1 THE LOSS OF ROMAN WAYS: 600-750

The fall of the last Roman emperor in the West in 476 was an event of little political significance and even less importance for commerce and shipping. The centre of the Mediterranean economy had long before shifted eastward, a fact acknowledged by the transfer of part of the Roman government to the shores of the Bosporus by Emperor Constantine in 330. The Byzantine Empire with its capital at Constantinople emerged as the strong state of the Mediterranean in the fifth century. In the sixth century it was the base for an effort to re-establish the entire former Empire under Emperor Justinian. Success was not complete but the result by 600 was unification of much of the Mediterranean coast under one government and the protection of trade by that government. The stability created by Justinian's conquest was destroyed by the emergence of a new political force from Arabia. The adherents to the teachings of the prophet Mohammad in the years after 630 very quickly established themselves on the southern and eastern shores of the Mediterranean, taking some of the richest provinces of the Byzantine Empire and presenting a direct threat to the continued survival of the Empire itself. That made the Mediterranean a battleground between

Illustration above: A simple open coastal vessel of early medieval ancestry, Gravelines, oldest town seal, first half of the thirteenth century.

two competing powers. It remained so for some centuries.

The former western provinces of the Roman Empire were ruled by a series of Germanic kings, leaders of tribal groupings which had migrated into the Empire in the fifth and sixth centuries. The remnants of Roman administration in the West gave a certain stability to government but in the course of the seventh century that disappeared. By 711 and the loss of Spain to invading Muslims the surviving German successor states on the Continent were the Lombard kingdom in Italy and the kingdom of the Franks. The latter was passing through a constitutional crisis which was not resolved until the mid-eighth century. The confused political situation in western and northern Europe left little or no institutional support for commerce or for the development of shipping. The direction taken by technical change in ship design there was a reflection of the retrogression in politics, in learning and in the economy.

Just as Europe inherited Roman language, literature and political institutions so too did it inherit Roman practice in ship design and shipbuilding. The essential features of Roman ships formed the starting point for builders in the Mediterranean in the middle ages. In northern and central Europe Roman influence on existing Celtic practice was surprisingly limited. The first- and second-century Romans built essentially two types of ships: galley and merchantman. A number of sub-groups or variations on the basic designs can also be identified. The differentiation into these two types was established by the middle of the second millennium BC. The Romans simply pursued the possibilities created by their inheritance from the Egyptians, Phoenicians and Greeks. The better-known galley was powered by oars and was long relative to its width. Though the galley was usually equipped with sails and though merchantmen might sometimes also have oars, it was always easy to distinguish the two types by the shape of the hull. Merchantmen were short, almost tubby and nothing like the slender galleys.

The Romans, having swept the seas of all opposition, needed only a light vessel for patrol and coast-guard work. The light and fast Liburnian type was the answer.[a] One bank of oars was adequate. Later versions may have had two banks of oars. There was always just one man to each oar. Speed and manoeuvrability were the principal features of the Liburnian. There was a single ram, the principal offensive weapon of the galley, at the bow. At the stern was a cabin for the commander. A single square sail was rigged to a single mast stepped amidships. A small square sail, an artemon, was slung under the bow to act as a headsail. The yard, often made of two spars fished together, could be as long as the mast. The sail only got in the way in a fight so it was retractable

and easily stowed between the lines of rowers. There was also a second and smaller rig which could be easily raised and may have been used to get out of difficulty. The sails were made of oblong blocks of cloth sewn together with boltropes on the edges and leather patches at the corners for reinforcement. Galley crews were free men. If there were any slaves on board they were the servants of the commander.[1] Galleys stayed close to shore not because of the frailty of the ship or lack of knowledge of navigation but because they needed to be close to supplies and had to stop at night since there was no place on board for the men to sleep. The vessel was controlled by using the oars and by side rudders, one on each side of the stern. The galley was originally designed for both trade and piracy. For short-distance trades and trades where speed was important, such as the shipment of animals, it was useful. It also made the ideal warship for the Mediterranean. Cargo vessels, on the other hand, were invariably slow and hard to handle relative to galleys. They were double-ended but on larger vessels the bow was low compared to the stern.[b] As a result they were anchored at the stern. Power came from a single large square sail on a mast stepped amidships or slightly forward. There was an artemon to aid in steering and by the third century there might also have been a small triangular sail above the mainsail, probably only used in fair weather, to aid in driving the ship.

On smaller merchantmen there was a handful of oars to be used in emergencies or as an auxiliary driving force. In some of the largest merchantmen there were three masts with a short mizzenmast added at the stern which also carried a square sail. This was probably to aid in handling as much as for propulsion. Merchantmen carried less canvas than was feasible and carried it low. This kept down speed, 4 to 6 knots with a favourable breeze, but it made the vessel much safer. The main-yard was very long and needed multiple lifts, ropes running from the deck to the top of the mast and then to blocks on the yard, to raise it. A massive forestay was needed to hold the mast in place. Shrouds, also for holding the mast, ran from the uppermost plank of the hull to the top of the mast and had tackles so that they could be adjusted. That meant it was not possible to use ratlines – that is, to make rope ladders out of the shrouds by adding small connecting pieces of rope. For getting to the top of the mast there was a rope ladder at the back of the mast. Sail was shortened by raising it up to the yard, not by lowering it. To do that Romans used brails, lines running up through the sail to the yard and then down to the deck. Thus sail could be shortened without going aloft. Also it was possible to shorten only a part of the sail and even to make a triangular sail out of the square one if the master wanted.

Added to the sails for control were two large steering rudders, one at either side of the stern. These were heavier than on galleys, better protected and more firmly fixed. They were manned by a single helmsman who held two tiller bars which ran to the centre of the ship from the rudders. On larger ships a slightly more complex arrangement was fitted. In any case the system was efficient.[2]

The shape of the hull was derived from Minoan practice of the second millennium BC. It was well rounded with curving stem and stern posts. The length-to-beam ratio was about 4:1 but could be as little as 3:1. It was kept low to add cargo space and also for safety. On freighters of any size there was a second deck. The deckhouse at the stern could be a fully enclosed cabin for the captain and perhaps a few select passengers. Most of the passengers, however, camped on deck. There was usually a galley fitted aft for heating meals.

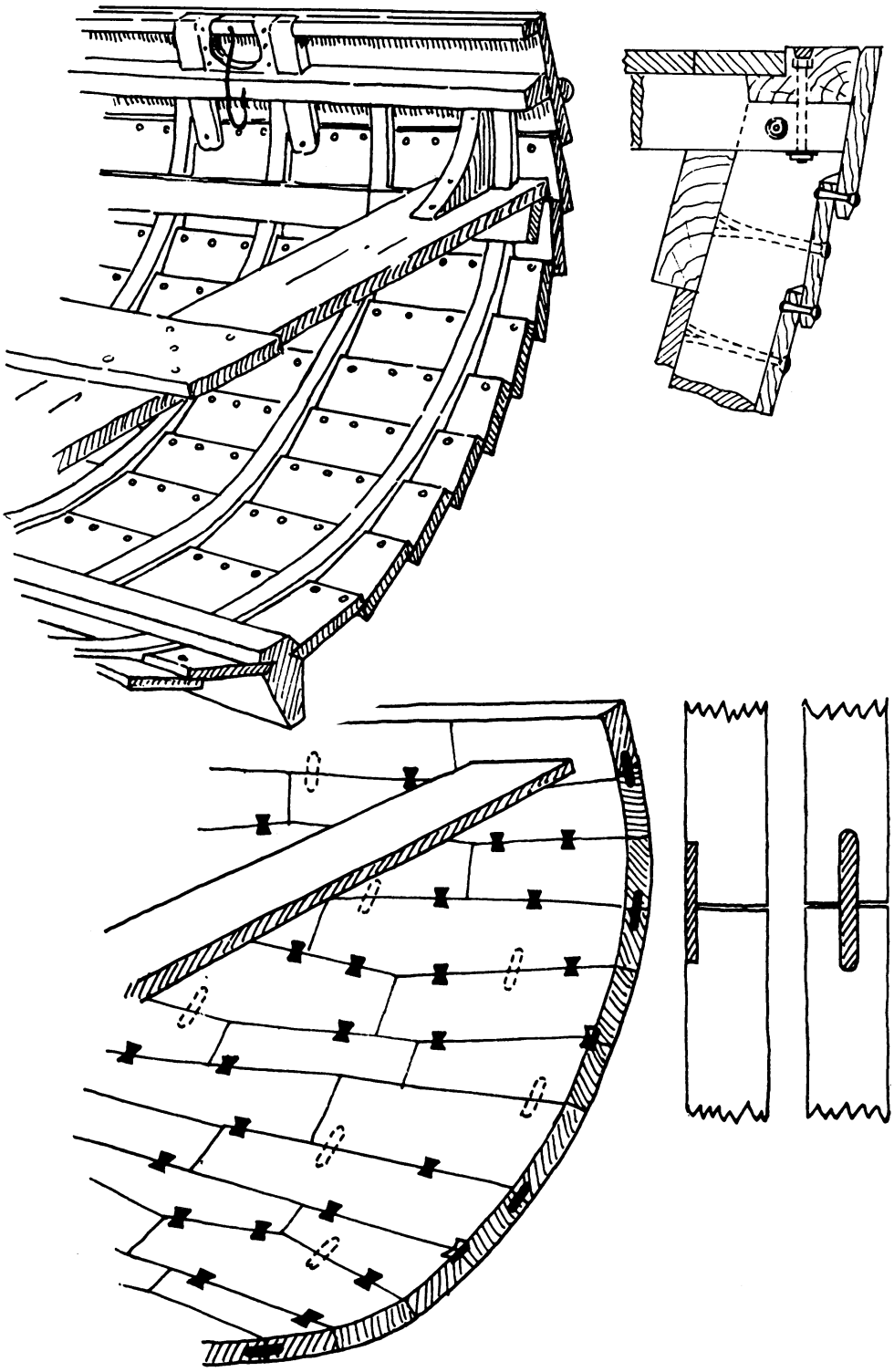
Freighters could be built to massive proportions. The smallest ships used on the open sea in trade were of 70 or 80 tons. The average was undoubtedly higher. Even by the fifth century BC ships of 100 to 150 tons were not uncommon and there were vessels up to 500 tons. In the third century BC there was a move towards building bigger warships and this may have caused an increase in the size of merchantmen. At that time perhaps the biggest cargo vessel of the classical world was built under the supervision of Archimedes at Syracuse. It was a grain carrier of 1,700 to 1,900 tons. Vessels of that size were not built again until the sixteenth century. In the first, second and third centuries AD, however, the Romans had an ambitious programme for the transport of the annual grain tribute of 150,000 tons from Alexandria in Egypt to Rome. The ships used also provided excellent passenger service with, in one case, 600 people carried. A size of 1,300 tons was usual for such vessels, with measurements of 55 metres over-all length, 13.72 metres broad and 13.25 metres deep in the hold. There were of course smaller vessels, size and dimensions depending on the job of the ship. For heavy goods such as wine or building stone dimensions would be 19 to 33 metres long and 7 to 10 metres broad while larger cargo vessels would rise to 40 metres by 10 metres. The total number of ships in service and the total tonnage of the Roman merchant marine was probably not equalled again in Europe until the sixteenth century. Roman merchant vessels, unlike the galleys, were manned by slaves. In fact even the master was often a slave.[3]

Roman ships were built like fine pieces of furniture. For strength they relied on the outer shell of the hull.[4] The external planking was placed end to end and held together by mortise and tenon joints. Both

the upper and lower plank were given alternating projections and grooves to fit into each other. Wooden nails, treenails, were then run through the planks and tenons. The treenails in turn were held in place by nails. The planks or strakes were .035 to .10 metres thick. The tenons were .05 metres thick and at times rising to nearly .10 metres. The tenons could reach halfway into the plank. Tenons were usually about .10 metres across and on seagoing ships mortises were never more than .25 metres apart and usually much less. The extreme and not uncommon case was that the tenons were next to each other forming an almost solid wall. This formed a strong and perfectly watertight compartment.[c] In construction the keel and posts at either end were laid down first. Then the hull planks were fitted in this careful manner. After the hull was finished the frames were added inside the hull for lateral strength. They were not regularly spaced but usually not over .25 metres apart and often closer together. They were secured to the completed hull with treenails which in turn were held in place by bronze spikes. After that heavy external planks were added running from stem to stern to give added strength at one or two points on the hull. These wales were held in place by spikes or bolts and were matched by similar planks, stringers, on the inside. Finally there were massive through-beams resting on the frames that extended through the sides of the ship to give some stiffening. The hull planking had to be a malleable wood – shipbuilders apparently preferred cypress – so that one strake could be practically fitted and formed to the one below. The keel, posts and tenons were of hardwood, usually oak.

