' – were built in Sicily at Syracuse to meet the growing seapower of Phoenician Carthage, and 'fours' and 'fives' were employed at the end of the century by Athens and in the Levant. After the death of Alexander, his successors in the late fourth and third centuries BC disputed among themselves the command of the Eastern Mediterranean in fleets of increasingly large denomination. Rome had to build fleets of 'fives' (quinqueremes) and accustom herself to their use in a war with Carthage for the control of Sicily. In 31 BC at the sea battle of Actium, fought in oared ships of a great variety of sizes, the young Octavian defeated Antony and Cleopatra and gained the mastery of the Roman world as the emperor Augustus.

To understand the naval confrontations of ancient history, on which the future of western civilization has so often turned, it is essential to know as much as possible of the nature and potentials of the vessels in which the two sides fought, as well as to form an idea of the economic and social aspects of the organization of fleets; and knowledge of the trieres is basic to the understanding of larger ships. The trieres was the first type of oared warship to be pulled by oars at three levels. No representation of an oared warship exists showing oars at more than three levels. It seems likely, then, that the types of denomination five to eight were pulled at three levels employing more than one man to an oar, in a five at two levels and in the others at all three levels. The four is likely to have employed two men at each of two levels and the types larger than eights to have employed gangs of men at big oars again at two levels. It follows that understanding of the trieres is important in relation not only to the deployment of that ship herself but also to the deployment of the larger ships which also were pulled by oarsmen at three levels.

To Athens in the fifth and early fourth century BC the importance of the trieres hardly needs to be emphasized. The fleet of 200 triereis built shortly before the second Persian invasion, when she was involved in a naval war with Aegina, enabled the Greeks successfully to repel the invasion when it came. The entrance fee to the club of naval powers was high, and we are told that Athens was only able to afford it by using, at Themistocles' suggestion, the proceeds of a lucky strike in the silver mines of Laurium. These ships were also, Plutarch tells us (Cimon 12.2), specially designed by Themistocles 'for speed and quick turning', information which suggests that he had his own ideas of trieres tactics. Only by understanding these tactics and the nature of the ships which employed them can we form an idea of how the Greeks were able to defeat a fleet three times the size of their own.

After the repulse of the Persian invasion a naval force under Athenian command proceeded to liberate the Greek cities of Asia Minor and the offshore islands, as well as parts of Cyprus, and later invaded Egypt. In the last third of the fifth century Athens, now at war with her Peloponnesian allies, ensured her power at sea with a mastery of that special skill in fighting with triereis which was the despair of her rivals, and which, in the end, led her to overestimate the value of sea power against a continental league. In 415 an overconfident and ill-planned naval expedition to Sicily ended in disaster, and was a prelude to Athens' ultimate defeat by Sparta and her allies in 404, after some brave attempts to reestablish her naval command of the Aegean. Even after her defeat and surrender she managed with inadequate resources and varying success to cling to some semblance of maritime supremacy in the eastern Mediterranean for more than three-quarters of a century, in competition with strong Peloponnesian, Theban and ultimately Macedonian fleets, until her defeat at sea by a Macedonian-led Phoenician fleet off Amorgus in 322. A fitting epitaph for Athenian sea power is the proud reply put into the mouth of an Athenian traveler by a comic poet (Aristophanes, *Birds* 108) in the year of the Sicilian expedition. Asked for his country of origin he gives the answer: 'Where the fine triereis come from.' It was, it seems, the superior quality of her ships of which she boasted. This, very briefly, is the story of the Age of the Trieres, and of the trieres as the weapon by which Athens achieved and maintained, and in which in the end she lost, her power and prosperity. The trieres was not only a battle weapon but also the means by which Athens deployed her military power quickly and for the most part effectively.

The need for a theoretical reconstruction
The trieres is important, firstly because her design is basic to the designs of some of the subsequent ancient oared warships, and secondly because she played so significant a role in preserving the political and economic conditions in which Athens was able to make her great contribution to ideas of human society, to art, literature and philosophy. We need to know, and modern historians of Greece have not yet told us, how the trieres played that role, or rather how it was that the Athenians exploited more successfully than others the potential of the three-level oared ship as a naval weapon, and what that potential was. We want to know how she was used, to attempt to recognize the tactical purposes for which she was built, her strengths, and the limitations on her use which those strengths necessarily imposed. Fundamental questions need to be answered about the physical environment provided for her crew, the practice of pulling and sailing, her performance under oar and sail, the pay and recruitment of her crew, and the materials with which she was built. All this may be called the theoretical reconstruction of the trieres, and it needs to be set out as far as the evidence we have will allow.

