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THE EVOLUTION OF NAVAL ARMAMENT

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A SIXTY-GUN SHIP OF LATE SEVENTEENTH CENTURY
From John Smith's *Sea-Man's Grammar* (1694 edition)

Frontispiece

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THE EVOLUTION OF NAVAL ARMAMENT

BY

FREDERICK LESLIE ROBERTSON

ENGINEER COMMANDER, ROYAL NAVY

WITH EIGHT HALF-TONE PLATES AND OTHER ILLUSTRATIONS

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PREFACE

THE notes on which these essays are based were collected in the course of two commissions spent under the lee of the Admiralty library, close to the Royal United Service Institution, and in touch with the Reading Room of the British Museum and other public sources of information.

The lack of a book describing in popular language the materialistic side of naval history is, I think, generally admitted. Historians as a rule have devoted small space to consideration of material; in particular, the story of the revolutionary changes in naval material which took place during the nineteenth century has never been placed before the public in convenient form. In the attempt to supply such a description I have taken the liberty, as an engineer, of treating of naval material as a whole; tracing, as well as my technical knowledge permits, the progress of all the three principal elements—ship, gun, engine—and their interdependence. The result, faulty and incomplete as it is, may nevertheless be of considerable service, it is hoped, in clarifying the work of the historians and bridging the gap which divides the classic histories from our modern text-books.

I have considered our modern navy to begin with the "Admiral" class of battleship, about the year 1880.

My respectful thanks are due to the heads of three Admiralty departments: Captain R. H. Crooke, C.B., lately Director of Naval Ordnance; Engineer Vice-Admiral Sir George Goodwin, K.C.B., LL.D., Engineer-in-Chief of the Fleet; and Sir Eustace T. D'Eyncourt, K.C.B., Director of Naval Construction; for their unofficial approval. I wish to acknowledge my indebtedness to the officials of the Admiralty and the R.U.S.I. libraries,

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for their invariable kindness; to the Directors of the British and S. Kensington Museums, for permission to reproduce pictures in their possession; to Mr. A. W. Johns, C.B.E., Assistant Director of Naval Construction, Engineer Commander E. C. Smith, O.B.E., R.N., Mr. H. W. Dickinson, of the S. Kensington Museum, Mr. Edward Fraser, and Sir George Hadcock, F.R.S., R.A., of Elswick, for various help and criticism; and especially to Mr. L. G. Carr Laughton, of the Admiralty library, of whose advice and knowledge I have often availed myself, and to whose encouragement the completion of the work has been largely due.

It only remains to state that the whole of the book is written and published on my own responsibility, and that it is in no manner or degree an official publication.

F. L. R.

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THE EVOLUTION OF NAVAL ARMAMENT

CHAPTER I

THE SAILING SHIP

TO attempt to trace in any detail the evolution of the sailing warship is a task, it must be at once admitted, far beyond the scope and intention of the present essay.

The history of naval architecture is, of course, a vast and many-sided subject. Few are the writers who have dealt with it, and, for reasons which will appear, few of those have written in the English language. Such books as treat of it are too cumbrous and technical for easy reading ; they are not written in the modern style ; by the frequent digressions of their authors on matters of general history, high politics, battles, economics, commerce, and even sport, they bear witness to the difficulties of the task and the complexity of the subject. The history of naval architecture still remains to be written. In the meantime the student will find the monumental *Marine Architecture*, of Charnock, and the smaller *Naval Architecture*, of Fincham, invaluable fields of inquiry ; among the historians the works of Nicolas, Laughton, Corbett and Oppenheim, will furnish him with the materials for the complete story of the evolution up to the end of the eighteenth century.

The following pages give a sketch, drawn chiefly from these authors, of the progress of the timber-built sailing ship and of the principal influences which guided the evolution. Lessons may still be drawn from this history, it is suggested, which even in the altered circumstances of to-day may be of value in some other application. One lesson, long unlearnt, the great blunder of two centuries, lies clearly on the surface. The

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evidence will show how, by our long neglect of the science of naval architecture, the British navy fought frequently at an unnecessary disadvantage ; but it will also show how, masters of the art of shipbuilding, we gave our fleets such a superiority in strength and seaworthiness as almost to neutralize the defects inherent in their general design.

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Before the fourteenth century the sailing ship, i.e. the ship in which sails were used as the chief motive power, could not compete in battle on equal terms with the oar-driven vessel ; both in the Mediterranean and in Northern waters the oar-driven galley possessed advantages of speed and handiness which relegated the heavy, high-built and capacious sailing ship to the position of a mere transport or victualler. The fighting ships were the galleys : long speedy vessels with fine lines and low freeboard, propelled by rowers and fought by soldiers clad in mail and armed with swords and lances. Sails were carried, but only as secondary power, for use when the galleys ran before the wind.

Sea tactics consisted in ramming and boarding ; the vessels were designed accordingly. The royal galleys of King Henry III, which formed the fighting fleet of Hubert de Burgh, are described as having each two tiers of oars, with platforms along each side over the heads of the rowers, on which the soldiers stood. Hung on the bulwarks in front of them were their shields. From the gaudily painted mast pennons and banners floated on the wind ; a large square cotton sail, embroidered with the royal arms, was triced to the yard. The masthead was crowned with a circular "top," a repository for bricks and iron bars wherewith to bilge an enemy vessel. At both ends of the galley were raised platforms or "castles" filled with picked soldiery, who during the approach to action would pour brass-winged arrows into the enemy and who, when the enemy had been grappled, leaped aboard. From mechanical engines low down in the waist large stones would be projected, and, if on the windy side, quicklime would be thrown, and other "instruments of annoyance." The galleys were lightly built, and carried no pumps. It was no uncommon sight, we are told, to see half the knights baling, while the others fought hand-to-hand with the enemy.

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By the year 1300 the size and utility of ships had made considerable advance. Two masts were given them, each supported by a few shrouds and carrying a single large square sail; neither masts nor sails were yet subdivided, but the sails could be enlarged by having one or more "bonnets" laced to their lower part. Of the two masts the taller, the foremast, raked considerably over the bows, and both were surmounted by tops, with flagstaff and streamers. A central rudder appeared in this century, in place of the paddle fixed to the quarter, and a rudimentary bowsprit. The largest *cogs*, as they were now called, were of 250 tons burthen. When hired of merchants for war service, they were converted by the addition of fore-, aft-, and top-castles, built high so as to overtop, if possible, the enemy. The war vessels were at this time lavishly decorated; the sails were silk, dyed red or embroidered with armorial designs, the tops and stages were aflame with banners and pennons, the masts and yards were gilt. Large sums of money were spent by the knights in beautifying their ships.

But in this century two great inventions brought to a close an epoch in warship construction. Gunpowder and the mariner's compass were discovered. Cannon were adapted to ships in place of the mechanical engines which had formerly been carried, and by aid of the compass, housed in its wood-pegged bittacle in the steerage, vessels began to venture out of touch with land and sail with a new security the uncharted ocean.

The effect of each of these two discoveries was the same: a growth in the size, strength, and capacity of ships, a decline in the use of oars and a greater reliance on sails. High sides were required against the waves, stouter timbers to support the weight of ordnance, more capacious holds for the stowage of the ballast, food, and cordage which would be needed for a long sea voyage. The galley, with its low flush deck and outward-sloping sides was ill adapted for the new conditions; a new construction was seen to be needed. Two new types were evolved, one in the Mediterranean and one, more gradually, in Atlantic waters.

Even before the Christian era there had been a distinct differentiation between the ships of the Mediterranean and those of the Atlantic seaboard. The latter, as shown by Nicolas' quotation from Cæsar, were more strongly built than the Roman galleys, with flatter bottoms, to "adapt them to the shallows and to sustain without danger the ebbing of the tide,"

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and with prows and sterns "very high and erect, to bear the hugeness of the waves": properties which, even before the advent of fire artillery, conferred on them important advantages.[1] Nevertheless, complete differentiation did not obtain until after the discovery of gunpowder and the mariner's needle. Before that time the vessels used by the Northern nations in war were of the galley type, built by themselves or, after the Crusades had revealed the superiority of the Mediterranean powers in warship design, hired not infrequently from Venetians or from Genoese. The Genoese were the chief naval mercenaries of Europe at this age: "Genoese were vice-admirals to the English king, and Genoese galleys fought for the French at Sluys."

The new type evolved in the Mediterranean was the *galleasse*. For centuries, as we have seen, large sailing ships had been used for commerce, both in the Atlantic and in the Mediterranean. With the inevitable increase in size brought about by the adoption of cannon, and by the desire for greater sea-keeping qualities, resort was now had by the Genoese and Venetians to sails in war vessels as a means of propulsion of equal importance with oars. Thus an uncomfortable compromise was effected between oars and sails; both were provided. The galleasse was originally a large decked galley, with three pole masts for its lateen sails, and with cannon spaced at intervals along its sides above the rowers. In form it differed little from the galley, but in the disposition of its armament it was entirely different; it represented the first stage in the evolution of the broadside fighting ship.

But the galleasse, though it might meet the requirements of Mediterranean warfare, was almost as unsuited as the galley to Atlantic conditions. Accordingly the warship underwent a separate and independent development at the hands of the Atlantic nations. Forsaking the galley, they took the lofty, strong and capacious sailing merchant ship as the basis of a new type, and from the lumbering carrack and caravel and dromon they evolved the vessel which eventually became known as the *galleon*. A distinctive naval architecture, Gothic rather than Byzantine in character, was thus founded on the Atlantic seaboard. The oar was entirely superseded by the sail. The ships were high, and their sides, instead of falling out like those of galleys, were curved inwards so as to "tumble

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[1] Sir Harry Nicolas: *History of the Royal Navy*

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home" above the water-line: an arrangement which protected the ordnance, added to the strength of the vessels, and tended to render them steadier gun-platforms. The top-castles were retained on the masts, but the end-castles disappeared, or rather, were incorporated into the structure of the lofty bow and stern, to provide accommodation for officers, and cover for the crew. The *voile latine* gave way to the *voile quarrée.* In place of the large lateen sails carried by galley and galleasse, were smaller sails and courses, square, more easily manipulated and allowing of greater variation in disposition and effective area, to suit the conditions of weather and the trim of the ship.

Throughout the fifteenth century the sailing ship developed. "While in the first quarter," writes Mr. Oppenheim of English shipping, "we find that men-of-war possess, at the most, two masts and two sails, carry three or four guns, and one or two rudimentary bowsprits, at the close of the same century they are three- or four-masters, with topmasts and topsails, bowsprit and spritsail, and conforming to the characteristics of the type which remained generally constant for more than two centuries." The English mariner had by this time acquired his honourable reputation. In merchant ships he carried Bordeaux wine, the casks of which became the unit for measurement of their tunnage; even in winter months, we are told, he braved the Bay with pilgrims on tour to the shrine of St. James of Compostella. Large royal ships of over 1000 tons burthen were built, in the early part of the century, in English yards. As builders the Normans seem at this time to have excelled.[1] But the most wonderful development of the science of seamanship in all its branches took place in the Peninsula. Largely through the inspiration of one man the greatest efforts of Spain and Portugal were directed to the cult of navigation and geography, the improvement of shipbuilding, and the discovery of new and distant lands and oceans. A brilliant impetus was given to the study of ship construction by the voyages of Columbus, the Cabots, Vasco di Gama, and other intrepid spirits who, by aid of the compass, braved the moral and physical terrors of far-distant voyages—"fighting immensity with a needle."

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[1] The greatest authoritative works on ancient and medieval shipping, it should be mentioned, are the *Archéologie Navale* and the *Glossaire Nautique* of M. Jal, published in 1840 and 1848 respectively.

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With the development of artillery the value of the sailing ship for sea warfare came gradually to view. Naval tactics suffered a complete change.

Until the early days of the sixteenth century sea-fights had been land-fights in character; ships came as quickly as possible to close quarters, grappled or charged one another, cut rigging, and essayed to board. The sailor was subservient to the soldier. The gun, represented in the main by serpentines, periers, murderers, and other quick-firing pieces, was primarily a defensive armament, for the defence, firstly, of the entire ship, or, in the event of the waist being captured, of the fortified end citadels or castles. "These castles, which in vessels especially constructed for war came to take the form of a forecastle and a half-deck, were made musket-proof; and being closed athwartship with similarly protected bulkheads, known as 'cubbridge-heads,' were impenetrable to boarders; while at the same time, by means of loopholes and quick-firing pieces in-board, they could enfilade the waist with musketry and murdering shot. Thus a ship of the English pattern, at any rate, could rarely be held even if boarders entered, until her 'cage works' or protected castles were destroyed by gunfire."[1] The ship itself, being deep-waisted and built with an exaggerated sheer upwards toward bow and stern, had no continuous deck: the decks were laid on various levels, rising from the waist by steps to the two citadels, an arrangement which did not contribute, as a flush-deck would have done, to the longitudinal strength of the vessel, and which was found inconvenient for the working and transport of ordnance of the heavier sort.

King Henry VIII, in his efforts to possess fighting ships superior to those of Spain, France and Scotland, raised not only artillery but ships themselves to a different rôle. As he personally urged the manufacture of ordnance in this country by the subsidizing of foreign talent, so he sought to improve the design of his ships by inviting Italian shipwrights to come to England and apply their knowledge to the royal vessels. Dockyards were founded at Woolwich, Deptford, and Portsmouth. Large ships were laid down, several were rebuilt, with many improvements embodied in them: chief of these

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[1] Corbett: *Drake and the Tudor Navy.*

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being a new artillery armament. The king had seized the advantages of the sailing ship with broadside fire. "The development of broadside fire," says Sir Julian Corbett, "was a question of gunnery, of naval architecture, and of seamanship. With Henry's introduction of heavy guns on board his larger vessels, however, the true note had been struck, and by the end of his reign the first two arts had made great strides. Guns of all patterns and sizes were being cast in England, both in bronze and iron, which were little inferior to those Nelson fought with." The result of the king's efforts was seen in the ships laid down in the last years of his reign. The frontispiece of Mr. Oppenheim's *History of the Administration of the Royal Navy* is a picture of one of these, the *Tiger*, a four-masted flush-decked vessel, with no sheer, little top hamper, a long tier of ordnance on the gun deck, and with a beak-head ending in a spur: one of a class "which shows a very great advance on anything before afloat and indicates a steady progression towards the modern type."

In short, a reversion to a smaller and seaworthier type took place. The large, unstable and unwieldy "great ship," such as the *Henry Grace à Dieu*, built on the Spanish model, with lofty ends overweighted with small ordnance, was not effective. A new invention, attributed to Descharges of Brest in 1501, viz. the adaptation of portholes to ordnance along the sides of a ship, perhaps suggested a better form. As the century advanced, as new and far-distant countries appeared on the map, the arts of seamanship and gunnery continuously improved; naval architecture made a corresponding progress. For sea fighting the high-charged and imposing "great ship" gave place to a more perfected type—the galleon. "It was the development of the galleon," insists the historian, "which changed the naval art from its medieval to its modern state." The galley, eminently suited to the Mediterranean, where winds were light and slave labour abundant, was found to be increasingly unsuitable for Atlantic warfare; the galley was in danger of being rammed, in any wind, by a strong, quick-turning sailing ship, and suffered from having nearly all its artillery in the bows; moreover, "the galley service was always repugnant to our national temperament." The galleasse, the hybrid between the oar-driven galley and the sailing ship, suffered from all the disadvantages of the compromise. The great ship had now proved to be cumbrous

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and expensive, crank and unseaworthy, leewardly and unmanageable in even a moderate breeze.

The galleon therefore became the type favoured by the English navy. Whereas the merchant ship was short in proportion to its beam, the galleon was built long, with a length equal to three times its breadth. It had also a long flat floor like a galley, and was of lower freeboard than a round-ship. "It was also like a galley flush-decked, and would seem always to have had the half-deck carried across the waist so as to make one flush-deck with the old forecastle. In the larger types the quarter-deck was also carried flush from stem to stern, so that latterly at any rate a true galleon had at least two decks and sometimes three. On the upper deck in the earlier types were erected both fore and aft high-castles as in a galleasse, but usually on curved lines, which gave the hull of the old-fashioned galleons the appearance of a half moon." [1] The depth of hold at the waist was only about two-fifths the beam. Its artillery was light but effective, being composed of light muzzle loaders, a mean between the man-killers and the heavy bombards of an earlier day. Its masts and spars were made heavy and large sail area was given it, for speed and quick manœuvring were the essential qualities which it was hoped to oppose to the lumbering, high-charged ships of Spain. Victory was to be sought by a skilful combination of seamanship and gunnery, rapid fire being poured into an enemy at a convenient range and bearing. "Plenty of room and a stand-off fight" sufficiently defines the sea tactics of the new era.