This shell technique of construction may have been copied from practice in the Indian Ocean and Red Sea. No matter its origin, which is still very much open to question, the method can certainly be distinguished from skeleton construction. In the latter system, strength came primarily from an internal frame which was set up first. The external planking was added for watertightness. The vessel was a covered frame. In shell-building the internal frame was there only as a supplement to the external planking. Hull planks were joined together and whether it was edge to edge or overlapped did not matter to this essential principle. In shell construction the exoskeleton determines everything about the ship. In skeleton construction the strakes have to be bent to the endo-skeleton so it is the framing which determines the form of the vessel. The categories are extreme but do accurately describe the two major and quite different approaches of Europeans in the middle ages to the problem of building a boat. At the same time both approaches were subject to modification and rarely reached the limit of either method.

1: Northern European Clinker-building with Overlapping Planks (top) and Roman Mortise and Tenon Construction (bottom)



Of course there was interaction between the two methods yielding composites or hybrids of both. The two approaches to the building of a boat presented entirely different problems. With shell construction work could be checked at each step against what had already been done. A plank could be tried against the next one and altered if the fit was not perfect. Frames were shaped to fit into the already constructed hull.[d] It was time consuming but it was incremental. On the other hand, with skeleton construction hull shape could only be known after all the ribs were cut and set up. To cut all the ribs to get the desired hull shape drawings were a great advantage but drawings were first used only in the last years of the sixteenth century. So the usual practice was apparently to set up the keel, posts and one or three main ribs, then bend battens to them to give a mould or indication of the shape of the hull. Then the builder knew how to cut the rest of the ribs. Once that was done, he could proceed to cover the hull with strakes.[5]

Roman shipbuilders were not bothered with such problems since they used shell construction. All planking, even for the decks, was joined with mortises and tenons. The method gave a vessel that was excessively strong. The approach, dating from the time of Homer and probably before, seems to have been exclusive to classical Greece and Rome. Apparently it was used on all vessels from the smallest skiffs to the largest grain carriers.[6] The availability of low-cost labour, the sizeable work force in shipbuilding and the tradition of building which was well established throughout the Roman world must have contributed to the continuation of that unique form of shell construction. The result was a vessel of the highest quality. The vessel was finished off with a protective covering. There was no need to caulk the seams – that is, to fill them with some pliable substance – since they were watertight. Instead a layer of wax was used on the hull, often with colouring, to protect the timbers. For smaller vessels, those that were beached, this was enough. For those with hulls that would never leave the water it was necessary to have some protection against the *teredo navalis*, the shipworm, which thrives in warm water and which slowly bores through a wooden hull. The Roman solution to the problem of marine borers was a layer of tarred fabric and then lead sheets over that, held in place by many copper tacks.[7] Though Roman cargo ships might not be all that manoeuvrable, though crews may have had troubles with them in storms, and though they could probably not sail closer than 80° to the direction of the wind, these vessels were still reliable, sturdy and capable of moving large quantities of goods.

The Byzantine Empire and the German successor states in the West,

with the exceptions of the Anglo-Saxons and the Franks, inherited the traditions of ship design from the Romans. They did not, however, inherit the thriving economy and sizeable transport of bulk goods typical of commerce in the first and second centuries AD. The wars and internal political disturbances of the third to sixth centuries disrupted trade within the Empire. They also led to higher taxes on both land and commerce which undermined the basis of trade. More serious than any action of government, though, was the recurrence of plagues. An outbreak in the second half of the second century took a heavy toll and another outbreak in the second quarter of the sixth century was probably even more severe. The countryside, especially in the western part of the Empire, was depopulated. Land which had been cultivated was abandoned, some of it turning into malarial swamps which increased the spread of disease and prevented recovery. Deforestation during the Imperial period, in part to supply the needs of shipbuilders, also disturbed the run-off of water from the hills, increasing flooding and the growth of swamps. Land, then, was in relative abundance, especially in the West. Total production of agricultural goods fell. Byzantium responded to the new situation by becoming a more maritime empire with less concern for the holding of land than had been typical of the earlier Roman Imperial government. Byzantine emperors took more interest in the promotion and taxing of trade and industry. They set up or rather extended the system of controls over border trade, especially trade to the East through the Persian Empire. To divert trade away from the lands of that traditional enemy, they also attempted to expand use of an old route for exchange of goods with the Orient. Trade to the Indian Ocean was well established in the reign of Augustus Caesar and by the third century AD Romans were trading directly to Burma and Malaysia. They may even have sailed to China. The trade in spices and silks was not abandoned by the Byzantines. In fact it increased, thanks to government support. The road system, especially in the western part of the old Roman Empire, deteriorated.[8] The Byzantine Empire was increasingly tied together by transport on the sea and not by transport on land.

The novel economic situation forced changes in the relative number of different types of ships. Galleys became more practical for trade compared to large sailing ships. Their greater speed, bought at higher cost, was an advantage worth paying for in the transport of luxuries.[e] Sailing ships did not disappear. The largest of sailing ships, those of over 1,000 tons used for the Alexandria-Rome grain trade, were no longer built, however. When the capital was moved to Constantinople

the population of Rome fell from its zenith of perhaps close to 1,000,000 and so could be fed by grain shipments from nearby North Africa and Sicily. The revival of trade under the guidance of Byzantine authority in the sixth and seventh centuries did not reach the earlier level of the Roman Empire. The government no longer sponsored the shipment of massive quantities of grain over long distances. Moving the grain tribute from Egypt to the Bosporus was nothing like the problem of moving it to Rome. Without a government guarantee of cargoes for such large ships they disappeared along with the ability to build them.

There was at the same time a general erosion of quality in the construction of ships. Roman methods were slowly abandoned. The decline in trade and rising costs of commerce associated with higher taxes and a decrease in security forced shippers and in turn shipbuilders to be more conscious of the high cost of Roman construction methods. At the same time the cost of skilled labour in all likelihood rose. The fall in population could hardly contribute to a fall in wages while a decrease in the number of shipbuilders gave those that continued to work in the trade a scarcity value. The sensible solution, and one which became apparent in the seventh century, was to turn to lighter construction and to adopt, to some degree, the skeleton technique. The result was a hybrid form where shell-building was partially abandoned. The pattern is suggested by two wrecks excavated at Yassi Ada, Turkey, one from the fourth century and the other from the seventh. Instead of building the entire hull and then adding internal frames, builders first pieced together the lowest strakes in a way similar to the old method. Then the frames were cut to fit and set up and the rest of the planks above the waterline pinned to the frames. This meant from the fourth century the gradual disappearance of the old system of tenoning. By 600 tenons were apparently used only as guides in setting the lower planks in place and they were no longer held in place by treenails. They had a good deal of freedom of movement within the mortises and were spaced irregularly and farther apart, more than .90 metres at the middle of the ship. Strength then came to a greater degree than in the past from the internal frames. Those were heavy and placed close together. Some of the frames were bolted directly to the keel. The planks of the hull were on the other hand relatively thin, some .035 to .040 metres thick. Above the waterline the hull was made up of alternating wales and planks. The wales were half-timbers, hardly finished, and they were bolted to the frames. They were still matched by stringers inside the frames. Deck beams were supported by hanging knees, triangular pieces of wood typically found underneath the timbers they are designed to

support but in this case found above them. All fastenings were of iron.[f] In general the method of construction was simpler and the materials more massive and not as well finished. The hull was not the finely built watertight case of the Roman period so the seams had to be caulked. Apparently anything at hand was used for that job.

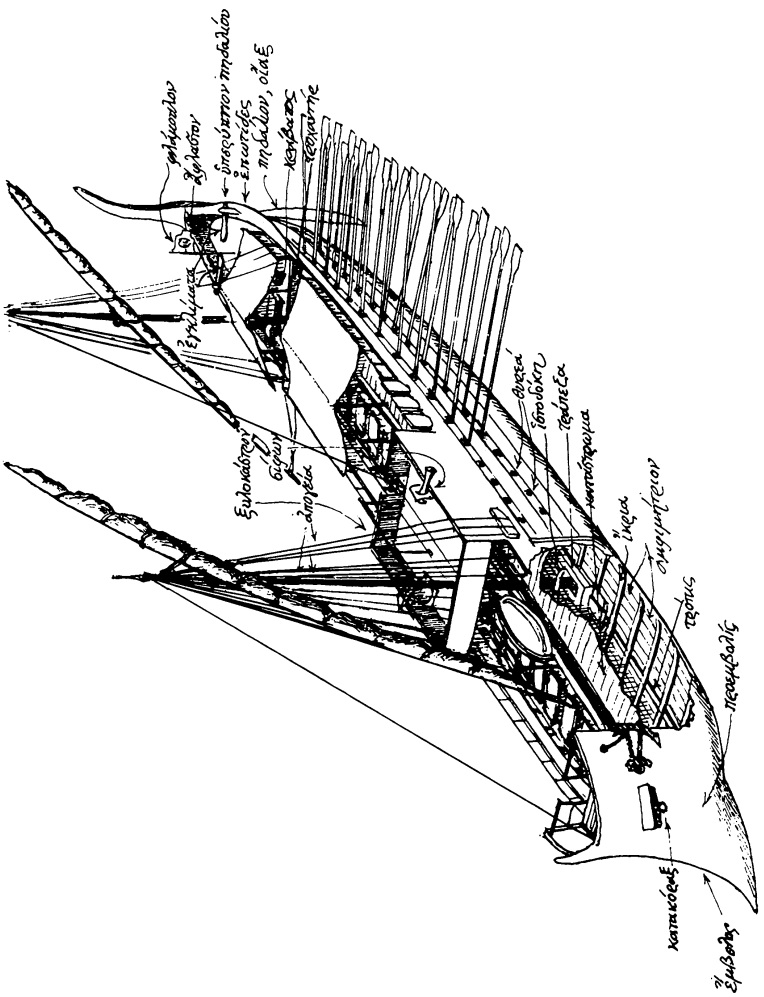
The form of construction of sixth- and seventh-century ships suggests a partial change from the Roman shell technique to skeleton construction. It is not possible to say precisely how much the ship depended on frames and wales for strength, and conversion to the uniquely western technique of skeleton building was not yet complete. For example, planks were still formed after being put in place in the hull, unlike skeleton construction where all such work was done in advance. However, the major step towards the invention of skeleton technique had already occurred by 600. The reason was apparently economic. The new method meant that far fewer man-hours of labour were needed in shipbuilding.[9] It also meant fewer nails, bolts and other fasteners. There was undoubtedly an increase in risk but, since vessels were smaller than those in use in the Imperial period, the chances of making a mistake in construction were decreased. The increase in the number and relative size of frames meant that more wood was used per ton of carrying capacity. The wood had to come from larger thicker hardwoods for those frames. The type and form of wood needed for the skin of the ship changed little. In the early Byzantine Empire there was no shortage of shipbuilding timber, so no effective constraint existed to prevent the conversion to skeleton construction.

Shipbuilders also dropped the Roman practice of hull protection against the shipworm, at least for cargo ships. It was still used for warships in the tenth century.[10] Even in Roman times smaller cargo ships did not have lead sheathing and the change to smaller vessels by the seventh century certainly contributed to the decrease in the use of such protection. The new building method meant that the condition of the exterior hull was not as crucial to the structural integrity of the ship. In general shipowners relied more on repairs. They chose to use the labour of ship carpenters throughout the life of the ship rather than make the same very heavy investment in capital and labour that had been typical of their Roman predecessors. These trends to less expensive construction, smaller vessels and a general decrease in investment in shipping were the logical results of a fall in the total volume of commerce.

