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## 2 VIKINGS AND BYZANTINES: 750-1000

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The rapid emergence of the Carolingian Empire, built on the Frankish kingdom of the Merovingians, created a unified state for western Europe. It also created a government with an economic and monetary policy. These creations, together with peace, could only help in the expansion of shipping. After 840 and the death of Charlemagne's son, Louis the Pious, political organisation became fragmented. The breakdown of the high levels of government led to chaos or at least insecurity through much of northern Europe as the stronger tried to improve their condition by force. Outside the Empire in lands to the north, Scandinavians embarked on a series of raids on the settled regions of the West which turned into two centuries of attacks by groups of these Vikings against Britain, Ireland and the Continent. The Viking attacks came in waves. They added another source of disruption, especially along the coasts and rivers, since the Vikings came by sea.

By the year 1000 a certain measure of stability had been re-established. In France the smaller political units which emerged brought some peace, as did the restored Roman Empire now in a central European

Illustration above: A Scandinavian sailing ship of the thirteenth century with the lines of earlier Viking cargo ships, Bergen, Norway, oldest town seal, second half of the thirteenth century.

form. The eastern frontier of the Empire was stabilised by the establishment of Christian kingdoms in Hungary and Poland. The same was true in Scandinavia where certain former tribal chieftains had been able to claim sovereignty as kings. This successful establishment of monarchical governments on the fringe of Europe meant, if nothing else, that violence was better organised, less sporadic.

In the Mediterranean, on the other hand, the naval contest between the Byzantine and Arab Empires continued, if anything, with greater intensity. The internal difficulties of the Caliphates made for changes in the level of Muslim naval activity and led by the end of the tenth century to a fragmented political structure with a number of Muslim states having varying ties among themselves. The Byzantines faced the threat of these states and also a challenge on the Black Sea from Russia. The Empire survived these assaults as well as a number of internal political crises and revolts. There were signs of a growing weakness in the Empire, however, and not on its northern border where there was some success against attacking Bulgars, but in the east in Asia Minor and in the west in south Italy. By 1000, in both southern and northern Italy, a number of port towns had increased their trade and their investment in shipping to the point where they could deploy some naval strength. They were not major naval powers but they were in a position to play an active part in Mediterranean commerce and to develop and expand their own shipbuilding.

The ships of northern Europe continued to include most of the types present before 750. Some were subjected to continuing development while others remained largely unchanged. Some types all but disappeared. In England at least in the eighth and ninth centuries wooden vessels replaced the large seagoing Celtic curragh. Building with wickerwork was not sturdy enough and perhaps required too much repair for carrying goods on the high seas. The smaller version using the same type of construction, the coracle, was still used but only for carrying small quantities of goods and people short distances. In general Celtic types were restricted to the coasts, to coastal fisheries and especially to the rivers. The form of the vessels remained consistent but they became, if anything, smaller. Many Celtic types were originally intended for river transport and had been thus used during the Roman period and before. Their efficiency in that capacity was recognised and their use was not challenged. The Celtic designs which enjoyed continued development were those that had by 750 already been found useful by Frisians. They were not pure Celtic types by that time, retaining only some features from their predecessors. In the hands of Frisian

builders and shippers these types had passed into use for long-distance trade.

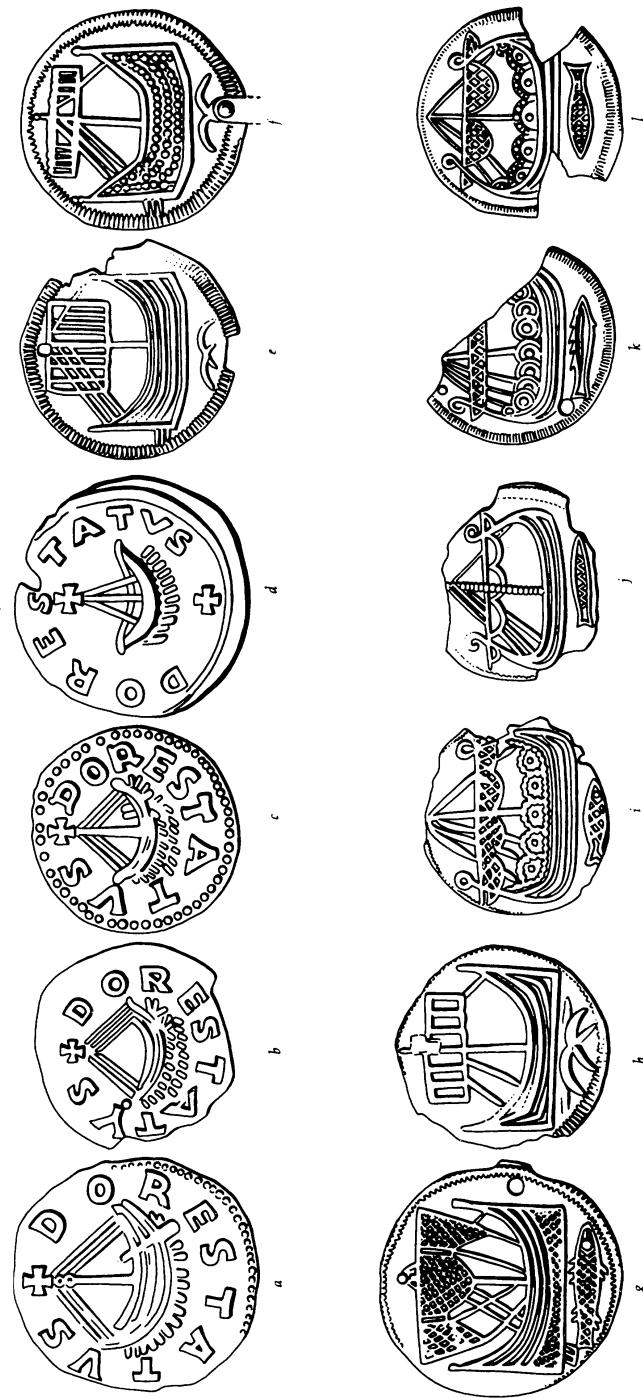
Builders in England in the ninth and tenth centuries developed a new type of oceangoing cargo ship. Its origins were Scandinavian rather than Celtic. It was called a keel because the addition of that heavy central piece set it apart from contemporary Frisian vessels, the cog and the hulk. The keel was a further development of the Scandinavian rowing barge like the one found at Kvalsund. It began as a warship for carrying men but by the tenth century was a cargo ship for carrying goods, especially across the North Sea and along the Atlantic coast. There was a single square sail on the single mast. The angle of the posts was sharper than on earlier rowing barges. There were oars but only at the ends because the centre of the vessel was an open hold for goods. The oars were used just to manoeuvre and to get in and out of harbours. The hull was clinker-built and similar in proportions to those of contemporary Scandinavian cargo ships. The length-to-breadth ratio was in the range of 3.5:1 to 4.5:1. A boat found in Kent from about 900 seems to fit into this category of ship. Though primarily for coastal trading the vessel was capable of crossing the Channel. Ribs were massive and set close together. The hull planks were nailed to the ribs. The posts were nearly vertical meeting the keel at something near right angles, a practice found on seventh-century Scandinavian vessels but later abandoned for most ships. The sides were not square with the bottom but instead met with horizontally overlapping planking. The keel itself was not straight but was lower amidships than at the ends. This was an advantage when trying to get the vessel off a beach so it was designed to use the simplest harbours. Strakes were pieced together and thin, the maximum thickness being only .03 metres.<sup>a</sup> The timbers amidships suggest a strong base for heavy cargo and toll records from the early eleventh century show that this type was used to carry wine in barrels from the Continent to London. Cargo was presumably carried around the mast.<sup>1</sup> The keel by 1000 was a common cargo vessel built in England and used along the coast of Britain, the Atlantic coast of France and the south shore of the North Sea. In a sense the keel was a substitute or alternative type to the hulk since they seem to have been used along many of the same routes. The keel sailed better in open waters and faster as well because it had a keel, but the hulk did better on rivers and in shallow waters. The keel could carry more goods for each metre of length. Since neither type was overwhelmingly superior in all trades they were used side by side. It is doubtful whether keels were built in the Low Countries, however, since designing for travel

along rivers took precedence there.

Both the hulk and cog continued in much the same forms through the tenth century. Both types were popular with Frisians trading from the Low Countries and especially from the commercial capital of the area, Dorestad. Illustrations on coins confirm this fact.<sup>b</sup> Frisian trade apparently continued to expand until the mid-ninth century. Frisians, taking advantage of inclusion in the Carolingian Empire, extended their ties up the Rhine and to England and Scandinavia. They moved goods in cogs east along the coast to the town of Hollingstedt where the goods and perhaps the entire ship were carried overland to Hedeby on the Baltic coast. So the Frisians portaged their cogs into the Baltic. The need to move them overland kept them small as did the typically shallow harbours in the Baltic. Moreover, those harbours were often hard to reach, being on rivers. Still, the Frisian vessels had cabins, a great advantage in comfort over Scandinavian open boats. The goods handled continued to be the same, the Frisians acting as middlemen between the handicraft industries of the Rhine Valley and the land-intensive industries, such as hunting, of the North. Trade to the Mediterranean through the Rhine Valley and the Alps – trade which developed in the reign of Charlemagne – was badly affected by attacks of Hungarian raiders in the late ninth and in the first half of the tenth century. On the other hand there seems to have been a revival of trade along the west coast of France and to Spain. The Frisians took part in that as well, for example fetching olive oil from Aquitaine for customers in the Rhine Valley. The Frisians still carried wine to Scandinavia in jars, despite the expense compared to carriage in barrels. Shipping to Scandinavia continued into the tenth century despite attacks by Vikings on Frisia and on Dorestad itself.<sup>2</sup>

The Frisians established trading colonies in the major ports of their trading network, following the practice of late Roman and Byzantine merchants who still maintained colonies of merchants in the Frankish kingdom in the sixth century. Since their ships and navigational techniques fixed certain trade routes as optimal, the Frisians knew which ports would be most used. They established colonies in London and York, in Hedeby and Birka, in Worms and Mainz and as far away as Rome. In Rome from 779 they had their own quarter with a church. It continued to exist until about 1300. From the early ninth century there were resident Frisian merchants living in ports, owning land or holding it on long-term lease and, if not living there all the time, at least using it as their base of operations and maintaining a family life in their home ports.<sup>3</sup> Frisian trade was certainly not promoted by the

5: Ships on Carolingian Coins of Dorestad : a-d hulks, e-h cogs and i-l Scandinavian warships



hostile actions of Scandinavians. The interruption of production throughout coastal regions, the attacks on ports and the periodic establishment of regions ruled by Vikings all made the task of the Frisian merchant harder. He also had to face competition from the Vikings since they acted as traders, sometimes bypassing established Frisian trading connections or finding alternative sources for goods. The Northmen first attacked Friesland in 810. The raids intensified and major assaults were mounted from 834 to 885. Dorestad was sacked in 834 and again in 835. The town was finally destroyed in 860. Merchants, and with them trade, migrated to Utrecht and to Tiel, the former keeping the Scandinavian connection and using cogs, the latter continuing trade with England using hulks.<sup>4</sup>

The adverse conditions did not immediately yield a change in ship types. Rather, advance in ship design seems to have been suspended like trade. The English keel and the Netherlandish cog and hulk remained much the same. The only major response to the Viking attacks was in warships. King Alfred the Great of England concluded that he could defend his realm only with a naval force able to meet and defeat the Vikings before they landed. He had ships built at the end of the ninth century for just that job. The design was probably similar to that of the English keel but King Alfred's ships were much larger. They were rowing boats with 30 oars to a side, which meant they had to be more than 40 metres long, much longer than a contemporary Viking ship. These vessels were reported to be bigger, faster and higher in the water than contemporary Danish or Frisian ships. The total fleet by the mid-tenth century was said to number 3,600 vessels but that is certainly an exaggeration.<sup>5</sup> These were not ships for the high seas. They were for coastal defence and designed to move a large number of men quickly to a point of attack. Frisian sailors were used to man them since the job was beyond the skill of Englishmen. The design of these ships appears to have had no effect on other vessels in northern Europe, however. They were special-purpose ships and were useful only for their single task. As the Vikings changed from hit-and-run raids to attacks by large armies these English warships lost their function. The long ship in the North developed not from the ships of Alfred the Great but rather from the highly effective Scandinavian sailing ship.