Throughout the reign of Elizabeth the galleon still remained the favourite type, though opinion differed, and continued to differ through the two following centuries, as to the degree to which it was desirable to "build lofty." The Hawkins family of Plymouth shipowners carried a great influence in the councils of the navy. Sir John Hawkins, whose experience of shipbuilding and seamanship rendered him a man of importance, was the author of improvements in this respect, as in so many others; "the first Elizabethan men-of-war, the fastest sailers and best sea-boats then afloat, were built to his plans; and from the time of his appointment as Treasurer of the Navy dates the change to the relatively low and long type that made the English ships so much more handy than their

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[1] Corbett.

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Spanish antagonists."[1] His kinsman, Sir Richard, on the other hand, preferred large and high-charged ships, "not only for their moral effect on the enemy, but for their superiority in boarding and the heavier ordnance and larger crews they would carry. Two decks and a half he considers to be the least a great ship should have, and was of opinion that the fashion for galleasse-built ships—or, as he calls them, 'race' ships—in preference to those 'lofty-built' had been pushed too far."[2] Ships with large cage-works had an advantage, he maintained, in affording cover for the crew and positions for quick-firing batteries; his opponents argued that the weight of top-hamper saved by their abolition could be put with better advantage into a heavy artillery.

The advocates of the fast, low-lying ships carried the day. War came with Spain, and there was soon work to show what the English ships could do. The *Armada Papers*[3] light up for us, by the fitful glare of the cressets of Hawkins and Co., the preparation of the fleet at Plymouth, and show us what state of efficiency the royal ships were in. "The *Hope* and *Nonpariel* are both graved, tallowed, and this tide into the road again," writes William Hawkins to his brother. "We trim one side of every ship by night and the other side by day, so that we end the three great-ships in three days this spring. The ships sit aground so strongly, and are so staunch as if they were made of a whole tree. The doing of it is very chargeable, for that it is done by torchlight and cressets, and in an extreme gale of wind, which consumes pitch, tallow, and firs abundantly." Not only the few royal ships, but the whole of the force which lies in the Sound is tuned for the fight. "For Mr. Hawkins' bargain," writes the Commander-in-Chief to Lord Burghley, "this much I will say: I have been aboard of every ship that goeth out with me, and in every place where any may creep, and there is never a one of them that knows what a leak means. I do thank God that they be in the estate they be in." The Spanish ships prove to be in a very different condition. High-charged and leewardly, poorly rigged and lightly gunned, they are so hammered and raked by Lord Howard's well-found fleet that, when bad weather ultimately comes, they are in no condition to combat the elements. With masts and rigging shattered, water-casks smashed, no

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[1] Oppenheim.

[2] Corbett.

[3] Navy Records Soc.: Edited by Sir John Laughton.

anchors; short-handed and leaking like sieves, they are hounded northwards to a disaster unparalleled in naval history.

And now, before tracing its evolution through the seventeenth and eighteenth centuries, let us glance at the warship as it existed at the end of the Elizabethan era, and note its chief constructive features.

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Athwart a keel of large squared timbers, scarphed together and forming with a massive inner keelson the principal member or backbone, were laid the curved frames or ribs which, bolted to each other and to the keel with iron bolts washered and clinched, gave to the hull its transverse strength and form. These frames were held together, as they curved upward from the ground or floor level, by thick longitudinal wales, worked externally along the frames at convenient heights, and curved so as to suit the degree of sheer desired.

At the fore end the wales and frames converged to the centre-line and the keel was prolonged upward to meet them in a curve or compassing timber, forming the bow or stem: to the beauty and shapeliness of which, with its projecting beak-head, the builder devoted much of his attention and skill. At the other end the frames and wales converged to a square and lofty stern. The stern post was a massive timber fastened to the keel and sloping somewhat aft from the vertical, and from it rose two fashion-pieces "like a pair of great horns," which formed, with the horizontal arch and transom timbers, the framework of the stern. When the frames had been built up to the requisite height the upper ends of each opposite pair were joined across by horizontal beams, which were secured to them by means of brackets or knees; such beams were worked at the level of the main and other decks, and served to support them when laid. Joined by its beams, each pair of frames thus formed a closed structure: a combination of members which was to resist crushing and deformation, the blows of the sea, the stresses of gunfire, the forces due to the weight of the guns and the vessel itself, and especially the forces thrown on it when the vessel was aground or on a careen. The rigidity of this combination was enhanced by the fitting of pillars which were placed vertically over the keelson to support each beam at its middle. And sometimes the lower pillars were supplemented by sloping struts, worked from the curve of the frames up to the middle of each beam above.

The skeleton of a ship thus formed, built with well-seasoned timber, was left standing on the stocks "in frame" for a considerable period, sometimes for years, exposed to the open weather. On it eventually a skin of planks was fastened, secured by wood trenails split and expanded by soft-wood wedges, both internally and externally; and inside the ship, to reinforce the frames and in line with them, timbers known as "riders" were worked. On the beams the decks were laid: the orlop below the water-line level, and above it, at a height suitable for the ordnance, the main or gun deck; above that the upper deck, on the ends of which were reared the poop (sometimes a half-deck, extending from the stern to the mainmast, sometimes on that a quarter-deck, over the steerage) and the forecastle.

Such, very briefly, was the mode of ship construction. The resulting structure, when caulked and swelled by sea-water, presented a water-tight and serviceable vessel. Timber provided, for ships up to a certain size, a suitable material. It afforded strength and buoyancy, and elasticity sufficient to obviate local strains and to spread the stresses due to lading, grounding, careening, or the actions of the wind and sea. The different parts of the ship's frame gave mutual support, and the pressure of the fluid on the exterior of the hull tended, by constraining the component parts, to preserve the vessel.[1]

But the timber-built ship possessed an inherent weakness. Metal plates or girders can be bolted or riveted together so efficiently as to leave the joints between them almost as strong as the sections of the plates or girders themselves. Not so wood beams. However skilfully they might be joined, their joints were necessarily weaker than all other sections: "it was then, and still is, impracticable to develop the full strength in end connections between wooden members."[2] The softness of the wood was an additional source of weakness. Two beams fastened together by iron bolts might form initially a close and rigid joint; but if, under the action of alternating or racking stresses, they became loosened even in a minute

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[1] Cases were known where ships, unfit for sea, completed their voyage in safety, to fall to pieces immediately on being taken into dock and deprived of that continual support which they derived from the water when afloat (*Charnock*).

[2] Chief-constructor D. W. Taylor, U.S.N.

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degree, the tendency to become still looser increased: the wood gradually yielded under the bolt washers, the bolts no longer held rigidly, "the very fact that wood and iron were dissimilar materials tended to hasten the disintegration of the structure." With planking a similar effect obtained. Trenails, expanded by wedges and planed off flush with the planks which they held together, had only shearing strength; if once they were loosened they had little power to prevent the planks from opening further. These weaknesses were recognised. To minimize their effects the butts of frames, decks, and side planking, were arranged so that no two neighbouring butts lay in the same line. But in spite of the most painstaking craftsmanship, the size of the wooden ship was limited by its inability to withstand a high degree of stress. As sizes increased extraordinary endeavours were made to meet the hogging and sagging strains, to prevent cambering of the hull, and to stiffen it longitudinally and circumferentially. Enormous masses of timber were worked into the internal structure in the form of riders, pillars, standards, and shores, "the whole of which had an appearance of great strength, but which in fact, from its weight and injudicious combinations, was useless, if not injurious."[1] Which did, in fact, clog the ship and usurp the space required for stowage.

As for the masts, experience fixed their number, size and position. In the earlier ships, as we have seen, four and sometimes five masts were fitted, after the Mediterranean style. But later this number was reduced to three. Of these the foremast was the most important, and it was stepped directly over the fore-foot of the vessel, the main and mizzen being pitched to suit. Their height varied with the service and type of ship. Taunt masts, like those carried by the Flemish ships, were best for sailing on a wind, for with them narrow sails could be used which could be set at a sharp angle with the keel; but short masts and broad yards were favoured by English mariners, as bringing less strain on a vessel's sides and rigging and as being less likely to produce a state of dangerous instability. The masts were short, very thick, and heavily shrouded; the standing rigging was led to channels and deadeyes on the outside of the bulwarks. The bowsprits were large and "steved" upward at a large angle with the horizontal; spritsails and spritsail topsails were set on them,

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[1] Creuze: *Shipbuilding*.

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of use mainly when sailing before a wind, yet retaining their place in our navy till, half-way through the eighteenth century, the introduction of the fore-and-aft jib brought about an improvement and in so doing affected the whole disposition of mastage.

One feature of the masting of the old ships is notable: the manner in which the various masts were raked. In the *Sea-Man's Dictionary*[1] the *trim* of a ship was defined as, "the condition, as to draught, staying of masts, slackness of shrouds, etc., in which a ship goes best." For a given set of conditions there was a certain rake of masts, a certain position of the centre of wind-pressure against the sails, which, when discovered, gave to the vessel its finest sailing qualities. The knowledge of this adjustment constituted no small part of the great art of seamanship. In the king's ships a high proficiency was attained in it; merchantmen sailed under more diverse conditions and showed, it appears, a lower level of scientific inquiry. "Next to men of war (whose daily practice it is) the Scotch men are the best in the world to find out the trym of a ship, for they will never be quiet, but try her all ways, and if there be any goodness in her, they can make her go." Generally, the effect of raking the masts aft was to make the vessel fly up into the wind, and vice versa; in ships with high-built sterns, especially, it was necessary to have the head-sails set well forward, to keep them out of the wind. To allow the masts to be raked as desired their heels were pared away, and wedges of suitable thickness were driven between them and the "partners."

Many other factors contributed to affect, in a manner always subtle and frequently inexplicable, the sailing qualities of a ship. The form of the body, the position of masts and the setting up of the rigging, the disposition of weights, the angle of the yards, the conditions of stability, all had their effect on the vessel's motion, and therefore on her speed through the water. Free water in a ship's bilge, for example, had an effect on her degree of stiffness, and from this cause her speed was not easily predictable. Charnock relates how, in the colonial wars of the late eighteenth century, an American vessel, the *Hancock*, was captured after an unprecedented chase, solely because her commander, injudiciously supposing that by lightening his ship he would enhance her swiftness, pumped

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[1] Manwayring.

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water out of her. It was noticed, again, that in certain circumstances the speed of a ship increased when the crew turned into their hammocks.

The lines of the ship were drawn without reference to any science of naval architecture, and merely by instinct and the accumulated experience of the builder; the laws of stability and of fluid resistance were at this time unknown. Experience indicated the desirability of a short keel, to make the ship turn quickly; of an ample rake forward from keel to beak-head—"more than a third the length of the keel, commonly," says Sir Henry Manwayring, for, "a great rake forward gives a ship good way and makes her keep a good wind, but if she have not a full bow it will make her pitch mightily into a head sea. . . . The longer a ship's rake is, the fuller must be the bow"; of a fine run aft, so as to let the water flow strongly and swiftly to the rudder and make the ship steer and sail well; of a narrow rudder, so as not to hold much dead water when the helm was over,—yet, "if a ship have a fat quarter, she will require a broad rudder." The correct formation of the bow was recognised as of the greatest importance, and the most difficult compromise in the design of a ship. A bow too bluff offered much resistance to motion through the water; on the other hand, too sharp a bow lacked buoyancy, and, from the great weight of mastage, headsails, anchors, etc., which it had to support, caused a vessel to pitch badly in a head sea. "If the bow be too broad," wrote Captain John Smith, in his *Sea Man's Grammar*, "she will seldom carry a bone in her mouth, or cut a feather, that is, to make a foam before her: where a well-bowed ship so swiftly presseth the water as that it foameth, and in the dark night sparkleth like fire."

Generally, a vessel built with fine lines lacked end support, and tended to become arched or camber-keeled, while its stowage capacity was inconveniently small. The ship's sides were made with a considerable degree of tumble-home above the water-line; though this, again, was a point of compromise and much argument. For while a reduced breadth of deck tended to give the hull more girder strength and to diminish the racking effect on it of heavy ordnance, yet this feature at the same time, by reducing the angle at which the shrouds could be set, augmented the stresses which were thrown on shrouds and bulwarks.

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With the seventeenth century a new age of scientific speculation opened, and, under the personal encouragement of the Stuart kings, the art and mystery of shipbuilding received an illumination which was of great value to the royal armaments.

The early interest of James I in his navy is signalized by his grant of a charter to the corporation of shipwrights : a corporation whose short-lived story is told by the editor of *The Autobiography of Phineas Pett*, recently published.[1] Before the sixteenth century, he tells us, no special trade was recognized for the building of warships, as distinct from traders. But in the early Tudor days, when, owing to the introduction of the new artillery the war vessel began to diverge in general design from the merchant ship, certain master shipwrights had been subsidized by the king for the building and repair of the royal vessels. The position of these officials was one of importance, their duties and privileges were extensive. The office was often hereditary. Thus, the royal patent granted to one James Baker in 1538 descended, with the accumulated lore and secrets of his profession, to his son Mathew Baker in 1572. And that granted to Peter Pett in 1558 descended to Joseph Pett in 1590. But as shipping grew and shipbuilding became more complex and widely distributed, the need for some central authority, which could regulate practice and standardize procedure, became increasingly felt. Accordingly a petition was presented. In 1605 the king granted a charter incorporating the master shipwrights of England as one body corporate and politic, for the good regulation of shipbuilding of all descriptions. In 1612 another charter was sealed, giving increased power to the confraternity : with instruction that it was to examine each new ship to see that it was properly built, "with two orlops at convenient distances, strong to carry ordnance aloft and alow, with her forecastle and half-deck close for fight." Shipwrights' Hall, as the corporation was called, surveyed and reported on tonnage and workmanship, and gave advice, when sought, to the lord high admiral. In the course of time its prestige declined. With the Commonwealth it grew into disuse, and by 1690 it was altogether extinct. For nearly a century the guild had struggled in vain to fulfil the intentions of its founders.

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[1] Navy Records Soc. ; 1918, *Edited by* W. G. Perrin, Esq., O.B.E,

The most distinguished of the master shipwrights of this period was Phineas Pett, sometime master of arts at Emmanuel College, Cambridge, who in 1612 succeeded old Mathew Baker as Master of the guild. Pett, who to a practical knowledge of design and construction added considerable sea experience, rose far above his contemporaries, most of whom were little more than mere carpenters, ignorant of many of the principles which are now accepted as governing ship design, and themselves governed almost entirely by tradition and blind precedent. Science was still in its veriest infancy. The progress of ship design was still by the tentative and costly method of full-scale experience ; not till the beginning of the nineteenth century, when new forces and materials had been discovered which in the end spelt the decline and supersession of the sailing ship, did science sufficiently direct the lines on which large sailing ships should be built.

By his bold deviation from established usage, says Fincham, Mr. Pett established his fame and advanced the interest and power of the British navy. Before reviewing his handiwork, however, it will be convenient to note the main directions in which improvement was at this period sought.

Sir Henry Manwayring, an acquaintance for whom Pett designed and built a pinnace in the year 1616, wrote at this time *The Sea-Man's Dictionary*. In the early years of the century were also written two treatises which, though not printed till a later date, had great effect in creating an interest in naval matters : Sir Walter Raleigh's *Observations on the Navy* and *Invention of Shipping*. In the former paper Sir Walter laid down the six requisites of a good ship : viz. that she should be strongly built, swift, stout-sided, carry out her guns in all weathers, lie-to in a gale easily, and stay well. For the attainment of these qualities he specified certain structural features : a long run forward, to make her sail well ; a long bearing floor and a " tumble home " above water from the lower edge of the ports, for stoutness and for stiffness sufficient to enable her to carry her lower ordnance (which must lie four feet clear above water) in all weathers. " It is a special observation," he wrote, " that all ships sharp before, that want a long floor, will fall roughly into the sea and take in water over head and ears. So will all narrow quartered ships sink after the tail. The high charging of ships it is that brings them all ill qualities." In the latter paper he recapitulated

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the various improvements in material of which he had himself been witness; from which for its interest we quote the following extract. "The striking of the topmast (a wonderful great ease to great ships both at sea and in harbour) hath been devised, together with the chain pump . . . the bonnet and the drabler. We have fallen into consideration of the length of cables, and by it we resist the malice of the greatest winds that can blow, witness our small Milbrook men of Cornwall, that ride it out at anchor, half seas over between England and Ireland, all the winter quarter. . . . For true it is, that the length of the cable is the life of the ship in all extremities. We carry our ordnance better than we were wont, because our nether overloops are raised commonly from the water, to wit, between the lower part of the port and the sea. We have also raised our second decks and given more vent thereby to our ordnance, tying on our nether overloop. We have added cross pillars in our royal ships to strengthen them, which be fastened from the kelson to the beams of the second deck. We have given longer floors to our ships than in elder times, and better bearing under water, whereby they never fall into the sea after the head and shake the whole body, nor sink stern, nor stoop upon a wind, by which the breaking loose of our ordnance or the not use of them, with many other discommodities are avoided. . . . And to say the truth a miserable shame and dishonour it were for our shipwrights, if they did not exceed all other in the setting up of our royal ships, the errors of other nations being far more excusable than ours." Sir Walter was inaccurate in attributing all the improvements enumerated to his own generation; bonnets, for instance, were in use long before his day. Nevertheless his paper constitutes one of the most important contributions to the history of naval architecture in this country.