There are two possible kinds of indisputable evidence for an ancient object: actual recognizable remains and a detailed description in contemporary literature. Neither exists for the trieres.

Recent activities of underwater archaeologists in the Mediterranean have produced no remains of a trieres to give a whole or partial answer to questions about the hull-structure or oarsystem, although numerous remains of ancient merchant ships have been found, some of them deriving from the fifth and fourth centuries BC and offering a useful analogy for building a trieres hull. Nor do historians writing at the time when the trieres was the standard warship of contemporary fleets give the kind of detailed descriptions of her such as we have of the monster double-hulled ‘forty’ which Ptolemy Philopator built or of the Byzantine dromon.

The enquirer must satisfy his frustrated curiosity by picking up information about the trieres from any contemporary source he can.

First will be the narratives of the historians describing the actions and voyages of the triereis at sea. These will give him a feel of what sort of ship the trieres was. The picture he gets will be supplemented by passing references to triereis or things connected with them in the poets – tragic and, in particular, comic – and even in the philosophers.

After literature, archaeology provides a variety of indirect information. The excavated remains of the Zea ship-sheds, built for triereis, give the maximum overall dimensions of the ship (c. 37 meters [approx. 121 feet] long, c. 5.9 meters [approx. 19 feet] broad). The surviving inventories of the Piraeus naval dockyards inscribed on stone and covering a number of years in the last third of the fourth century, provide a wealth of detailed information, in particular the length and number of the oars in the various categories. Finally there are the vase paintings, reliefs and coins which can be claimed to represent the trieres, though no ship is labelled as such.

The intricate process of piecing together the clues from all these sources has the fascinating quality of a detective story and has attracted professional interest not only among classical scholars.

The foundations of the present investigation were laid in *Greek Oared Ships* in 1968, but although the general principles of the trieres' oarsystem there presented seem now to be generally accepted, a good deal more work remained to be done. The use of the ship in battle and moving from place to place has had to be more closely studied, and the nature of the ship and her characteristics have had to be deduced as ground rules for a theoretical reconstruction. These ground rules have then had to be embodied in a detailed design which would satisfy the demands of the naval architect as well as those of the historian and archaeologist.

The need for a practical reconstruction

The next step was to build a trieres. One reason for doing this was the truth that the proof of this particular pudding is very much in the eating, since it had to be borne in mind that a three-level oared ship was an elaborate and highly sophisticated phenomenon without parallel elsewhere in time or place. The picture of the trieres which could be pieced together in a book is by the nature of the evidence necessarily a fragile construction, resting on interpretations of difficult texts and puzzling representations. The joint authors of this book by working together for the first time brought to bear on 'the trireme problem' three systems of knowledge: the learning of the scholar and traditional archaeologist, the more recent knowledge of ancient ship construction gleaned by underwater archaeologists, and the professional skill of the modern warship designer. In the light of that pooled expertise there appeared to be, apart from details, only one practicable design for the trieres which conformed to the available evidence. That thesis was strengthened during the development of the design as more features were worked out and found to knit together neatly, with the need for no more than minor adjustments to the main parameters. Thus we had on paper a ship which was not only a practical proposition but was also very likely to be in essentials the only possible solution to the trieres problem. Such a ship seemed well worth building.

A reconstructed ship ought to accord with the known evidence about the original in dimensions, materials, construction, appearance and performance. If that is not completely possible, the exceptions should be defined and explained. Consequences or side effects of the exceptions should be made clear.