The development of the Viking ship in the eighth century was the most important change in European ship design from 750 to 1000. It combined many features of earlier types and incorporated major advances over those designs. It is probably correct to downgrade some of the extravagant claims made for these ships. The success of modern

full-size reconstructions, however, does indicate some of the remarkable capabilities of the type.<sup>6</sup> The Viking ship marked a significant improvement in the ability to move people. It demonstrated the advantages of certain major design features, features later borrowed by builders outside Scandinavia. The design of the Viking ship was by no means static. It too was improved as the potential of the type was explored.

There was in eighth- and ninth-century Scandinavia a need for a vessel to carry men. The poor farmland of the Norwegian and Swedish coasts made farmers into part-time fishermen so there were always boats and boat builders among the farms. The vessels were used to travel among the relatively isolated settlements in the fjords. There is evidence that the population of Scandinavia was rising through the eighth and ninth centuries, and this increased the need to move goods but, more important, to move people so that they could resettle elsewhere. Migrants covered ever-increasing distances, more regularly over open waters. This was in a sense a continuation of the migration of people from Scandinavia dating from the first century AD. By the eighth century the type of vessel for the migration had been markedly improved to deal with the high seas and longer voyages. The Viking ship was primarily a ship for moving men. The demand was formed by the social organisation in Scandinavia. These tribal societies were grouped into clans in which family connections were the qualification for status. The aristocrats of the society, the landowners and leaders of the clans, had boats built for their private use. The vessels had to serve to carry them and their relatives and retainers. The ships had to be good for fighting since authority depended on physical strength and the support of relatives. Settlements were never large nor were the kin groups themselves, so the boats themselves did not have to be of any great size. The owners of these ships had a great deal of say in the design of the ship, a fact that could certainly lead to whimsical requirements. But the leader of the clan group was himself constrained by fear of other groups, by the size of his band of followers, by the weather and by the waters of the fjords. All those problems were reflected in the final design of the Viking ship.

Scandinavian society was based on continuing conflict. Physical prowess in battle was praised. The continuation of family vendettas to adjudicate disputes guaranteed fighting. The economy was a confiscatory one, the seizure of goods or land being considered almost the same as the purchase or exchange of property. This was especially clear in commerce. The dividing line between trade and piracy was not clear cut. There is in fact some question as to whether such a categorical differentiation existed among Scandinavians. Buyers of ships then

wanted a vessel primarily to carry people, but also usable in both trade and fighting. The only constraint on these voyages of raiding was the ability of the ship to make the trip. Equipped with their new ship from the mid-ninth century on, Vikings were able to attack Iberia at least six times and in one case they even went as far as the Dardanelles and perhaps even to Alexandria.<sup>7</sup> They pursued the established trade routes in search of any opportunity, living off what they could buy, barter or take. All Viking ships had to be light and fast and that kept unit carrying costs high. Typically the goods freighted were luxuries. Though there was a clear distinction between warships and ships intended for trade, even the latter had relatively small carrying capacities and many of the same design features since they were subject to similar constraints. No matter the goal, the Viking ship of the ninth and tenth centuries was a vessel with good manoeuvrability, with great potential range, with good stability and excellent handling characteristics. Properly sailed it was a safe ship. It was also easily beached and refloated and light enough to be moved across land for short distances.

This new type made possible all of the extensive voyages throughout northern European waters, through Russia to the Black and Caspian Seas and across the North Atlantic to Iceland, Greenland and Canada. The voyages of discovery and colonisation were a side effect of the development of a successful deep-sea sailing vessel. They were at the same time the product of better navigational techniques developed to deal with long-distance open-water sailing. The Vikings did make mistakes in navigation but in most cases these caused only mild inconvenience. They may also have benefited from, on average, better weather in the North Atlantic with steadier winds and longer summers than were to be typical of the late middle ages. Still, weather conditions in the North were always worse than those in the Mediterranean, making navigation more difficult. The improved navigational techniques of the Vikings may in fact have developed as part of a compulsive sequence in which the increased capabilities of their ships led them to investigate and experiment with long-distance sailing to try and exploit more fully the potential of the ship.<sup>8</sup>

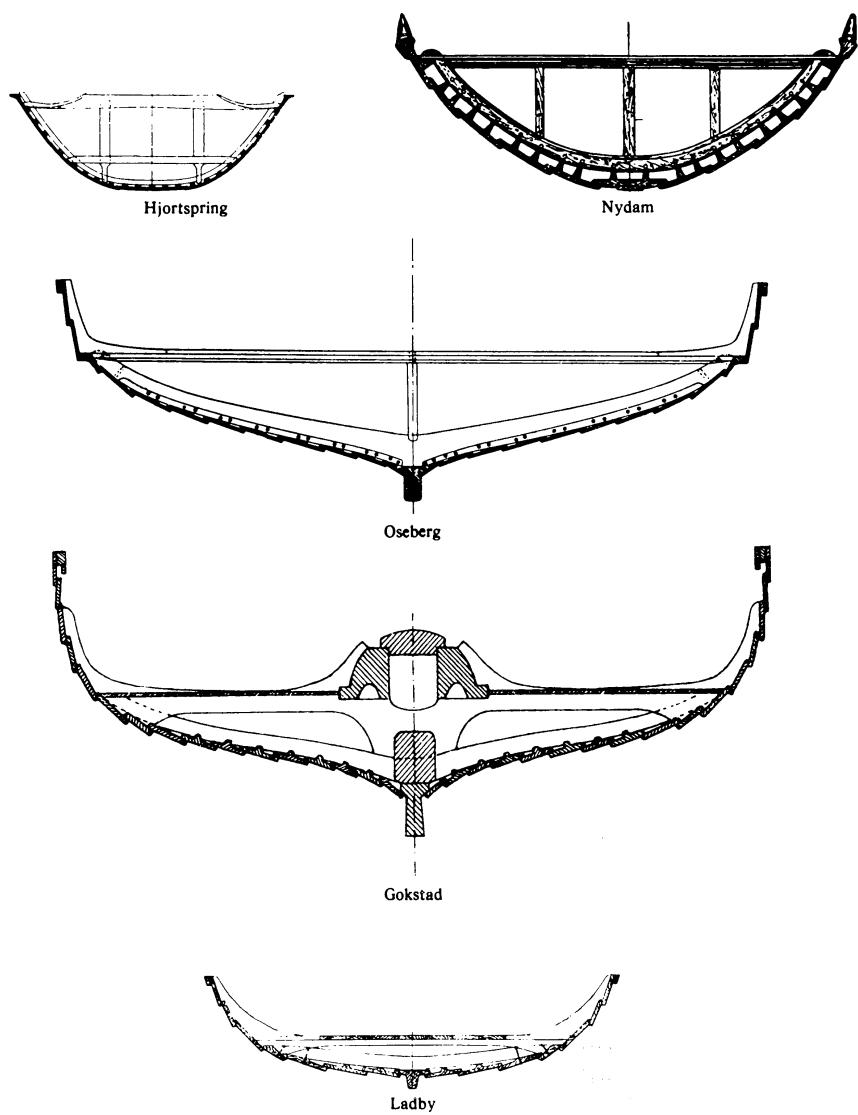
The Viking ship built originally for Scandinavian aristocrats was not the longship which was built after 1000. It was smaller and if anything more versatile. Knowledge of Viking ships is based on finds of partially preserved ships among others from Oseberg, Tune and Gokstad in Norway, Ladby and Skuldelev near Roskilde in Denmark and of an early or even pre-Viking ship at Äskekärr in Sweden. The rare illustrations from the years up to 1000 and information about ships and sailing

from the Norse sagas supplement the archaeological evidence. It is possible to distinguish two basic types of Viking ships. The better-known type is the warship, primarily a personnel carrier for coastal and short sea voyages, the finest example being the Gokstad ship. The other type is the cargo ship. Both shared the same characteristics of fine curving lines and double-ended pointed hull. They were both clinker-built. The warship, however, had a length-to-beam ratio of from 4.5:1 to over 7:1. For cargo ships that ratio was from 2.3:1 up to 5:1. The warship relied on oars for propulsion and on larger warships there was an auxiliary sail. For the cargo ship the sail was the source of power. The few oars at bow and stern, as with the English keel, were only used in special circumstances. The ship had higher freeboard to hold more cargo in the open space amidships. With warships freeboard had to be low to get an efficient angle of entry into the water for the oars.<sup>9</sup> For cargo ships the greater angle was no problem since the oars were rarely used.

Despite these and other distinguishing features which show up in the wrecks, the two types were just variations on the same design. This is obvious from the cross-section of the ship.<sup>c</sup> The keel had become a fully integrated part of the construction. It was heavy and full. Posts were scarfed to the keel at either end. From the keel clinkered strakes ran out in a smooth curve, almost flat amidships. Then the planks turned upward just at the top of the ribs. The angle is very sharp on warships and not so extreme on cargo ships. Running across the ship at that point and resting on the tops of the ribs are the *bites*. Above that was more planking reaching a heavier strake at the waterline called the *meginhufr*. Between these two heavy planks ran the cross-timbers separated from the *bites* by small posts. This combination of keel, ribs, planks and cross-timbers gave the ship its strength and stability and also its speed, since all the structural apparatus was very low. This also gave the vessel a shallow draught. It is the opposite of the Byzantine cargo ship which was a large box, an internal frame, covered with planking. The Byzantine ship as a result had a much greater carrying capacity than a Viking ship of the same length. To add some capacity the sides of Viking ships were built up with further planks, few for the warship and more for the cargo ship. These were clinkered and also attached to hanging knees which sat on the cross-timbers. The ship had a great deal of elasticity since strength came primarily from the external planking and compact internal frames. The ribs were there to keep the planking together but they were there also to maintain the shape of the vessel.

There is no question that Viking ships were of shell construction.

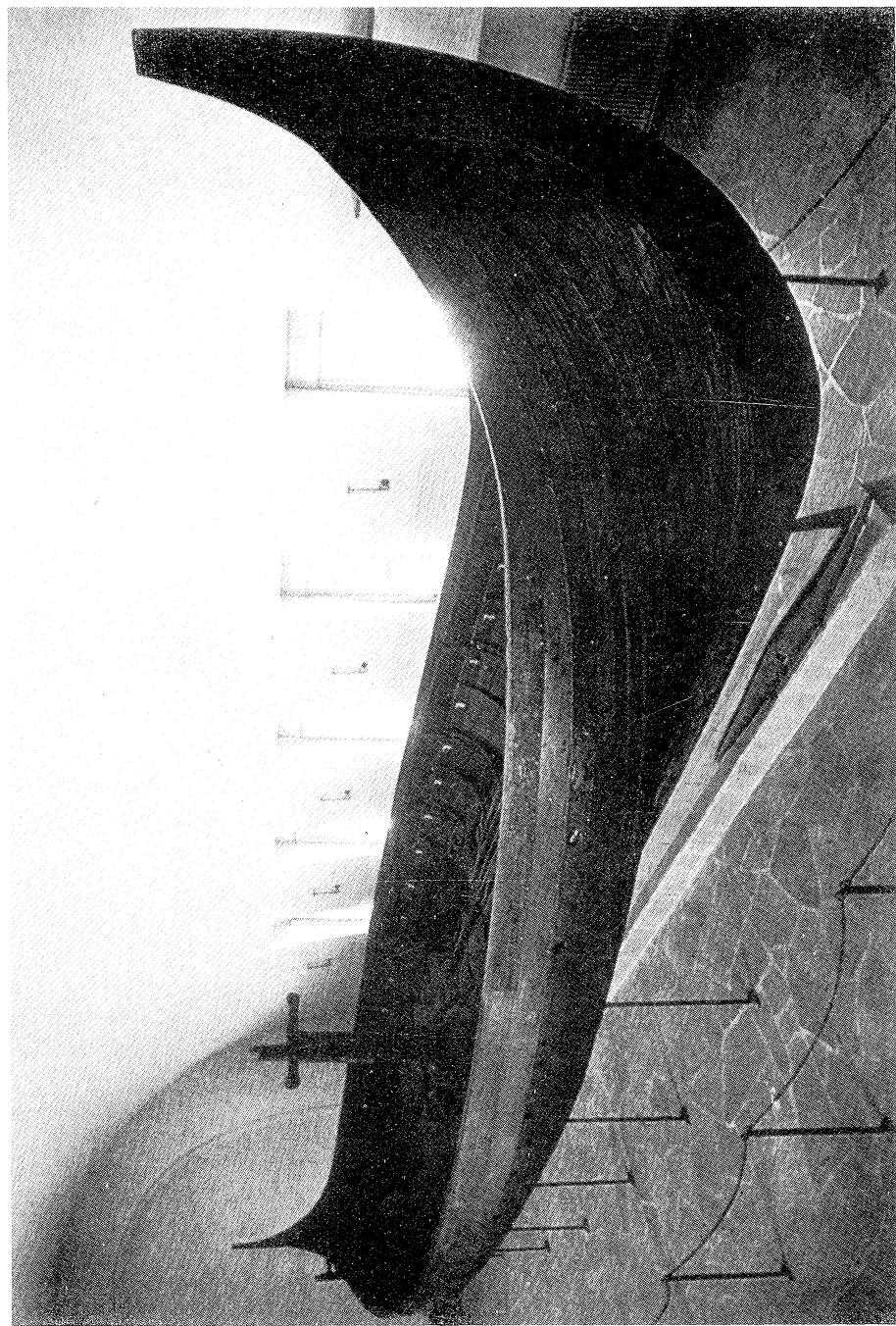
6: Midship Sections of Northern European Clinker-built Boats from the Hjortspring Boat (c. 300 BC) to the Ladby Boat (c. 1000)