In the early years of the century, too, evidence as to the shortcomings of contemporary naval construction was furnished by a fierce critic, Captain Waymouth. He proclaimed that English shipwrights built only by uncertain traditional precepts and observations; that none of them could build two ships alike or predict with accuracy their draught of water; that all their ships were crank, leewardly—"a great disadvantage in a fight"—difficult to steer and sail, too deep in the water, of less capacity than the Hollanders, and so badly built and designed as frequently to require "furring,"

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or reinforcing by extra planking. He advocated building ships longer, broader, with longer floors so as to reduce their draught, and snugger in respect of upper works. And though he failed on trial to translate his ideas into successful performance, his criticisms are accepted by historians as being probably well-founded.

The opinions expressed by the above writers[1] indicate for us in general terms the chief particulars in which the ships of this period fell short of naval requirements. They were designed without knowledge of the laws governing the strength of materials, stability, and the motion of bodies through water; they were built without adequate supervision, frequently of green timber badly scarphed or cut across the grain, and were overburdened with ordnance. Their holds were cumbered with large quantities of shingle ballast which tended to clog the limber-holes of the bilge and rot the frames and floor timbers; while the stowage space amidships was further usurped by the cook-rooms, which were placed on the shingle, and which, by the heat radiated from their brick sides, did damage to the timbers and seams in their vicinity. Vessels were rarely sheathed. Though John Hawkins had devised a system of sheathing by a veneer of planking nailed over a layer of hair and tar, it was only to ships going on special service in seas where the worm was active that sheathing was applied. Sheathing possessed, then, some significance. In 1620, for instance, the Venetian ambassador reported to his government the discovery that some of our ships were being sheathed, and from this fact deduced an impending expedition to the Mediterranean.

With the navy in the depths of neglect and with shipbuilding in the state described, Phineas Pett began to impose his permanent mark on design and construction. The mechanism by which he secured his results, the calculations and methods and rules used by him, were veiled in profound secrecy, in accordance with the traditions of his profession. He began by new-building old ships of the Elizabethan time, giving them an improved form so far as practicable. His friend and patron was the young Prince Henry, for whom in 1607 he made a model which the king greatly admired. And shortly after this, in the face of much jealousy on the part of his rivals, he laid down

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[1] Captain John Smith's *Sea Man's Grammar* also appeared in the early part of this century.

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by command a new great ship—the *Prince Royal*, of 1187 tons, with a breadth of 43 feet and a keel length of 115 feet, double-built and sumptuously adorned, in all respects the finest ship that had ever been built in England. She carried no less than fifty-five guns, her general proportions were of a unity, and her strength was of a superiority, far in advance of current practice. In strength especially she marked an advance which yielded benefit later, in the wars with Holland. She was double planked, "a charge which was not formerly thought upon, and all the butt-heads were double-bolted with iron bolts."

But how difficult a matter it was for a builder to depart from tradition, is shown from Pett's account of the inquisition to which he was subjected in connection with the building of this famous ship. His rivals took advantage of the "Commission of Enquiry into the abuses of the navy," of 1608, to indict him for bad design, bad building, and peculation. So much hard swearing took place on both sides that at last King James himself decided to act as judge, and at Woolwich, with the wretched Phineas on his knees before him, opened his court of inquiry. "Much time," says the diarist, "was spent in dispute of proportions, comparing my present frame with former precedents and dimensions of the best ships, for length, breadth, depth, floor, and other circumstances. One point of proportion was mainly insisted upon and with much violence and eagerness urged on both sides, which was the square of the ship's flat in the midships, they affirming constantly upon their oath it was full thirteen feet, we as constantly insisting that it was but eleven foot eight inches." In the end the king called in a mathematician and had the controversy settled by actual measurement. None of the charges brought against him being sustained, Phineas was acquitted and restored once more to royal favour, to his own delight and to that of his youthful patron, Prince Henry.

The *Prince Royal* marks a new epoch in ship design. She was such a departure from all previous forms that she made the fame of Phineas Pett secure. She became, indeed, the parent or type of all future warships down to the beginning of the nineteenth century; for (says Charnock), were the profuse ornaments removed, her contour, or general appearance, would not so materially differ from that of the modern vessel of the same size as to render her an uncommon sight, or a ship in which mariners would hesitate to take the sea. In her a final

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departure was made from the archaic form imposed on fighting ships by tradition. The picture Charnock gives of her is of a highly ornamented but low and flush-decked vessel armed to the ends with two tiers of heavy guns. The projecting beak-head, a relic from the galley days which had been so prominent a feature of Tudor construction, has almost disappeared : the bow curves gracefully upward to a lion close under the bowsprit. The wales have little sheer ; the stern is compact and well supported, with beautiful lines. The quarter galleries are long, and are incorporated in the structure in a curious manner : in the form of indented, tower-like projections, with ornamented interspaces. The whole picture gives evidence of stout scantlings and invaluable solidity. Although in many respects the *Prince Royal* was a masterpiece she was primitive in the variety of her armament. On the lower deck she carried two cannon-petro, six demi-cannon, twelve culverins ; on her upper deck eighteen demi-culverins ; and on quarter-deck and poop a number of sakers and port-pieces. Also, unfortunately, she was built of green timber, so her life was short.

In building a ship of unprecedented burthen Pett had the support of a large public opinion. The advantages attaching to large size were by this time generally appreciated : in the case of fighting ships, in respect of strength, artillery force, and sea endurance, in the case of merchant ships, in respect of carrying capacity and economy of crew. The growth in the size of merchant shipping during the reign was indeed remarkable. Trade followed the flag, and the Jacobean merchant made haste to profit by the conquests of the Elizabethan adventurer. For a short while after the war with Spain our mercantile marine was stagnant ; at the accession of James I only small vessels of less than a hundred tons were being built, and English merchants were having strange recourse to the hiring of foreigners. But this state of things did not last for long. The story of the success of the Earl of Cumberland and his 800-ton *Scourge of Malice*, and the sight of the great Portuguese carrack captured in 1592, are said to have stimulated the merchants of London to possess themselves of vessels fit for the Eastern trade. It is said, again, that the appearance of two large Dutch ships in the Thames supplied the sudden impulse to build big. Be that as it may, " the idea spread like wildfire." Larger ships were laid down, and by the end of the reign the country possessed a considerable fleet of ships of

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500 tons and above. In one instance, at least, the pendulum swung too far, and experience soon exposed the disadvantages of excessive dimensions: the reduction in strength, the unhandiness in shallow waters, the almost impossibility of graving and breaming, the risking in a single bottom of too great a venture. The *Trades Increase*, built for the new East India Company in 1605 by William Burrell and launched by the king at Deptford, was of no less than 1,100 tons burthen. On her first voyage to Java she was lost by fire, and no more ships of her size were ordered by the Company.

With the expansion of merchant shipping and with the recognition of artillery as the main instrument of naval warfare fighting ships made a corresponding advance in size. The Commission of Reform of 1618, on whose report the subsequent reorganization of the Navy was based, held that the primacy of the big gun had at last been established. "Experience teacheth," the Commissioners recorded, "how sea-fights in these days come seldom to boarding, or to great execution of bows, arrows, small shot and the sword, but are chiefly performed by the great artillery breaking down masts, yards, tearing, raking, and bilging the ships, wherein the great advantage of His Majesty's navy must carefully be maintained by appointing such a proportion of ordnance to each ship as the vessel will bear." They recognized the extravagance of small ships, and advised that in future the royal navy should consist of a nucleus of about thirty large ships, which with the merchant fleet should form one complete service; royal ships of over 800 tons; great ships of over 600 tons; middling ships of about 450 tons. They also formulated the chief requirements of naval construction in considerable detail. This pontifical pronouncement on ship dimensions was doubtless of value in connection with the contemporary project to which their work had reference; nevertheless it formed a dangerous precedent for future administrations. It shackled the genius of the shipbuilder. It degraded design. The ship, especially the timber-built sailing warship, was essentially a compromise between a number of conflicting elements. To obtain full value from his skill the designer required as free as possible a choice of means to his end; and any over-drawing of the specification, or surplusage of data beyond the barest requirements, tended to tie his hands and render impossible a satisfactory design. It was this over-specifying of dimensions in the interests of

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standardization which, as we shall presently see, stultified shipbuilding in England not only in the seventeenth but throughout the whole of the eighteenth century.

But the report of 1618 was doubtless of great value as a guidance for the building of the new Stuart navy. "The manner of building, which in ships of war is of greatest importance, because therein consists both their sailing and force. The ships that can sail best can take or leave (as they say), and use all advantages the winds and seas afford; and their mould, in the judgment of men of best skill, both dead and alive, should have the length treble the breadth, and the breadth in like proportion to the depth, but not to draw above 16 foot of water because deeper ships are seldom good sailers. . . . They must be somewhat snug built, without double galleries and too lofty upper works, which overcharge many ships and make them loom fair, but not work well at sea." As for the strengthening of the royal ships the Commissioners subscribed to the manner of building approved by "our late worthy prince": "first, in making three orlops, whereof the lowest being two feet under water, both strengtheneth the ship, and though her sides be shot through, keepeth it from bilging by shot and giveth easier means to find and stop the leaks. Second, in carrying their orlops whole floored throughout from end to end. Third, in laying the second orlop at such convenient height that the ports may bear out the whole fire of ordnance in all seas and weathers. Fourth, in placing the cookrooms in the forecastle, as other ships of war do, because being in the midships, and in the hold, the smoke and heat so search every corner and seam, that they make the oakum spew out, and the ships leaky, and some decay; besides, the best room for stowage of victualling is thereby so taken up, that transporters must be hired for every voyage of any time; and, which is worst, when all the weight must be cast before and abaft, and the ships are left empty and light in the midst, it makes them apt to sway in the back, as the *Guardland* and divers others have done."

The ships built under the regulations of the Commissioners were certainly an improvement on earlier ships in many respects, but in one element of power they proved to be deficient, namely, in speed. The stoutly built, full-bodied, lumbering English two-deckers were out-sailed and outmanœuvred, it was noticed, by the relatively light and fine-

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lined Hollanders. Moreover our smaller ships were known to be no match in speed for the Dunkirk privateers which at this time infested the seas. A new type was seen to be necessary. The existing differentiation of warships into rates or classes was insufficient. For the line of battle there must be ships in which force of artillery was the predominant quality; but for other duties there must also be ships in which speed, and not force, was the distinguishing note. From this necessity was evolved the *frigate*.

Soon after the accession of Charles I an attempt was made to establish the new type by building small vessels on the model of the largest, miniatures which it was hoped would prove good sailors and capable, although square-sailed, of sailing near a wind. The Ten Whelps were laid down: flush-decked three-masted vessels of 200 tons, 62 feet long on the keel and 25 feet in breadth. They were not a success. It was left for Dunkirk, "the smartest dockyard in Europe," to found the new model. In imitation of a captured Dunkirk privateer our first frigate was built in 1646 by Peter, son of Phineas Pett, and her success was such that he had the achievement recorded on his tomb. The *Constant Warwick* was 85 feet in keel-length, 26 feet 5 inches in breadth, of 315 tons burden and 32 guns. She was "an incomparable sailer." Before the first Dutch war was over she had taken as much money from privateers as would have completely laden her.

It seems probable that the prestige of his name was sufficient to give Peter Pett a freedom from interference in his design which was not accorded less distinguished shipbuilders. In '45 Andrews Burrell, in a remonstance addressed to Parliament, protested, "For the love of heaven let not the shipwrights that are to build them [three frigates for special service] be misled by those that would, but cannot, direct them, which error hath been very hurtful to the navy heretofore." By the interference of Sir John Pennington, he asserted, the builders of the Ten Whelps were so misled that they proved sluggish and unserviceable. "Let no rules be given the shipwrights more than their tonnage, with the number and weight of their ordnance, and that the number and weight of their ordnance may be suitable to the burden of each frigate."

King Charles, whose personal interest in the royal navy equalled that of his father, favoured the tendency to enlarge the tonnage and the individual power of his fighting ships.

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The *Prince Royal* displayed the advantages of size. The Dutch people, jealous of the interference with their eastern trade, were known to be building large ships. Across the channel an ambitious and all-powerful minister was envisaging the possession of a navy in which an inferiority in numbers might be neutralized by the superiority of the unit. In France a vessel of 1400 tons had been laid down. Charles determined to take up the challenge, obtaining the money by hook or by crook wherewith to build a greater. In the year 1634 the decision was made. A model of a great three-decker mounting a hundred and four guns was presented to him by Phineas Pett, and shortly afterwards the master of the shipwrights received the royal command to build a ship, and to proceed in person to the forests of Durham to select the thickstuff, knee timber, and planking requisite for the task.

Opposition to the building of such a prodigious vessel appeared from different quarters. Great ships, in the opinion of Sir Walter Raleigh, were "of marvellous charge and fearful cumber." The cost of so large a ship must needs be great, for not only the whole cost, but the cost per ton, increased with the size of the vessel; so wasteful a process was the building of a great ship, indeed, that it was not unusual to build a small ship simultaneously, out of the timber discarded: a practice known as "building a small ship out of a great one's chips." Ships of the greatest size, again, were "of little service, less nimble, less mainable, and very seldom employed." Nor was it believed that so large a vessel as that projected could be built. Trinity House, when they heard of the design, uttered a formal protest. Such a ship, they argued, would be too big for service, and unsafe from her enormous size. To carry such a number of pieces she must be a three-decker, and to build a serviceable three-decker was beyond the art or wit of man; if the lower tier were too low they would be useless in a sea, if at 5 or 5½ feet above the water-line then the third tier would be so high as to endanger the ship. In spite of this protest the new ship was laid down, and nearly two years later, in the autumn of '37, she was launched at Woolwich, "the pride and glory of the Caroline navy."

The *Sovereign of the Seas*, the *Sovereign*, or the *Royal Sovereign*, as she was called by successive governments, was another great advance in size and solidity on all preceding construction, and was the masterpiece of Phineas Pett. Her

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length by the keel was 128 feet, her main breadth 48 feet, her overall length 232 feet She had three flush decks and a forecastle, a half-deck, a quarter-deck, and a roundhouse. Her armament showed an approach to symmetry ; the lower tier consisted of cannon and demi-cannon, the middle tier of culverins and demi-culverins. In one respect she was less advanced than Pett's earlier effort, the *Prince Royal*, in that she had an old-fashioned beakhead, low hawses and a low and exposed forecastle. In general form she was extolled by all, and bore witness to the genius of her designer. No better form, said a later critic and constructor[1] after making an analysis of her lines—no better form could have been devised for a ship built (according to the prevailing customs of the times) so high out of water and so overloaded with ornaments. The king took a personal pride in her, and during her construction visited Woolwich and "seriously perused all the ship within board." For him an elaborate description was written which, quoted at length by various writers, serves to show the extent to which mere decoration contributed to the cost of a royal ship. Two pictures of the vessel are reproduced by Charnock, of such obvious disparity that they serve to show (as the author observes) to what a degree artists may differ in the presentment of the same vessel. They confirm, besides, the profuseness of the ornamentation which was massed on her—the trophies, angels, emblems, mouldings—which made her the occasion of loud complaints against ship-money, and "a miracle of black and gold."

The *Sovereign of the Seas* had a distinguished career. When cut down a deck she proved to be an exceptionally serviceable unit, taking part in all the great actions of the Dutch wars and crowning her work at La Hogue, where she engaged, crippled, and forced to fly for shallow water the great *Soleil Royal*, 104, the French flagship. At length, when laid up at Chatham in 1696 in order to be rebuilt, she was set on fire by negligence and destroyed.

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By the outbreak of the first Dutch war the modern ideas introduced by Phineas Pett had received a general embodiment in the navy. Blake found to his hand ships well suited to the intended warfare, nor was he much concerned to add either to their number or their magnitude. Only in one feature

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[1] Sir J. Knowles, F.R.S.

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did the new vessels built show any difference from older construction : their depth in hold was reduced, probably to render them more suitable for work among the shallow waters of the coast of Holland.[1] In other important respects improvement had preceded the opening of hostilities.

The lofty stern with which it had been the custom to endow the sailing ship was a feature which had survived from ancient times. In the galley, whose armament was concentrated in the bows, the after part was not devoted to military fittings, but was appropriated chiefly to the accommodation of the officers. So it was in the galleon or sailing ship. With the desire and need for increased accommodation the extra space was obtained by prolonging aft the broad horizontal lines of the vessel and terminating them in a square frame. To give more space, quarter galleries were then added, outside the vessel. Then extra tiers of cabins were added, also with quarter galleries, each storey, as in the case of domestic architecture, projecting over that beneath it, and the whole forming, with its surmounting taffrails, lanterns and ornaments, an excessively weighty and top-heavy structure. Similarly, at the fore end of the ship there remained the survival of the ancient forecastle.