The purposes of building a full-scale trieres need to be defined. Reconstruction of the past, by itself, in most cases hardly justifies the expense and effort involved. The best reason for making reconstructions of past artifacts is to improve our understanding of important aspects of history. As most artifacts are made for use, reconstructions can generally serve their main purpose only if they too work, and their performance can be assessed by proper measurements. An historically authentic working ship reconstruction can give us an insight into the realities of ancient seafaring, mercantile or naval, which would otherwise be unattainable. Another aspect of reconstructions, well expressed by Howard I. Chappelle (1936), the historian of American sailing ships, '…is that of learning to appreciate the intellect and ability of past generations. It is perfectly natural for each successive generation to look upon itself as far better equipped mentally than the ones before. If, however, one may judge from a comparison of naval architecture of the past with that of today as represented by modern sailing craft, there is little to support this self-admiration … men of earlier years had the same abilities and powers of reason and intellect that can be found in similar stations of life today.' The design of the trieres reconstruction has not only fully demonstrated Chappelle's point, but also borne witness to the very high level of craftsmanship in wood achieved in ancient times. The reconstructed ship has brought home to many that techniques of wood construction were as refined as those in stone and metal with which we have for a long time been familiar through numerous surviving examples of ancient architecture and sculpture.

The importance of ship reconstructions from the ancient Mediterranean world is enhanced by three further facts. The first is that stone and metal played a role in the general constructive and manufacturing effort of those societies that was relatively minor compared with that of wood, though of course surviving relics would overwhelmingly and quite erroneously indicate the opposite.

Secondly, ships represent solutions to more complex and testing structural problems than arise in land-based structures. Thirdly, among ships, those for war were developed to points nearest to the edge of technical feasibility at the time, regardless, it seems, of safety, expense or effort: they were, and indeed always have been, in modern terms, the high-technology products of their time.

The purposes of the reconstructed ship were four: (1) to prove that the reconstruction designed to the historical requirements and built in accordance with archaeological evidence would have a performance consistent with historical accounts; (2) to improve understanding of naval operations in the Mediterranean from the fifth to the third centuries BC; (3) to broaden appreciation of the technical, economic and naval achievements of Hellenic society and culture from the fifth to the third centuries BC by exhibiting the reconstruction to the public in Greece with explanatory material; (4) to recreate one of the major artifacts of Hellenic civilization and a unique ship-type of outstanding interest to naval historians and architects.

From Hale, John R. *Lords of the Sea: The Epic Story of the Athenian Navy and the Birth of Democracy.* Viking Penguin, 2009.

Actual naval battles were rare events in early Greek history. Homer knew nothing of fleet actions on his wine-dark sea, though in his Iliad and Odyssey he often cataloged or described ships of war. Their operations were limited to seaborne assaults on coastal towns (of which the Trojan War itself was just a glorified example) or piratical attacks at sea. As the centuries passed, two sizes of sleek, fast, open galley eventually became standard among the Greeks: the triakontor of thirty oars and the pentekontor of fifty. The traders, soldiers, or pirates who manned these galleys (often the same men), thirsting for gain and glory overseas, usually pulled the oars themselves.

It was the Phoenicians of the Lebanon coast who literally raised galleys to a new level. These seagoing Canaanites invented the trireme, though exactly when no Greek could say. Enlarging their ships, the Phoenician shipwrights provided enough height and space to fit three tiers of rowers within the hull. Their motives had nothing to do with naval battles, for such engagements were still unknown. The Phoenicians needed bigger ships for exploration, commerce, and colonization. In the course of their epic voyages, Phoenician seafarers founded great cities from Carthage to Cadiz, made a three-year circumnavigation of Africa (the first in history) in triremes, and spread throughout the Mediterranean the most precious of their possessions: the alphabet.

The first Greeks to build triremes were the Corinthians. From their city near the Isthmus of Corinth these maritime pioneers dominated the western seaways and could haul their galleys across the narrow neck of the Isthmus for voyages eastward as well. The new Greek trireme differed from the Phoenician original in providing a rowing frame for the top tier of oarsmen, rather than having all the rowers enclosed within the ship's hull. Some triremes maintained the open form of their small and nimble ancestors, the triakontors and pentekontors. Others had wooden decks above the rowers to carry colonists or mercenary troops. Greek soldiers of fortune, the "bronze men" called hoplites, were in demand with native rulers from the Nile delta to the Pillars of Heracles.