The Byzantine Empire inherited from Rome the responsibility of maintaining order at sea. Byzantium in fact enjoyed such naval dominance that fleets were only built for specific tasks, such as meeting the

threat of Vandal pirates based at Carthage or Avro-slavs from the Balkans. The naval situation changed completely in 645 when Alexandria fell to the Arabs and Byzantium was faced with a threat to its control of the Mediterranean. The result over time was the emergence of a complex naval organisation in Byzantium and of certain ship types to deal with Arab attacks. Throughout the history of the Empire there was pressure on government to promote the development of the navy and merchant marine. Apparently the only check on a strong Byzantine fleet was the availability of money for its support. The two were connected. Much of the money for the fleet came from taxes on trade carried in merchant ships which in turn relied on the navy for protection.

Byzantine warships are known largely from written sources. Though most of the sources date from the tenth century, it appears that the essential design features had been established by 600. In general Byzantine warships were of middling size, larger than Roman ones and with some major modifications to make them higher and stronger warships with maximum firepower crowded into a fixed space. To get that they gave up speed and carrying capacity. There was still a differentiation between ships with a length-to-beam ratio of about 3:1 and long ships where the ratio was always greater than 6:1. The typical Byzantine longship was the dromon. It was presumably developed from the Roman Liburnian. Dromon appears to have been a generic term for all oared warships but was used also to distinguish the most common of Byzantine warships. It was two-banked, that is with two levels of 25 oars on each side. The 100 oars were accommodated in a length of from 40 to 50 metres. The beam was about 5 metres. There was always one man per oar on the lower banks. In bigger dromons a wider beam made it possible to have two or three men for each oar on the upper ranks. That gave greater speed. It also meant that many of the rowers on the upper banks could be released for fighting duties when the ship grappled with an enemy. It was in general a blunt ship and had little or no upperworks and a low waist. Draught was shallow, about 1.5 metres. Displacement was usually less than 120 tons. Shields were hung along the sides to protect the rowers as was later done in Viking ships. The oarsmen below were protected by the deck. The bottom was almost flat amidships while at the bow and stern the ribs were almost vertical above the keel. There were no internal stringers. Strength came from the strakes and external wales. The hull was narrow and trim. In general construction appears to have been lighter than that for merchant vessels. That was to be expected since the dromon, which meant 'runner', was built for speed.



2: Byzantine Dromon from about 850 with Four Rows of 25 Oars

There were two other types with the same lines as the dromon. The *ousiakos* may have been the ancestor of the larger dromon. It carried a crew of some 108 men. Ramming was its major offensive action. A larger version, and indeed the largest of Byzantine warships of the seventh and eighth centuries, the *pamphylos*, carried a crew of at least 162. On that type there were two men at each of the upper oars. The difference among the three types did not depend on hull design or dimensions but rather on the size of the crew and the way the vessel was used in a fight. All had rams, but the dromon was expected to come alongside an enemy ship and use its large crew to take the ship in hand-to-hand combat. There were three gangways, one on each side for marines so they could repel boarders and another in the middle which also acted as a stiffener to prevent hogging. Sagging of the ends was a constant problem with longships and turned up even in second-millennium BC Egypt. On most Byzantine warships there was a platform at the bow to give marines a base for firing at the enemy and on the biggest dromons there was a similar platform amidships. Hull planking below these castles was strengthened to support them. The top of the castle amidships could be 6.5 metres above the keel. There were also a quarterdeck and poopdeck aft with a place for the commander to recline on the quarterdeck. Oars approached 10 metres long with about 30 per cent of the length inboard. They had hollow blades.[g] There were two rudders set in pegs on the gunwales aft and held fast there, like the oars, with leather. Propulsion came not only from the oars but also from two sails, one on each of the masts. Some of the larger dromons may have had three masts but the mainmast and mainsail were always much larger than any others. Apparently masts were not lowered in action and so may have been permanently stepped. Yards were in two pieces, fished together. When not in use the yards were kept on crutches on the central gangway.

This dromon was the major unit, in its various forms, of Byzantine naval forces throughout the tenth century. There were other types including the galley, a single-banked dispatch vessel, and the *dromonia* which was probably nothing more than a little dromon with two banks of oars but too light to do battle in the Mediterranean. Rather it was used in the ninth and tenth centuries against the small and lightly built vessels of the Russians on the Black Sea, vessels probably like those of the Vikings. Byzantines typically used cypress as the chief building material for all their warships, like their Roman predecessors. Western Mediterranean builders used a greater variety of wood if for no other reason than that they had more at hand.

Cargo vessels were also pressed into naval service. Indeed some ships passed back and forth from the navy to the merchant marine. In the expedition against the Vandals in 533 the Emperor Justinian sent a fleet of 92 war vessels – dromons – and 500 transports. The navy, and there may have been a standing force with naval bases and shipyards from the reign of Justinian, was expensive, relying heavily on the labour of rowers.[11] They were not slaves or convicts but rather paid sailors. The fact that they could double as fighting men once ships grappled made them even more valuable. If building technique changed for warships as it did for merchant vessels then capital expenditure at the outset was lower and that could be offset against the high labour cost involved in using rowers. Sailing ships were still too small and too unreliable to be used effectively in battle and their firepower was not any greater than that of warships.

The most effective defensive weapon of Byzantine warships was an incendiary solution known as Greek fire.[h] It was effective only at a short range and so one of the major functions of warships was to get close enough to the enemy to use it, something not possible with round ships. Greek fire, according to the traditional story, was invented by a Syrian who left his Arab-ruled homeland to bring it to Constantinople. Machines were built to fire the new invention and from 672 it was used against the Arabs. It was probably some combination of sulphur, saltpeter and petroleum. It was a liquid and so was fired from siphons with one large siphon fitted in the bow of each dromon. There might be additional flame throwers amidships and on the poop on the largest of dromons. There were defences against these and other incendiaries. Sides could be covered with hides and those in turn covered with smooth substances to protect against fire.[12] But it took some time to develop these defences and when the Byzantines first used Greek fire against the Arabs it proved an overwhelming advantage and was decisive in driving off the second Muslim siege of Constantinople in 717.

Not all cargo vessels were round ones. Trade was still carried on in long rowed vessels. These were used to carry passengers and cargo which needed rapid transport or, in wartime, to carry dispatches. In general such merchant galleys were beamier than dromons. Merchant galleys are mentioned more frequently than are the coasters and larger sail-powered cargo carriers because merchant galleys were pressed into service in wartime. Nevertheless, and despite the fact that they were similar to Greek and Roman merchant galleys, it is still not possible to know exactly what they were like. It is clear that different types of merchant galleys existed, that size varied, that each carried a mast and

sail but that oars were the principal form of propulsion.

Byzantine cargo vessels, oared or not, were rarely larger than 300 tons. A writer in the early seventh century described a ship of that size as having unusually large proportions. He also mentioned a ship of 230 tons but the shipbuilder, apparently through lack of experience with vessels of that size, was not able to launch it. The best example of a Byzantine ship yet excavated is a coaster of 40 tons and such vessels were probably not uncommon. The smaller size and smaller crews gave less protection against attack by pirates or enemy forces. But for the sixth and much of the seventh century this was not a problem in most of the Mediterranean, thanks to the power of the Byzantine fleet.[13] The smaller coasters carried what bulk goods were traded. The volume of such trade fell while that in luxuries rose relative to the total volume of trade. The change was perhaps most obvious in the Black Sea. Byzantium imported a sizeable quantity of its oriental goods through Black Sea ports. Increasingly, merchant galleys must have been pressed into service to carry these luxury items.

The smaller size of all vessels and the increasing accent on speed, in the merchant marine, both results of the relative rise in importance of goods of high value per unit volume, contributed to the abandonment by Byzantine shipbuilders of Roman techniques. The square sail, the only sail used on large ships in the classical world, was dropped and replaced by the lateen sail. This change in the propulsion system generated different manpower requirements on cargo ships and increased the sailing capabilities of all vessels. The lateen sail is triangular or a quadrilateral which is almost triangular, the former version being the type used by the Byzantines. The leading edge of the sail is stretched to a dipped yard. This type of sail was known in Roman times as were forms of lug and fore-and-aft spritsails, sails with many of the same properties as the lateen. All were used on small craft. These may have developed from the way Romans trimmed their square sails in some circumstances.[i] In any case the earliest known illustration of a lateen sail is from the second century AD. Another illustration dates from the fourth century AD. An early fifth-century description and another of the sixth century show that lateens were not uncommon on larger ships. The first picture of a lateen sail being used by Byzantine sailors is from about 800. By that date, though, the lateen sail was the dominant one for all Mediterranean craft. The sprit-rig and the lateen sail may in fact have been introduced into the Roman Empire from the Far East, from Indonesia through Ceylon where triangular sails were in use well before the classical era. That form of rig, then, was available to Roman ship-

3: The Lateen Sail in the Mediterranean from a Greek Manuscript of c. 880

builders. They chose to use it for smaller craft, for coasters and fishing boats only. The Byzantines promoted it to use on all vessels. Since the size of vessels was falling the change was not as dramatic as it might at first appear. The earliest dromons may have had square sails but certainly by 533 the typical rig was two masts, one amidships and the other as close to the bow as possible, both carrying long yards and a lateen sail hanging from each. On the largest dromons the third mast set close to the stern also carried a lateen sail.[14] While in the sixth century this may have been new for warships, the use of lateens was well established on cargo ships.[j]

The lateen had certain distinct advantages. It was not a true fore-and-aft sail – that is, its leading edge did not pivot on the mast. For example, with the spritsail, a rectangular piece of canvas held up by a long sprit running from the base of the sail on the mast to the upper outer point and with the leading edge attached to the mast, changing direction just meant putting the helm over. The sail comes over by itself. With the lateen, on the other hand, if the yard is just brought around then the sail presses against the mast. Sailors tried to avoid coming about with a lateen sail since that meant that the yard had to be carried over the masthead in order to keep the longest edge of the triangle into the wind. The spritsail is much easier to handle. A much longer sprit is needed for each square metre of sail area, however, than with the yard of a lateen sail. A longer sprit also meant a taller and stronger mast and presented greater problems of stability, already a concern with dromons with length-to-beam ratios in excess of 6:1. By allowing the lateen to bag slightly it is possible to generate an eddy of wind inside the sail and get more force than with a sail kept perfectly flat. So, all in all, using the lateen sail instead of the spritsail or the square did not involve a great sacrifice in propulsion.

The principal advantage of the lateen sail over the square rig was that the former made it possible to sail closer to the wind, as close as 60°.[15] Sailors of large Roman vessels may not have been completely confined by the cut of the sail to going only before the wind but it is clear that they preferred that situation. Lateen rig expanded opportunities. Presumably not as much time had to be spent in port waiting for a fair breeze. Ships were more manoeuvrable, which certainly must have recommended the rig to warships as well as to coasters. There were disadvantages. The lateen sail required more skill and more men to handle it per unit of area than the simpler square sail. Carrying the yard over the masthead was difficult work, especially in a strong wind. Unlike a square sail a lateen cannot be shortened. The Roman system of brails

disappeared. When winds freshened the only option was to change to a smaller sail and, if the wind was strong enough, a smaller yard. That meant that more rigging had to be kept on board and space had to be found to stow it. The increase in manpower probably did not mean an increase in crew size on small ships. For warships there was always more than enough labour at hand. So for the moment no new cost was implied by the different type of sail. Given the size of Byzantine vessels and the inherent advantages of the lateen sail, its adoption for almost all ships was a logical choice. By increasing the capabilities of vessels Byzantines may have been able to decrease the size of ships and perhaps their number for each ton of goods moved per year. All this implied a greater efficiency in shipping, which helped to counteract the general decline in markets. The Byzantine types – warships, round cargo ships and trading galleys – all showed their Roman ancestry but at the same time had certain marked advantages over their predecessors. The most notable changes, such as in the method of constructing the hull and in propulsion, lowered transport costs. The risks involved in moving goods and people by sea must have increased with the lower quality of ship-building practised by the Byzantines; but that was a necessary sacrifice. The general insecurity of life on land probably made greater insecurity at sea more easily acceptable.