With the acceptance of artillery as the medium for battle, with the decay of boarding tactics and the decline in value of small man-killing firearms, close-fights and end-castles, the lofty forecastles and sterns ceased to possess much of their special value. The arguments of Sir Richard Hawkins' day in favour of large cage-works no longer held ; nor could the preference of some shipbuilders for high sterns, as allowing a quick sheer and thereby contributing to the girder strength of the hull, be considered sufficient to justify their retention. The stern galleries held a great deal of wind and tended to rot the decks in their vicinity ; their weight put a strain upon the supporting keel ; but, chiefly, the danger of their taking fire in action induced the authorities to cut them down. For similar reasons the forecastles were attacked. But there was strong opposition to their elimination, because of the cover which they afforded in a fight. In 1652 the *Phœnix*, one of the finest frigates in the service, was taken by a Dutch ship, " having no forecastle for her men to retire to." In the second Dutch war experience confirmed their usefulness. " All the world," wrote

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[1] Willett : *Memoirs on Naval Architecture.*

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Mr. Secretary Pepys in his diary for the 4th July, 1666, "now sees the use of forecastles for the shelter of men."

No general increase in the size of our ships took place till toward the end of the third Dutch war. Until that time the navy of France was a negligible quantity; in 1664, it is said, the only war-vessel at Brest was one old fireship. The Dutch, our only strong opponents, fought in ships not unlike our own, stout, buoyant vessels mounting from 24 to 60 guns, and of from 300 to 1200 tons burden. Geography had a curious influence on their construction. Owing to the shallowness of their coasts the Hollanders built their ships with less draught and flatter floors than those of other countries; from which policy they derived advantages of a greater carrying capacity and, in pursuit, an ability to retreat among the shallows; but on account of which they suffered a serious handicap in the hour of action, when, faced by English ships built of superior material and with finer bottoms which enabled them to hold a better wind, they were weathered and out-fought.[1]

There was no apparent advantage, therefore, in augmenting the size of our ships. Improvement was sought, rather, from a further unification of the calibres of the guns, and from an increase in the number carried. Their characteristics of shortness and large bore were such as to make them well-suited to the form of battle now favoured by English leaders—the close-quarter action.

In solidity of construction the English ships compared favourably with those of the Dutch. The thick scantlings introduced by Phineas Pett now proved of great value; the wood itself, tough English oak, was unequalled by any other timber. English oak was the best, as Fuller noted. Even the Dutch had built some of their ships of it; while other countries frequently built of inferior fir, the splinters of which killed more than were hit by hostile cannon balls. To what was the superiority of the English timber due? To the soil and climate of this favoured country. Under the influence of successions of warmth and cold, of rain and sunshine, frost and wind, all in a degree most favourable for alternate growth and consolidation, the English oak attained an unrivalled strength and durability. Trees planted in forests, where mutual protection was afforded

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[1] It has been suggested that the restricted draught given to the Dutch ships, owing to the shallowness of their coast waters, had the result of necessitating a generous breadth, and therefore made them generally stiffer than vessels of English construction.

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from wind and cold, grew rapidly, but were inferior in quality to trees planted in small parcels or along the hedgerows ; these latter, slow-growing and tough, felled "at the wane of the moon and in the deep of winter," supplied the thickstuff, knees, and planking for generations of our royal ships. Their endurance was frequently remarkable. The bottom timbers would last for fifty or sixty years, but the upper works, which were subject to alternations of heat and cold, dryness and moisture, decayed in a much shorter space of time. The *Royal William* is quoted by Charnock as a case in point. This first rate ship was launched in the year 1719, and never received any material repair until 1757. A few years later she was cut down to a third rate of 80 guns. Participating in all the sea wars of the time, she was surveyed in 1785 and converted into a guardship, which post she filled till early in the nineteenth century.[1]

Much attention, as we have noted, was given in this scientifically minded Stuart age to the form of body best suited to motion through water, but the efforts to improve design were largely misdirected. Many of our ships were unsatisfactory, not only from their slowness but because they were crank or tender-sided, and unable to bear out their lower guns or even to carry a stout sail. They were so clogged with timbers internally that they could not carry the victuals and stores necessary for long voyages ; and vessels built by contract were often found to be carelessly put together, of green, unseasoned, and unsuitable timber.

After the Restoration the mantle of the Petts descended on a master shipwright of Portsmouth, who became an authoritative exponent of ship design, and to whose ability several improvements were due. "Another great step and improvement to our navy," recorded Mr. Pepys in 1665, "put in practice by Sir Anthony Deane, was effected in the *Warspight* and *Defiance*, which were to carry six months' provisions, and their guns four and a half feet from the water." In the same diary for 19th May of the following year occurs the following characteristic note : "Mr. Deane did discourse about his ship the *Rupert*, which succeeds so well, as he has got great honour by it ; and I some, by recommending him. The king, duke, and every body, say it is the best ship that was ever built. And then he

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[1] Derrick in his Memoirs refers to this ship as having been built of burnt instead of kilned timber, and as having special arrangements for circulating air in all its parts.

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fell to explain to me the manner of casting the draught of water which a ship will draw, beforehand, which is a secret the king and all admire in him ; and he is the first that hath come to any certainty beforehand of foretelling the draught of water of a ship, before she is launched." The calculations used by Sir Anthony Deane to forecast the draught of a projected ship might win him applause among the philosophers ; but the scoffer at theory was able to point to considerable achievements wrought by men who made no pretence of any knowledge of science. In 1668 the *Royal Charles*, 110, was launched at Deptford. "She was built," wrote Evelyn, "by old Shish, a plain, honest carpenter, master builder of this dock, but one who can give little account of his art by discourse, and is hardly capable of reading."

The interest of Charles II in naval architecture may be gathered from a letter written by him in 1673 : "I am very glad that the *Charles* does so well ; a girdling this winter, when she comes in, will make her the best ship in England : the next summer, if you try the two sloops that were built at Woolwich that have my invention in them, they will outsail any of the French sloops. Sir Samuel Morland has now another fancy about weighing anchors ; and the resident of Venice has made a model also to the same purpose."

To girdle a ship, was to fasten planks along her sides some two or three strakes above and below the water-line ; this had the effect of adding to her beam and thereby rendering her stiffer under sail. Incessant girdling seems to have been necessary at this period, to counter the defective conditions in which English ships were designed, built, and sent to sea. Ships were consistently restricted in beam, in compliance with the faulty "establishments," and under a mistaken notion that narrowness, in itself, directly contributed to speed. "Length," says Charnock, "was the only dimension regarded as indispensably necessary, by the ancients for their galleys and by the moderns for galleons. Breadth was not considered, or if considered was accepted as a necessary evil." Pepys remarked, "that the builders of England, before 1673, had not well considered that breadth only will make a stiff ship." It was an inquiry ordered by Sir Richard Haddock in 1684 which brought to light the fulness of the fallacy ; ships were subsequently made broader, and experience showed that a good breadth was beneficial, not only for stability but for speed and sea-keeping qualities.

But even if a ship were built initially broad enough, the continual addition of armament and top-hamper to which she was often subjected had the effect eventually of impairing her stability. In such a case there were two remedies : to ballast or to girdle. The former expedient was objectionable, as it involved an increase both of displacement and of draught. Girdling was therefore generally practised. By this means the vessel was made stiffer, her buoyancy was improved, and her sides were also rendered less penetrable between wind and water. Even if, when thus girdled, she proved to be less stiff than the enemy this was not altogether a disadvantage : she formed a steadier gun-platform, her sides were less strained by the sea and, because her rolling was less violent, her topmasts were less liable to be sprung. But sufficient stiffness was necessary to allow of her lowest and heaviest tier of guns being fought in moderate weather ; and for this reason alone, girdling was preferable to ballasting, in that the former tended to keep the guns high out of water while the latter brought them nearer the water-line.

Although rigidly restricted in dimensions, ships put to sea in these days under such varying conditions that it was difficult indeed to foretell whether a vessel were seaworthy or not. A commissioner of James the Second's reign complained bitterly of the injudicious management whereby " many a fast sailing ship have come to lose that property, by being over-masted, over-rigged, over-gunned (as the *Constant Warwick*, from 26 guns and an incomparable sailer, to 46 guns and a slug), over-manned (*vide* all the old ships built in the parliament time now left), over-built (*vide* the *Ruby* and *Assurance*), and having great taffrails and galleries, etc., to the making many formerly a stiff, now a tender-sided ship, bringing thereby their head and tuck to lie too low in the water."

In spite of these strictures it must be remembered that our ships had qualities which, brought into action by brave crews and resolute leaders, served the nation well in the day of battle. In no naval war, perhaps, did superiority of material exert such a consistent and preponderating effect as in the seventeenth century wars between this country and Holland.

The tactics of the English leaders involved close-quarter fighting. The material, both guns and ships, certainly favoured these tactics ; though to what extent tactics dictated the form of the material, or material reacted on tactics, it may be

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difficult to decide. In one respect tactics undoubtedly directed the evolution of the material: while the Dutch employed a "gregarious system" of mutual support of their vessels by others of various force, fighting in groups and throwing in fireships as opportunity offered, the English always sought to match individual ships.[1] Forming in line ahead—a formation, said to have been first used by Tromp, which enabled our vessels to avoid the fireships—they came to close quarters in a series of duels in which the strength and prowess of each individual ship was its only means of victory. The success of this plan caused the Dutch to imitate it. The size of their ships rapidly grew; their weakest units were discarded. Three-deckers were laid down, at first carrying only 76 guns, but later, after the peace of 1674, as large as the British first rates. But by that time the critical battles had been lost and won. And the success of the British is ascribed, in Derrick's memoirs, chiefly to the superior size of our ships, "an advantage which all the skill of the Dutch could not compensate."

With the institution of the line of battle a need arose for a symmetry between ships which had never before existed. From this arose, not only that more complete differentiation of force[2] which lasted through the following century, but a still more stringent ruling of dimensions according to "establishments," which ruling, injudiciously applied, was henceforth to exercise so harmful an effect on English naval construction.

After the peace of 1674 the navy sank into inefficiency. The French navy, on the other hand, ascended in power with an extraordinary rapidity. By 1681 it had expanded so much under the fostering care of M. Colbert that it comprised no fewer than one hundred and fifteen ships of the line. In design, as apart from construction, French ships were superior to ours. In size especially they had an advantage, being universally larger than British ships of the same artillery force: an advantage based on the law, known to our own shipbuilders but never applied, that *the greater the dimensions of a ship, relatively to the weight she has to carry, the better she will sail.* So superior were some French ships which visited Spithead seen to be, that in imitation of them Sir Anthony Deane was ordered to design and build the *Harwich*; and from the plans of this ship nine others were ordered by parliament, the class constituting the greatest advance in naval architecture of that

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[1] Charnock. [2] Colomb: *Sea Warfare.*

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time. But this departure from precedent had little effect. In dimensions as compared with tonnage we continued parsimonious. In the face of French experience we cramped our ships to the requirements of the faulty " establishments " ; and until the end of the century no increase in size took place except in the case of some ships laid down in the year 1682, when the threat of a war with Louis XIV not improbably caused them to be constructed on a more extensive scale than had ever before been in practice.

In another respect our ships were inferior in design to those of our chief rivals : in the extreme degree of " tumble home " given to their sides. Adhering to ancient practice in this particular, in order to obtain advantages which have already been mentioned, we suffered increasingly serious disadvantages. The sides of our ships were so convex that, when sailing on a wind, every wave was guided upward to the upper deck, thereby keeping the crew continually wet. The deck space required for the efficient working of the sails was contracted. Moreover, ships having this high degree of convexity were more easily overset than were wall-sided ships. This exaggerated convexity had a striking effect on one feature of our construction, viz. the manner in which we affixed the chain-plates, to which the shrouds were secured, in a low position on the curve of the hull ; while Holland and France raised them to a more convenient height—over the upper tier of guns, in their two-decked ships.

On the other hand the horizontal lines of our ships were (in the absence of science) cleverly moulded. The after lines in particular were well suited for supporting the stern and at the same time allowing a free run of water to the rudder ; other nations, overlooking the importance of this part of the vessel, adhered to the old-fashioned square tuck and stern which was a chief but unappreciated factor of the resistance to the passage of the vessel through water.

When war actually broke out in 1689 the balance of material between English and French was much the same in character as it had been between English and Dutch. Our fleet was once more in a seaworthy and efficient condition. Our guns were generally shorter and of larger bore than those of the French ; our ships were narrower and less able to bear out their ordnance, but their sides were thicker, and better able to withstand the racket of gun fire. Once more, at La Hogue, the British

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squadrons showed that they possessed the offensive and defensive qualities which favoured victory in close-quarter fighting; and the end of the century found the prestige of the navy at a level as high as that to which Cromwell and Blake had brought it.

In the decade which ended in 1689 the navy had passed, on its administrative side, "from the lowest state of impotence to the most advanced step towards a lasting and solid prosperity." In Pepys' rare little *Memoirs* the story of this dramatic change is told. We read how, after five years' governance by the commission charged by the king with the whole office of the Lord High Admiral, the navy found itself rotten to the core; how in '85 the king resolved to take up its management again, helped by his royal brother; how he sent for Mr. Pepys; how at his instigation new, honest, and energetic Commissioners were appointed, including among them the reluctant Sir Anthony Deane; how Mr. Pepys himself strove to reorganize, how new regulations were introduced, sea stores established, finances checked, malpractices exposed, the navy restored both in spirit and material.

Mr. Pepys claimed to prove that integrity and general knowledge were insufficient, if unaccompanied by vigour, assiduity, affection, strictness of discipline and method, for the successful conduct of a navy; and that by the strenuous conjunction of zeal, honesty, good husbandry and method, and not least by the employment of technical knowledge, the Royal Navy had been rendered efficient once again.

The following extract from an Essay on the Navy, printed in 1702, is here quoted for its general significance:

> "The cannon (nearly 10,000 brass and iron) are for nature and make according to the former disposition and manner of our mariners' fighting (whose custom was to fight board and board, yard-arm and yard-arm, through and through, as they termed it, and not at a distance in the line, and a like, which practice till of late our seniors say they were strangers to), they are therefore much shorter and of larger bore than the French, with whom to fight at a distance is very disadvantageous, as has been observed in several fights of late, their balls or bullets flying over our ships before ours could reach them by a mile. . . . ." etc., etc.

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In Laputa, early in the eighteenth century, the people were so engrossed in the mathematics that the constant study of abstruse problems had a strange and distorting effect on the whole life of the island. Their houses were built according to such refined instructions as caused their workmen to make perpetual mistakes; their clothes were cut (and often incorrectly) by mathematical calculation; the very viands on their tables were carved into rhomboids, cycloids, cones, parallelograms, and other mathematical figures!

To most Englishmen of that time any attempt to apply science to shipbuilding must have appeared as far-fetched and grotesque as these practices of the Laputans. Ship design was still an art, veiled in mystery, its votaries guided only by blind lore and groping along an increasingly difficult path by processes of trial and error. The methods of applied science were as yet unknown. The builder was often a mere carpenter, ignorant of mathematics and even of the use of simple plans; the savant in his quiet study and the seaman on the perilous seas lived in worlds apart from each other and from him, and could not collaborate. Such speculative principles as the shipbuilder possessed were almost wholly erroneous; no single curve or dimension of a ship, it is said, was founded on a rational principle. Everything was by tradition or authority. Knowledge had not yet coalesced in books. Men kept such secrets as they had in manuscript, and their want of knowledge was covered by silence and mystery. Preposterous theories were maintained by the most able men and facts were denied or perverted so as to square with them. "Forgetful of the road pointed out by Lord Bacon, who opposed a legitimate induction from well-established facts to hypothesis founded on specious conjectures, and too hastily giving up as hopeless the attainment of a theory combining experiment with established scientific principles, they have contented themselves with ingeniously inventing *mechanical methods* of forming the designs of ships' bodies of arcs of circles, others of ellipses, parabolas, catenaries—which they thought to possess some peculiar virtue and which they investigated with the minutest mathematical accuracy. So they became possessed of a System. And, armed with this, they despised all rivals without

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one; and, trusting to it, rejected all the benefits of experiment and of sea experience." [1]

The intervention of the philosophers had not had any appreciable effect. Sir William Petty had indeed projected a great work on the theory of shipbuilding; he had carried out model experiments in tanks, and had invented a double-keeled vessel which, by its performances on passage between Holyhead and Dublin, had drawn public attention to his theories.[2] In his discourse before the Royal Society on Duplicate Proportions, he had opened out new and complex considerations for the shipbuilder; inviting him to forsake his golden rule, or Rule of Three, and apply the law x *varies as* y^2 to numerous problems in connection with his craft. But it could soon be shown, by a reference to current practice, that this new law could not be rigidly applied. And the shipbuilder, realizing his own limitations and jealous of sharing his professional mysteries with mathematicians and philosophers, was willing to laugh the new theories out of court.