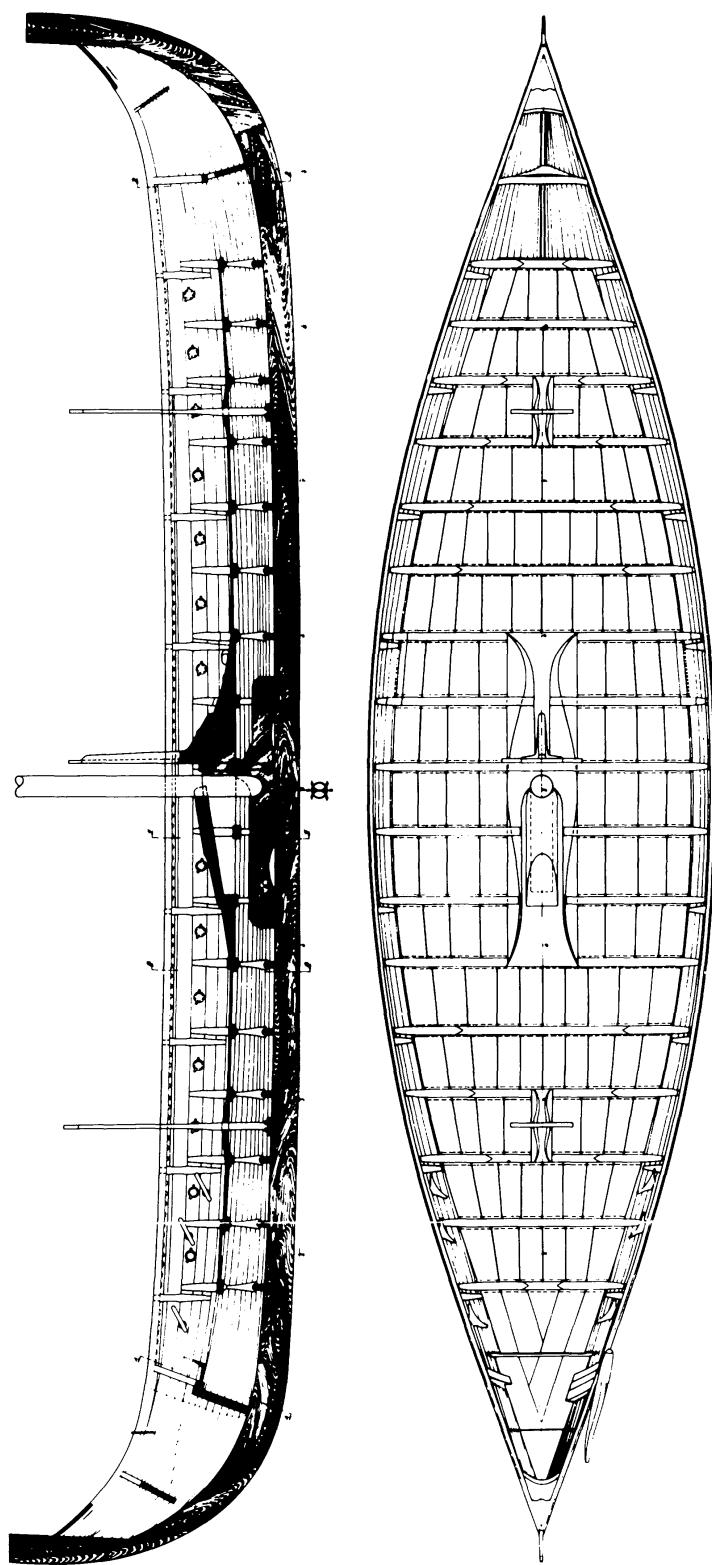
The keel was laid down first, the posts attached, and then planking added up to the waterline. The heavy *meginhufr* was riveted on and then the ribs and cross-timbers were put in place. Builders selected wood shaped as much like the end product as possible, thus keeping the number of joints to a minimum. Then the hanging knees and upper planks were added. Narrower planks led to the posts in a rising curve and above them were decorative pieces. The next step was to add the large block to hold the side rudder. A withy was passed through the rudder to hold it to that block and to the heavy frame at the stern designed to take the strain. These were balance Rudders and if the turning axis was right only the slightest effort was needed by the helmsman handling the tiller to overcome the friction of the suspension system. Since the ship was perfectly symmetrical the movement of the rudder turned the ship easily.<sup>d</sup> Experiments with full-scale models show that the helmsman with one finger on the tiller could overcome all the efforts of the rowers to get the ship to go in the opposite direction. Since the rudder extended as much as half a metre below the keel it was necessary to be able to raise it by rotating it on the large block of wood.<sup>10</sup>

Both types of Viking ship had the same form of rig but the arrangement for holding the mast was slightly different. In warships on top of the ribs amidships there was a large block of oak, a simple form of keelson, which was held in place by knees on its sides and by resting over the ribs. In this piece there was a socket for the base of the mast. It was rounded and open forward so that the mast could be slipped in. Above that and lying on the cross-timbers was the mast partner or mast-fish, a name given it because of its distinctive shape. The mast partner was the largest single piece of wood in the ship. These timbers were put in the ship as the ribs and cross-timbers were being added. The mast partner was held to the cross-timbers by two mortise and tenon joints. The hole in the mast partner corresponded to that in the heavy piece below and was open at one end. The arrangement made it possible to slide the mast through the hole in the mast partner and then swing it up. Once raised the mast was kept in place by a wedge which fitted into the open end of the mast partner. The system was much simpler and less dangerous than trying to raise the mast vertically. It was also quicker. On cargo ships the mast was held permanently in place by similar heavy pieces of wood. The height of the mast was probably a little more than half the length of the ship, the length of the yard a little less. That gave a sail with a small area relative to the size of the ship. The mast was held in place by a single forestay running to the bow and two

7: The Gokstad Ship, Preserved in the Vikingskipshuset, Oslo



8: Skeleton Drawing of the Gokstad Ship



backstays. The sail was square. To hold the sail close-hauled and keep it from flapping there was a spar on each side fitted in a small wooden block on the gunwale abreast of the mast and running to the opposite edge of the sail.<sup>e</sup> This *beitiass* compensated for some of the limitations of the square rig. It was possible using the two spars to change course without having to wait for the wind to change, apparently common practice even in the ninth century. Though Viking ships could go to windward, it was still probably much faster to row. Running before the wind, speeds of 8 knots were easily attained and a maximum of 11 to 12 knots was possible. The average on long voyages, however, was probably more like 3 to 4 knots.<sup>11</sup>

The Gokstad ship, dated about 900, is the best example of the warship type. The Tune and Oseberg ships from the ninth century are smaller but show similar characteristics. All these belong to that class of ships with 12 to 32 oars, private vessels called *karven*. The Gokstad ship had 16 strakes to each side. The cross-timbers were at the tenth plank and then strakes 11 to 16 were held in place by the hanging knees. Plank 14 was stronger and was pierced with 16 holes on each side for the oars. A small shutter over each oarhole ensured that water would not enter when the oars were not in use. A small slit in the oarholes made it possible to pass the oars out from inside the ship. The distance between the ribs was about one metre, which gave space to pull the oars since there was one rower on each side above each rib. By having oarholes freeboard could be greater thus giving protection from the sea when sailing heeled over, all without sacrificing power since the angle at which the oars entered the water was still low.<sup>f</sup> The Gokstad ship was built entirely of oak. There was a slight but even curve to the keel so that it drew .30 metres more amidships than at the stem or stern. The scarf joints of the planks were always pointed aft so that water and ice would be shed when the ship was in motion. Planks were held to each other by iron nails. The ribs on the other hand were lashed to projections left on the planks for the purpose. The ribs were not fastened to the keel. There was a rack along the gunwale to carry shields, 32 for each side but these were only hung there while in harbour to show the rank and honour of the ship. The mast was about 13 metres high, the yard 10 to 11 metres long, giving a sail area of about 70 square metres. The oars were about 5.5 metres long and small and narrow for minimum weight. Since this was a coastal vessel it was equipped with beds and tent poles for the camp which was made every night.<sup>12</sup> Three small boats were found with the Gokstad ship, the longest being under 10 metres.<sup>g</sup> These showed all the same features of construction as the large

ship, of course without the rig.<sup>13</sup>

The Tune ship, shorter than the Gokstad ship by some four metres, had about the same length-to-beam ratio. It also had the same thin planking to keep it as elastic as possible. The hull cross-section was different. The Tune ship rode lower in the water. The strakes were slanted more markedly outward so it would lie better in the water and also keep out spray when heeled over under sail. The Oseberg ship, on the other hand, showed in general a weaker build. This vessel was slightly beamier than the Gokstad ship. With only twelve strakes on each side, it had lower freeboard than the Gokstad ship.<sup>h</sup> There were 15 pairs of oars. It was probably more of a pleasure craft and not used in the hard conditions warships typically faced. The foundation for the mast was weaker than with either of the other two ships. In fact, it had broken under pressure and had been repaired with two large iron bands. In the Gokstad ship the floorboards were loose and only placed on top of the cross-timbers but those on the Oseberg ship were nailed in place. There was apparently not as great a need to get at the bilge where, on the Gokstad ship, equipment and food were stored. The Oseberg ship was also luxuriously decorated with fine carvings.<sup>14</sup> In all these vessels there was no place for the oarsmen to sit. Presumably they brought along sea chests with all their personal gear and moved those into place when it came time to row.

Warships found in Denmark at Ladby and Skuldelev show the same characteristics.<sup>i</sup> The Ladby ship dating from the mid-tenth century was more of a rowing barge than the Gokstad ship, since it had a higher length-to-breadth ratio. There were only seven planks to each side. Ribs were lashed to cleats on the planks in the typical fashion for warships. It did have a sail since there were four rings on the gunwales to hold shrouds. The Skuldelev warships date from about 1000. One warship was much like the Ladby ship and had a crew of only 24 oarsmen. The other, unfortunately not as well preserved, shows the tendency towards longer warships of the late tenth and eleventh centuries. At more than 29 metres long it had from at least 40 up to a possible 60 oars.<sup>15</sup> The structure remained the same but this longship marked a departure from the typical Viking warship of the ninth and tenth centuries.