In the western Mediterranean shipbuilders followed the pattern in the East. Many of the major seaports remained in Byzantine hands into the eighth century. Trade was carried on with the Byzantine Empire and presumably shipbuilders could and did move within the Empire. The result, especially with Byzantine towns in North Africa and in Italy, was the construction of ships following the Roman tradition but with modifications. In ports outside the Byzantine Empire there must, however, have been some loss of shipbuilding skill, because of a general decline in trade and therefore a loss of interest in maritime affairs. The Germanic tribes which established successor states in the western part of the Roman Empire had no reason to destroy commerce and ship-building. But in most cases their lack of knowledge of government, of business and of maritime affairs meant apathy. The exception was the Vandal kingdom established in North Africa. After seizing the old Roman province in 439 Gaiseric, the king of the Vandals, established a pirate fleet based at the port of Carthage. The skills were Roman, the personnel was Roman and the ships were in all likelihood Roman as well. The ships were used to transport Vandals to attack the islands of the western Mediterranean and to attack Rome itself in 455. On the death of Gaiseric in 477 organised attacks decreased. In 533 a Byzantine

fleet took North Africa and put an end to Vandal naval activity.[16]

In the Latin West there was no government in a position to mobilise a naval force as Byzantium did in 533. As long as the Byzantine Empire kept the western Mediterranean under the defensive umbrella of its fleet, the absence of a strong government in the West did not create a problem for shipping. As the Byzantines came under ever greater pressure from Arab attacks and as what government there was in the West further deteriorated, piracy must have increased. By about 700 pressure from pirates and a general instability must have directed expenditure away from trade goods. Ships in the West became small and probably resembled the coasters of the eastern Mediterranean. The adoption of the lateen sail in the western Mediterranean may have been the result of it being brought there by Arab fleets. More likely the warships and merchant vessels of the Byzantine Empire, certainly lateen-rigged in the sixth century, were the source of the conversion to the different type of sail. The goods carried by ships in the western Mediterranean were probably even more likely to be luxuries than those carried by ships in the eastern Mediterranean and Black Sea. Discussion among historians continues on the nature of trade between the two parts of the Mediterranean basin in these years. There does seem to be general agreement, however, that the West bought goods such as silks and spices which could only be obtained from the Far East and in exchange westerners sent slaves and sylvan products. Except for timber and logs, all of these goods were of high enough value to make speed important in their delivery. This was especially true of slaves. At the same time large ships were not an advantage. It was probably not even an advantage in the shipment of lumber since logs were often simply towed behind the ship. With shipping in both directions handling goods with similar transport needs, there was little reason for western shipwrights to deviate from the pattern set in the eastern Mediterranean. There was a limited coastal trade in the West and of course some fishing. So shipbuilding did not by any means cease. At the same time there was internal trade in those typical bulk goods of the Mediterranean: grain, wine and olive oil. Rome still received grain in the early seventh century from Sicily. Distances were not great so again there was no pressure for larger ships. In fact distances covered by shippers in the western Mediterranean were probably less than in the eastern part of the sea.

For bulk goods most packaging had changed by the seventh century from the clay jars, the *amphorae* typical in the Roman Empire, to barrels. This was a major and even revolutionary change in shipping.

While the jars took up as much as 40 per cent of cargo space, the wooden barrels lowered that proportion to almost ten per cent.[17] The process of change was a slow one but may well have occurred sooner in the West than in the East. It meant another source of falling transport costs. It was yet another reason to build smaller vessels. Ship size could be reduced by up to 30 per cent with no noticeable difference in payload when the change was made to barrels.

Despite general economic and political confusion, despite commercial decline, there was a number of significant advances in the techniques of shipbuilding and shipping. The advances were in part generated by exactly that economic malaise. The Mediterranean cargo ship of 750, though smaller, was more efficient, and especially more efficient for its specific tasks, than the massive Roman cargo ship of the first and second centuries AD. The improvement in ships contributed to the survival of commerce in the face of shrinking markets. The ability of the Byzantine Empire to survive and to maintain some prosperity in part depended on the more efficient shipping sector.

The development of Arab naval forces remains something of a mystery. In general Arab policy was to leave the indigenous political and economic arrangements intact. In the short run that meant a continuation of the shipbuilding traditions of the Byzantine Empire along the conquered eastern and southern shores of the Mediterranean. The military struggle with the Byzantine Empire dictated conflict at sea, however. The Greeks used their naval superiority to threaten Arab conquests. The governor of Syria, Moawiyah, who was later to found the Ommayad caliphate, appreciated the importance of sea power and so in 648 organised the first Arab naval expedition, that against Cyprus. The success of the expedition led to expanded naval operations. The first actions were largely piratical and Byzantium did not see these Arab naval advances as a major threat, at least nothing like the threat on land. That changed with the defeat of a Byzantine fleet commanded by the emperor at the Battle of the Masts by a smaller and inferior Arab fleet in 655.[18]

Byzantine naval organisation did not change immediately but it was clear that a new type of navy was required. The Greeks added flotillas of coast-guard vessels to interdict Arab pirate raids. This was especially important along the south coast of Asia Minor. The fleet of dromons, heavy warships for the protection of Constantinople and major Aegean trade routes, remained intact. Byzantium then had a permanent fleet, a standing force requiring continuous support. The administrative system of themes, districts responsible for fitting out and maintaining ships

and crews and with taxing power all integrated into a single command structure, gave the Empire the necessary defensive force. The system had been instituted by about 700. The direct threat to Constantinople by an Arab fleet from 672 to 678 was certainly an inspiration to action. The second siege by the Arabs in 717 led to a reorganisation of the system of themes. Theme fleets after that were to act as forward defences in the Aegean and along the coast of Asia Minor. A new command system developed at the same time. Provincial fleets were given a great deal of autonomy. Theme fleets were equipped with all types of vessels from the smallest galleys to the largest dromons. They also had Greek fire. It meant the diffusion to the provinces not only of power but also of knowledge of the construction of the largest of warships. It also meant more effective action against the Arab pirates and assurance of protection for commercial shippers along the major trade routes. The system was established in full and functioning effectively by the middle of the eighth century, giving a renewed tranquillity to the eastern Mediterranean. The reorganised navy could not, however, prevent Arab expansion in the West. The progressive fall of Byzantine naval bases and then the conquest of Spain in 711 gave the Arab fleets a free hand in that part of the Mediterranean.[19]

The Arabs used former Byzantine naval bases in Egypt and the Coptic Christian shipbuilders who worked there. Some of these artisans were imported to the Syrian coast by Moawiyah to build the first Arab war fleet. One thousand Copts and their families were sent to Tunis after it was established as an Arab naval base in 700. Crews were typically Egyptian in the eastern Mediterranean but the marines were Arabs. The largest Arab warship, the qarib, was a two-banked galley like the dromon and may have had the same design. Arabs also had lighter galleys for patrol work. Although the direct evidence on Arab warships is scarce, still the fact that they used the same personnel, the same ports and the same raw material supplies suggests that early Arab war fleets were just re-creations of Greek fleets. The Arabs, however, seem to have respected the superior experience of Greek sailors. Their loss of over four times as many warships due to storms from the seventh to the tenth century compared to the Greeks demonstrates how much Arab seamen had to learn. The Arabs preferred to do their fighting on land, to use ships as transports. When forced into a naval battle they tried to make it into a land battle as much as possible, grappling with enemy ships and then leaving the fighting to the Arab marines. As a result Arab warships were probably on average larger than Byzantine ships in order to carry extra troops. That meant they were slower as well. There was also a

minor change in the shape of the lateen sail, Arabs using a sail of quadrilateral instead of perfectly triangular shape. It was a short-luff dipping lug sail rather than a true lateen. Differences in performance and in manning were marginal, however, and the rig was essentially the same as that on Greek ships. Though Muslims used lateen sails in the Mediterranean, they apparently did not in the Indian Ocean. It may have been Portugese ships around 1500 that finally brought the rig to the Arabian Sea.[20] In the Mediterranean though, Muslim ships always carried lateen rig.

The Arab conquests gave them all the supplies of naval stores which they needed to carry on an effective naval campaign against the Greeks. They obtained the raw materials for the development of a commercial fleet the equal of the Byzantines'. Arabs also had the option to raid the coast of Asia Minor to get timber. At least in the early years of the contest between Arabs and Byzantines, neither side suffered a shortage of wood or any other stores such as iron for nails and palm fabric and papyrus for rope. The Arabs did have a problem moving wood from mountainous regions to the shipbuilding yards. The great rise in demand for timber in the seventh century and to the end of the ninth century to build the massive fleets of the two competing naval powers presented a second problem for the Arabs. The forests of the southern Mediterranean had already suffered from gradual deforestation from the early years of the Roman Empire and so by the fifth century some districts were left without trees. The expansion of waterborne commerce within the Arab empire also put new demands on the forests. The end result was a lively trade in wood throughout the Arab world and the emergence of a number of small ports specialising in handling wood. The trade was important economically but also strategically and the Byzantines tried to deny Arabs this necessary raw material by outlawing the export of shipbuilding timber. The prohibition included Byzantine ports in Italy where wood supplies were more abundant and more easily accessible and where Muslim markets were close by. The typical use of the lateen sail meant that long spars were required, long or longer than the masts themselves. Tall fir-trees, then, became especially valuable. Improvements in Byzantine coastal defences may have been in order to deny Arabs access to supplies of cypress for planking from Asia Minor. The government of Egypt even embarked in the seventh century on a programme of forest legislation to protect domestic supplies. A great deal of wood was also imported, from as far afield as India. Though the Arabs were not really free of problems with the supply of shipbuilding wood, their conquests and raids at least through-

out the eighth century guaranteed that they could get enough wood for their needs.[21]

The Arabs could not match the superior Byzantine naval organisation. They always had difficulties when they challenged the Greek navy at sea. The Byzantines effectively used Greek fire to tip the balance in their favour if there was ever a question of superior strength, despite the fact that Arabs used the weapon from the first half of the ninth century. The total destruction of an Arab fleet said to number 1,000 dromons off the coast of Cyprus in 747 by a smaller Greek fleet drove the Arabs from the seas for the following 80 years. The Byzantines were then able to clear the seas, to enforce order and put an end to piratical raids. The peace which followed for the next 75 years was beneficial for Greek commerce. It must also have been an advantage to Muslim shippers. In their first challenge to Byzantine naval supremacy the Arabs did not produce anything novel in the design of warships. That was to be expected since they faced the same conditions as did their Greek adversaries. Indeed, the pattern of trade seems to have been changed little by the early Arab conquests, with the exception of the end of the shipping of the grain tribute from Egypt to Constantinople. If anything the Arab conquests brought an expansion of trade and increased prosperity for the regions captured. If the Arabs did cause decline in the extensive commerce, it was because of a changed political situation after about 700, internally and in relations with the Byzantine Empire. Both Arabs and Greeks moved towards the restriction of trade with each other. The Greeks developed a system of funnelling trade through certain specified border stations, directing commerce into a more fixed pattern.[22] The over-all decline in trade created adverse conditions for the development of ships. The shrinking of opportunities meant a stability in ship design from the sixth to the end of the eighth century. The sudden injection of a new religious and political force into the Mediterranean in the seventh century did generate, in reaction, new forms of naval administration. That, in turn, laid the basis for the development in government shipyards in the ninth century of a new type of heavier ship. But for commercial vessels the situation was hardly changed.

In northern Europe shipbuilders faced entirely different problems. The tides of the Atlantic Ocean and North Sea, the less reliable winds, the greater likelihood of storms, all created requirements for ships which never existed in the Mediterranean. Moreover, commerce and naval activity were not subject to any effective government direction. The economy itself could not match that of the Mediterranean basin in

complexity, diversity, or prosperity. Byzantine influence in the North appears to have been nil. And, despite the long presence of Romans in the North, their shipbuilding traditions left no indelible mark. While Gaul and Britain were part of the Roman Empire the Romans concentrated their activities inland, leaving coastal and river transport and, along with it, shipbuilding to indigenous Celtic populations. The Romans did build some types of Mediterranean design in the North, adapted for the different conditions, and they did use galleys there but, with the decline in trade and the withdrawal of Romans from the North in the third to the fifth century, those Roman types and building techniques disappeared, thus allowing the domination of northern waters by types which had existed during Roman rule and were used by the numerous Celtic merchants of the Empire.