Again, of what practical use had been the discovery of the "solid of least resistance" or of that "cono-cuneus" which Dr. Wallis had investigated with a view to its application to the bows of a ship? A final blow to the scientists was given when the *Royal Katherine*, a three-decker of 80 guns, designed by the council of the Royal Society, was found so deficient in stability that it was deemed necessary to girdle her. Old Shish had beaten Sir Isaac Newton and all the professors! The impossibility of applying abstract scientific principles to so complex a machine as a sailing ship, moving in elements so variable as air and water, was patent to everyone. The attitude of the professional may be judged from the resigned language of William Sutherland, a shipwright of Portsmouth and Deptford Yards, who in 1711 published his *Ship-builder's Assistant*:

"Though some of our preceding Master Builders have proposed length as expedient to increase motion, yet it has seldom answered; much extra timber is required to make them equally strong. Besides, if the solid of least resistance be a blunt-headed solid, extreme length will be useless to make cutting bodies."

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[1] Creuze: *Papers on Naval Architecture.*

[2] Even the scientific Sir William Petty cast a veil of mystery over his processes. "I only affirm," he writes, "that the perfection of sailing lies in my principle, *finde it out who can!* (See Pepys' Diary for 31st July, 1663.)

Again, in connection with the dimensions of masts:

"Though several writers say, that the velocities are the square roots of the power that drives or draws the body; from which it should be a quadruple sail to cause double swiftness. Hence, unless the fashion is adapted to the magnitude of the ship, all our Art can only be allowed notional, and the safest way of building and equipping will be to go to precedent, if there be any to be found. But this is a superfluous caution, since 'tis very customary, that let a ship be fitted never so well by one hand, it will not suit the temper of another. Besides, the proper business of a shipwright is counted an very vulgar imploy, and which a man of very indifferent qualifications may be master of."

Science was, in short, discredited. The corporation of shipwrights had disappeared, not long surviving the fall of the house of Stuart. No master-builder had succeeded the Petts and the Deanes having sufficient influence and erudition to expose the faulty system under which warships were now built, English shipbuilding had once more become a craft governed entirely by precedent and the regulations. The professor was routed, and the practical man said in his heart, There is no knowing what salt water likes.

Yet the science of naval architecture was at the dawn. Not in this country, but in France, in the early part of the eighteenth century, research and inquiry received such encouragement from the State that it conferred on their fleets a superiority of design which they retained for long: a superiority which enabled them, in the *guerre de course* which was developed after La Hogue under the intrepid leadership of men like Jean Bart, Forbin, and Duguay-Trouin, to strike us some shrewd blows.

We propose to summarize as briefly as possible the principal events which mark the evolution of the scientific side of naval architecture.

A mere enumeration of the names and works of the men who chiefly contributed to the discovery of the true natural principles underlying the performance of sailing ships would suffice to show the debt owed by the world to French effort, and the tardiness with which this country faced the intellectual problems involved. In the year 1681 a series of conferences was held at Paris on the question of placing the operations of naval architecture on a stable scientific basis; but before that date, in 1673, Father Pardies, a Jesuit, had published the

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results of his attempts to calculate the resistance of bodies moving in fluids with varying velocities. In '93 the Chevalier Renaud and Christian Huyghens were engaged in public controversy on the merits and deficiencies of Pardies' laws. In '96 James Bernouilli entered the lists on Huyghen's side, and in the following year a remarkable work appeared from the pen of another Jesuit, Paul Hoste, professor of mathematics at Toulon. Father Hoste, having noticed the frequency with which vessels of that time required girdling, had put the question, why they should not be built initially with the form which they had when ultimately girdled. The replies given him being unsatisfactory, the professor investigated a whole series of problems : the relation between speed and resistance, the effect of form on resistance, stability, stowage, the properties affecting pitching, and the best form of bow. Though incorrect in much of his theory, he had admittedly a great influence on later research. He was followed, in 1714, by John Bernouilli, professor at Basle, whose investigations were purely theoretical. And then, a few years later, M. Bouguer made his great discovery of the *metacentre*, that all-important point in space whose position in a ship, relatively to its centre of gravity, marks with precision the nature of the vessel's stability.

A treatise by Euler, entitled *Scientia Navalis*, was published in 1749, and a little later, stimulated by prizes offered by the Société Royale des Sciences, Don G. Juan in Spain, Euler in Russia, and Daniel Bernouilli in Germany, all published the results of their investigations into the forces acting on a rolling ship. Euler's contribution was especially valuable. Treating the ship as a pendulum he laid down two definite rules for the guidance of shipbuilders, (1), not to remove the parts of a ship too far from the longitudinal axis, (2), to make the most distant parts as light as possible.

Up to this time the discoveries of the mathematicians had had little practical effect on shipping. The abstruse form in which new truths were published, and the lack of education of the shipbuilders, prevented that mutual collaboration which was necessary if the art of shipbuilding was to benefit by the advances of science. Soon after 1750, however, a succession of able men, possessed of imagination and initiative, led inquiry into practical channels, and by actual trial proved, incidentally, that much of the accepted theory was faulty. The Chevalier de Borda, a naval captain and a member

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of the Academy of Sciences, investigated with models the resistance of fluids to motion through them, and enunciated laws which shook confidence in current beliefs. The result was a commission from the government to three eminent men, M. D'Alembert, the Marquis Condorcet and the Abbé Bossut, to report on and continue de Borda's investigations. The report, read by the Abbé before the Academy in 1776, confirmed generally de Borda's theories, and revealed new problems—in particular, the alteration in shape of the free water surface and the effect of wave resistance, the latter of which was ultimately to be solved in this country by Mr. W. Froude—that required investigation. The circumstances of this commission illustrate the enlightened interest of the State in the advancement of knowledge, significant testimony to which was paid by Abbé Bossut. "M. Turgot," he said of the Comptroller-General of Finances, who took responsibility for it, "who is not only an admirer of the sciences, but has pursued the study of them himself amidst his numerous important official functions, approved of our intentions, and granted every requisite for prosecuting them."

In the same year curious and important discoveries were made by M. Romme, professor of navigation at La Rochelle. In an endeavour to find the form of ship body which would give good stability in conjunction with small resistance, he ascertained the importance of the "run" or after part. Hitherto the form of bow had absorbed attention to the almost entire exclusion of the form of run, except in so far as it had been shaped to allow water to flow freely to the rudder. M. Romme called in aid methods which are now approved as scientific, but which were then conspicuously novel: he experimented by comparative trials between models in which all variable features except one had been carefully eliminated. He was rewarded by some new discoveries. By fixing the length and successively varying the curvature of different parts of his models he laid bare an important paradox. While at low speeds the resistance was least when a sharp end was in front and a blunt end in rear, at higher speeds the opposite obtained. This accounted for a great deal of the contradictions of previous investigators. M. Romme went further: the curves by which the bow of a ship was connected with her middle body, hitherto looked on as all-important, were shown to be relatively immaterial. He astonished the world of

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science by proving that, given certain conditions, the resistance upon an arc of a curve is the same as that upon the chord of this arc. His deductions were proved by commissions to be well founded. Experience confirmed that the form of the bow curve did not much influence the resistance experienced in passing through water; on the other hand the form of the run was shown to have a far greater effect than had hitherto been suspected.

In the year before M. Romme published the results of his experiments a treatise appeared, full of empirical rules and shrewd reasoning, by one of the greatest naval architects, Henry de Chapman, chief constructor of the Swedish navy, an Anglo-Swede who came of an old shipbuilding family of Deptford. Chapman was a most gifted shipbuilder. Though his formulæ were empirical, they were founded on careful observation and induction, and his name ranks with those of Phineas Pett and Anthony Deane in the history of naval architecture.

Nothing, so far, had come from English writers. "The only English treatise on shipbuilding that can lay any claim to a scientific character was published by Mungo Murray in 1754; and he, though his conduct was irreproachable, lived and died a working shipwright in Deptford dockyard."[1] But indifference was at last giving place to interest. Inspired by the formation of the Society of Arts in 1753 (which Society was itself inspired by the recognition, on the part of the founder, of the value of prizes and rewards in improving our breed of racehorses) a London bookseller named Sewell succeeded in 1791 in forming a Society for the Improvement of Naval Architecture. "Impressed with the many grave complaints which reached him as to the inferiority of our warships as compared with those of France and Spain," he gained the interest of Lord Barham and other influential men. A meeting was held at which it was decided, as something of a novelty, that the theory and art of shipbuilding were subjects of national importance; that a radical deficiency in knowledge of the same existed; and that the most effective remedy was a focussing of the wisdom of the country on this matter by the institution of the above Society.[2]

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[1] Creuze: *Shipbuilding, Encycl. Brit.*, 7th Edition, 1841. It should be mentioned that the work of Dr. Colin McLaurin, of Edinburgh, in giving a mathematical solution for the angles at which a ship's sails should be set, had received considerable attention on the Continent.

[2] See a paper by Mr. Johns, R.C.N.C., in *Trans. I.N.A.* 1910.

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For a time the society flourished. A learned paper by Atwood before the Royal Society, on the stability of a rolling ship, proved that this country was not wholly destitute of mathematical talent. An interesting series of experiments was carried out for it by Colonel Beaufoy, a devoted student who had made his first experiments on water resistance before he was fifteen years old. It appears that his attention was first drawn to the subject by hearing an eminent mathematician state one evening that a cone drawn through water base foremost experienced less resistance than with its apex foremost; and it was said that sailors always took a mast in tow by the heel. The paradox excited young Beaufoy's curiosity. Before bedtime, with the assistance of a neighbouring turner, he was making experiments in one of the coolers in his father's brewhouse, a large bunch of counting-house keys being put into requisition as a motive power. Though the society was dissolved in 1799 Beaufoy continued to pursue this subject with unabated zeal until his death. In one direction, especially, he did good work. Attracted by the frequency with which North Sea fishing vessels, fitted with wells for carrying the fish, foundered at sea, he showed experimentally the loss of stability involved in carrying open tanks of water. He also demonstrated to English builders by means of models that Bouguer's diagram of metacentric stability was of great practical value, even for large angles of heel. "His experiments," says Mr. Johns, "should take an important place in the history of stability of ships."

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We now revert to the beginning of the eighteenth century. In the desultory warfare which was carried on during the reign of Queen Anne events occurred to demonstrate the superiority in design of the French warship over its English opponent of the same nominal force. One in particular, an expedition under Count Forbin which was intended to cover a descent on the Scotch coast in favour of the Pretender, "showed, even in failure, that in material France held a lead on us." Chased back to its ports from the latitude of Edinburgh by larger English forces, Forbin's squadron proved a superiority over all our ships, both in speed and seaworthiness. In weather which disabled many of our vessels the French

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squadron arrived home with the loss of only three—and these all English built.

At about the same time the capture by us of a 60-gun ship, the *Maure*, of extraordinarily large dimensions for her rate, showed the direction in which French design differed from our own. The recapture, not long afterwards, of the *Pembroke*, which was now found to carry only fifty, instead of her original number of sixty-four guns, corroborated (says Charnock) the direction in which improvement was sought and found.

But for some time the lesson remained unlearnt. For a number of years the inferiority of our design was an accepted fact; "every action won by British valour was a stigma to British science." Throughout the whole of this century we set no value on scientific principles as applied to naval architecture, and were content to remain copyists. Although before the advent of the Napoleonic wars we had thus endeavoured to reduce their balance of advantage, yet even so the French still maintained an absolute superiority in design. In the first half of the century this superiority was especially conspicuous; and, in conjunction with an inferiority of seamanship and workmanship which in the end more than neutralized all its advantages, it was the cause of the disreputable incongruities which Charnock has depicted in his well-known epigram: *Very few ships captured by the enemy from the British have ever continued long the property of their possessors. If it has so happened, that one of them, being in company with others of French construction, has ever fallen in with any English squadron, that ship, almost without exception, has been among those captured, and most frequently the first which has fallen. On the other hand, the recapture of any ship from the British, which was originally French, is a circumstance extremely uncommon. Captured French ships were sought for as the best commands, which not infrequently were the means of recapturing captured English vessels.*

Very seldom was our failure to overhaul the speedy Frenchman attributed to inferiority of design; nearly always to the fortuitous circumstance that we were foul-bottomed and the enemy clean; which may have been sometimes true, but which was evidently a partial and inaccurate explanation.

We have already made mention of the periodic "establishments" of dimensions to which ships built for the royal navy were made to conform. The first of these, after the rules laid down by the commissioners of James I, was decreed in 1655,

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when Blake was organizing a new standard navy. In 1677 dimensions were established for ships of 100, 90, and 70 guns, but were exceeded in the case of those ships which were actually built; and in '91 a revised establishment for all classes, very similar to those which previously governed practice, appeared. In 1706 a new establishment was decreed, a compromise between the ideas of the Surveyor and the master shipwrights, in which the dimensions of each class were slightly increased. The dimensions still remained small compared with those of all foreign ships, however, and still "all superior faculties of sailing were attributed to the mere length of the vessel itself, without any but trivial regard to shape or form of bottom." Assuming that the ships built under this establishment derived some slight advantage over earlier construction on account of their augmented tonnage, yet this was nullified when, in 1716, the force of their armament was raised. As the work of a committee presided over by Admiral Byng, a new establishment of guns was ordered, a change being made in calibres but not in numbers:—

First and second rates, instead of carrying 32-pounders on the lower, 18-pounders on the main, and 9-pounders on the upper deck, were ordered to carry, 42-pounders (or 32-pounders) on the lower, 24-pounders on the main, and 12-pounders on the upper deck. Eighty-gun ships, instead of carrying 24-pounders on the lower, 12-pounders on the main, and 6-pounders on the upper deck, were ordered to carry 32-pounders on the lower, 12-pounders on the main, and 6-pounders on the upper deck. Seventy-gun ships, which in the previous century had carried 18-pounders on their main, and 9-pounders on their upper deck, and which during the reign of Queen Anne had carried 24-pounders and 9-pounders, were now ordered to carry 24-pounders and 12-pounders. And so on with the smaller rates.

In 1719 a new establishment for ships was decreed, the dimensions slightly exceeding those of 1706, but being totally insufficient for satisfactory construction. In '32 and '41 attempts were made to formulate new rules; but the master shipwrights seem to have been loth to accept the lesson which the French enemy was teaching them, and hesitated to recommend any radical departure from traditional practice.

At length, in 1745, general complaint of the inferiority of our ships in size and scantlings forced improvement on the

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authorities. Spain, who had joined France in war against us, possessed ships which exceeded in size even French ships of the same rate. The capture in 1740 of a Spanish 70-gun ship, the *Princessa*, by three of our ships, nominally of equal force with herself but of far inferior dimensions and scantlings, is said to have been the chief cause of the new reform. Their lordships of the Admiralty, surveying naval construction in this country, noted that our royal ships were weak and crank, while those of other nations went upright. There was no uniform standard of size, ships of the same class were of different dimensions, the existing establishment was not adhered to. They therefore decided on a new establishment, based on the latest armament of guns ; which should result in ships which would carry their lower tier six feet above the water, and four months' provisions.

The new standard was of little avail, for the same error made some thirty years previously was now repeated : with the augmentation of the ship dimensions the armament was also raised in calibre. The first rates were ordered to carry the 42-pounder (which had before been optional) on their lower deck ; the 90-gun ships, 12-pounders on their upper decks ; the eighties, 18-pounders and 9-pounders instead of 12's and 6's ; the seventies, which were only two hundred tons in excess of the former establishment, 32-pounders and 18-pounders, instead of 24's and 12's. "The ships, therefore, built by this establishment proved, in general, very crank and bad sea-boats."[1]

This establishment was, in point of fact, little adhered to. The war with France during the years 1744–8 repeatedly revealed the defective nature of our ship design. Experience pointed to the necessity either of reduced gun-weights or of larger ships. Able administrators were now willing, under the inspiration of such names as Hawke and Anson, to initiate improvements. Our naval architecture at last took benefit, though still by slow and cautious degrees, from foreign experience. Some time was necessary for results to show themselves ; not only were new decisions slowly formed, but the rate of building was deliberately slow. The *Royal George*, for instance, described as "the first attempt towards emancipation from the former servitude," was ten years building. But, when war broke out again in 1756, the improvements already embodied

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[1] Willett: *Memoirs on Naval Architecture.*

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in the newest construction proved of considerable benefit. The establishment of '45 was given the credit. "The ships built by the establishment of 1745," says Derrick in his Memoirs, "were found to carry their guns well, and were stiff ships, but they were formed too full in their after part; and in the war which took place in 1756, or a little before, some further improvements in the draughts were therefore adopted, and the dimensions of the ships were also further increased."