Like the Phoenician cities of Tyre and Sidon, Corinth was both a great center of commerce and a starting point for large-scale colonizing missions. Triremes could greatly improve the prospects of colonizing ventures, being able to carry more of the goods that new cities needed: livestock and fruit trees; equipment for farms and mills and fortifications; household items and personal belongings. For defense against attack during their voyages through hostile waters, or against opposition as the colonists tried to land, the large crew and towering hull made the trireme almost a floating fortress.

The earliest known naval battle among Greek fleets was a contest between the Corinthians and their own aggressively independent colonists, the Corcyraeans. Though the battle took place long after the Corinthians began building triremes, it was a clumsy collision between two fleets of pentekontors. The outcome was entirely decided by combat between the fighting men on board the ships. Naval maneuvers were nonexistent. This primitive procedure would typify all Greek sea battles for the next century and a half.

Then, at about the time of Themistocles' birth, two landmark battles at opposite ends of the Greek world brought about a seismic shift in naval warfare. First, in a battle near the Corsican town of Alalia, sixty Greek galleys defeated a fleet of Etruscans and Carthaginians twice their own size. How was this miracle achieved? The Greeks relied on their ships' rams and the skill of their steersmen rather than on man-to-man combat. Shortly afterward, at Samos in the eastern Aegean, a force of rebels in forty trireme transports turned against the local tyrant and crushed his war fleet of one hundred pentekontors. In both battles victory went to a heavily outnumbered fleet whose commanders made use of innovations in tactics or equipment. Ramming maneuvers and triremes thus made their debut in the line of battle almost simultaneously. Together they were to dominate Greek naval warfare for the next two hundred years.

Now everyone wanted triremes, not just as transports but as battleships. Rulers of Greek cities in Sicily and Italy equipped themselves with triremes. In Persia the Great King commanded his maritime subjects from Egypt to the Black Sea to build and maintain trireme fleets for the royal levies. The core of Persian naval power was the Phoenician fleet, but the conquered Greeks of Asia Minor and the islands were also bound by the king's decree. All these forces could be mustered on demand to form the huge navy of the Persian Empire. Themistocles believed that Athens' new trireme fleet might soon face not only the islanders of Aegina but the armada of the Great King as well.

While many cities and empires jostled for the prize of sea rule, ultimate success in naval warfare called for sacrifices that few were able or willing to make. Only the most determined of maritime nations would commit the formidable amounts of wealth and hard work that the cause required, not just for occasional emergencies but over the long haul. With triremes the scale and financial risks of naval warfare escalated dramatically. These great ships consumed far more materials and manpower than smaller galleys. Now money became, more than ever before, the true sinews of war.

Even more daunting than the monetary costs were the unprecedented demands on human effort. The Phocaean Greeks who won the historic battle at Alalia in Corsica understood the need for hard training at sea, day after exhausting day. In the new naval warfare, victory belonged to those with the best-drilled and best-disciplined crews, not those with the most courageous fighting men. Skillful steering, timing, and oarsmanship, attainable only through long and arduous practice, were the new keys to success. Ramming maneuvers changed the world by making the lower-class steersmen, subordinate officers, and rowers more important the propertied hoplites soldiers. After all, a marine's spear thrust might at best eliminate one enemy combatant. A trireme's ramming stroke could destroy a ship and its entire company at one blow.

Themistocles had specified that Athens' new ship should be fast triremes: light, open, and undecked for maximum speed and maneuverability. Only gangways would connect the steersman's small afterdeck to the foredeck at the prow where the lookout, marines, and archers were stationed. The new Athenian triremes were designed for ramming attacks, not for carrying large contingents of troops. By committing themselves completely to this design, Themistocles and his fellow Athenians were taking a calculated risk. For many actions, fully decked triremes were more serviceable. Time would tell whether the city had made the right choice.

The construction of a single trireme was a major undertaking: building one hundred at once was a labor fit for Heracles. Once the rich citizens who would oversee the task received their talents of silver, each had to find an experienced shipwright. No plans, drawings, models, or manuals guided the builder of a ship. A trireme, whether fast or fully decked, existed at first only as an ideal image in the mind of a master shipwright. To build his trireme, the shipwright required a wide array of raw materials. Most could be supplied locally from the woods, fields, mines, and quarries of Attica itself. Many local trades and crafts would also take part in building the new fleet.