Not as many cargo ships have been found. The earliest, the Äskekärr ship, dates from the end of the eighth century. Its length-to-breadth ratio was considerably less than that of the warships. It had the earliest maststep yet found on a Scandinavian ship.<sup>j</sup> There can be little question it was intended to be a sailing ship. It had a side rudder and 13 planks to each side. By 1000 cargo ships were longer than the approximately

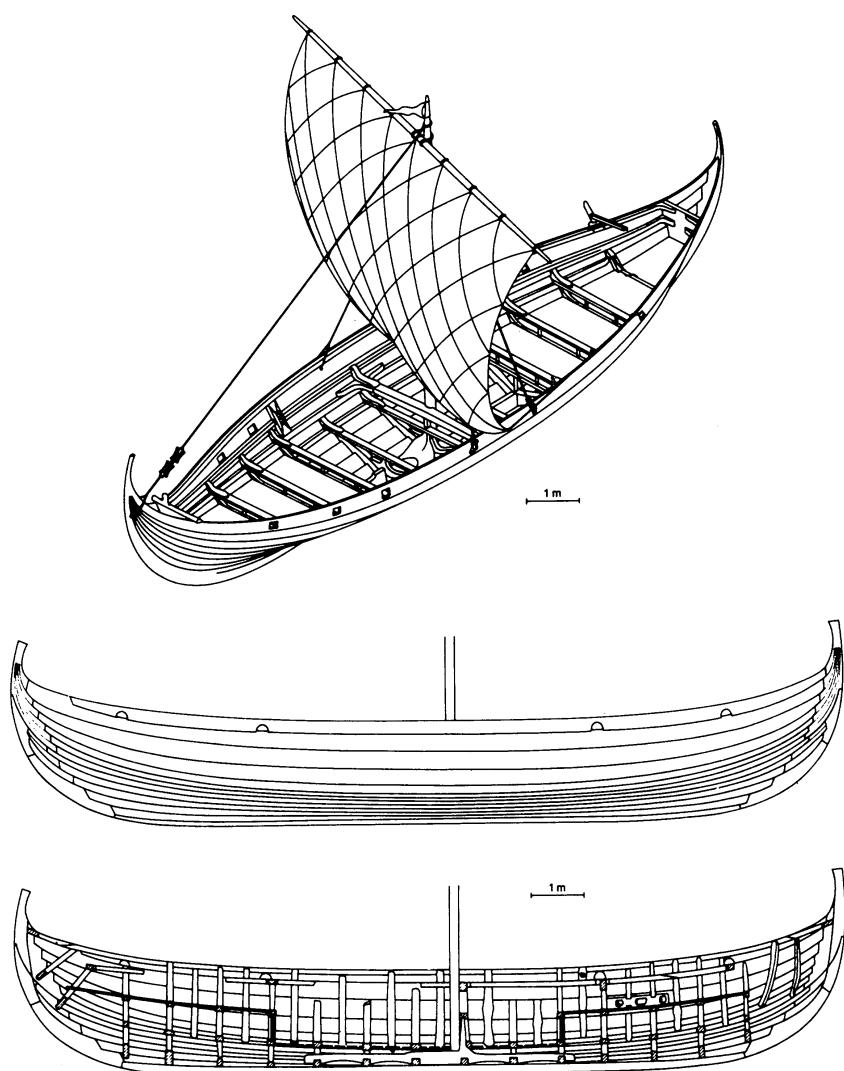
9: The Oseberg Ship, Preserved in the Vikingskipshuset, Oslo



16-metre length of the Åskekärr ship, and they were able to carry up to 60 people. This *knarr* type was not like smaller cargo ships which could only survive in the Baltic and North Seas. The knarr could make long-distance voyages in the Atlantic and it was regularly used for trips to Iceland and Greenland. Knarrs were used from 870 to carry colonists to Iceland. The typical cargo was 20 or 30 family members, their cattle, goods, fodder and furniture. Typically the knarr was a better sailor than the warship, having a deeper draught. There was no mastfish since the mast was permanently set. There were short half-decks at the bow and stern. The keel was flat or rather hardly curved. The capacity of knarrs was probably at least 10 tons and often higher. The large Skuldelev cargo ship had a capacity of 30 tons and knarrs travelling to Iceland must have been able to carry 50 tons. These were only some 25 metres long, not much longer than the Gokstad ship. The smaller Skuldelev ship, a cargo carrier for the Baltic, could handle only some 9 tons and had a crew of ten to twelve men. The larger Skuldelev cargo ship, the knarr, had a crew of twelve while for the largest ones used in trading to Iceland 16 was a logical figure. This gave them manning ratios much lower than for a warship but the same as, or more than, for a cog. One distinctive feature of cargo ships was the fact that frames, instead of being lashed to the planking, were held with wooden nails, treenails. This was the case in the Åskekärr ship, so the practice already existed by 800. It meant sacrificing some elasticity and lightness but for the cargo carrier neither was as crucial as strength.<sup>k</sup> The Skuldelev finds also show that the ribs or frames were set closer together, about .90 metres, than was the case with the warship.<sup>16</sup> The Skuldelev knarr shows that all the variations on Viking cargo ships still owed much to the open rowing barge. Cargo ships never had any cabin or permanent protection for the crew. For coastal trade and travel that was no problem but on voyages to Iceland conditions for the crew must have been hard.

The Viking ship, because of the improvements made over its predecessors, required more labour for its construction. Moreover, the labour had to be more skilled. Selection of timber was less crucial. Since planks were scarfed and pieced, a wider variety of trees could be used. Careful selection was still needed in finding timber, though, since the frames had to have the right natural shape. Once the timber had been collected more work was needed to form it into this type of ship than to earlier northern types. There was, in fact, a division of labour in building these ships, with one man in charge of the entire project while certain workers with special skills were given the job of finishing

10: Two Viking Cargo Ships from Skuldelev: Baltic Ship (top)  
and Seagoing Knarr (bottom)



certain parts such as the keel, stem and stern. Specialists must also have been employed to do the carving. Despite what appears in written sources, these men had a wide variety of tools. Their kit was well developed including axes, adzes, augers and gouges. They also had saws but only small handsaws.<sup>1</sup> The timber was not cut from logs. Instead the logs were split and then dressed to shape. On the Skuldelev ships marks show the use of axes and planes and other tools but no sign of a saw. The frame saw was known and used in the Roman Empire and such saws were used during the middle ages. Scandinavian boat builders did not use this big saw for ripping timber into boards, perhaps out of ignorance or, just as likely, they may have found sawn planks too weak for the job.<sup>17</sup>

If population was rising then there should have been no problem in finding a larger number of workers. Finding skilled craftsmen was, of course, more difficult. But as these shipwrights turned out a better product, since the invention of the unique cross-section arrangement of frames and timbers made their ships more productive, the rewards to these men could rise, thus making boat building an attractive job. The employer, the landowner and leader of the family group, for his own reasons was obviously very interested in promoting shipbuilding thus also contributing to better rewards for skilled ship carpenters. The promotion of design improvement by shipowners, combined with borrowing from other designs and the apparently independent invention of the shaping and support of the clinkerbuilt hull, all combined to expand the capability of Scandinavian ships. The Viking warship was faster than its predecessors, like the Sutton Hoo ship, and had the added potential of using sail power to get it to the scene of fighting. It was the advantage in fighting that brought the new design into widespread use, Vikings using these ships on their first raids on the British Isles in the years before 800. With the success of those first attacks Vikings made more and more frequent voyages, which gave them a chance to improve their sailing techniques and gave builders more opportunities to experiment with the designs. If the Vikings were not quite convinced about the superior effectiveness of their warship, they had a removable dragon's head at the prow to scare the enemy.<sup>m</sup>

At the same time as the Viking warship gave Scandinavians a superiority in fighting, the increased reliability, speed and range of the cargo ship also gave them an advantage in commerce. The simultaneous development of a cargo ship which incorporated all those beneficial features of the fighting ship meant that the Vikings could move goods at lower costs than had previously been the case in Scandinavia. Crew

requirements fell sharply with the adoption of sailing ships. The cargo ship did not imply a great loss in speed compared to the rowing barge. Luxury goods could then be moved marginally slower for a sizeable saving in costs. That made it possible to ship such goods greater distances out into the Atlantic, and still do so at a profit for the trader. The Vikings continued with the same trading pattern and goods as the Frisians. In fact some of their raiding voyages to the West may just have been voyages to get manufactures from the Rhineland. The Vikings added to the collection of luxury goods handled by the Frisians other luxury items from the East, from Persia and the Byzantine Empire, brought by river through Russia to the Baltic and then re-exported to western Europe. The Vikings sold furs and slaves from the North around the Black Sea for silver coins and the spices and silks of the Orient. They also traded in some bulkier goods. The capacity of 50 tons was enough to make economic the export of dried cod from Iceland by about 1000, thus saving the colony from disaster since to that time there was no export good and the balance-of-payments deficit with the Continent was impoverishing the settlers. The success of Scandinavian colonies in Russia depended less on improvements in ship design, that is once the basic *karv* had been developed, than on the internal political situation. Scandinavian trade routes stretched over such great distances were highly vulnerable to disruption.<sup>18</sup> The result of Viking voyages was to extend the realm of northern trade, to promote the full integration of Scandinavia into a northern trading network and to intensify trade within that network. The emergence of northern Europe about the year 1000 from the difficulties, political and economic, of the preceding 150 years was certainly a result of the end of raids by Vikings in their warships. But it was also a result of the ability of Scandinavians to turn their new type of vessel to commercial advantage.<sup>19</sup> Despite improvements in both the cargo ship and the warship and despite the advantage of the design, the Scandinavian type was still capable of only limited services. The warship had to be beached at night since there were no quarters for the crew. There was no protection for anyone on board on long voyages. The vessels could not sail in the winter. Skippers of cargo ships waited in port until they had a favourable breeze. Though cargo ships could carry up to 50 tons this was still not a very large payload. In the tenth century that did not present a problem but in the years after 1000 it became clearer that the essential design of the Viking ship was not capable of development into an effective carrier for the bulk goods of the northern trade.

At the end of the tenth century quays began to be built again in

northern Europe, for the first time since the end of Roman rule. This too was an indication that the Viking ship was not able to solve all transport problems. Viking ships were beached and goods then unloaded along a gangplank. The same was true with hulks and keels. Thus ports were typically an open piece of beach or shore without obstructions. To supplement facilities there might also be sledges and a windlass to help haul the vessel on shore.<sup>20</sup> The method was simple and predated Roman times.<sup>20</sup> Viking ships were ideal for this type of port facility. But so long as only that simple type of loading place was used, there was a limit to the size and carrying capacity of ships. A large ship could not be beached without taking grave risks. The cog with its flat bottom and without a keel could not use a simple beach, so builders could not experiment with that type built for waters with sandbanks and tidal harbours outside a limited area. The simple form of loading place made it hard to handle cargo and still keep it from getting wet. Time available for shifting goods was limited by the tides, and it took a great deal of manpower to move cargoes on and off ships. Quays appear in written records in the early eleventh century so presumably they were first built not long before 1000. In the course of the eleventh century quays were built in the major ports of the North and Baltic Seas, thus providing opportunities for moving more goods more safely and for building larger ships. Using a simple see-saw device – cranes did not appear until the thirteenth century – goods could be shifted in the same amount of time using fewer men.<sup>21</sup> Stevedoring became a less important task for sailors. With the introduction of quays, ships of the Scandinavian type lost one advantage which had recommended them. Designers no longer had to incorporate the ability to be beached into their ships. With that constraint removed it was to their advantage to pursue quite different designs from the Scandinavian type.

For southern Europe in the ninth and tenth centuries comparison with the North is almost impossible. The differences in ship design were dramatic and obvious in almost every feature: the steering system, the method and form of propulsion and the design of the hull and its supports. It was not the climate alone which made for this distinction. Differences were also generated by a dissimilarity in the demand for transport of goods and men. Certainly luxuries formed the most valuable portion of goods transported in both regions. But in the North these tended to be manufactures from handicraft industries in the region. In the South where such industries were more widespread there was less need to distribute these goods. The luxuries shipped in the South were typically the products of the Orient, silks and the spices

which could only be grown in south and southeast Asia. In general trade goods, even luxuries, were of higher value per unit volume in the Mediterranean than in the North. The conversion to using barrels for moving bulk goods, however, came earlier and more fully in the North than in the South. All these factors and the different political situation, along with the stronger influence of Roman designs, combined to make ships of the Mediterranean a collection quite distinct from those of the North.

The Byzantine navy continued to face the challenge of Muslim sea-power. The challenge might wax and wane but the Byzantine warships remained consistent in design. The naval and commercial situation changed much for the worse in 827 when the Arabs conquered the island of Crete, thus gaining control of the major sailing route from Egypt and the eastern shore of the Mediterranean to the West. This placed them in a position to challenge Greek commercial vessels in the Aegean, and increased the pressure on the fleets of the themes set up to defend the coasts. The loss of trade, much of it transferred to Arab shippers, meant less money available in the Byzantine Empire for the theme fleets and the Imperial fleet at Constantinople. This, in turn, led to a decrease in the ability of Byzantium to deploy adequate protection along the trade routes and along the coast. The cost and the size of the navy grew but the expansion was not enough to overcome the Arab strategic advantages. The Mediterranean became a no man's land between Christian and Muslim naval forces with Crete as a base for pirates. Greek shippers were forced to rely on local trade and the use of coasters. The smaller vessels which had become typical cargo carriers in the Empire in the years to 750 remained throughout much of the ninth and tenth centuries the standard cargo carriers. The loss of Crete led to the loss of Sicily by the Byzantines. It was impossible for the navy to command the waters around that important outpost. The slow conquest by Arabs from North Africa was completed by their capture of the naval base at Syracuse in 878. Losses in the West also meant loss to the Byzantines of trade in the Tyrrhenian and later even the Adriatic Sea. The longest trading voyages of the eighth century were no longer feasible. For Greek shippers the average distance of a voyage must have fallen sharply.