To meet the advances in French construction a new classification of rates took place, with French captured ships as models. The capture of the *Foudroyant*, for instance, in 1758, provided us with the form and dimensions of a splendid two-decked 84-gun ship. Our 80-gun three-deckers were thereupon abolished, and no three-decker was thenceforth built with fewer than 90 guns. The capture of the *Invincible*, in 1757, gave us a valuable model for a 74-gun ship, a rate highly esteemed, which bore the brunt of most of this century's warfare.[1] From her was copied the *Triumph*, and other experimental 74's, with dimensions varying from those of the *Invincible*, were at this time laid down. All 50-gun ships had already dropped out of the line of battle; they were now followed by the 60's. No more 60 or 70-gun ships were built; their places were taken by 64's and 74's respectively, of relatively large size and displacement.

Nor was improvement confined to form and dimensions. Attention was now paid to material. New rules were made for the cutting and seasoning of timber, and for its economical use. Sheathing was tried; in 1761 the frigate *Alarm* was sheathed in copper for service in the West Indies, where the worm was active. The copper was found to keep clean the hull, but at the expense of the iron fastenings; so when, in '83, copper sheathing became general, an order was issued for all new royal ships to be copper fastened up to the water-line: an order beneficial on another count, since even without the presence of copper sheathing, iron bolts had always been liable to corrosion from the acids contained in the oak timbers. Ventilation was also studied, more for its effects on the hull timbers than on the health of the crews. The scantlings of all

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[1] At the beginning of the eighteenth century the English first rates carried 100 guns. The second rate comprised two classes: (1) a three-decker of 90: (2) a two-decker of 80. Ships of these rates were few in number and very expensive. The bulk of our fleets consisted of third rates: two-deckers of 70 guns in war and 62 in peace time and on foreign stations (*Charnock*).

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ships were strengthened. Taffrails and quarter-pieces were reduced in size, and the weight thus saved was devoted to strengthening the sterns and reinforcing the deck supports; additional knees and fastenings were provided throughout the structure. Moreover, towards the middle of the century the formation of the sails was gradually altered, first in the smaller rates and afterwards in the larger ships. The old-fashioned spritsail, which had been of greatest effect when going free, but which had also been used with the wind abeam by the awkward expedient of topping up its yard, gave place in our navy to the fore and aft jib, which could be used with the wind before the beam. Later the lateen sail on the mizzen gave place to a spanker hung from a gaff or half-yard. These alterations had a general effect on the size and position of masts and sails.

The order of 1745 was virtually the last of those rule-of-thumb establishments which had imposed rigorous maximum limits of length, beam and draught in conjunction with an equally rigorous minimum of armament weight, and which had been a glaring example of the evil effects of standardization when unscientifically and unsuitably applied. The East India service, the contract-built ships of which were designed by architects untrammelled by the rules which cramped and distorted the official architecture, provided the clearest proof that the King's ships were, as a whole, of poor design. Naval opinion confirmed it.[1]

For further evidence that it was the system and not the men at fault, we may note Charnock's statement that, given a free hand, Englishmen proved themselves better shipbuilders than foreigners. "It stamps no inconsiderable degree of splendour on the opinion which even the arrogance of Spain felt itself compelled to hold in regard to the superior practical knowledge possessed by the British shipwrights in the construction and art of putting a vessel together, when brought in comparison with that of their own people. The builders in all the royal dockyards and arsenals, the Havanna excepted, were Britons."

How many, we may wonder, of the ships shattered by Lord Nelson at Trafalgar were constructed by our countrymen? The *Victory*, which was to bear his flag, was laid down (we may note in passing) in the year 1759: she was 186 feet in length on the gun-deck, 52 feet broad, and of 2,162 tons burthen.

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[1] Sir C. Knowles: *Observations on Shipbuilding.*

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In 1774 the American war broke out. The colonists, who possessed a small but efficient frigate navy, were joined soon afterwards by France, and then by Spain, and Holland. Lord Rodney acknowledged the superiority of the French in speed, who, though his ships were equally clean with theirs, yet had the power daily to bring on an action. The war proved a rough test for our honest but unscientific construction. "In 1778, assailed by numerous enemies, England put forth all her naval strength. Powerful fleets had to be found simultaneously for the Channel, the North Sea, the East Indies, America, and the West Indies. Five years of such warfare proved exhausting, the ships on paying off in 1783 were in a terrible state of decay. Several foundered returning home, owing to their ill-construction and rickety condition; their iron bolts broke with the working, and the ships were mere bundles of boards. All this was owing to want of a better system of building, such as has since been brought to such perfection by Sir R. Seppings."[1]

After the peace the size of the French ships continued to increase, and every effort was made to improve their design; but they were weak both in construction and material. Large three-deckers were once more built; the *Commerce de Marseille*, 120, was of such extraordinary dimensions that English critics thought that "size had now reached its ultimatum." In 1786 the French abolished the use of shingle as ballast; it created a damp vapour between decks and gave a high centre of gravity. Iron ballast had been tried in the frigate *Iphigène* with great success. "She was very easy in a sea when under her courses; her extremities were not overloaded with cannon; she mounted only 13 guns a side, whereas she had room for 15. She was the best sea boat, and fastest sailing ship, perhaps, ever built. Her length was more than four times her breadth."[2]

In England, as witnessed by the formation of the Society for the Improvement of Naval Architecture, feeling was widespread at this time that something was lacking in our methods of ship construction. The navy was in process of reorganization by a great administrator. In 1784 Sir Charles Middleton created an establishment of naval stores. He took under consideration shortly afterwards the growing scarcity of timber and its more ecomonical use. And in the course of his inquiry views were expressed on naval shipbuilding which had an influence on subsequent practice.

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[1] *Letters of Sir Byam Martin:* N.R. Soc.

[2] Sir C. Knowles: *Observations on Shipbuilding.*

The conditions under which ships were built for the East India Company were far more scientific than those obtaining in the royal dockyards. The timber was more carefully picked, and better seasoned. The hulls were laid up under cover and well aired; they stood in frame for six months, and then, when the planks had been tacked on, they stood again, and no tree-nails were driven till all moisture had been dried out of the timber. In design they were in many ways superior; in fact, they were reputed the best and safest vessels in Europe.

Mr. Gabriel Snodgrass, the Company's surveyor, under whose supervision, it was claimed, 989 ships had been built and repaired between the years 1757 and 1794, only one of which had been lost at sea, gave illuminating evidence. "I am of opinion," he said, "that all the ships of the navy are too short, from ten to thirty feet according to their rates, And if ships in future were to be built so much larger as to admit of an additional timber between every port, and also if the foremost and aftermost gun-ports were placed a greater distance from the extremities, they would be stronger and safer, have more room for fighting their guns, and, I am persuaded, would be found to answer every other purpose much better than the present ships. The foremasts of all ships are placed too far forward; the ships are too lofty abaft, and too low in midships; they would be much better and safer, if their forecastles and quarter-decks were joined together; for if they carry two, three, or four tiers of guns, forward and abaft, they certainly ought to carry the same in midships, as it is an absurdity to load the extremities with more weight of metal than the midships. No ships, however small, that have forecastles and quarter-decks, should go to sea with deep waists: they certainly ought to have flush upper decks."

Ships of the navy, he considered, were too weak; they had plenty of timber, but were deficient in iron fastenings, brackets, and standards. Knees should be of iron, which was lighter, cheaper, and stronger than wood. The bottoms of all navy ships were too thin; the wales and inside stuff too thick. He particularly recommended diagonal braces from keelson to gun-deck clamps: six or eight pairs of these, secured with iron knees or straps, should prevent ships from straining as they did. He would reduce the tumble-home given to the topsides, and thus add to the strength both of hulls and masts; he would abolish quarter-galleries and give less rake to the sterns.

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Finally, he would design ships so as to require a minimum of compass timber ; make no use of oak where he could substitute fir or elm with propriety ; and have all timbers cut as nearly to the square as possible, to conserve strength.

His evidence, ending in a recommendation to the government to improve the status of the naval shipwrights, has been handed down as a remarkable exposition of sound knowledge and good sense. The proposals were beneficial, so far as they went, but they did not go far enough : the whole system on which the hull timbers were disposed was wrong. The continuous increase in the size of ships was gradually exposing their weakness. And though in the next century a more scientific disposition was to be adopted, for some years yet construction continued on the ancient lines.[1]

The great wars with France, which broke out in the year 1792, found us adding both to the length and to the scantlings of our new ships. Three years before, the Admiralty had ordered two 110-gun ships to be built, of 2332 tons burthen. One of them, the *Hibernia*, not finished till the year 1805, was made more than eleven feet longer than originally intended. Both of these ships were established with 32-pounder guns for their main deck.[2] The unwieldy 42-pounder, used on the lower decks of first and second-rate ships, was now displaced, in most ships, by the more rapidly worked 32-pounder. Lord Keppel had tried, also, to substitute 32-pounders for 24-pounders on the main deck of the *Victory* and other ships in commission, so as to establish them generally ; but they were found too heavy on trial. He replaced 6-pounders by 12-pounders, however, on the quarter-decks and forecastles. Carronades were now making their appearance. In excellence of material and honesty of workmanship our fleets were pre-eminent.

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[1] In 1784 Thomas Gordon published a treatise entitled *Principles of Naval Architecture*, drawing attention to the work of the French scientists and advocating increased length and breadth, finer lines, and a more systematic disposition of materials, for improving the strength and seaworthiness of our royal ships. No notice was taken of his communications to Lord Sandwich, but there is no evidence that his predicted fate overtook him : "to be traduced as an innovator theorist, and visionary projector, as has been the fate of most authors of useful discoveries in modern times, particularly in Britain."

"The bigotry of old practice," recorded Mr. Willett in 1793, "opposes everything that looks like innovation."

[2] Fincham says their armament was established as, thirty 32-pounders on the lower deck, thirty 24-pounders on the middle deck, thirty-two 18-pounders on the upper deck, and on the quarter-deck and forecastle eighteen 12-pounders.

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The value of large dimensions was by this time discerned; where possible extra length was given to ships building and those under repair. Size still increased. The great *Commerce de Marseille*, brought home a prize by Lord Hood in '94, was forthwith matched by the *Caledonia*, which, ordered in this year but not completed until 1810, was the greatest ship which had ever been built in this country. Still, side by side with news of world-shaking victories, came evidence of our ships' inferiority in design. Not only the French, but the Spanish dockyards, produced vessels which could often outsail ours. Four large prizes taken at the battle off Cape St. Vincent surprised their new owners: "under their jury-masts, and poorly manned as they necessarily were, they beat all the English ships working into the Tagus." [1]

As the great wars went on, Britain deployed a constantly increasing naval force. Prizes went to swell the number of ships put in commission. "Mr. Pitt was foremost in gettng every possible ship to sea; and under this pressure rotten old ships were doubled and cross-braced and otherwise strengthened and rendered fully adequate to temporary service. Trafalgar followed, and the efforts of the civil departments were rewarded." [2]

We have made little mention, in the foregoing pages, of the actual tonnage or dimensions of ships, for the reason that the figures would be for the most part unreliable or misleading in import. The basis on which tonnage was measured was constantly changing. It was difficult to obtain accurate measurements of the principal dimensions; length, especially, was an indeterminate dimension, and, in the days when a large fore and aft rake was given, the length of keel gave no indication of the over-all length. Even if the over-all dimensions could be accurately measured, they gave small information as to the form of the hull: the fullness or fineness of the lines, the form of the bow-curves and tuck, the position of the section of maximum breadth, both longitudinally and relatively to the water-line—proportions on which the sailing qualities of a ship largely depended. In the seventeenth century the tonnage figures were generally untrustworthy; the *Sovereign* was quoted by three different authorities as being of 1141, 1637, and 1556 tons burthen. In the eighteenth century tonnage and dimensions possessed greater comparative

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[1] James *Naval History.* [2] *Letters of Sir Byam Martin*: N.R. Soc.

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value. We confine ourselves to quoting the following table of typical dimensions, taken from Charnock, showing the gradual expansion which took place in the hundred years which have just been reviewed.

Establishment		Length (gun-deck)	Keel	Breadth	Depth	Tonnage
1706	100-gun ships	171′ 9″	139′ 7″	49′ 3″	19′ 6″	1809
1719		175′ 0″	140′ 7″	50′ 3″	20′ 1″	1883
1745		178′ 0″	145′ 2″	52′ 0″	21′ 6″	2091
Commerce de Marseille (120)		208′ 4″	172′ 0″	54′ 9″	25′ 0½″	2747
Caledonia (120)		205′ 0″	170′ 9″	53′ 8″	23′ 2″	2616

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The slow progress of naval architecture up to the end of the eighteenth century, an advance the rate of which may be gauged from the fact that, except for sheathing and pumps, no important improvement was patented between the years 1618 and 1800, has been characterized as consisting mainly of approximations to the successive forms and arrangements of Italian, Portuguese, Spanish, and French ships, all of which had been in their turn superior to ours. Until the end of the eighteenth century the " bigotry of old practice " had effectually opposed any radical improvement, even though such improvement had been operating for years in foreign navies and were brought continually before the eyes of our professionals, embodied in captured prizes. In his *Naval Development of the Century* Sir Nathaniel Barnaby has drawn attention to the remarkable similarity which existed between the *Caledonia* of the early nineteenth, and the old *Sovereign* of the seventeenth century: " Almost the only things of note were the reduction in height above water, forward and aft, and a slight increase in dimensions. The proportion between length and breadth had undergone but little change. There was almost the same arrangement of decks and ports; the same thin boarding in front of the forecastle; the same mode of framing the stern, the same disposition of the outside planking in lines crossing the sheer of the ports; nearly the same rig; the same external rudder-head, with a hole in the stern to admit the tiller; and probably the same mode of

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framing the hull. For the ships of 1810 had no diagonal framing of wood or iron, but the old massive vertical riders; no shelf or waterway to connect the beams with the sides; no fillings above the floor-head; and no dowels in the frames. Ships were still moored by hempen cables, and still carried immense stores of water in wooden casks."

To Sir Robert Seppings was due the series of innovations in constructional method which placed shipbuilding on a relatively scientific basis and thereby rendered it capable of meeting the increasing demands involved in the growing size and force of warships. His scheme, some elements of which had already been tested in H.M. ships, was described in a paper read before the Royal Society in 1814. In the briefest language we will attempt to explain it.

In the theory of structures, a jointed figure formed of four straight sides is known as a *deficient* frame, since it has not a sufficient number of members to keep it in stable equilibrium under any system of loading. A triangle, on the other hand, is a *perfect* frame, since it has enough, and not more than enough, members to keep it in equilibrium however it may be loaded.

The hull of a timber-built ship consisted of a number of rigidly jointed frames or cells, some lying in horizontal, some in vertical, and some in intermediate planes: the unit cell being a quadrilateral, whose sides were formed by the frames and vertical riders and by the planks, wales, and horizontal riders. Practically all the materials composing the fabric of a ship were disposed either in planes parallel to the plane of the keel or in planes at right angles to it. And up to the end of the Napoleonic wars our ships, without appreciable exception, were built on this primitive quadrilateral system. The system was essentially weak. All warships showed a tendency to arch or hog—to become convex upwards, in the direction of their length—owing to the fact that the support which they derived from the water was relatively greater amidships than in the neighbourhood of their extremities. In the old days when ships were short in length this tendency was small, or, if appreciable, a remedy was found in working into the structures additional longitudinal and transverse riders, until the holds were not infrequently clogged with timber. But as ships increased in length, the forces tending to "break the sheer" of a ship and arch its keel increased in greater ratio

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than the ship's power of resistance to the distortion; and by the end of the eighteenth century, in spite of the aid of iron knees, stronger fastenings, and improved material generally, the essential weakness of our mode of construction had been gradually exposed. The *Victory* herself suffered from arching. The extremities of a 74-gun ship dropped six inches, sometimes, when she entered the water from the stocks. A similar tendency to hog took place also across the breadth of a ship, occasioned by the dead weight of her guns. When rolling in heavy weather the momentum of her top weights caused large racking stresses to be thrown on the joints between the frames and the deck-beams. The biographer of Admiral Symonds quotes Captain Brenton as follows: "I remember very well, when I was a midshipman in a 64-gun ship coming home from India, cracking nuts by the working of the ship. We put them in under the knees, as she rolled one way, and snatched them out as she rolled back again."

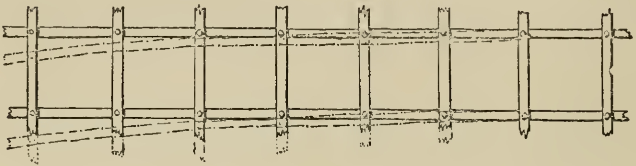

DIAGRAM ILLUSTRATING DISTORTION OF FRAMES UNDER LOAD

From these remarks it will be clear that a new method of construction which, by substituting the triangle for the rectangle, prevented the distortion of a ship's hull under the stresses of hogging and sagging, would constitute an important innovation: even more important if, in addition, the new method resulted in a large economy of material. Such a system Sir Robert Seppings introduced. Treating the hull as a girder liable to bend, he disposed the timbers to the best advantage to resist deformation. The rectangular system, wherein frames and riders formed rectangular cells with no other power of resisting distortion into rhomboids than that derived from the rigidity of the joints, had been proved inefficient; just as a common field gate would be inefficient, and would easily distort, if built up solely of vertical and horizontal timbers without any diagonal brace to make it a rigid figure. He solved the problem with the triangle. By bracing each quadrilateral cell with a diagonal timber he thereby divided it into two rigid and immovable triangles, and thus made the

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whole ship rigid. The quadrilateral, when braced, was known as a *trussed frame*. All the chief frames in the ships he trussed; and since all bending took place from the centre of the ship downwards to its ends, he made the trussed frames symmetrical about the centre: the diagonals sloped forward in the after body, and aft in the fore body, so as to resist the arching by extension. The truss frame was embodied, not only in the lower part of the vessel (where its effect in resisting longitudinal bending was comparatively small), but in the more nearly vertical planes, and even in the topsides between the gun-ports (where it was most effective). Its use was estimated to result in the saving of nearly two hundred oak trees in the building of a 74-gun ship.