First, timber. The hills of Attica rang with the bite of iron on wood as the tall trees toppled and crashed to the ground: oak for strength; pine and fir for resilience; ash, mulberry, and elm for tight grain and hardness. After woodmen lopped the branches from the fallen monarchs, teamsters with oxen and mules dragged the logs down to the shore. The shipwright prepared the building site by planting a line of wooden stocks in the sand and carefully leveling their tops. On the stocks he laid the keel. This was the ship's backbone, an immense squared beam of oak heartwood measuring seventy feet or more in length. Ideally this oak keel was free not only of cracks but even of knots. On its strength depended the life of the trireme in the shocks of storm and battle. Oak was chosen for its ability to withstand the routine stresses of hauling the ship onto shore and then launching it again. Once the keel was on the stocks, two stout timbers were joined to its ends to define the ship's profile. The curving sternpost rose as gracefully as the neck of a swan or the upturned tail of a dolphin. Forward, the upright stempost was set up a little distance from the keel's end. The short section of keel that extended forward of the stempost would form the core of the ship's beak and ultimately support the bronze ram.

Between the stern- and stemposts ran the long lines of planking. In triremes the outer shell was built up by joining plank to plank, rather than by attaching planks to a skeleton of frames and ribs as in later "frame-first" traditions. For the ancient "shell-first" construction the builders set up scaffolds on either side of the keel to support the planking as the ship took shape. They cut the planks with iron saws or adzes. Because the smooth lengths of pine were still green from the tree, it was easy to bend them to shape. Along the narrow edges of each plank the builders bored rows of holes: tiny ones for the linen cords, larger ones for the *gamphoi* or pegs. The latter were wooden dowels about the size of a man's finger that acted as tenons. Starting on either side of the keel, the shipwright's assistants secured the rows of planks by matching the row of larger holes to the tops of the pegs projecting from the plank below, then tapping the new plank into place with mallets. The pegs, now invisible, would act as miniature ribs to support and stiffen the hull. No iron nails or rivets were used in a trireme.

Once the planks were in place, the shipwright's assistants spent days squatting on the inside of the rising hull, laboriously threading linen cords through the small holes along the planks' edges and pulling them tight. Greek farmers sowed *linon* or flax in autumn, tended and weeded the fields over the winter, and harvested the crop in spring when the blue flowers had faded. The stems were cut, soaked, and allowed to rot. After beating and shredding, lustrous white fibers emerged from the decayed husk and pith. Twisting these fibers into thread produced a substance with near-miraculous properties. Linen cloth and padding were impenetrable enough to serve in protective vests or body armor for hoplites on land and marines on board ship, while a net of linen cords could hold a tuna or a wild boar. Yet linen could be spun so fine that one pound might yield several miles of thread. Unlike wool it would not stretch or give with the working of the ship at sea. Linen also possessed the very proper nautical quality of being stronger wet than dry.

The system of construction made a strong hull that could withstand severe shocks. Only after the hull was pegged and stitched with linen – or, as an Athenian would have said, *gomphatos* and *linorraphos* – did the builder insert the curving wooden ribs. And should a rock or an enemy ram punch a hole through the planking, a wooden patch could be quickly stitched into place to close the breach.

On top of the long slender hull the shipwright now erected the structure that set Greek triremes apart from their Phoenician counterparts: the wooden rowing frame or *parexeiresia* (that is, a thing that is "beyond and outside the rowing"). Sometimes referred to as an outrigger, the rowing frame was wider than the ship's hull and in fact performed multiple functions.

First, the rowing frame carried the tholepins for the upper tier or thranite of oars, and its wide span allowed for a long rowing stroke. Second, side screens would be fastened to the rowing frame when the ship went into battle to protect the thranite rowers from enemy darts and arrows. And third, the top of the frame could support a covering of canvas or wood. On fast triremes such as Themistocles had ordered, white linen canvas was spread above the crew to screen them from the hot sun while rowing. On a heavy trireme or troop carrier, wooden planking would be laid down on top of the rowing frame to make a deck on which soldiers or equipment could be transported. Finally, the stout transverse beams that crossed the ship at the end of the rowing frame served as towing bars to tow wrecked ships or prizes back to shore after battle.