After 870 the Byzantines, realising the importance of the loss of Crete, embarked on a vigorous naval counter-attack. Their goal was to re-establish the old borders, to pacify the Aegean, assure communications by sea there and above all to retake Crete. The last was accomplished in 961. It was followed by the recapture of Cyprus and re-estab-

lishment of Byzantium as the arbiter of affairs in the eastern Mediterranean.<sup>22</sup> The naval expansion also led Byzantine builders to increase the size of their warships. The larger size of oar-powered vessels in the tenth century made an important contribution to change in cargo ships. The recapture of Crete required enormous effort from Byzantium. The 960 expedition against the island included the largest Byzantine fleet ever fitted out. According to contemporaries there were 100 dromons, 200 other ships of all types armed with Greek fire and 307 transports. Some of the warships had as many as 250 rowers. Some of the supply ships were equipped with ramps to disembark horses quickly. This massive fleet could be assembled and fitted out in part because of improvements in Byzantine naval administration in the second half of the ninth century. A new command structure was combined with a reinforcement of the fleets of themes and granting the themes more autonomy.<sup>23</sup> All these developments completed the system of naval administration which was founded in the seventh century. The stability in the administration and organisation of the navy was reflected in the tenth century in a consistency of design and in the greater maximum size of Greek warships.

Despite the reopening of the sea lane from the Black Sea to the West and despite the return to Byzantine dominance of the eastern Mediterranean, Greek merchants and shippers were not able to seize the opportunities which the navy had created. Native merchants certainly did not suffer from the recapture of Crete but the situation of the eighth century was not restored. Byzantium proved unable by force of arms to re-establish a dominant position in south Italy; thus one end of the trade route was not within the scope of the Byzantine restrictive trading system. More important, though, was the government policy or perhaps lack of it which allowed more and more of the trade of the Empire to fall into the hands of foreigners and especially those just at the periphery. The government concern with restoring borders and the need to fight border wars led to a policy in the late tenth and early eleventh centuries of ignoring the fleet and the protection of commerce. Byzantium fitted out a strong navy only sporadically, at times when good administration was combined with enough money in the treasury. The decline in commerce also meant a shortage of skilled personnel for the navy. As early as 910 the navy recruited Russians in sizeable numbers. Those Varangians supplied manpower throughout the tenth and eleventh centuries. All in all, the Byzantine Empire was relatively passive in long-distance trade and Greek merchants did not trade outside the Empire.<sup>24</sup> So the Byzantine success in retaking Crete created as many, or more,

possibilities for Italian as for Greek shippers and merchants.

In those circumstances as little improvement was to be expected in cargo ship design as in design of the ships of the Byzantine navy. The slow pace of development was another sign of the erosion of Byzantine maritime strength. There were instances of larger ships having an extra pair of steering oars at the bow to give a total of four.<sup>o</sup> The expansion in the control system was not matched by any change in the sails. One or two lateen sails, with three on the largest warships, was typical. The dromon retained its basic design. The variations were in size rather than in form. The *pamphyle* was the smallest combat galley with only some 40 men on board. The *chelandia* was a transport but descended from the fighting galley. It was a massive slow vessel, having four rows of oars with one row of benches above the other as in classical times and two men to each bench. The newest member of the family was the largest of the fighting galleys, the *pamphyilon* or big dromon. The measurements were much the same as with earlier dromons, with length and draught only slightly increased. It carried more than 200 and as many as 300 men, was well armed and despite that was still faster than other galleys. The hull was more built up, thus improving seaworthiness and reliability. The higher sides were to accommodate the extra row of benches for rowers. Thus there were 56 to 60 benches on each side. There were only a few of the two large types in the fleet but vessels on this scale were needed in the campaigns mounted against Crete for a half-century before it finally fell. The sheer size of these ships was impressive and Byzantines used that fact to gain diplomatic advantages.<sup>25</sup> By 1000 the naval forces of the Fatimids of Egypt had at least been able to check Byzantine naval power. The result was a stability of relationships, a stability in the navy and naval administration and a stability in ship design.

The Byzantines had to face another threat at sea, this one from the Russians in the Black Sea. Because of the volume of trade and the size and character of the population of the Black Sea littoral this challenge did not generate anything like the problems of that from the Arabs. The Russians probably used vessels of Scandinavian design, specifically the *karv*. Russian armadas attacked Constantinople four times between 860 and 1043 but they were able to mount such an assault only when the Byzantine navy had been weakened in action elsewhere. Still, the threat from the north further complicated Byzantine naval defence and required the maintenance of a flotilla of small, highly mobile galleys to patrol the Black Sea. The Russians, like the Vikings in northwestern Europe, were divided on whether they were interested in plunder or in

trade. Typically, attacks against Byzantium were followed by the renewal of trading arrangements. Russian naval strength was, after all, based on exactly those ships used to carry goods along the rivers north to the Baltic. In any case, it appears that Byzantine shipbuilders had ample opportunity to see the building style of northern Europeans. Scandinavians trading and fighting in the Black and Mediterranean Seas, both for and against Byzantium, had ample opportunity to observe the design of southern ships. Despite that, the two approaches to ship design remained distinct.

By the end of the tenth century the shortage of timber had become an acute problem for the Arabs. The loss of Crete and, soon after, Cyprus to the Byzantine Empire was a major factor in denying them supplies of shipbuilding timber. The attempt by the Fatimids to dominate the Mediterranean, their attacks on Byzantium, on Italy and on Spain in the ninth and tenth centuries, all increased the demand for ship timber. The contest over Crete in the middle of the tenth century, leading to the use of larger ships, placed an even greater strain on already stretched supplies throughout the Muslim world from Mesopotamia to Spain. The control of the principal east-west trade route in the Mediterranean had given them access to stores from Sicily and North Africa, including iron and timber; it meant expansion of the merchant marine, a source of skilled manpower for the navy and a prosperity which was a source of finance for the navy, and it also meant a greater demand for wood. Even during the period of their naval dominance in the ninth century Arabs were forced to import wood from Italy, Dalmatia and Anatolia. Crete itself was a major source of timber, supplying cypress for building galleys on the island and in Egypt, and it was also the centre of the wood trade. When it fell to Byzantium the Muslim position became critical. Recognising this, Byzantine emperors tried to prevent the export of timber and other naval stores from the Empire and from Italy through Venice. Though the embargo was only partially effective it certainly served to aggravate Muslim difficulties. Areas which had been sources of timber in the seventh and eighth centuries increasingly showed signs of deforestation. Transhumance, introduced in some cases by nomads, contributed to deforestation in many areas. Government efforts to control the cutting and use of the limited timber supplies in areas of greatest shortage, for example in Egypt, did not solve the problem of precariousness of supply. The reconquest of Crete and of Cyprus and of northern Syria by the Byzantines meant that Egypt, the naval centre of the Fatimid Empire, was reduced to importing wood all the way from India and smuggling

contraband wood from Venice.<sup>26</sup> High prices were the result of those difficulties and led to the decline of Fatimid naval power in the late tenth and eleventh centuries. Presumably at the same time, there was a decrease in the number and size of commercial vessels. Muslim builders had generally built ships larger than those of the Greeks. They probably had little trouble in scaling down those designs to comply with the change in demand since the vessels used by Muslims in the Indian Ocean, while similar to those of the Mediterranean, had always been smaller.

Shipwrights in the Arab states, however, failed to overcome, through design change or through invention, the shortage of wood supplies. Losing a source of a major raw material has often proved to be a force for directing technical change into efforts to save or replace that good. It did not happen with the Muslims or for that matter with any other builders in the middle ages. Technology in related fields had not reached the point of presenting a viable alternative to wood for hulls and masts. At the same time there were always builders — in the case of the Muslims it was Italians — who had abundant sources of wood and who could use that advantage to offer vessels at lower prices, thus creating a fall in orders for builders already short of timber and so decreasing their chances for developing designs which would save wood. Marginal savings could be made, of course, but those would lead to increased risk and at some point the probability of loss would outweigh any saving. The easiest way to save wood was to build larger ships, thus decreasing the amount of wood required for each ton shipped. There were two problems with that solution. First, the conditions which accompanied a wood shortage were exactly opposite to those which promoted construction of larger ships. A decline in the volume of commerce, the loss of major long-distance trade routes and the presence of many ship-builders looking for work for their yards, all decreased profitability and the likelihood of the construction of large ships. Second, larger ships typically had to be built from larger trees to get strong enough frames. Generally a wood shortage meant a shortage especially of just those bigger, taller and thicker trees. Moreover, in the middle ages the loss of a supply of a raw material did not, as in the last two centuries, occur in a short period of time. Governments could not close off supplies instantly and wars were not so general as completely to stop the movement of goods. Egypt, after all, was still able to import wood from Dalmatia through Venice and from India and that mitigated against the pressure to change designs. Slow deterioration does not apparently have the same effect on technicians as a sudden shock. Throughout the middle

ages the loss of wood supplies or the long-term increase in the cost of such supplies formed the one problem which builders and designers never overcame. Invention never allowed shipbuilding to escape from reliance on abundant supplies of wood. The deterioration of supplies led, with the rarest of exceptions, to the deterioration of shipbuilding. It was a recurrent pattern in medieval Europe and the Renaissance.

The re-establishment of Byzantine naval strength and the decline of the Fatimid navy were in part the cause of a change in the character of piracy in the eastern Mediterranean. The western part of the sea did not completely escape the shift. Throughout the tenth century piracy usually meant coastal raids. Ships were used to carry men to the district selected, the men disembarked, carried out their raid and returned to the ships. The practice of descending on the coast not only damaged shipping and commerce but also led to the impoverishment of many areas along the shores. The fleets of the Byzantine themes were originally set up to meet precisely that threat. The original Arab fleets, especially in the western Mediterranean, were pirate flotillas. The effectiveness of the Byzantine navy in dislodging pirates and in protecting the coasts, combined with a declining interest among Arabs in what was, at best, a dangerous profession, turned piracy after the tenth century from coastal raiding into the more familiar method of attacking ships at sea. The Muslims were apparently the first to make the change. It made piracy easier and, if commerce was lively, more profitable. The process was a slow one but change did present entirely new problems to governments, shipbuilders and shipowners.<sup>27</sup> Defence against piracy became more complex. The coast-guard fleets of the Byzantines lost much of their value. Pirates became by definition involved in sporadic activity. Their ability to strike at almost any point at almost any time left governments without effective methods to deal with them. Coastal raiders had often stayed for some time sweeping the countryside so it was possible to reinforce local defences or bring up reserves to trap the pirates. Such options were no longer open. For shipbuilders defensibility of ships became a more pressing requirement. The two simple solutions, increased size and increased speed, were seemingly contradictory for sailing ships, but this was not necessarily the case. Large crews which could fight off attacks became more of an advantage, and contributed to the trend towards larger galleys. Longships were kept in use for carrying goods which could not be called luxuries. A galley was, after all, much more manoeuvrable and defensible than a sailing ship with the same capacity. For shipowners there was a significant addition to costs, as they had to use ships which were larger than needed for the

job or retain a crew larger than needed to handle the vessel or simply pay bribes to pirates when they came alongside the ship threatening to take it. The response of using larger galleys was apparently typical also in the western Mediterranean.

The design of ships there continued to follow Roman and earlier Byzantine traditions. Venice, for example, the most successful port in the western Mediterranean in the ninth and tenth centuries, was still legally a part of the Byzantine Empire. Though political ties loosened over time, the commercial ones increased. In the years from 900 there were signs of a general expansion in the commerce of towns in the western Mediterranean, and, more than that, of a counter-attack by seamen from certain Italian towns against the naval power of the Muslims. The economic and naval difficulties of Byzantium while Crete was in Arab hands gave Italian merchants and pirates an opportunity to make inroads into traditionally Greek trading areas. The Italians, and especially the Venetians, did not hesitate to trade with Muslims and over time they were able to establish themselves as the intermediaries of trade between the eastern and western Mediterranean. After 961, despite the capture of Crete, the Byzantines found themselves relying on Italian merchants and Italian towns to handle their trade with the West and to maintain contact with the Muslim markets.