Celtic ship design included at least five different traditions. Julius Caesar commented on one of these, the seagoing cargo vessel powered by sail which was built by coastal peoples of northern Gaul. The type was relatively flat-bottomed, was built entirely of oak, had heavy ribs held in place by iron bolts and was planked, the planking probably being fitted end to end. Unlike in Roman ships, the planks did not have mortise and tenon joints. Stem and stern were relatively high. The mast was carried forward, about one third of the way back from the bow. On larger vessels there was a deck. There was no keel. The vessel had high freeboard.[k] The ship could be beached and was able to sail in the open sea, making long-distance voyages along the Atlantic coast from Britain or northern France to Spain.[23] A second Celtic type, also mentioned by Caesar as being in use in southwest Britain, was the curragh. It is usually associated with Ireland and apparently used extensively along that coast and out into the Atlantic. Curraghs were skin boats with wickerwork used to fill in the space between the ribs. Hides were then stretched over the hull to give watertightness. They could reach 12 metres in length and could carry a sail though they were more commonly rowed. The shape of the hull allowed them to bob like corks and so they were well suited to the open ocean and capable of regular voyages to the Faeroes and Iceland from Ireland.[24] The stern was drawn up more sharply than the bow.[l]

There were other Celtic types, perhaps partially influenced by Mediterranean design but still retaining their unique characters. The extensive riverborne commerce of the northern Roman Empire made for the wide diffusion of these types. Excavation at Zwammerdam in the Netherlands in the old bed of the Rhine River, a natural barrier which formed much of the northern border of the Roman Empire, has

unearthed the variations made in the simple dugout design to carry goods on inland waterways. The four wrecks all date from around 200 AD. One of them was built using Roman techniques. The rest were of an entirely different type. In the simplest form a tree was hollowed out. The next step in the evolution was apparently the addition of planks, one on each side, to allow deeper draught without swamping. In its most sophisticated form the river boat had a floor made of planks placed edge to edge. At each side the last floor plank was L-shaped so it was at the same time the first plank of the side. A second side plank was placed above it overlapping the first, not inside but outside it. There were also right-angled frames nailed both to the floor and to the side planks. The final result was a box which could ride deep in the water. The biggest of the Zwammerdam wrecks was 36 metres long. Another, 22.75 metres long, was made of oak and could carry 30 tons of heavy cargo such as building stone. These boats were probably pulled along the rivers and not sailed. This punt or pram type reappears often throughout northern Europe, for example in a fishing boat from about 1300 found near Flasterbo in southern Sweden and in a vessel from about 1100 excavated near Egernsund, Denmark, which was probably a ferry.[25] Apparently many Celtic types were elaborations of the simple punt design.

The largest of Celtic types from the Roman period and before used sails. Most, however, were towed or relied on oars as a means of propulsion. Construction of Celtic vessels ranged from skeleton as with the curragh to skin as with the heavy planked sailing boat. In some cases the two were combined. Control was given by various forms of paddles and steering oars designed to handle specific problems. One strange feature was that nails for attaching planks to ribs were often bent over after being driven through. The points were bent even further to pass almost at a right angle into the rib.[m] Nailing planks to ribs in this form was a vestigial feature of Celtic shipbuilding and may constitute a measure of Celtic influence on the design of later types.[26] This collection of different designs left northern Europe, after the departure of the Romans, with a wide variety of ships for a whole range of purposes. The variety served as a source of numerous features and approaches which could be and were absorbed into other types.

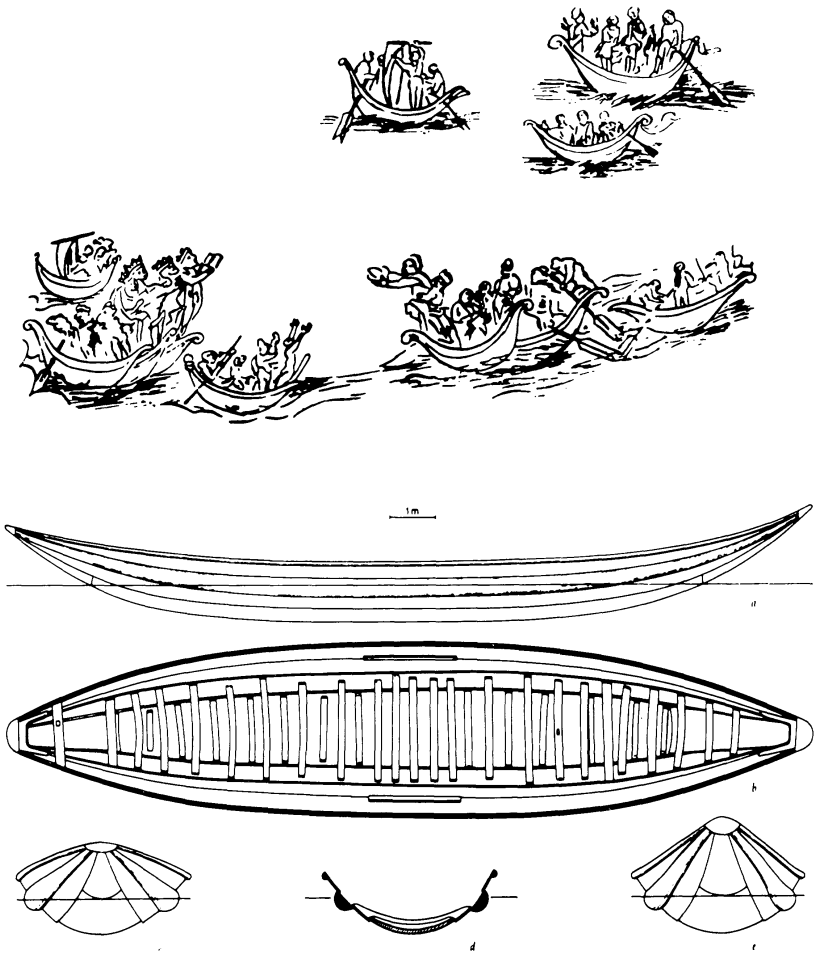
Along with the various Celtic design traditions two general types were typically used by the Germanic peoples who migrated to the borders and into the Roman Empire. These were probably modified versions of Celtic types. They were for use along the coast and not inland. Broadly the vessels can be divided into those intended to trans-

port men, devoted to maximising speed, and those primarily intended for cargo, designed to get more space in the hold. In solving the latter problem of moving goods, shipbuilders along the south coast of the North Sea found two successful approaches, each in turn fostering a long design tradition. All three types by the seventh century were built with shell technique. The ribs, the internal frames, in general were only there as an afterthought.

For moving men the German tribes used a vessel that was essentially a rowing barge. A ship built in the fourth century and excavated in the late nineteenth gives an excellent impression of the nature of these ships.[n] The Nydam ship, almost 24 metres long, had a length-to-breadth ratio of 6.3:1, a figure comparable to that of Mediterranean dromons. There was no mast or arrangement for a sail. Propulsion came from 15 pairs of oars rowed against oarlocks lashed to the top hull plank or gunwale. The hull was clinker-built, that is with overlapping planks. The ribs were inserted after the planking had been completed and were naturally curved to fit. The ribs were lashed to projecting clamps which had been left on the inside of the hull planks. There was no keel but just a centre-line plank which was wider and thicker than other planks. Since it was not a sailing ship, the lack of a keel was not a serious problem. Fragments of another boat found in the same place and of about the same date but built of fir did show that it was possible to build a keel. The Nydam ship was double-ended and the stem- and sternposts rose about 3 metres above the line of the centre plank. The side planks or strakes, five on each side, were single pieces of oak. Unlike on earlier vessels, the planks were fastened to each other with iron rivets. This new and superior method of holding planks became popular and typical during the fifth and sixth centuries. Control was given by a large side rudder. It is not clear exactly how this was fitted.[27] All in all it was a simple vessel designed to handle a simple problem – the rapid movement of a number of men. Though the Nydam boat itself showed a number of primitive features, by the seventh century builders had made enough improvements to make the type a durable seagoing vessel.

The two types of cargo vessels, the hulk and the cog, owed a great deal to Celtic designs. Knowledge of the hulk is based on an eighth-century ship found at Utrecht. The location of the find suggests that the vessel was a type of riverboat with the ability to travel in the open sea. The strongly built hull had the form of half an egg shell or a hollowed-out banana.[o] It had no keel but rather a very broad centre plank which made it easy to beach. There were no posts. The ends were rounded with the planks just coming together. The Utrecht ship had an

4: Hulks from the Utrecht Psalter of the Early Ninth Century (top) and the Utrecht Ship of c. 800 (bottom)



over-all length of almost 18 metres. As expected, it was beamier than the Nydam rowing barge. The centre plank was made from one log. The two strakes on each side overlapped. Wooden pegs held them in place. Over the seam between the two planks on each side a heavy, almost half-round plank was added. This gave watertightness as well as lateral strength. The 38 curved floor timbers found inside were small and offered little in the way of support. The vessel was probably decked. One estimate of carrying capacity is about 23 tons. Control was given by two side rudders, as can be seen in vessels in nearly contemporary illustrations. The ship had only two oars, inadequate for propulsion. There was a mast step, however, about one-third of the way back from the bow. There was a small rectangular hole in the eleventh floor timber and this was probably for a mast but no other strengthening was found. Without some other support for the mast it would have been extremely difficult to use the sail at sea. There may have been some strengthening at deck level or the mast may have been only for towing. Still, the size and shape of the hull suggest a fast sailing ship capable of travelling in the North Sea. The location of the mast step well forward is similar to practice on Celtic sailing ships.[28] By 750 the hulk had already passed through a number of changes and was established as an effective cargo carrier in the North Sea, used by Frisian traders for voyages to England. It was strong and therefore relatively reliable. The hulk could negotiate the tidal estuaries and rivers of the Low Countries and Britain and reach existing ports.

The cog or kaag was also used for carrying goods in the Low Countries. Knowledge of this quite different design is based on a find made at Bruges of a boat from the second or early third century.[p] There was no keel and the bottom was flat with the planks laid end to end. There were posts with a sharp angle to the bottom. The planks on the sides, of oak like the rest of the boat, were nailed to the heavy ribs. The angle between sides and bottom was also sharp, about 32°. The Bruges boat, about 14.5 metres long, and 1.4 metres at its greatest width, was even beamier than the Utrecht hulk. The planking on the sides was probably not overlapping but rather fitted edge to edge as in other Celtic sailing vessels. The type was double-ended. The ship could not be beached. Rather it was designed to ride with the tide into a sandbank and settle there for loading and unloading during low tide while it was lying dry. The vessel was refloated with high tide. Conditions in the Wadden Zee on the north coast of the Low Countries were ideal for the use of this cog and similar conditions were common along much of the south coast of the North Sea. While the hulk was a vessel for the high seas the cog

was a special vessel for areas with sandbanks and tidal harbours. The cog was a sailing vessel. The mast was held in place by a widened rib as on other large Celtic sailing cargo ships. The sail was a square one. There was one or perhaps two side rudders for control. The design of the hull meant there was high freeboard.[29] That, along with the other features, guaranteed relatively large carrying capacity, and won the cog the dominant position as a coastal trading vessel from the Low Countries north into Scandinavia in the relatively peaceful eighth century.