As the great size of the rowing frame suggests, oars were the prime movers of the trireme. At two hundred per ship (a total that included 30 spares), Themistocles' new fleet required twenty thousand lengths of fine quality fir wood for its oars. The long shaft had a broad, smoothly planed blade at one end, and at the other the handle ended in a round knob to accommodate the rower's grip. One man pulled each oar, securing the shaft to the upright tholepin with a loop of rope or leather. The 62 thranite oarsmen on the top tier enjoyed the most prestige. Inboard and below them were placed the wooden thwarts or seats for the 54 zygian oarsmen and the 54 thalamians. The latter took their name from the ship's *thalamos* or hold since they were entombed deep within the hull, only a little above the waterline. All the rowers faced aft toward the steersman as they pulled their oars.

Once all these wooden fittings of the hull were complete, it was time to coat the ship with pitch, an extract from the trunks and roots of conifers. Once a year pitch-makers tapped or stripped the resinous wood of mature trees. In emergencies they cut down the firs and applied fire to the logs, rendering out large pools of pitch in just a couple of days. Carters conveyed thousands of jars of pitch to the shipbuilding sites in their wagons. The poetical reference to "dark ships" or "black ships" referred to the coating of pitch.

More than hostile rams or hidden reefs, the shipwrights feared the *teredon* or borer. Infestations of this remorseless mollusk could be kept at bay only by vigilant maintenance, including drying the hull on shore and applications of pitch. In summer the seas around Greece seethed with the spawn of the teredo, sometimes called the “shipworm.” Each tiny larva swam about in search of timber: driftwood, dock pilings, or a passing ship. Once fastened to a wooden surface, it quickly bored a hole by wielding the razorlike edge of its vestigial shell as a rasp. From that hiding place the teredo would never emerge. Once inside the hole it kept its mouth fixed to the opening so as to suck in the life-giving seawater. The sharp shell at the other end of the teredo’s body continued to burrow deeper. As the burrow extended into the timber, the animal grew to fill its ever-lengthening home.

Within a month the sluglike teredo could reach a foot in length. Now it was ready to eject swarms of its own larvae into the sea, starting a new cycle. Once planking and ribs were riddled with their holes, a ship might suddenly break up and sink midvoyage. Even when a wreck reached the bottom of the sea, the teredo would continue its attacks. In a short time no exposed wood whatever would be left to mark the ship’s resting place. Through conscientious maintenance – new applications of pitch, drying out and inspection of the hulls, and prompt replacement of unsound planks – an Athenian trireme could remain in service for twenty-five years.

The trireme’s design approach the physical limits of lightness and slenderness combined with maximum length. So extreme was the design that not even the thousands of wooden pegs and linen stitches could prevent the hull from sagging or twisting under the stresses of rough seas or even routine rowing. On Athenian triremes huge *hypozomata* or girding cables provided the tensile strength that the wooden structure lacked. A girding cable weighed about 250 pounds and measured about 300 feet in length. Each ship carried two pairs. Looped to the hull at prow and stern, the cables stretched around the full length of the hull below the rowing frame. The ends passed inside where the mariners kept them taut by twisting spindles or winches. Just as pegs and linen cords formed the joints of the hull, the girding cables acted as the ship’s tendons.

The trireme requires many other ropes as well. Made of papyrus, esparto grass, hemp, or linen, ropes supplied the rigging for the mast and sail, the two anchor lines, the mooring lines, and the towing cables. The ship’s tall mast and the wide-reaching yards or yardarms that held the sail were made from lengths of unblemished pine or fir. For the sail, the women of Athens wove long bolts of linen cloth on their upright looms. Sailmakers then stitched many such bolts together into a big rectangle. Despite their great weight – and their great cost – the mast and sail were secondary to the oars and, when battled threatened, were removed from the ship altogether and left on shore. Some triremes also carried a smaller “boat sail” and mast for emergencies.

The ship’s beak had already been fashioned in wood as part of the hull. To complete the trireme’s prime lethal weapon, the ram, metalworkers had to sheathe the beak with bronze. The one hundred rams needed for Themistocles’ triremes required tons of metal – a gigantic windfall for the bronze industry. Bronze, an alloy of nine parts copper to one part tin, does not rust and is more suitable than iron for use at sea. Some of the bronze poured into the rams of the Athenian triremes was recycled, melted down from swords that had been wielded in forgotten battles, from keys to vanished storerooms, images of lost gods, and ornaments of beautiful women long dead. Master craftsmen made the rams with the same lost-wax method that they used to cast hollow bronze statues of gods and heroes for the temples and sanctuaries.