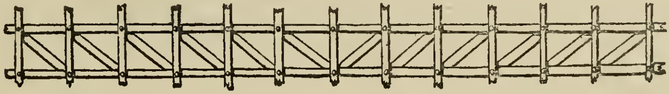

DIAGRAM REPRESENTING A SHIP WITH TRUSSED FRAMES

This was one element of Seppings' system. The others were: the filling in of the spaces between the ground frames of the ship, so as to oppose with a continuous mass of timber the tendency of the lower parts to compress longitudinally, and to form a thick and solid bottom; the omission of the interior planking below the orlop clamps; the connection of the beams with the frames by means of shelf-pieces, waterways, and side binding-strakes to the deck; and the laying of the decks diagonally.

In two other important respects Seppings improved on previous construction.

At Trafalgar the *Victory*, during her end-on approach to the enemy line, was raked, and her old-fashioned forecastle, with its thin flat-fronted bulkhead rising above the low head, was riddled and splintered. This and similar experiences led to the introduction by the Surveyor of an improved bow, formed by prolonging the topsides to meet in a high curved stem, which not only deflected raking shot, but also consolidated the bow into a strong wedge-shaped structure supporting a lofty bowsprit, and capable of being armed to give ahead fire from a number of guns.

Similarly the weakness of ships' sterns was remedied. The broad flat overhanging stern which had been given to our ships

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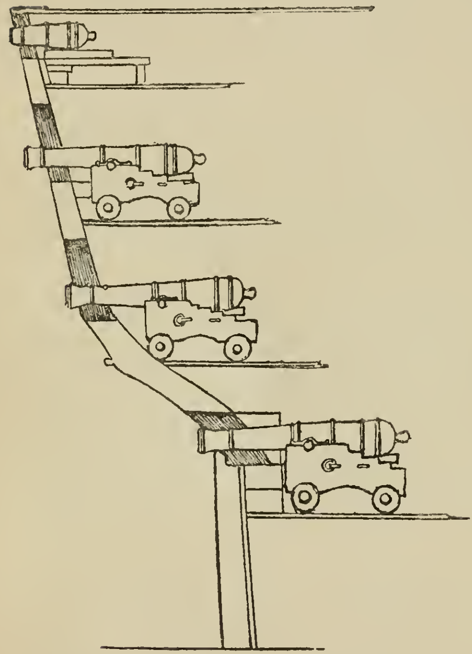
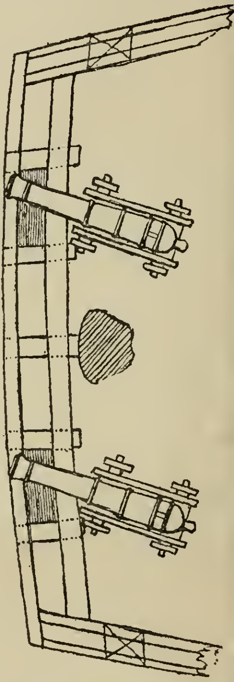
throughout the eighteenth century was not only structurally, but defensively weak. In many actions, but notably in Admiral Cornwallis' fighting retreat from the French in 1795, the weakness of our stern fire had been severely felt; and, especially in view of the possible adaptation of steam to ship propulsion, at this time foreshadowed, the desirability of an improvement was evident. Seppings abolished the flat stern in all new two- and three-deckers, substituting sterns circular (as seen from above), more compactly embodied, and having ports and embrasures in them for guns capable of fire along divergent radii. The circular stern gave place, after a few years, to an elliptical stern, which presented a more graceful appearance and afforded increased protection to the rudder-head. "The principal curves visible in it," it was said, "harmonize so well with the sheer lines of the ship, that she appears to float lightly and easily upon the water."





In the opening years of the new century important advances were made, too, in the organization of the royal dockyards. The interests of naval architecture were served notably by Sir

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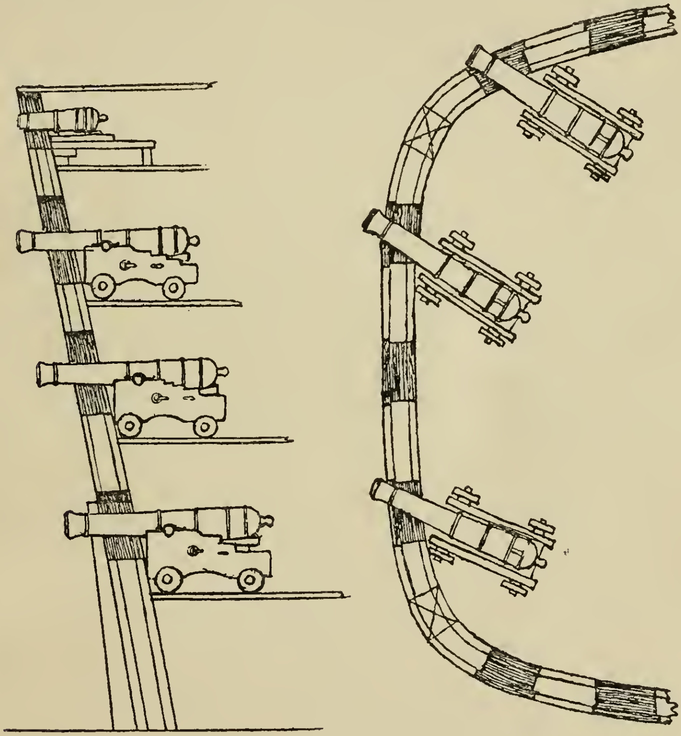
Samuel Bentham, brother of the famous jurist and an ex-shipwright, who acquired honours in Russia and returned to England to be Civil Architect and Engineer to the navy. Bentham became a courageous Commissioner, and did much to stamp out abuses and to encourage efficiency ; he was instrumental in checking the sale of stores, in abolishing " chips," in introducing steam pumps, block machinery, and dry dock caissons, in improving the methods of building ships and of mounting carronades.



But still naval architecture, considered either as an art or as a science, was stagnant. As a class the Surveyors were men of very restricted education—" there is scarcely a name on the list of any eminence as a designer or a writer." Those who ordered ships at the Board were " busy politicians, or amateurs without a knowledge of science, or sailors too impatient of innovation to regard improvements." In no other profession, perhaps, were theory and practice so out of sympathy with each other. The native art of the builder was numbed and

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shackled by the restrictions imposed upon him as to tonnage and dimensions; the study of ship form, with a view to analysing the forces under which sailing ships moved by wind through water and to discovering the laws which those forces obeyed, was still mainly an academic pastime of the Society for Improving Naval Architecture, and outside the province of the naval authorities. Our ships were still formed on no rational principle. Captured French ships served as models to be copied. Often our builders would make fanciful variations from the originals—a little more sheer, a little more beam, etc. etc.—and as often they spoiled their copies. Whenever they followed closely the forms and features of the originals they succeeded in producing vessels which were pronounced to be among the best ships in the navy.

With this state of affairs, it is no matter for surprise that much of the new construction of the period was of small value. "Sir Joseph Yorke produced a set of corvettes, longer and narrower than brigs, none of which answered; and they were sold out of the service. Then came the 'Forty Thieves,' a small class of 74's; but in justice to the designer, Sir H. Peake (who copied them from a French ship), it must be added that his lines were altered by the Navy Board, and the vessels were contract-built. Lord Melville built half a dozen 'fir frigates,' which neither sailed nor stood under canvas. The 22-gun and 28-gun donkey frigates 'could neither fight nor run away'; it was dangerous to be on board them; and the bad sailing of such vessels was the chief cause of our ill success in the American War. The old 10-gun brigs, or 'floating coffins,' as they were significantly styled, were equally dangerous and unsightly. They had no room to fight their guns; no air between decks, which were only five feet high; extra provisions and stores were piled above hatches; and the fastest of them sailed no more than eight or nine knots."[1]

The merchant service was in even worse plight. The tonnage rules had had a deplorable effect upon merchant shipping. The ancient method of assessing a ship's burthen was by measuring the product of its length and breadth and depth, and dividing this by a constant number, which varied, at different periods, from 100 to 94. Early in the eighteenth century, however, a simplification was innocently made: the depth of the average ship being half the beam, a new formula was approved—length

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[1] Sharp: *Memoirs of Rear-Admiral Sir W. Symonds.*

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multiplied by half the square of the beam, divided by 94.[1] The result might have been anticipated. Dues being paid only on the length and breadth, vessels were given great depth of hold, full lines, and narrow beam. Absolved by the convoy system from trusting to their own speed for self-protection, English merchantmen became slugs: flat-bottomed, wall-sided boxes, montrosities of marine architecture of which it was said that they were 'built by the mile and served out by the yard.'

To raise the skill and status of our builders, the Committee of Naval Revision of 1806 presided over by Lord Barham advised the establishment of an official school, in which the more highly gifted apprentices might study the science involved in naval architecture. In 1811 the school was opened at Portsmouth, with Dr. Inman, a senior wrangler, as president. Ships were designed by Dr. Inman and his pupils excellent in many respects, and generally on an equality with those of the Surveyor and the master shipwrights. Yet still they were very imperfect. The official designs were hampered, not only by the hereditary prejudices and dogmas and by the cautious timidity of the builders themselves, but by the restrictions still imposed by the Navy Board, who insisted on a certain specified armament in combination with a totally inadequate specified tonnage: who laid down incompatible conditions, in short, under which genius itself must fail of producing a satisfactory result.

The chains were broken in 1832.

In that year, when the whole administration of the navy was in process of reorganization, the office of Surveyor was offered to and accepted by a naval officer, Captain W. Symonds, R.N.: accepted by him on the condition that he should be given a free hand in design and allowed to decide himself of what tonnage and dimensions every ship should be. Sir Robert Seppings was superannuated. The school of naval architecture was abolished. The sensation produced was powerful. "Except on matters of religion," said Sir James Graham, when the appointment was being debated in the House of Commons some years afterwards, "I do not know any difference of opinion which has been attended with so much bitterness—so much anger—so much resentment, as the merits of Sir W. Symonds and the virtues of his ships."

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[1] Hannay: *Ships and Men*. This formula was known before, for Bushnell mentions it in his *Compleat Shipwright* of 1678.

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These violent differences and resentments have long since been composed, and Sir William Symonds has been accorded the position due to him in the history of naval architecture. His opponents, those who had resented his appointment as against the best interests of the service, rejoiced that he had freed ship design from the traditional restrictions under which it had stagnated; his chief admirers were led in the course of time to agree in the desirability of having as Surveyor a man thoroughly grounded in the scientific principles underlying the motion of bodies through water, their stability in water, and all the forces acting on a ship at sea.

In the year 1821 Lieutenant Symonds, while holding an appointment at Malta, had designed and built for himself a yacht which he called *Nancy Dawson.* Yachting had at this date become a national sport, and the interest of influential patrons in sailing matches was already acting as a stimulus to the study of ship form. The chief cause of the beneficial reaction from the indifference of former generations, says his biographer, was the establishment of the Yacht Club, after the peace of 1815, and the interest which men of rank and fortune henceforth took in shipbuilding, and in procuring the best native models.[1] So great was the success of the *Nancy Dawson*, that (in his own words) he was led to believe that he had hit upon a secret in naval architecture; while experiments on other sailing boats seemed to confirm him in his principles. Great breadth of beam and extraordinary sharpness—in fact, what was described as "a peg-top section"—were the characteristic features of his system, with a careful attention to stowage, the stand of the masts, and the cut and setting of the sails.

"Upon this most slender basis was the whole fabric of Sir William's subsequent career built. The yacht gained him the notice of noblemen and others, then followed a pamphlet on naval architecture (in which the defects of existing ships were pointed out, and great breadth of beam and rise of floor advocated); then came a promise from the First Lord of the Admiralty, Lord Melville, that he should build a sloop of war on his plans, which he did, the vessel being called the *Columbine* (promotion intervening); then further patronage from the Duke of Portland and the Duke of Clarence, the latter of whom, when he became Lord High Admiral, ordered him to lay down

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[1] Sharp: *Memoirs of Admiral Sir W. Symonds.*

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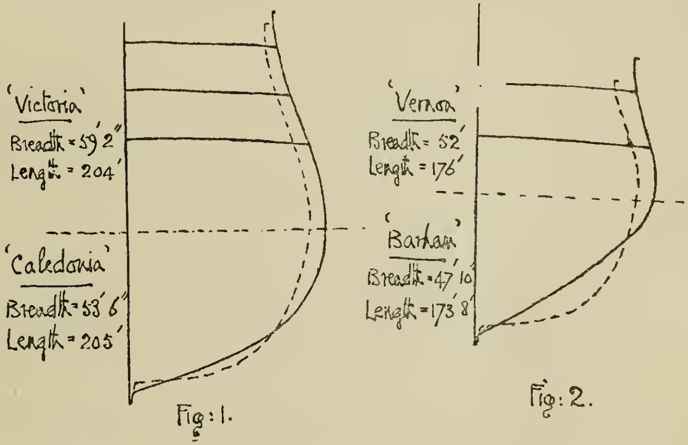
a 40-gun frigate (promotion again intervening); then the building of the *Pantaloon*, 10-gun brig, for the Duke of Portland, from whom the Admiralty purchased her; then the patronage of that most mischievous civilian First Lord, Sir J. Graham; then the order for the *Vernon*, 50-gun frigate; and then, in '32, the Surveyorship of the Navy."[1]

To Sir Edward Reed and other shipbuilding officers the appointment of this brilliant amateur to the supreme control of the department seemed an act of war, not only on professional architects, but upon naval architecture itself. They admitted the success of the Symondite ships in speed and certain sailing qualities, but denied the correctness of his principles and strenuously resisted his innovations. A great breadth of beam was particularly objectionable to the scientific builder; not only did it imply a large resistance to the passage of the ship through water, but it contributed to an excess in metacentric height, abnormal stiffness, and an uneasy motion. "For a time his opinions triumphed; but after a while the principles expounded by his subordinates (Creuze, Chatfield, and Read) were accepted as correct, while not a single feature of Sir William's system of construction is retained, except certain practical improvements which he introduced."[2]



TYPICAL SECTIONS OF "SYMONDITE" AND CONTEMPORARY SHIPS

Nevertheless his opponents, as before remarked, freely acknowledged the value of his services to the country, especially in breaking down the restrictions which had hitherto been

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[1] E. J. Reed: *On the Modifications to Ships of the Royal Navy.*

[2] *Ibid.*

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imposed on constructors in respect of dimensions. His biographer pays tribute to the intuitive genius which enabled him to tell at a glance the trim required for a sailing ship, and to sketch out, as a brilliant impromptu, the best form of hull. But were these efforts entirely spontaneous? Were they not the reward of hidden and persistent work, observation, and calculation, carried out for years by the young officer who never let a sailing ship come near him without contriving to board her and ascertain her principal properties and dimensions? Here, surely, is the undramatic but praiseworthy method by which he attained success: a method, essentially scientific, which enabled its user, even without knowledge of other important principles governing ship design, to perform a national service in revolutionizing our methods of naval architecture.

Under the control of Sir William Symonds the improvement in the form and qualities of our ships, begun under the surveyorship of Sir Robert Seppings, continued to progress. Ship dimensions increased, and now bore a more correct relation to the dead-weight of armament, stores, and crew, which they had to carry. All classes from cutters to first-rates carried a more generous beam, and gained by the novel feature. Sounder rules were devised, partly as the result of a succession of sailing trials, for the pitching of masts and the methods of stowing. In short, naval architecture entered upon a new and promising era. Foreign observers recorded the progress made. Instead of being servile imitations of the products of French and Spanish models the vessels which flew the English flag became objects of admiration to all the world.