The cog then was the ideal ship for the trading network of Frisian merchants. These merchants were responsible for much of the inter-regional seaborne commerce of northern Europe in the seventh and eighth centuries. They undoubtedly used both the cog and hulk types since they needed these two different vessels in the two large spheres of their activity, to Britain and to Scandinavia. The hulk could also be used effectively along the Rhine, and the Rhine Valley was a significant source of their trade goods. The volume of Frisian trade was small and, though the distance through which the merchants moved goods might be great, from the upper Rhine to the central Baltic coast of Sweden, voyages were accomplished in short stages. They avoided open waters, preferring to stay close to the coast. Even with voyages to England, sailing in the open sea was kept to a minimum. By the end of the sixth century northern Europe was generally sparsely settled. Therefore most areas had no trouble in supplying the needs of the Frisian merchants. The principal problem was cultivating enough land to generate needed grain. Timber, furs, honey and numerous other products could be taken from forests which were always nearby. Since essential goods were close at hand, traders were left to deal in luxuries and, more important, luxury manufactures. For example, the glass trade, started during the Roman Empire, continued and Frisians shipped drinking glasses made in the Rhineland to Sweden from the mid-seventh century. Frisians bought slaves in England, presumably for shipment to the Continent. They also got wool there for the Low Countries cloth industry. The high-quality product was an important export. The connection with the Rhineland gave Frisians access to some agricultural goods such as grain and wine but more important in value were goods brought over the Alpine passes from the Mediterranean, such as silks and spices. Frisians also exported Frankish swords which enjoyed a reputation for high quality in northern Germany and Scandinavia. They also carried less exotic wares of local origin. Certainly the principal function of the Frisians in the years before 750 was to distribute luxuries. They extended the trading network to new areas, especially to the Baltic. Indeed,

in the early middle ages there was no lack of trade routes, only a lack of resources and of demand to exploit them.[30] Frisians played an important part in the development in the eighth century of the Scandinavian ports of Hedeby, near modern Schleswig, and Birka on Lake Mälar near modern Stockholm. Birka for example had a *kugghamn* or cog harbour, presumably suited to the design of that Frisian ship type. The port of Dorestad, which by 750 had exceeded the much older nearby Utrecht as the major port of Frisian trade, had close ties with the new port of Hedeby.[31] The high point of Frisian trade was probably reached in the 100 years after 750. The goods and methods of transport stayed the same as in earlier years. In the North the ships were needed to move luxury goods and people. The former are mentioned in written sources while bulk goods rarely appear, the principal exception being Rhine wine. The latter included not only missionaries but also migrants. Slaves fell into both categories. The requirements of transport then were for fast ships with crew size of little importance. Shipbuilders failed to fulfil those precise needs. Cargo vessels tended to be heavy like the Utrecht ship. They did not become large because of the lack of long-distance bulk cargoes. There was short-distance bulk carriage, especially on rivers and inland waterways. Ocean transport was largely an extension of that shipping. At least ship design did reflect that need. The lively trade along western Europe's rivers attests to the continued successful use of boats of Celtic design like those found at Zwammerdam.

Waterborne transport faced strong competition from overland carriage. For many of the luxuries value was so high relative to volume that transport, no matter the form, had only a small effect on price. Goods from the Mediterranean travelled part of the way overland, across the Alps, and so could easily continue by land rather than transfer to water. With goods of such high value merchants preferred to sell them as quickly as possible. It was not wise to tie up limited funds for too long. Land transport was always faster than water even with political instability and the poor condition of the roads. Travel by land was also less restricted. Given knowledge of navigation, skippers tended to adhere to one route while travellers on foot or horseback could move rather freely. It was a more flexible means of moving goods, if more expensive per kilometre, than moving goods by water. That competition may have kept shipbuilders from extensively exploring designs for the rapid movement of luxury goods.

For the movement of people fast ships were built and used. For the migration across the North Sea from Germany to Britain, Saxons used vessels which were the successors of the rowing barge found at Nydam.

The migrants themselves supplied the manpower needed to pull the oars so the expense of the crew was not a consideration. An impression of one vessel used in that traffic, from about 600, was found in the earth at the bottom of a burial mound at Sutton Hoo in England.[q] This was a great open rowing boat of an over-all length of 27 metres. There was no keel. Instead there was a heavy centre-line plank, rounded at the bottom. On each side were nine strakes clinkered to each other, held by iron rivets. Twenty-six ribs stiffened the hull. There is no question that they were added afterwards. The ship was of shell construction. There were 38 oarsmen altogether. The planks were not single pieces but made up of several lengths of timber riveted together at overlapping joints or scarfs. That and the use of more and thinner strakes formed a significant improvement over the construction of the Nydam boat. Not only was the hull made more flexible but also the need for finding trees of the right length and shape was eliminated. Control was given by a side rudder. There is no evidence that there was any type of mast or sail to supplement the oars.[32] The cargo was relatively light and so the barge rode high in the water, an advantage for oarsmen. The voyage from Saxony to England was not that long. Saxons first infiltrated into Frisia and from there they made their way along the coast and then turned west for the short trip to the coast of Kent or East Anglia. Freeboard was low so that the oars could function. The vessel was not therefore suited for the open sea. The Kvalsund ship of about 700, found in western Norway, was similar to the Sutton Hoo ship showing many of the same improvements. It was shorter but still had a length-to-beam ratio typical of a rowing barge. The centre-line plank was reinforced with a fillet on the underside which made it stronger, giving something closer to a true keel. As a result the vessel was more stable. It was possible to have a broader hull and there was more room on board. The rudder was also markedly improved. Again no sign of a sail was found.[33] Up to 750 this was still essentially a coastal vessel without the capability for long-distance open sea travel of the hulk or for that matter of the Celtic sailing cargo ship or the curragh. The rowing barge did, on the other hand, solve the problem of moving people in the seventh century. By the eighth the migration period had ended and as a result the design of this type could and did change.

In the years to 700 Scandinavia apparently had few sailing ships. Certainly examples of sailing ships existed. Northern Europeans probably knew that ships in the Mediterranean typically carried a sail. Illustrations suggest, however, that it was not until 700 that sails were in general use, except on small craft, in Scandinavia. Sailing ships like

the Celtic cargo ship were known in the Atlantic and to a lesser extent in the North Sea up to 750.[r] But further north sails were only added in the sixth and seventh centuries.[34] The influence from nearby regions certainly promoted the change. Important as that influence may have been, the need was to build vessels to handle the trade of the region, a trade which was increasingly connected with that of Frisia. The longer distances, the smaller crew on a cargo ship compared to a ship carrying men, and the heavier load on board, all recommended the conversion to a different form of propulsion.

The slow pace of change in design throughout the North must have been in part the result of a lack of over-all demand for ships. The quantities of goods handled could not compare with those moved in the Roman period, largely for demographic reasons. Since demand for ships was limited so too were opportunities for experiment and for the development of a stable industry where builders in company with other builders could devote their time exclusively to improving ships. The situation bred a wide variety of types and if anything an increasing variety as Celtic designs remained in use besides those developed to deal with specific conditions and circumstances.

The ships which were built did not apparently yield any great fall in the cost of transporting goods. The general decline in specialised production for a wide market, the basis of long-distance commerce, meant a decline in the carriage of goods. The demand for ships, and especially for ships of special type, declined in turn. Since shipbuilders had to produce vessels able to handle a variety of tasks, the scope for economising and design development was also limited. A feature added to make the ship handle better on rivers might detract from performance at sea, for example. In sum there was a loss of skills, a technical retrogression. Though this was more obvious in the Mediterranean it was true in the North as well. The disappearance of Roman political organisation in the North, for example, meant the disappearance of quays. Harbours turned into beaches and so builders had to construct vessels that could be run up on the shore for loading.[35] The need was for simpler ships as well as easier ways of building them. The poorer economy could not afford the relatively expensive capital goods that were Roman ships. By adjustments shipbuilders were at least able to ease this downward spiral. The losses in the durability of ships were partially compensated for by lower original cost. At some point that compensation was enough to offset the loss and halt the decline in shipping, but at a much lower level.

The presence of piracy, or more precisely the lack of governments

strong enough to suppress piracy, was to blame for the sharp decline in travel. Shipbuilders, however, did not help. They failed to overcome the problems of moving people. Over all then, individuals could only move about with difficulty. The lack of contact not only contributed to the cultural poverty usually associated with the 'Dark Ages' but also meant a decrease in economic opportunities. The turn to smaller vessels throughout Europe meant decreased opportunities for people to move. Only in the North Sea did sizeable numbers travel by sea, and there it was only in one direction. Even there numbers declined to 750. The design of ships did nothing to prevent the decline in interregional contact. In fact the new types contributed to it.

The volume and the pattern of trade which emerged meant that the merchant community was smaller relative to the total population than had been the case before. The number of shipbuilders also fell. The industry was less important numerically, economically and socially. Backyard shipbuilding, with the exception of naval construction in the eastern Mediterranean, was the rule. This lack of specialisation among builders had an effect on technology. More important, the generally smaller commercial and shipping sector deprived the economy of workers relatively more productive than those in agriculture. Productivity in the shipping sector also declined. The conversion to smaller vessels meant that the number of sailors and especially masters did not fall by the same percentage as the fall in the total volume of commerce. The conversion to the use of the lateen sail in the Mediterranean meant crew size did not fall as rapidly as tonnage since it took more men to handle that sail than a simple square sail. Crewmen had to be more skilful to handle the lateen. The new sail did offer some productivity gain because of shorter over-all time for voyages, but that could not offset the losses associated with decreased size. The share of the population living in cities fell. This was especially noticeable along the coast since large ports and port facilities were no longer needed. Goods were not marshalled at a single location so it took vessels longer to gather a full cargo or forced them to travel with less than their maximum payload. This meant in turn higher costs and constituted another reason for moving to, on average, smaller ships. These types, it is true, put less strain on finance and for many duties they sufficed, as they had in the Roman Empire. But the result could only be a long-term rise in costs for the shipment of goods and so a fall in the volume of trade, a fall in average productivity for the society and a drift away from urbanisation. These were changes which shipbuilders through their designs did not effectively combat. The emergence of the Arab challenge to the Byzan-

tine Empire led to a complete change in the organisation of naval forces and also in the level of violence in the Mediterranean. For the first time in centuries naval powers created a continuing struggle. Governments had to develop a system of administering these massive organisations. Unlike the administration of armies which could expand or collapse with the level of hostilities, naval organisation had to have a continuing existence to maintain the ships. That meant keeping up shipyards and employing skilled shipbuilders. The growth of navies in the eastern Mediterranean led to an expansion of government bureaucracy. In northern Europe political organisation was nothing like that in the South. There was not the same confrontation between two powerful states. Northern Europe did not have the infrastructure and established pattern of trade that existed in the Mediterranean. The large oared ship, most effective in fleet action in the Mediterranean, was not built in the North. Thus there was no pressing need for governments to develop a sizeable and continuing naval force. In the North, because of the size and scope of vessels in use, commerce and the whole business of shipping was in the hands of private traders with no connection with government. Both constraint and support from political authority were rare. This meant greater flexibility in water transport. Indeed, throughout Europe, the design of ships promoted such flexibility. The advantage gained was small, however.

The pattern of development in ship design was set in the seventh century at least for the years up to 1000. There was to be a concentration on relatively small vessels for cargo. The size was small in comparison to Roman predecessors and the types which would follow, and apparently small relative to the potential size of ships. It was impossible to support the large crew and the high capital cost associated with a larger ship given the small cargoes available, the lack of back cargoes, the poor organisation of commerce and the potential for instability. Defensibility was based on speed rather than on size. Shipbuilders concentrated, especially in the Mediterranean, on supplying ships with greater speed and manoeuvrability. Warships in a sense were already differentiated from cargo vessels. They certainly were in the Roman Empire. The addition of Greek fire to the Byzantine naval arsenal made the warship even more unique. In the North cargo ships were easily differentiated from the rowing barges used for naval purposes and also used to carry people. At least in the broadest sense there was specialisation in ship design. The principal change of the years to 750 was the choice made by shippers and shipbuilders to accept high unit costs for moving goods. The ship types of these years reflected the choice and

over time made it the only choice. The direction was away from the large efficient bulk carrier. It took some centuries and a rather devious route for shipbuilders finally to arrive at the design for such a type.

NOTES

1. Lionel Casson, 'Sailing', in Carl Roebuck (ed.), *The Muses at Work, Arts, Crafts and Professions in Ancient Greece and Rome* (MIT Press, Cambridge, Mass., 1969), p. 174. Also L. Casson, *The Ancient Mariners, Seafarers and Sea Fighters of the Mediterranean in Ancient Times* (Victor Gollancz Ltd, London, 1959), p. 213, and *Ships and Seamanship in the Ancient World* (Princeton University Press, Princeton, 1971), pp. 141-7, 231-8, 322-6. To people of the middle ages the typical Roman ship was the galley, and it was that vessel which they drew to illustrate Roman ships: Lucien Basch, 'Ancient Wrecks and the Archaeology of Ships', *IJNA*, I (1972), p. 2.