The form of the ram was first modeled in sheets of beeswax directly onto the wooden beak, so that each would be custom made for its ship. As the artists worked the wax onto the beak, it warmed up and softened, becoming easier to handle. At the ram's forward end the wax was built up into a thick projecting flange, triple-pronged like Poseidon's trident. When every detail of the ram had been modeled, the wax sheath was gently detached from the wood and carried over to a pit dug in the sand of the beach.

The next step called for clay, the same iron-rich clay that went into Athenians' red and black pottery. With the wax model turned nose downward in the pit, clay was packed around its exterior and into its conical hollow to create a mold. Thin iron rods forged by the blacksmiths were pushed through the wax and the two masses of clay. When the wax was entirely encased in the clay except for its upper edge, the massive mold was inverted and suspended over a fire until all the wax was melted out. A hollow negative space in the exact shape of the ram had now been formed inside the packed clay. It remained only to fill the mold with molten bronze. But this was a complex and difficult undertaking.

Wood fires could not produce the necessary heat; the process required charcoal. A trireme's ram had to be cast in a single rapid operation. First the bronze workers erected a circle of small upright clay furnaces around the rim of the pit. A channel led from the foot of each furnace to the edge of the mold. Broken bronze, whether from ingots or scrap, was divided among the furnaces. With the lighting of the charcoal, the metal in each furnace quickly became a glowing, molten mass. At a signal, the bronze workers and their apprentices removed the clay stoppers from all the furnaces. Simultaneously the bright hot streams poured down the channels and filled the hollow in the clay mold left by the melting of the wax. The casting happened with a rush, and the bronze cooled and hardened quickly. When the clay mold was broken (never to be used again), the bronze ram itself, smooth, dark, and deadly, saw the light for the first time. After cutting away the iron rods, finishing off the back edge, and polishing the surface, the bronze workers slid the new ram into place over the trireme's wooden beak, fastening it securely with bronze nails.

Quarrymen and stone workers provided fine white marble from Mount Pentelicus near the city, and from thin slabs of this marble the sculptors carved a pair of *ophthalmoi* or "eyes" for each trireme. A colored circle painted in red ochre represented the iris. The eyes were fixed on either side of the prow. Athenians believed that these eyes allowed the ship to find a safe passage through the sea, completing the magical creation of a living thing from inanimate materials. In Greek terminology, the projecting ends of the transverse beam above the eyes were the ship's ears, and the yardarms were its horns; the sail and banks of oars were its wings, and the grappling hooks were its iron hands.

Blacksmiths fashioned a pair of iron anchors for each trireme, to be slung on either side of the bow. They would prevent the ship from swinging while its stern was grounded on the beach. Tanners and leather workers provided the tubular sleeves that waterproofed the lower oar parts. From the same workshops came the side screens of hide for the rowing frames. Pads of sheepskin would enable the trireme's oarsmen to work their legs as they rowed, thus adding to the power of each stroke.

Finally goldsmiths gilded the figurehead of Athena that would identify each ship as a trireme of Athens. The goddess wore a helmet as well as the famous breastplate or aegis adorned with the head of Medusa, the gorgon that could turn a mortal to stone with a single glance. As patron deity of arts and crafts, a goddess of wisdom and also of war, Athena had been presiding over the entire project from beginning to end.

From the mines of Laurium the silver had flowed through the city's mint, where it was transformed into the coins that bore the emblems of Athena. Then as Themistocles had planned, the river of silver broke into a hundred separate streams, passing through the hands of the wealthy citizens who organized the great shipbuilding campaign. During the months of shipbuilding the silver was disbursed to all those workers, from loggers to shipwrights to bronzesmiths, whose efforts made Themistocles' vision a reality. In the end, the money returned to many of the same citizens who had voted to give up their drachmas for the common good. By the time one hundred new triremes gleamed in the sunlight at Phaleron Bay, the Athenians were already a changed people. In the great contest that lay ahead, as they hazarded their new ships and their very existence in the cause of freedom, their sense of common purpose would grow stronger with every trial and danger.