The towns of the Campanian coast of Italy were from the early ninth century involved in fighting and trading with Muslims in Sicily, and were forced into a policy of destroying Muslim pirate nests when they were established on the Italian mainland. The next step was to attack Muslims on the islands of the western Mediterranean and along the African coast. Towns further north, especially Pisa and Genoa, became most active in that fighting in the tenth century. They acted like traditional pirates descending on coastal districts. All this contributed to the development of indigenous naval and commercial strength, something which Byzantium found it could not control.<sup>28</sup> Even though the Greeks lost the carrying trade to Italian shippers, Byzantine industry, agriculture and trade were as prosperous as ever in the past, thus giving shippers more goods to carry.

Since towns like Pisa and Genoa were committed to piratical attacks against the Muslims they used warships — warships like those of the Byzantines. Venice too, because of problems with pirates in the Adriatic, found it had to maintain a navy. The ships used by Venice were of the larger type like the *pamphyilon* and the *chelandia* developed in the East in the tenth century. These bigger galleys had a more extensive superstructure, something like castles built up above the decks, which allowed

marines to fire down on the enemy. Greek fire and heavy catapults were apparently not used as naval weapons. Simpler spears, rocks and arrows were the standard missiles. Rig remained the same: two masts each carrying one lateen sail. There were two banks of rowers and the arrangement of rowers was the same as in the earlier dromons. The ports on the west coast of Italy, at least in the eighth century, did not deploy dromons like the Byzantines, so they were probably still using galleys of the Roman Liburnian type. By the tenth century, however, they had adopted something more like the typical dromon design but lower, wider and faster. The development and extensive use of these larger types gave Italian towns, and especially Venice, a naval advantage over Muslims. It allowed her, over time, to pursue a policy increasingly independent of that of Byzantium. The larger warships also offered examples of a type with greater carrying capacity which could be turned effectively to commercial use with a minimum danger of piratical attack. Though the inspiration for these larger galleys may have originally been naval, generated by the contest between Byzantium and the Fatimids, it was turned to the greatest advantage by Italian traders to carry their increasing share of the east-west trade through the Mediterranean. Such vessels are mentioned as carrying 1,000 men and more and, therefore, when they were not fitted out as warships, there was certainly space for a sizeable cargo.<sup>29</sup>

As commercial vessels these ships served to bring back luxuries from Byzantium and especially from Constantinople itself. Along with the spices of the Orient the Italians brought back manufactures from Byzantine shops and agricultural products not easily acquired in the West. The West sent timber, iron and slaves in exchange but that was probably not enough to cover the cost of goods imported from the East. Given the relative value of the goods, most ships probably left the West filled and returned with a good deal of empty cargo space. There was another trade added to these, that in pilgrims. The idea of religious pilgrimages was already established in Latin Christendom in the sixth century. But it expanded in the tenth century, in part thanks to a general religious revival and the emphasis placed on pilgrimages by the monastic reform movement of the Cluniacs. Pilgrimages were no longer limited just to Compostella in northwestern Spain or to Rome, both usually reached by land, but were expanded to include the ultimate in pilgrimages, that to the Holy Land. The Muslims who held the Holy Land did not object to such pilgrimages and in no way tried to prevent them. The groups of pilgrims were large and the total number of trips grew over time. The new larger galley was well suited to carrying these

people. Its speed was an asset since the health of everyone was at risk at sea. The longer one spent on the voyage the greater was the likelihood of disease. The vessels still stayed close to the coast, moving only cautiously into open water. The masters needed landmarks to guide them and with such large numbers of people on board the ships had to stop at night.

The pilgrim trade added the final element to the basis for Italian commercial expansion, expansion which would continue throughout the thirteenth century. The growth began in the context of maritime disorder, of piracy and war at sea by rival powers seeking the support and aid of the Italian towns. Faced with this atmosphere of disorder the Italian port towns and more specifically the shipbuilders in those ports borrowed designs which were best suited to deal with naval action. They had the basis of known designs and they could borrow design features from other parts of the Mediterranean. But the need for effective fighting ships set stringent limits on their ability to borrow and to develop ship types.

Mediterranean shipbuilders converted to carvel-building. The carvel-built ships retained the edge-to-edge planking typical of Roman ships. But first tentative steps taken in the sixth century towards greater reliance on internal structure for support of the hull by 1000 had changed to almost complete use of the frames to give the ship strength and form. The planking was then just a covering to keep the water out. The change was exclusive to the Mediterranean Sea. Some ships were only partially carvel-built, where the shell had some vestigial function in protecting the vessel and holding its shape. Undoubtedly Mediterranean builders gradually, through experiment, moved towards complete skeleton construction. A ship excavated at Serçe Liman off the coast of Turkey and dated 1024/1025 shows no sign of the old Roman technique of mortise and tenon joints to create a stiff hull. Rather it had heavy frames and light planking attached to them with nails or small treenails. The vessel was a sailing ship of moderate size, about 17 metres long over all. In 1000 not all ships built in the Mediterranean were of pure skeleton build but by that date it was clear that carvel-building would be the typical construction method for all vessels beyond the smallest in that part of Europe. The skeleton system was unique to southern Europe, developed there and diffused from there. At least Mediterranean carvel-building had moved to the stage where after the keel and posts were fixed many, if not all, of the frames were set up. They were then connected to each other and to the posts by one or two heavy side planks, wales, running the length of the ship.<sup>p</sup> Then the hull planking was added.<sup>30</sup>

Skeleton construction started at least by the early years of the Byzantine Empire. It was impossible to support the many highly skilled workers needed to build the fine piece of furniture that was a Roman ship, so the Roman construction method was gradually abandoned. It was not necessary to give up shell construction completely because the demand for shipping tonnage fell. The loss of skilled ship carpenters did not press the adoption of extreme design changes to save labour. In the second half of the tenth century the volume of trade, at least in Italy and to some degree in Byzantium, did rise. Shipbuilders then faced a demand for a larger number of ships. That alone might have put pressure on the available supply of skilled ship carpenters. Added to it, however, was the need to build the ships more quickly to meet the needs of sporadic naval campaigns and, equally important, there was a demand for bigger ships. The greater size in tonnage and also in height out of the water meant that designers had to find a way to support the bigger unit. The solution was to move fully to the use of the skeleton to supply strength. For skeleton-building the shaping of the keel, posts and frames required skill of the highest level. The addition of the planking, on the other hand, could be done by carpenters with less knowledge and experience. The latter work was relatively simple since the frames gave the form. The planks, after being cut to shape, were nailed to the frames. Strakes were scarfed so mistakes could be corrected without great difficulty. This led, in the course of the eleventh and twelfth centuries, to a division among ship carpenters, with some retaining the status of designers of ships and others being relegated to more repetitive tasks. This latter group must have been relatively easy to generate since population was rising and the training period for such men did not have to be long. With edge-to-edge hull planking and with no connection between the planks, the ship had to be caulked, caulked well and caulked again at regular intervals. This maintenance work could also be handled by men with lesser training. The same was true of the replacement of planks which had been attacked by the shipworm. The change in construction from the Roman method meant a big saving in the labour costs of building a ship. Weighed against that were rises in the cost of maintenance and probably an increase in risk. This change to skeleton-building was a sign of greater technical skill, of an ability to develop an alternative type of construction suited to the immediate demands of shippers. It did not show a technical superiority to Roman shipbuilding, however. After all, the Italians of the tenth century were not called on to build cargo ships anything like as large as those of the Romans.

Skeleton construction was used for sailing ships as well as for galleys.

The round ships used in the Roman and early Byzantine Empire had their descendants which were used primarily for the carriage of bulk goods. The much lower length-to-beam ratio compared to the galley gave the type its distinctive shape. There was a pair of steering oars and one mast with a lateen sail. In general these vessels were used over short distances; they also stayed small. That is not to say that the total volume of bulk carriage was insignificant. Rather, these types relied on frequent trips rather than a large hold to keep up the volume of goods moved annually. Expansion in total output, an increase in demand for tonnage and the example of the larger size of naval vessels contributed to a probable increase in the average size of these round ships. But they still remained far below their maximum potential size, a potential which was increased by the adoption of skeleton construction.

The form and character of demand for ships was different in northern and southern Europe. Shipbuilders faced different requirements in the two parts of Europe and so the ships they built evolved along distinct paths. There were similarities in some of the results. Since all shipbuilders sought to increase the capability or efficiency of the vessels they built, the outcome of better designs was to expand the economic possibilities. The rise in the value of trade, usually accompanied by an increase in volume, led directly to an improvement in total welfare. But the character of design changes had some effect on how that improvement was distributed.

The Viking ship was the product of the demand of aristocrats, of Scandinavian landowners, for a vessel which could do everything that contemporary coasters and fishing boats could do plus have the capacity to carry their kinship groups. The vessel produced for them satisfied those needs and more. The Viking ship was effective for trading and for raiding. The success of the first raids increased the tempo of such operations against western Europe. In the East the success of the first trading expeditions into Russia had the same effect of promoting the use of this type. The Vikings started out as amorphous groups of pirates or traders but after their first successes they began to have some cohesion. More important than that, the unit of operation of these men became the group in the sailing ship; this was the effective fighting or trading unit. It was the mutual reliance of these men in each vessel which gradually took precedence over the mutual reliance of the kinship group. A naval or military unit replaced the family unit, and meant a deterioration in the power of the aristocrats over their relatives and especially over dependants who worked on or near their lands. The naval power which came with the improved ship brought about the

establishment of some naval organisation. That organisation was not based on the independent action of aristocrats, however, but on the action of ships, of units of a naval force in the service of some monarch. The embryonic Scandinavian kingdoms which had emerged by 900 did not owe their existence to the design of the Viking ship. But the ability of the kings to mobilise forces to defeat powerful aristocrats and to contest for the loyalty of their followers did depend on the way fighting and trading were carried on with that vessel. By the end of the tenth century Viking attacks were not the piracy of independent free-booters but rather raids organised and directed by a monarch as part of an over-all political strategy. This change derived in part from the unique development of Scandinavian ship design in the eighth and ninth centuries.

The construction of ships became more complex. This was most noticeable in western and northern Europe where the entire business of shipbuilding and also of shipping took on some of the attributes which had long been familiar in the Byzantine Empire. The larger number and larger average size of ships and the longer distance of the voyages contributed to changing what had been a simple matter into an operation involving many people in different capacities. Trade at sea and, more important, the maintenance of a naval force now required more personnel, more skilled personnel and an administrative apparatus far beyond the capabilities of western European governments of the seventh and eighth centuries. Governments of states with a coast or governments of politically independent towns had a new task to perform, to protect and defend their shores and their merchants' ships. Many of the new governments, for example the increasingly localised governments of France, failed to take on the task. But governments such as the English monarchy, the monarchies of Scandinavia and especially a number of Italian port cities found that maritime operations and naval power were an integral part of their existence, their welfare and their prosperity. Albeit tentatively, they developed some kind of naval policy. They emerged with governments noticeably different from those of states tied just to the land. The political units with maritime connections had different sources of income, different types of expenditure and a different perception of their function as governments, all of which made them more than just givers and enforcers of laws.

The increase in the percentage of the population living in towns, a trend which became clear by the end of the tenth century in western and northern Europe, was a logical result of the improvements made in

ships through the eighth, ninth and tenth centuries. The Viking *karv* and the knarr made possible profitable trade from Scandinavia to the Near East and into the North Atlantic, to Iceland, Greenland and North America. These trading connections were highly fragile. The volume of trade was small. The goods, be they silver coins from Persia or white falcons and polar bears from Baffin Island, were of high value and could rarely form the basis for a continuing trade in bulk. The nature of the trade and the long distances involved meant these routes were highly susceptible to changes in weather and the more expected changes in the political climate. Despite that, they did expand the scope of trade and of European trade goods. That extension at the geographic margin led to the intensification of trade at the centre. The ships built in the ninth and tenth centuries were as efficient or more efficient in terms of annual costs to move a ton of goods than were their predecessors; this led to an increase in the volume of trade in the North. There is every indication that the volume of goods which changed hands in the Mediterranean also increased, even if some of those goods were originally seized by force by Italian or Muslim pirates.