2. Romola and R. C. Anderson, *The Sailing-Ship* (George G. Harrap and Co. Ltd, London, 1926), pp. 49-51. In *HSUA*, pp. 72, 76-7, Throckmorton rightly notes that no wrecks of Roman merchantmen of above 300 tons have yet been found. The number of big ships was small and so is the chance of excavating one. That means that knowledge of the largest ships comes from contemporary illustrations and descriptions only. Lionel Casson, *The Ancient Mariners*, pp. 174, 218-20, points out that the triangular topsail may date from the Hellenistic period. But there are no surviving illustrations of Hellenistic merchant ships so it is only possible to guess about the earliest date of that kind of sail. Also see L. Casson, *Ships and Seamanship in the Ancient World*, pp. 224-8, 239-43, 269, 275-85.

3. Lionel Casson, 'Sailing', pp. 189-90, *The Ancient Mariners*, pp. 216-17, 235-6, and *Ships and Seamanship in the Ancient World*, pp. 171-81, 185-90, 297, 329. J. S. Morrison in *AB*, pp. 155-66.

4. The understanding of Roman ship construction has changed over the last 25 years. Compare Romola and R. C. Anderson, *The Sailing-Ship*, p. 52, with Arne Emil Christensen, Jr, 'Lucien Basch: Ancient wrecks and the archaeology of ships A comment', *IJNA*, II (1973), p. 138. The change has come about largely because of new archaeological evidence.

5. Lucien Basch, 'Ancient wrecks and the archaeology of ships', pp. 15-18. *AB*, pp. 60-8.

6. Lionel Casson, *Ships and Seamanship in the Ancient World*, pp. 201-8, 211, and 'Sailing,' pp. 191-4. Lucien Basch, 'Ancient wrecks and the archaeology of ships', pp. 23-30. Arne Emil Christensen, Jr, 'Lucien Basch: Ancient wrecks', pp. 138-43. While mortise and tenon construction was not the only shipbuilding method in use within the political boundaries of the Roman Empire, it was certainly the dominant one in the centre of the Empire, that is in the Mediterranean basin.

7. D. J. Blackman, 'Further early evidence of hull sheathing', *IJNA*, I (1972), pp. 117-19. The earliest known example is from the fourth century BC. Lionel Casson, *The Ancient Mariners*, p. 217, *Ships and Seamanship in the Ancient World*, pp. 211-12, and 'More Evidence for Lead Sheathing on Roman Craft', *MM*, LXIV (1978), pp. 135-42 and also the reply by Honor Frost, pp. 142-4.

8. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean A. D. 500-1100* (Princeton University Press, Princeton, 1951), pp. 15, 26-7, 33-7. The road system was built originally for the movement of troops and was not suited to commerce. The size of the Imperial merchant marine demonstrates that. But

merchants did use the roads and the lack of government interest in them was certainly no help to commerce. See also Lionel Casson, *The Ancient Mariners*, p. 232, and, George F. Hourani, *Arab Seafaring in the Indian Ocean in Ancient and Early Medieval Times* (Princeton University Press, Princeton, 1951), pp. 38-40.

9. The description of seventh-century shipbuilding is heavily based on the seventh-century Yassi Ada ship. Another ship found at Pantano Longarini in southern Italy shows some of the same features and gives support to the conclusions. Lionel Casson, *Ships and Seamanship in the Ancient World*, pp. 208-9. Frederick van Doorninck, 'The 4th century wreck at Yassi Ada an interim report on the hull', *IJNA*, V (1976), pp. 119-31.

10. R. H. Dolley, 'The Warships of the Later Roman Empire', *The Journal of Roman Studies*, XXXVIII (1948), p. 51. Aly Mohamed Fahmy, *Muslim Sea-Power in the Eastern Mediterranean from the Seventh to the Tenth Century A.D. (Studies in Naval Organization)* (Tipografia Don Bosco, London, 1950), p. 85.

11. Hélène Antoniadis-Bibicou, *Etudes d'histoire maritime de Byzance A propos du 'Theme des Caravisiens'*, pp. 21-2, and 'Problèmes de la marine byzantine', *Annales (ESC)*, XIII (1958), p. 376. G. La Roërie and J. Vivielle, *Navires et Marins de la rame à l'hélice* (Editions Duchartre et van Buggenhoudt, Paris, 1930), pp. 85-7. R. H. Dolley, 'The Warships of the Later Roman Empire', pp. 47-53. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean*, pp. 22-30. Ekkehard Eickhoff, *Seekrieg und Seepolitik zwischen Islam und Abendland* (Walter De Gruyter and Co., Berlin, 1966), pp. 136-50.

12. Louis Bréhier, 'La Marine de Byzance du VIII^{e} au XI^{e} Siècle', *Byzantion*, XIX (1949), p. 9. The Syrian was Callinicus from Baalbek (Heliopolis). F.W. Brooks, 'Naval Armament in the Thirteenth Century', *MM*, XIV (1928), pp. 115-19. R. H. Dolley, 'The Warships of the Later Roman Empire', p. 52. Lionel Casson, *The Ancient Mariners*, pp. 241-3, and *Ships and Seamanship in the Ancient World*, pp. 152-3. *HSUA*, p. 135. An incendiary compound similar to Greek fire was used by the Byzantines in 516.

13. *HSUA*, pp. 139-40.

14. H. H. Brindley, 'Early Pictures of Lateen Sails', *MM*, XII (1926), pp. 9-14. His discovery of the illustration of 880 in the Bibliothèque Nationale in Paris convinced scholars for a number of years that the lateen sail came into use by Greeks in the eighth and ninth centuries and that they had borrowed it from the Arabs. R. H. Dolley, 'The Rig of Early Medieval Warships', *MM*, XXXV (1949), pp. 51-5, doubts an Arab origin for the lateen since they were landsmen. The absence of any illustration of lateens on Greek ships may be explained by the suppression of artistic work during the period of the Iconoclastic emperors (723-843). Lionel Casson, *Ships and Seamanship in the Ancient World*, pp. 244-5, 277. Richard Lebaron Bowen, Jr, 'The origins of fore-and-aft rigs', pp. 155-60, 183-7, and 'Note: The Earliest Lateen Sail', *MM*, XLII (1966), pp. 239-42. In the light of Casson's evidence he felt compelled to change his opinion and claims that the Indonesians got the sail from the Romans and not the other way around. G. La Roerie, 'Note: Fore and Aft Sails in the Ancient World', *MM*, XLII (1966), pp. 238-9: Casson's claim for the presence of the lateen sail in the ancient world is not without opposition. Joseph Needham, *Science and Civilization in China*, vol. IV, part III, pp. 588-90, 606, 617.

15. Richard Lebaron Bowen, Jr, 'The origins of fore-and-aft rigs', p. 183. Lionel Dimmock, 'The Lateen Rig', *MM*, XXXII (1946), p. 35. Barbara Kreutz, 'Ships, Shipping and the Implications of Change in the Early Medieval Mediterranean', *Viator*, VII (1976), pp. 79-99. J.H. Parry, *Discovery of the Sea* (Weidenfeld and Nicolson, London, 1975), pp. 11-14, and *The Age of Reconnaisance* (New American Library, New York, 1963), pp. 74-5.

16. Louis Bréhier, 'La Marine de Byzance du VIII^{e} au XI^{e} Siècle', p. 1. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean*, pp. 13, 19-20. Walther Vogel, *Geschichte der deutschen Seeschiffahrt* (George Reimer, Berlin, 1915), pp. 51-2. The Romans apparently tried to deny barbarians knowledge of shipbuilding and to some degree were successful.

17. F. C. Lane, 'Progrès technologiques et productivité dans les transports maritimes de la fin du Moyen Age au début des Temps modernes', *Revue Historique*, 510 (April-June 1974), pp. 278-9.

18. Hélène Ahrweiler, *Byzance et la Mer La Marine de Guerre La Politique et les Institutions Maritime de Byzance au VII^{e} – XV^{e} Siècles* (Presses Universitaires de France, Paris, 1966), pp. 17-18. Aly Mohamed Fahmy, *Muslim Sea-Power*, pp. 116-17. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean*, pp. 54-7. Ekkehard Eickhoff, *Seekrieg und Seepolitik*, pp. 19-22. George F. Hourani, *Arab Seafaring*, pp. 55-9.

19. Hélène Ahrweiler, *Byzance et la Mer*, pp. 19-34. Louis Bréhier, 'La Marine de Byzance du VIII^{e} au XI^{e} Siècle', pp. 2-7. Hélène Antoniadis-Bibicou, *Etudes d'histoire maritime de Byzance*, pp. 53-8, 115. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean*, pp. 60-5, 73-5. Lynn T. White, 'The Diffusion of the Lateen Sail', *Medieval Religion and Technology* (University of California Press, Berkeley, 1978), pp. 256-60.

20. Lionel Casson, *The Ancient Mariners*, pp. 186, 244, and *Ships and Seamanship in the Ancient World*, p. 154. Aly Mohamed Fahmy, *Muslim Sea-Power*, pp. 80-1, 103-5, 120-7. Richard Lebaron Bowen, Jr, 'Note: The Earliest Lateen Sail', p. 241. The Arabs may have got this different type of sail from the Indian Ocean where it was introduced by the Romans. The Arabs then diffused the sail through the Mediterranean. Ekkehard Eickhoff, *Seekrieg und Seepolitik*, pp. 152-5.

21. Hélène Antoniadis-Bibicou, *Etudes d'histoire maritime de Byzance*, pp. 22-4. Aly Mohamed Fahmy, *Muslim Sea-Power*, pp. 76-84. Maurice Lombard, 'Arsenaux et bois de marine dans la Méditerranée musulmane (VII^{e} – XI^{e} siècles)', *TCHM*, II, pp. 53-66, 81-96. Prohibitions of the export of wood by Byzantines did not begin until the early ninth century.

22. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean*, pp. 69-72, 79-99. For a contrary view see Renée Doehard, 'Méditerranée et économie occidentale pendant le haut Moyen Age', *Cahiers d'histoire mondiale*, I (1954), pp. 579-81. Aly Mohamed Fahmy, *Muslim Sea Power*, pp. 127, 137. Ekkehard Eickhoff, *Seekrieg und Seepolitik*, pp. 48-50, 154-6.

23. E. G. R. Taylor, *The Haven-Finding Art. A History of Navigation from Odysseus to Captain Cook* (Abelard-Schuman Ltd, New York, 1957), p. 66. She translates the statement from Caesar's *Gallic Wars*, as does Lionel Casson, *Illustrated History of Ships and Boats* (Doubleday and Co., New York, 1964), p. 59. Romola and R. C. Anderson, *The Sailing-Ship*, pp. 59-62. James Hornell, 'The Sources of the Clinker and Carvel Systems in British Boat Construction', *MM*, XXXIV (1948), pp. 244-5. *HSUA*, pp. 118-22. The Blackfriars boat of the second century AD excavated in London by Marsden, about 16 metres long, almost 6.5 metres broad and just over two metres deep amidships, seems to have been of the type described by Caesar. The vessel was of about 30 tons. A vessel that Marsden also investigated at New Guy's House, London, appears to have been a smaller version of the same type. Detlev Ellmers, 'Keltischer Schiffbau', *Jahrbuch Römisch-Germanischen Zentralmuseums Mainz*, XVI (1969), pp. 73-82. The same type was apparently also used along the Rhine.

24. *FHMN*, p. 76. Detlev Ellmers, 'Keltischer Schiffbau', pp. 106-16. Archibald R. Lewis, *The Northern Seas, Shipping and Commerce in Northern Europe A.D. 300-1100* (Princeton University Press, Princeton, 1958), pp. 106-7, 168-9.

HSUA, p. 115. Caesar saw skin-boats like these in 55-54 BC and used them in 49 BC having his men build them along the Spanish coast.

25. M.D. DeWeerd, 'Schepen voor het Opscheppen', *Spiegel Historiael*, VIII, 7/8 (July-August 1973), pp. 390-7. Ole Crumlin-Pedersen, 'The Ships of the Vikings', in Thorsten Andersson and Karl Inge Sandred (eds), *The Vikings* (Uppsala University, Uppsala), pp. 39-40. Peter Marsden, 'A boat of the Roman period found at Bruges, Belgium, in 1899, and related types', *IJNA*, V (1976), pp. 44-7.

26. Detlev Ellmers, 'Keltischer Schiffbau', pp. 75, 81, 118-21. On other Celtic design traditions and the inventiveness of Celtic shipwrights in dealing with specific conditions, see pp. 84-106. Lucien Basch, 'Ancient wrecks and the archaeology of ships', pp. 41-3, differs, claiming that Blackfriars boat does not exhibit true shell technique but his argument is not convincing. *HSUA*, p. 122. *AB*, pp. 68-70.

27. Ph. Humbla, 'Björke-båten från Hille Socken', *Från Gästrikland* (1949), pp. 5-30. This vessel, built about 100 AD, was a smaller version but still essentially the same type and a forerunner of the Nydam boat. The preserved boat is now in the provincial museum in Gävle, Sweden. Romola and R. C. Anderson, *The Sailing-Ship*, pp. 66-8. Tacitus about 100 AD mentioned the use of double-ended craft by the Suiones, a tribe he placed in Scandinavia. He may have been referring to vessels similar to that found at Nydam. Harald Åkerlund, *Nydamskeppen En Studie I Tidig Skandinavisk Skeppsbyggnadskonst* (Sjöfartsmuseet, Gothenburg, 1963), pp. 155-7. The measurements, which he reported again in the English summary cited here, are based on a correction factor for the shrinking of the vessel. That is one of the few aspects of Åkerlund's radically revisionist and imaginative work which is convincing. *HSUA*, pp. 162-4. Archibald R. Lewis, *The Northern Seas*, pp. 46-8, is undoubtedly right in saying that the Nydam type was not like the ships used by Saxon pirates to attack Roman Britain in the third and fourth centuries AD. But exactly what type of vessel they used is not known. *AB*, pp. 178-83.

28. Siegfried Fliedner, ' "Kogge" and "Hulk" Ein Beitrag zur Schiffstypengeschichte', *Die Bremer Hanse-Kogge Fund Konservierung Forschung* (Verlag Friedrich Röver, Bremen, 1969), pp. 54-62, gives a complete and exhaustive discussion of the derivation of the name of the hulk type. *HSUA*, pp. 186-7. *FHMN*, pp. 59-63. The identification of the Utrecht ship as a hulk is based on later coin evidence. He believes that planks were originally end to end in this type with the external plank over the seams to hold them together. This is likely. Paul Heinsius, *Das Schiff der Hansischen Frühzeit* (Verlag Hermann Böhlaus Nachfolger, Weimar, 1956), pp. 70-4. Johannes P. W. Philipsen, 'The Utrecht Ship', *MM*, LI (1965), pp. 35-46. The iron nails found with the ship were either used for minor structural features or added later in repairs. The ship may have been as much as 200 years old when buried. Edward P. von der Porten, 'Note: The Utrecht Boat', *MM*, XLIX (1963), pp. 50-1.

29. Siegfried Fliedner, ' "Kogge" and "Hulk" ', pp. 39-54. The name cog is connected to Frisian usage and apparently meant 'shell'. For other theories on the origin of the name see Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, pp. 12, 70-6. M. A. Nagelmackers, 'Le bateau de Bruges', *MAB*, VIII (1954), pp. 193-201. Ole Crumlin-Pedersen, 'Cog-Kogge-Kaag Træk af en frisisk skibstypes historie', *Handels- og Søfartsmuseets På Kronborg, Årbog* (1965), pp. 96-102. *FHMN*, pp. 63-4, 69-70. Samuel Eliot Morison, *The European Discovery of America The Northern Voyages A.D. 500-1600* (Oxford University Press, New York, 1968), pp. 15-27. *HSUA*, pp. 122-3. From similarities to the Blackfriars boat he suggested an earlier date for the Bruges boat and the possibility that it was a Celtic vessel predating German incursions into the Roman Empire. While his recent work

has confirmed a Celtic origin the critical point is the extensive use of this type by German-speaking traders. Peter Marsden, 'A boat of the Roman period found at Bruges', pp. 23-9, 37-44.

30. Herbert Jankuhn, 'Der fränkish-friesische Handel zur Ostsee im frühen Mittelalter', *Vierteljahrschrift für Sozial- und Wirtschaftsgeschichte*, XL (1953), pp. 205-22, 228-30. All writers cite coin evidence, which is extensive, for the scope, pattern and dating of Frisian trade. More generally Herbert Jankuhn, *Haithabu: Ein Handelsplazt der Wikingerzeit*, fourth expanded edition (Karl Wachholtz Verlag, Neumünster, 1963). Dirk Jellema, 'Frisian Trade in the Dark Ages', *Speculum*, XXX (1955), pp. 15-23. Barbara Rohwer, *Der friesische Handel im frühen Mittelalter* (Robert Noske, Leipzig, 1937), pp. 7-9, 23-37. P. C. J. A. Boeles, *Friesland tot de Elfde Eeuw* (Martinus Nijhoff, The Hague, 1927), pp. 127-30, 152-5, 162-71.

31. Ole Crumlin-Pedersen, 'Cog-Kogge-Kaag', pp. 116-21. For a more sceptical view of Frisian activity in the Baltic see Aksel E. Christensen, 'Birka Uden Frisere', *Handels- og Søfartsmuseet På Kronborg, Årbog* (1966), pp. 17-38. For reports on renewed archaeological investigations at the site of Dorestad see *Spiegel Historiael*, XIII, 4 (April 1978), pp. 194-314.

32. R. L. S. Bruce-Mitford, *The Sutton Hoo Ship Burial A Handbook* (The Trustees of the British Museum, London, 1968), pp. 40-3, 48-51. The grave goods are important for, among other things, showing the close ties between England and Sweden in the seventh century. The wood of the ship has completely disappeared and only the impression is left. Many details are not known, such as the height of the stem and sternposts and the nature of the decoration. *HSUA*, p. 124; he, like most other writers, finds it hard to believe that a vessel the size of the Sutton Hoo ship would not have had a sail. If there was a sail it was obviously small and for propulsion of little significance compared to the oars. *AB*, pp. 178-88, on finds of this type. Angela Care Evans, 'The Sutton Hoo Ship', in Valerie Fenwick *et al.*, *Three Major Ancient Boat Finds in Britain*, National Maritime Museum, Monographs and Reports, no. 6 (1972), pp. 26-33.

33. *HSUA*, pp. 164-5. The importance of the Kvalsund boat lies in its transitional nature showing the change to the use of iron rivets in Norwegian boat construction. Haakon Shetelig and Fr. Johannessen, *Kvalsundfundet og Andre Norske Myrfund av Fartøier* (John Griegs Boktrykkeri, Bergen, 1929). Similarity to later Viking ships is not unexpected since reconstruction of the ship from the few pieces found is based on ninth-century finds.

34. Sibylla Haasum, *Vikingatidens Segling och Navigation* (Scandinavian University Books, Stockholm, 1974), p. 56. The evidence for the introduction of sails to Scandinavia in the seventh century comes from drawings on stones on the island of Gotland. That was one result of the work of Sune Lindqvist, *Gotlands Bildsteine* (Kungl. Vitterhets Historie och Antikvitets Akademien, Stockholm, 1942).

35. *FHMN*, p. 158. There is some question as to whether deterioration of quays led to a change in ship design or the generally smaller size of ships led to the abandoning of quays.

NOTES TO ILLUSTRATIONS

a. Lucien Basch, 'Ancient wrecks and the archaeology of ships', *IJNA*, I (1972), p. 2. *HSUA*, pp. 84-5. Björn Landström, *The Ship*, nos. 94-6. Lionel Casson, *Illustrated History of Ships and Boats*, nos. 49-50. Claude Farrère, *Histoire de la Marine Française*, pp. 6-7. G. La Roërie and J. Vivielle, *Navires et Marins de*

la rame à l'hélice, vol. I, pp. 57-9.

b. Lionel Casson, *Illustrated History of Ships and Boats*, nos. 60-2, 65, 66. *HSUA*, pp. 72, 80, 86. G. La Roërie and J. Vivielle, *Navires et Marins*, vol. I, pp. 63-9, 76. Björn Landström, *The Ship*, nos. 103-10. Romola and R. C. Anderson, *The Sailing-Ship*, pp. 49-51. G. S. Laird Clowes, *Sailing Ships, Their History and Development*, part I, plate V. Claude Farrère, *Histoire de la Marine Française*, p. 6. Richard Lebaron Bowen, Jr, 'The origins of fore-and-aft rigs', *AN*, XIX (1959), p. 278.

c. Lionel Casson, *Ships and Seamanship in the Ancient World*, nos. 159-60, and *Illustrated History of Ships and Boats*, no. 56. *HSUA*, pp. 70-1.

d. Lionel Casson, *Ships and Seamanship in the Ancient World*, no. 163, and *Illustrated History of Ships and Boats*, no. 56.

e. Lionel Casson, *Ships and Seamanship in the Ancient World*, nos. 138, 141.

f. *HSUA*, pp. 137-8, 140-2, 154, 157-8. Hélène Antoniadis-Bibicou, *Etudes d'histoire maritime de Byzance. A propos du 'Thèmes des Caravisiens'*, between pp. 24 and 25, no. 1. Frederick van Doorninck, 'The 4th century wreck at Yassi Ada. An interim report on the hull', *IJNA*, V (1976), pp. 122, 130.

g. R. H. Dolley, 'The Warships of the Later Roman Empire', *The Journal of Roman Studies*, XXXVIII (1948), plate V. The pictures are of his model of a dromon which leaves something to be desired. Björn Landström, *The Ship*, nos. 221-4, for later dromons. *HSUA*, p. 132: this is a rare illustration of a late Roman warship from northern Europe. Its relationship if any to the dromon is an interesting and unanswered question.

h. *HSUA*, p. 145. Lionel Casson, *Illustrated History of Ships and Boats*, no. 52, and *Ships and Seamanship in the Ancient World*, no. 134.

i. Lionel Casson, *Illustrated History of Ships and Boats*, nos. 64, 70-4, *Ships and Seamanship in the Ancient World*, nos. 147, 175-9, 180-2, 188, and 'The Sprit-Rig in the Ancient World', *MM*, XXXXVI (1960), p. 241. Richard Lebaron Bowen, Jr, 'The origins of fore-and-aft rigs', pp. 156, 187, and 'Note: The Earliest Lateen Sail', *MM*, XLII (1966), p. 240. Björn Landström, *Sailing Ships*, nos. 70-6. *HSUA*, pp. 148-9.

j. H. H. Brindley, 'Early Pictures of Lateen Sails', *MM*, XII (1926), opposite p. 12. Hélène Antoniadis-Bibicou, *Etudes d'histoire maritime de Byzance*, between pp. 24 and 25, nos. 2-3. Björn Landström, *The Ship*, nos. 209, 215, 218. Richard Lebaron Bowen, Jr, 'The origins of fore-and-aft rigs', p. 184. Romola and R. C. Anderson, *The Sailing-Ship*, pp. 102-3.

k. Detlev Ellmers, 'Keltischer Schiffbau', *Jahrbuch Römisch-Germanischen Zentralmuseums Mainz*, XVI (1969), pp. 74, 78, 80. *HSUA*, pp. 117, 120-1, 126-9.

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o. J. P. W. Philipsen, 'The Utrecht Ship', *MM*, LI (1965), opposite p. 4: the model built as a reconstruction is not reliable. E. P. von der Porten, 'Note: The Utrecht Boat', *MM*, XLIX (1963), p. 51. *FHMN*, pp. 54-5, 285-6. *HSUA*,

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q. R. L. S. Bruce-Mitford, *The Sutton Hoo Ship Burial A Handbook*, *passim*. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, p. 39. *HSUA*, p. 131. *AB*, nos. 121, 122.

r. *HSUA*, pp. 161, 169. Björn Landström, *The Ship*, nos. 138-45, 159. Ole Crumlin-Pedersen, 'Cog-Kogge-Kaag', p. 125. *FHMN*, p. 28. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 48-9, 95. *AB*, no. 123.