The extension and expansion of trade allowed for greater specialisation in production or at least created the possibility for farmers or manufacturers to find a market for any surplus they might produce. Shipping was not inexpensive enough for consumers to rely on long-distance transport of essential supplies. Those were still produced within small regions. On the other hand, there was an opportunity to expand any specialist local production, such as the manufacture of glass or of woollen or silk textiles. Those industries then found it to their advantage to be located in a port or in a town easily accessible to water-borne transport. In the tenth century there is some evidence that industry inland which relied on local markets and transport overland declined relative to industry near the coast.<sup>31</sup> While, in the Mediterranean, industry had never become as localised as that in northern Europe, there is still some suggestion in the growth of ports like Venice, Amalfi, Pisa and a number of others that the process there was similar.

Towns along the shore could not grow when they were under constant threat of attack from pirates. A city the size of Constantinople, which was sure to be defended by the government, was not in danger. But for most towns, and especially smaller port towns, there was a good chance of being raided. The situation was the same along shorelines held by Christians or by Muslims since both sides indulged in piracy. It was impossible to defend most ports since they lay in the open and were often surrounded by hills. The only way to protect the population

was to hold that high ground. The simple solution, and one followed through much of Italy, the Balkans and Asia Minor, was for people to move to the hills and protect themselves behind fortress walls. The change in the methods of piracy after the tenth century decreased the direct threat to the stability and safety of life in smaller ports. The change in political circumstances, along with the development of ships which contributed to that change in piracy, created an opportunity to return to a secure life for many urban dwellers. Such towns could expand since town sites did not have to be periodically abandoned. It was the same kind of movement back to the shoreline which was simultaneously promoted by the economics of shipping. In northern Europe the depredations of the Vikings were similar to those of Arab pirates. Certainly these attacks did not help urbanisation at ports such as Dorestad, which Vikings raided and burned until it was no longer worth bothering with. Still, the Vikings, because of their interest in trade, did generate urban centres within Scandinavia. The Vikings did bring towns to Ireland where they had not existed before. Moreover, the general economic recovery in the North in the second half of the tenth century and, more important, the change in the character of Viking attacks from hit-and-run raids to the organised deployment of forces for political gain gave something like the same result as that in the Mediterranean, that is after the tenth century.

Port facilities improved throughout Europe. Not only were quays built again for the first time in the North since the Roman withdrawal but also harbours were restored or improved in the South. Town governments such as those in Italy, realising the importance of trade to their prosperity, devoted more effort to keeping up docks. Private individuals could and did do the same. Throughout western Europe by 1000 there was a turnaround in the quality of ports. The process of deterioration and simplification was checked and a start was made on improving facilities. Mediterranean ship types were well suited to quays but they could also be beached and then unloaded and loaded. This had all the same problems of inefficiency as in the North. The lack of tides in the Mediterranean meant that the ship had to be hauled out of the water – effort which could be saved by using quays. The improvement of port facilities was a logical concomitant of larger towns, of the tendency towards urbanisation. At the same time those facilities could act to draw ships and trade to a port. The greater concentration of population in port towns, the concentration of trade goods and merchants in those towns and the better facilities for the exchange and shipment of goods, all meant that shippers could find a cargo more easily. The time spent

in port could fall and so the total quantity of goods moved annually by a ship could rise. That implied a saving to the shipowner and a saving to society in total resources needed for a given quantity of transport. The trend of the years before 750 had then been reversed. The trend became clearer after 1000.

The choice of carvel-building for ships by Mediterranean builders and shipowners did not decrease the number of shipbuilders. Rather, over time, it increased the need for men to carry out the more frequent repairs. The absolute and relative rise in the number of shipbuilding workers in port towns made the industry more important to the economy of ports. Moreover, shippers had to use ports where they could be sure of finding men to do repair work. Certainly, a skipper along with his crew could do much of the periodic caulking and the irregular repairs to a ship. He could still use small ports or the beaches for docking. But there was clear pressure on skippers to use ports with repair facilities, ports with a body of men able and available to do caulking and repair work. There was, then, a long-term trend towards the concentration of trade in larger ports, a tendency which was by its nature cumulative and self-reinforcing. The improvements in design, the extension of trade routes, increased specialisation in production, the changing character of piracy, the move to carvel-building in the Mediterranean, all contributed to an increased urbanisation. The development of towns and the concentration of population was not so much because of the increase in total production and total population but because of the rise in the total quantity of goods carried by water. Agriculture could never generate urbanisation on a sizeable scale. Commerce on land was too flexible to force the concentration of people into specific locations with specific geographical features the way seaborne commerce did.

The larger galleys of the western Mediterranean in the hands of Italian merchants and skippers proved to be profitable carriers of goods. The expansion of the total volume of trade and the effective naval action which drove Muslim naval forces and pirates back from the major sea lanes contributed to the greater possibilities for successful, that is profitable, shipping operations. Investment in shipping, which meant principally an investment in the ship itself, therefore rose both absolutely and relatively. In northern and southern Europe, but especially in the South, there was an alternative to investment in land. That is not to say that there was no investment in ships before the tenth century. But in previous centuries the money was usually raised by the skipper himself and possibly with the help and co-operation of a merchant. The new-found profitability of trade in Italy drew in a new group

of investors, men who otherwise had nothing to do with trade or ships. Traditionally their investment had been entirely in land. Land remained for them and for the economy in general the overwhelming stock of productive capital. The alternative of investing in commerce was, in part, because of improvements in ship design. It was an attractive alternative in terms of immediate return and potential return since possibilities in shipping were certainly expanding more rapidly than in agriculture. The development of the Viking ship had a similar effect but with the added result that the landowners became not only owners of ships but also active in their operation.

The development of improved ships allowed for the diversification of investment by the rich, especially noticeable in Italy. This served to lessen the division between merchants and landowners. In northern Europe professional merchants had been attached to a single nobleman or monastery and acted as the supplier of goods for that specific consumer. The consumers had little part in the operations of trade. The distinction decreased through the ninth and tenth centuries. It was never as extreme in southern Europe but any indication of such a separation economically and socially was further eroded by the introduction of landowners as passive investors in ships and in trading ventures. Landowners then became involved in the same activities as merchants. Merchants presumably seized their earliest opportunity to join in the same activities as landowners by diversifying their own investments into land. In northern Europe there emerged a body of professional merchants, men who devoted their full energies to shipping and trade. They were not tied to or supported by one specific customer. They were not part-time farmers who did some sailing and trading in the summer to supplement their incomes. Their operations took on a new permanence. That professionalisation of traders undoubtedly existed in the South, indeed it may never have disappeared through the early middle ages. But the improvements in ships, the growth of trade and the participation of other investors all served to intensify the professionalisation of merchants, to make their function more important and to improve their own position both socially and politically. That pattern became more obvious in the following 250 years.

The increased capital requirements and the participation of landowners generated group ownership of vessels, and thus distributed the risk. Part ownership, the division of ownership among a number of shares, 8, 16, 32, was known in the Roman Empire so it was not a novelty in the middle ages.<sup>32</sup> It was little used in the early middle ages, however, because of the small scale of investment. The rise in risk

relative to Roman ships increased the need for such a division of ownership. Even stronger pressure came from the need to raise greater quantities of capital. Ships were never cheap but the increasing size of cargo galleys in the tenth century made the need to find new sources of financial support crucial to successful shipping operations. The general result was a broadening of investment to include more people and people with more different types of income and wealth. This was more and more the case as ships became more expensive and the number of ships increased. It is perhaps easy to overemphasize the importance of investment in ships relative to land or to armament on board or to cargoes. The point, however, is that investment in ships rose over time and an increasing share of all European investment went into ships. The presence of the necessary capital and its mobilisation made possible the use of novel ship designs.

Many Italian towns began their expansion by piratical activities, by attacking Muslim traders and towns to seize goods. This was certainly less true of Venice than, for example, Pisa but the Venetian government did not hesitate to raise a fleet and become involved in fighting when it was thought that there was a threat to the trading position of Venetian merchants. The governments of Italian towns typically became committed to a policy of violence, to the protection and support of those men whose function was violence at sea. Indeed it was those very men, enriched by their acts of piracy and settled down to a life of trading or of owning land, who came to be the administrators of the towns. The ships which these men used, the increasingly large galleys modelled on the Byzantine dromon, were easily used for war. They were fully interchangeable and could be converted from the carriage of goods or pilgrims to warships in a matter of minutes. With such vessels in use, the result was that violence became an integral part of maritime policy. The Vikings in the North had ships which enjoyed, to some degree, the same dual capabilities of warship and cargo ship, or at least troop transport. The Vikings found it difficult to comprehend a difference between trading and raiding. In the Mediterranean, while that distinction might be perceived, the character of the ships in use was even less constraining in the ability to shift from one to the other. The political instability around the Mediterranean, the failure of Byzantium to maintain protection for shipping throughout the ninth and first half of the tenth century, and the religious undertones of the contest helped to make fighting at sea a fully accepted part of life. By 1000 a level of peace had been restored in the Mediterranean. Trading could and did become the typical function of merchants and of shippers. But the

design of the ships did not change with the increase in stability. The potential for violent action remained. Nor did town government policy change. Violence was always a part of the thought and action of the governments of Italian port towns. Since they had the equipment they could and they did use their naval potential to gain trade advantages. That was a typical feature of Mediterranean commerce in the following centuries. It placed a new demand on shipbuilders to produce ships which could bring a return to investors and still be used against pirates, against Muslims and, increasingly important, against commercial competitors.

#### NOTES

1. Ole Crumlin-Pedersen, 'The Viking Ships of Roskilde', *Aspects of the History of Wooden Shipbuilding*, The National Maritime Museum, Greenwich, Maritime Monographs and Reports, no. 1 (1970), p. 11. He thinks there was no difference between the English keel and the Scandinavian cargo vessel but, given the dates of development and later illustrations, a strict correlation is doubtful. *FHMN*, pp. 47-58, 89; his claim for independent and parallel development in England and Scandinavia seems more likely. Valerie H. Fenwick, 'The Graveney boat. A pre-conquest discovery in Kent', *IJNA*, I (1972), pp. 119-29. The stem-post has been lost so it can only be assumed that it was fixed at a right angle like the sternpost. The keel did extend for the full length of the vessel, 6.5 metres. It was only .08 metres thick, however, and .445 metres across. See also Valerie H. Fenwick *et al.*, *Three Major Ancient Boat Finds in Britain*, pp. 9-25. Basil Greenhill, 'The Graveney Boat', *Sjöfartshistorisk Årbok* (1970), pp. 33-40; no maststep was found but there is every indication that there was a sizeable one resting on the floor timbers. *AB*, pp. 221-6.

2. Dorestad was the largest and most important town in Frisia. It had the chief toll station of the Carolingian Empire, the mint for the area of the lower Rhine, and itself covered twelve hectares, which incidentally made it less than half the size of Hedeby. *FHMN*, pp. 237-8. Herbert Jankuhn, 'Der frankisch-friesische Handel zur Ostsee im frühen Mittelalter', pp. 228-32, 237, and *Haithabu* . . . , pp. 148-9, 240-2. Dirk Jellema, 'Frisian Trade in the Dark Ages', pp. 30-4. Barbara Rohwer, *Der friesische Handel im frühen Mittelalter*, pp. 14-15, 32. Archibald R. Lewis, *The Northern Seas*, pp. 184-6, 190-200, 220-6, 296-7.

3. *FHMN*, pp. 17-23, 179-84. Dirk Jellema, 'Frisian Trade in the Dark Ages', pp. 25-6, 35; the colony system continued after 1000 with a Frisian trading guild at Sigtuna, the successor of Birka, and colonies in ports such as Bremen and Riga. J. F. Niermeyer, 'Het Midden-Nederlands rivierengebied in de Frankische tijd', *Tijdschrift voor Geschiedenis*, LXVI (1953), p. 168. There were four *scholae* of merchants at Rome and the Frisians were the last, following the Anglo-Saxons.

4. Barbara Rohwer, *Der friesische Handel im frühen Mittelalter*, pp. 75-87. Dirk Jellema, 'Frisian Trade in the Dark Ages', pp. 34-5. J. H. Holwerda, *Dorestad en Onze Vroegst Middeleeuwen* (A. W. Sijthoff's Uitgeversmij. N.V., Leiden, 1929), pp. 16-22, 135. He blames the shift of trade from Dorestad on a flood of 864 which changed the mouths of the Rhine. Such a change would have been more final than the attacks of Vikings. In any event the increasing competition from ports like Hamburg and Bremen in the North Sea and Dordrecht in Holland

after 1018 relegated Frisian trade to a position of lesser importance.

5. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen* (Unieboek, Bussum, 1974), p. 19. His claim that this was the greatest breakthrough in ship-building of the period is not valid. A. W. Brøgger and Haakon Shetelig, *The Viking Ships, Their Ancestry and Evolution* (Dreyers Forlag, Oslo, 1971), p. 135. Archibald R. Lewis, *The Northern Seas*, pp. 262-3, 315. His suggestion that this type may have been inspired by Byzantine dromons must remain pure conjecture without any substantiating evidence. P. H. Sawyer, 'Wics, Kings and Vikings', in Thorsten Anderson and Karl Inge Sandred (eds), *The Vikings* (Uppsala University, Uppsala, 1978), p. 28. His suggestion that competition between merchants and pirates led to advances in ship design in this period is thrown into question by the failure of the merchants, the Frisians, to innovate despite the tremendous advances of the pirates, the Vikings.

6. Sibylla Haasum, *Vikingatidens Segling och Navigation*, pp. 57-8. Her complaint that scholars too easily accept claims for excellent sailing qualities for these ships is sound. The basis for her statement is questionable: Ole Crumlin-Pedersen, 'Viking Seamanship Questioned', *MM*, LXI (1975), pp. 130-1. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 91-2; in 1893, for example, a full-size replica of the Gokstad ship sailed from Norway to Chicago crossing the Atlantic in less than four weeks. Ole Crumlin-Pedersen, 'Two Danish Side Rudders', *MM*, LII (1966), p. 257.

7. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean*, pp. 147-8, 197. The Viking ability to attack Iberia depended on the weakness of the navy of Ommayid Spain. See also Archibald R. Lewis, *The Northern Seas*, pp. 245-52, 285. Bailey W. Diffie, *Prelude to Empire* (University of Nebraska Press, Lincoln, 1960), pp. 6-8.

8. G. J. Marcus, 'The Navigation of the Norsemen', *MM*, XXXIX (1953), pp. 112, 117-31. Navigation was done by dead reckoning, probably aided by some simple method of measuring the height of the sun. If Vikings did have a compass it was a primitive affair giving only an indication of direction and not consistently used for navigation. Roald Morcken, 'Europas eldste sjømerker', *Sjøfartshistorisk Årbok* (1969), pp. 7-48; the Scandinavians had marks on shore for navigation well before they appeared in the Mediterranean. Roald Morcken, 'Norse Nautical Units and Distance Measurements', *MM*, LIV (1968), pp. 393-401. His claims for the extensive use of celestial navigation by the Vikings are based on thirteenth-century sources. Sibylla Haasum, *Vikingatidens Segling och Navigation*, pp. 87-110; a number of other aids to navigation were used. E. G. R. Taylor, *The Haven-Finding Art*, pp. 65, 72-84. N. Rosenberg, 'The Direction of Technological Change: Inducement mechanisms and focusing devices', pp. 4-5, 10.

9. Olaf Olsen and Ole Crumlin-Pedersen, 'The Skuldelev Ships (II)', *Acta Archaeologica*, XXXVIII (1967), p. 118. Ole Crumlin-Pedersen, 'The Viking Ships of Roskilde', p. 11. *FHMN*, pp. 33-5, 118-19.

10. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 77-8, 85-6, 90-2. Olaf Olsen and Ole Crumlin-Pedersen, 'The Skuldelev Ships (II)', pp. 108, 155. Ole Crumlin-Pedersen, 'Two Danish Side Rudders', pp. 251-7. This type of rudder was superior to the later sternpost rudder in that it required less energy to turn it.

11. Ole Crumlin-Pedersen, 'Kaellingen og Kløften . . .', *Handels- og Søfarts-museets Pøl Kronborg, Årbog* (1972), pp. 63-80. G. J. Marcus, 'The Navigation of the Norsemen', pp. 114-15. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 48, 86-94; on smaller Viking ships shrouds and stays may not have been used at all – the low aspect ratio rig could be held in place by the base alone. Sibylla Haasum, *Vikingatidens Segling och Navigation*, pp. 20-1, 59-83. For a more positive and at the same time more cautious view about the sailing qualities

of Viking ships, Erik Anderson, 'Hals og skaut mast og segl, Både og råsejilrigninger på Norskekysten', *Norsk Sjøfartsmuseum, Årsberetning* (1975), pp. 47-100.

12. Romola and R. C. Anderson, *The Sailing-Ship*, pp. 70-6. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 79-99, 129; the word *karve*, Old Norse *karfi*, comes from the Greek *karabos*, Russian form *korabi*, and is mentioned for a number of expeditions by Scandinavians to the Black Sea. The type was well equipped to handle the river routes and portages of Russia. *AB*, pp. 211-14.

13. On an experiment in reconstructing an exact replica of one of these boats, interesting especially for the method used, see Sean McGrail and Eric McKee, *The Building and Trials of the Replica of an Ancient Boat: The Gokstad Faering*, The National Maritime Museum, Greenwich, Maritime Monographs and Reports, no. 11 (1974), 2 parts.

14. *HSUA*, pp. 166-8. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 104-15. *AB*, pp. 208-11.

15. Knud Thorvildsen, *The Viking Ship of Ladby* (The National Museum, Copenhagen, 1967), pp. 5-6, 20-2. Olaf Olsen and Ole Crumlin-Pedersen, 'The Skuldelev Ships (II)', pp. 140-5. The measures reported in this survey have since been revised for the larger warship. It proved longer than expected. Ole Crumlin-Pedersen, 'The Viking Ships of Roskilde', pp. 8-9. *HSUA*, p. 184. The top three strakes of these warships were of ash which may explain why the English called the Vikings *aescmen*, *aesc* meaning ash.

16. G. J. Marcus, 'The Evolution of the Knörr', *MM*, XLI (1955), pp. 116-17, 119-20. The knarr was also called the *hafskip*. See also G. J. Marcus, 'The Navigation of the Norsemen', pp. 112-15. *FHMN*, pp. 45-6, 257-62. Olaf Olsen and Ole Crumlin-Pedersen, 'The Skuldelev Ships, A preliminary report . . .', pp. 171-4, and 'The Skuldelev Ships (II)', pp. 108-9, 127-32.

17. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, p. 76. The evidence for division of labour comes from a thirteenth-century writer describing events which occurred about the year 1000. Olaf Olsen and Ole Crumlin-Pedersen, 'The Skuldelev Ships (II)', pp. 160-1. W. L. Goodman, *The History of Woodworking Tools* (G. Bell and Sons Ltd, London, 1964), pp. 125-6, 131-2. Henry C. Mercer, *Ancient Carpenters' Tools*, third edn (The Bucks County Historical Society, Doylestown, Pennsylvania, 1960), pp. 14-17, 92-3; Norwegian boat builders continued to split their wood rather than saw it into the seventeenth century. Sean McGrail in *AB*, pp. 234-8.

18. Herbert Jankuhn, 'Der fränkisch-friesische Handel zur Ostsee im frühen Mittelalter', pp. 231-6. Archibald R. Lewis, *The Northern Seas*, pp. 271-5, 349-82. Else Ebel, 'Kaufman und Handel auf Island zur Sagazeit', *Hansisches Geschichtsblätter* XCV (1977), pp. 1-21.

19. *HSUA*, p. 183; Baltic commerce especially along the south coast was also increased by development both in design and number of Slavic vessels; the Scandinavians appear to have traded to Russia through Finland and avoided the south coast. *FHMN*, p. 89.

20. The holes in the forepost of, for example, the Graveney boat may have been to take the rope from a windlass to haul it out of the water. Valerie H. Fenwick, 'The Graveney boat', p. 125. *FHMN*, pp. 138-46.

21. *FHMN*, pp. 150-1, 158-69.

22. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean*, pp. 103-9, 132-42, 186-9. Hélène Ahrweiler, *Byzance et la mer*, pp. 35-9, 92-115; the loss of Crete was largely a result of internal political difficulties in the Byzantine Empire and not any long-term decline in Byzantine sea power. It was almost an accident, the island being taken by some freebooters from Spain. Ekkehard Eickhoff, *Seekrieg und Seepolitik*, pp. 1-3, 65-70.

23. Hélène Antoniadis-Bibicou, *Etudes d'histoire maritime de Byzance*, pp. 98, 115-16. Hélène Ahrweiler, *Byzance et la mer*, pp. 97-9. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean*, pp. 185-6. He gives a total figure for the fleet of 3,360 vessels, which seems too high. It comes from contemporary chronicles. Ekkehard Eickhoff, *Seekrieg und Seepolitik*, pp. 81-2. His total of 40,000 men for all Byzantine fleets is probably accurate.
24. Hélène Antoniadis-Bibicou, *Etudes d'histoire maritime de Byzance*, pp. 35-6, and 'Problèmes de la marine byzantine', p. 335. Hélène Ahrweiler, *Byzance et la mer*, pp. 102-3, 117. She is perhaps too positive about the revival of Byzantine shipping in the second half of the tenth century.
25. Louis Bréhier, 'La Marine de Byzance du VIII<sup>e</sup> au XI<sup>e</sup> Siècle', pp. 12-15; a fleet including eleven *chelandia* carrying 1,450 soldiers was sent to south Italy to escort a mission to the Lombards – the show of strength was of course a bargaining ploy. G. La Roërie and J. Vivieille, *Navires et Marins*, p. 88. For figures on the size of the Byzantine navy see Hélène Ahrweiler, *Byzance et la mer*, pp. 91-2, and Hélène Antoniadis-Bibicou, *Etudes d'histoire maritime de Byzance*, pp. 92-4. Hélène Antoniadis-Bibicou, 'Problèmes de la marine byzantine', pp. 330-2, 336. Ekkehard Eickhoff, *Seekrieg und Seepolitik*, pp. 135-7, 147-8, 316, 342.
26. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean*, pp. 150-63, 189. Maurice Lombard, 'Arsenaux et bois de marine dans la Méditerranée musulmane', *TCHM*, II, pp. 58-60, 64-7, 72-3, 81-97. Embargoes on the export of wood from Byzantium date from the start of the ninth century. Ekkehard Eickhoff, *Seekrieg und Seepolitik*, pp. 124-34.
27. Hélène Ahrweiler, *Byzance et la mer*, p. 269. She dates the change in piracy to the twelfth and thirteenth centuries but her own evidence suggests that this is much too late a date. On piracy in general, Regina Goutalier, 'Privateering and Piracy', *The Journal of European Economic History*, VI (1977), pp. 199-213. This is a summary report of the International Commission on Maritime History meeting held in San Francisco in 1975 on exactly that topic.
28. Hélène Antoniadis-Bibicou, 'Problèmes de la marine byzantine', pp. 198-202. The Carolingian Empire tried to stabilise the naval situation in the western Mediterranean in the early ninth century but that gave way to a return to piracy as the Empire collapsed, leaving the coastal towns to fend for themselves. They did not revive until the tenth century.
29. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean*, pp. 205-6. Maurice Lombard, 'Arsenaux et bois de marine dans la Méditerranée musulmane', p. 59. Ekkehard Eickhoff, *Seekrieg und Seepolitik*, pp. 4, 151. *HSUA*, p. 207. Jules Scottas, *Messageries Maritimes de Venise XIV<sup>e</sup> et XV<sup>e</sup> siècles* (Société d'Éditions Géographiques, Maritime et Coloniales, Paris, 1938), p. 52.
30. Lucien Basch, 'Ancient wrecks and the archaeology of ships', pp. 17, 34, 39-40. His illustration of Mediterranean skeleton construction is dated 1290 but archaeological evidence suggests that the change had occurred earlier. George F. Bass and Frederick van Doorninck, 'An eleventh century shipwreck at Serçe Liman, Turkey', *IJNA*, VII (1978), pp. 119-32.
31. Archibald R. Lewis, *The Northern Seas*, pp. 292-5, 388-98.
32. L. A. Boiteux, *La Fortune de Mer, le Besoin de Sécurité et les Débuts de l'Assurance Maritime* (SEVPEN, Paris, 1968), p. 45. *FHMN*, pp. 267-9. Herbert Jankuhn, 'Der frankisch-friesische Handel zur Ostsee im frühen Mittelalter', p. 235. Jelle C. Riemersma, 'Trading and shipping associations in 16th century Holland', *Tijdschrift voor Geschiedenis*, LXV (1952), pp. 330-1.

NOTES TO ILLUSTRATIONS

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