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A TUDOR SHIP OF PERIOD 1540–50
From a Cottonian MS. in the British Museum

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CHAPTER II

THE SMOOTH-BORE GUN

ON the question of the date at which the discovery of gunpowder took place writers have held the most divergent views. The opinion of the majority has been that its properties were known in the remote ages of antiquity, and this opinion has been formed and confirmed by the accounts given of its origin by most of the medieval writers. The Chinese claim to have known it long before the Christian era. And from hints in classical literature, and on the broad ground of probability, it has been inferred by some authorities that the explosive properties of gunpowder were known to the ancients. The wonderful property of saltpetre, they argue, must certainly have been known to the wise men of old : its extraordinary combustive power when mixed with other substances. Melted alone over a hot fire saltpetre does not burn ; but if a pinch of some other substance is added, a violent flame results. In many fortuitous circumstances, they say, saltpetre must have been found in contact with that other essential ingredient of gunpowder, charcoal. And such a circumstance has been pictured by one writer as occurring when camp fires, lit upon soil impregnated with nitre (like that in parts of India), were rekindled ; the charred wood converted into charcoal forming with the nitre a slightly explosive mixture.

Other investigators maintain that gunpowder, which claims a spurious antiquity, is really an invention of the Middle Ages. Incendiary compositions—Greek fire, and other substances based on the properties of quicklime, naphtha, phosphorus, etc. —were undoubtedly known to the ancient world. But explosive compositions, based on saltpetre as the principal ingredient, were certainly not known in all their fearful power. The silence of history on the subject of the projection of missiles by explosive material, says a recent authority,[1] is

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[1] Lieut.-Col. H. W. L. Hime : *The Origin of Artillery.*

eloquent; the absence of its terminology from such languages as Chinese and Arabic, conclusive.

Whichever of the two views may be correct it is certain that a knowledge of gunpowder was possessed by the great alchemist, Roger Bacon, who in A.D. 1249 committed to paper an account of its properties.[1] To Berthold the Black Friar is given the credit for its application to military ends; whom legend, in an impish mood, has hoisted with his own discovery.

In a learned work on the early days of artillery an English writer has described the difficulties encountered in tracing the first stages of the evolution of guns and gunpowder. Confusion was caused by the fact that, after gunpowder had been introduced, military engines were still known by the same generic names as those borne in pre-gunpowder days. No contemporary pictures of guns could be discovered. The loose statements of historians, the license of poets, and the anachronisms of the illuminators of the medieval MSS., all tended to lead the investigator astray and to make his task more difficult. The statements of the historians are indeed whole hemispheres and centuries apart; as for poets, our own Milton assigned the invention of artillery to the devil himself; and "from the illuminators we should gain such information as, that Gideon used field pieces on wheeled carriages with shafts, when he fought against the Midianites, as in a MS. in the British Museum." [2]

Of all the clues which throw light on the origin of artillery the most important yet discovered lies in some MSS. belonging to the city of Ghent. After a list of municipal officers for the year 1313 occurs the entry: "Item, in this year the use of bussen was first discovered in Germany by a monk." And there is evidence that in the following year "guns" were manufactured in Ghent and exported to England.[3] The same century was to witness a wonderful development of the newfound power.

It was but natural that the first application of gunpowder

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[1] In the *Histoire d'Artillerie* of MM. Reinaud and Favé long excerpts from Bacon are examined, from which it appears that he suggested the use of gunpowder in military operations. Gibbon says: "That extraordinary man, Friar Bacon, reveals two of the ingredients, saltpetre and sulphur, and conceals the third in a sentence of mysterious gibberish, as if he dreaded the consequences of his own discovery."

[2] Lieut. H. Brackenbury, R.A.: *Ancient Cannon in Europe*. Vol. IV and V of Proc. R.A.I.

[3] Schmidt: *Armes à feu portatives*.

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to warlike purposes should have been, not only to strike terror by violent explosion and thus obtain an important moral effect, but to project the missiles already in military use: arrows and ponderous stones. Two distinct types of artillery were thus foreshadowed. The first took the form of a dart-throwing pot or vase, a narrow-necked vessel from which, in imitation of the cross-bow, stout metal-winged arrows were fired; while, for projecting stones of great size and weight in imitation of the ancient siege-machines, large clumsy pieces made of several strips of iron fitted together lengthways and then hooped with iron rings were eventually developed.

In the first half of the fourteenth century the guns manufactured were of the former type. In *The Origin of Artillery* a reproduction is given of an illuminated MS. belonging to Christ Church, Oxford, dated 1326, showing an arrow-throwing vase: the earliest picture of a gun which is known. And, from a French document quoted by Brackenbury, it appears that in 1338 there was in the marine arsenal at Rouen an iron fire-arm—*pot de fer*—which was provided with bolts ("carreaux," or quarrels) made of iron and feathered.

But the unsuitability of the arrow for use in conjunction with gunpowder as a propellant was, even at this date, realized. There was obvious difficulty in preventing the powder gases from escaping through the windage space between the arrow-shafts and the neck of the vase, even with the aid of leather collars. So the arrow almost immediately evolved into a stone or metal sphere; the narrow neck of the vase increased to the full diameter of the vessel. And as early as 1326, the date of the picture of the arrow-throwing vase, cannon of brass, with iron balls, were being made at Florence for the defence of the commune. The use of the new weapons quickly spread. By 1344 the cannon is mentioned by Petrach as "an infernal instrument of wood, which some think invented by Archimedes," yet "only lately so rare as to be looked on as a great miracle; now, . . . it has become as common as any other kind of weapon." By 1412, according to unquestionable testimony supplied by public documents, cannon were employed in English ships: breech-loading guns with removable chambers.[1]

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[1] Sir Harry Nicolas, in his *History of the Royal Navy*, attributes the documents to the reign of Edward III: an error of more than seventy years. The mistake is exposed by a writer in Vol. XXVI of *The English Historical Review*, in an article on "Firearms in England in the Fourteenth Century." The writer also gives the English records relating to the use of firearms at Cressy.

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In 1346 Edward III fought Cressy. Whether or no cannon were used in this decisive battle has been a matter of considerable controversy. According to Villani, an old Florentine chronicler who gave an account of the campaign, they were; but no mention of them was made by Froissart, who wrote some years later. The silence of Froissart has been attributed, however, to a desire to avoid offending our court by implying that the victory was due to other than the prowess of the Prince of Wales; or tainting our success with any mention of "devilish machines which were universally regarded as destructive to valour and honour and the whole institution of chivalry." Though English chronicles contain no mention of gunpowder till some years after Cressy, yet evidence exists that artillery—"gunnis cum sagittis et pellotis"—was extensively used in this campaign. "But the powder was of so feeble a nature and the cannon so small, that the effect of a few of them, fired only a few times, could not have been very noticeable compared with the flights of arrows."[1]

Cannon in the first half of the fourteenth century were indeed feeble weapons compared with the huge mechanical engines of the period; yet their moral effect was very great and their physical effect by no means negligible. They were destructive of chivalry, in a quite literal sense. The value of cavalry as an arm was greatly reduced by their adoption in the field. They took from the horseman cased in complete armour all the advantage he possessed over other troops. Instead of forming the nucleus of the fighting strength of an army, the armour-clad nobles and their mounted retinues became somewhat of an encumbrance, and a change in the composition and strength of armies from this time ensued. Tournaments went out of fashion, chivalry declined.

Against material, cannon proved even more effective. As the arrow-throwing gun gradually disappeared, giving place to small cylindrical cannon firing lead and iron balls, other ordnance, designed for projecting large stones against the gates and walls of forts and castles, grew rapidly to an enormous size. Made usually of forged iron bars welded and strengthened circumferentially by coils of iron ribbon or rope, and using a weak gunpowder, these giant "bombards" began to play an important part in land warfare, especially in those internecine wars which were constantly being waged in Flanders and in

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[1] Brackenbury.

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Northern Italy. Two peoples were conspicuous at this period for their wealth, culture, and energy: the Lombards and the Flemings. The former, by their contact with the East, had drawn into their hands most of the commerce of Europe; the latter, welded together in the Hanseatic League, were in the van of northern civilization. It was in Italy, probably, that cannon were first employed, and in Italy where they developed most rapidly. Their use had an immediate effect on land warfare; the defensive value of masonry was suddenly depreciated, and town-gate, fort, and campanile, which had for centuries defied the old mechanical engines, could no longer be considered impregnable.[1]

In the following century the development of the bombard continued. The Lombards cast them in bronze, adorned them with elaborate mouldings and furnished their ends with swellings like capstan-heads, of equal diameter, to facilitate rolling and parbuckling. In the hands of the Flemish artisans this type reached a remarkable degree of perfection in a famous bombard called "Dulle Griete," which was made at Ghent about A.D. 1430. The bombard of Ghent consists of two parts, a larger part to form the barrel for the stone sphere of 25 inches diameter, a smaller part, of much thicker metal, to form the chamber in which the powder charge is placed. These two parts are screwed together, screw threads being formed on a boss on the front end of the chamber and in a hole in the rear end of the barrel. This is thought to be the piece described by Froissart as "une bombarde merveilleusement grande, laquelle avoit cinquante trois pouces de bec, et jetoit carreaux merveilleusement grands et gros et pesants; et quand cette bombarde descliquoit, on l'ouoit par jour bien de cinq lieues loin, et par nuit de dix; et menoit si grand' noise au descliquer, que il sembloit que tous les diables d'enfer fussent au chemin."

A fine example of the built-up bombard is "Mons Meg," the piece which now lies at Edinburgh Castle, and which was made at Mons about A.D. 1460: formed of longitudinal wrought-iron bars welded and hooped circumferentially, of

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[1] The secrecy of the early writers of Italy on gunnery and kindred subjects has been remarked on by Maurice Cockle in his *Bibliography of Military Books*. He attributes it to two motives: fear that the Infidel (the Turk) might profit by the knowledge otherwise gained, and a desire to keep the secrets of the craft in the hands of their countrymen, whose knowledge and assistance the foreigner would then be forced to purchase.

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20 inches in the bore, and designed to fire a stone ball of over three hundred pounds' weight.

It was in the hands of the Turks, then at the zenith of their power, that medieval ordnance achieved its greatest development, and it is thought probable that Flemish pieces served as the model on which the Ottoman artillery was based. The siege of Constantinople, in the year 1453, was notable for "the reunion which it presented of ancient and modern artillery—catapults, cannon, bullets, battering rams, gunpowder and Greek fire." And it was especially notable from the power of the modern artillery there assembled, an artillery which represented a climax of size and military value. Gibbon has given us a vivid description of the Ottoman ordnance and its capabilities. "Mahomet studied with peculiar care the recent and tremendous discovery of the Latins; and his artillery surpassed whatever had yet appeared in the world. A founder of cannon, a Hungarian, a deserter from the Greek service, was liberally entertained by the Sultan. On his assurance a foundry was established at Adrianople; the metal was prepared; and at the end of three months Urban produced a piece of brass ordnance of stupendous and almost incredible magnitude; a measure of twelve palms is assigned to the bore; and the stone bullet weighs above six hundred pounds. A trial was held, a proclamation having warned the populace. The explosion was enormous and was heard one hundred furlongs off, and the ball, by the force of the gunpowder, was hurled above a mile."

"A stranger as I am to the art of destruction," continues the historian—who, we may note in passing, had been through his courses at Hilsea and was a major in the Hants Militia—"I can discern that the modern improvements of artillery prefer the number of pieces to the weight of metal; the quickness of fire to the sound, or even the consequence, of a single explosion. Yet I dare not reject the positive and unanimous evidence of contemporary writers; nor can it seem improbable that the first artists, in their rude and ambitious efforts, should have transgressed the standard of moderation. . . . The great cannon, flanked by two fellows of almost equal size, was set up. Fourteen batteries thundered at once against the walls, one of which contained 130 guns! Under a master who counted the minutes, firing could take place seven times in a day."

Interesting corroboration of Gibbon's account has since been

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discovered in a MS. by a contemporary Greek writer, found at Constantinople in the year 1870.[1] According to this chronicler the cannon are actually cast on the field of action. Mahomet summons the gunmakers and discourses with them on the kind of ordnance required to beat down the walls of the city. They reply that larger cannon are necessary than any they possess; and they suggest melting down the pieces available to form others of sufficient size and power. The Sultan commands the thing to be done. Quantities of plastic clay are kneaded, linen and hemp and threads being mixed with it to stiffen it for forming gigantic moulds. Furnaces are erected, and charged with copper and tin. Bellows are worked for three days and three nights, and then, the metal being ready, the molten mass is poured. Within sight of the beleaguered city huge cannon are cast which, placed on wooden sleepers on the ground with their butts supported to prevent recoil discharge stones weighing nearly 700 pounds against the walls.

But there is no need of documentary evidence to attest the power of the Ottoman artillery of this period; cannon built on the above model have guarded the Dardanelles for centuries, and, what is more, have proved sufficiently effective in modern engagements. In 1807 Sir John Duckworth's squadron was struck repeatedly by stones of enormous weight, discharged from these cannon in an attempt to prevent its passage. And it is known that some of them were made shortly after the taking of Constantinople. These cannon, says General Lefroy, were cast on their faces, "the dead-head being left at the breech-end and hewn off with axes, probably while the metal was hot." In one of them brought home to England "the axe marks are plain; similar marks may be observed on other early guns which have the breech cut off square." The similarity of design between this Turkish gun and the Flemish bombards is too close to be accidental; their construction is of peculiar interest and has the main features in common. "The external form of the gun is a cylinder, the muzzle being as large as the breech; but either half is relieved by a boldly projecting moulding at each end, which is divided transversely by sixteen cross-bars into as many recesses: thus serving to give a purchase to the levers used in screwing the two parts

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[1] *The Great Cannon of Muhammad II:* Brig.-Gen. J. H. Lefroy, R.A., F.R.S. Vol. VI of Proc. R.A.I.

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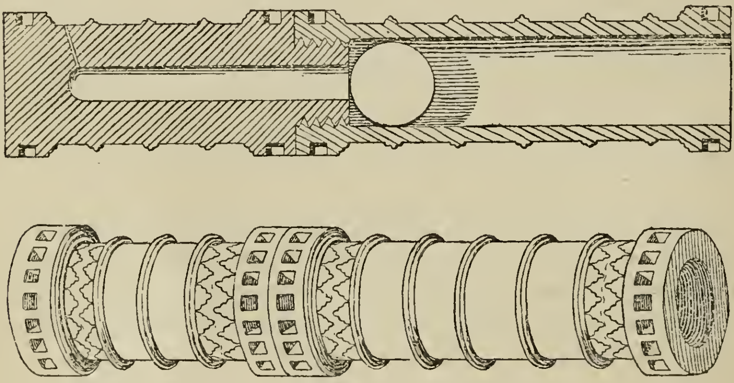
together." How the screw threads were cut is not known, but "we can suppose that moulding pieces were first cut in wood and nicely fitted and then applied to the clay moulds." The charge of powder used with this type of piece was as much as a hundredweight. In spite of the weakness of the squib-like powder its physical and moral effect was undoubtedly important. "Thus inconceivable and incredible," writes the chronicler of 1467, "is the nature of this machine. The ancient princes and generals did not possess and had no knowledge of such a thing. . . . It is a new invention of the Germans or of the Kelts made about one hundred and fifty years ago, or a little more. It is an ingenious and happy discovery, especially the powder, which is a composition made of saltpetre, of sulphur, of charcoals, and of herbs, from the which composition is generated a dry hot gas. . . ."



TURKISH BRONZE CANNON
From Lloyd and Hadcock's *Artillery*

The founding of these enormous cannon on the field of action is in itself a tribute to the energy and resourcefulness of the nation who have been described as being, at that time, the finest engineers in the world. Of the effectiveness of the Ottoman artillery there is evidence in the results achieved. Constantinople fell to the giant bombards. And in the early part of the following century Rhodes, the last outpost of the Knights, fell to the same great power. The invention of the Christians[1] was, in fact, the weapon which gave supremacy to the Infidel in the eastern part of Europe.

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[1] Ascribing the deliverance of Constantinople from the Saracens in the two sieges of A.D. 668 and 716 to the novelty, the terrors, and the real efficacy of

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In the meantime the evolution of artillery was taking a new direction. The large and relatively feeble ordnance of the Turks was, in the circumstances, not entirely unsuitable for the purpose for which it was intended: the smashing of masonry and the breaching of gates and walls. The maximum of effect was obtained from a missile of enormous mass projected with a low velocity. Nevertheless its disadvantages were obvious. Large cannon cast in bronze were necessarily of great expense and weight, their discharges were few and far between, they wore rapidly and were thus short-lived, and they possessed the dangerous property of becoming brittle when heated. An increase in power and a reduction in weight were required for the achievement of a portable artillery, and the progress of mechanical science pointed to wrought iron as the material of which such an artillery might be made.

The extraction of iron in small quantities from ferruginous ore was a comparatively simple operation, even in primitive times. With the aid of bellows and a plentiful supply of wood charcoal the smith was able to make his furnace yield small masses of metallic iron of the purest quality. This iron, wrought on an anvil, could be drawn out into plate or bar as desired, the resulting metal being, by reason of the purity of the charcoal used in its extraction, of great toughness, homogeneity, and strength. In Spain and Italy were mines which had long been famed for their iron. In England the Roman had made good use of the metal found in the Sussex mines, and all through the middle ages the wealds of Kent and Sussex were the centres of the English iron trade. In the fourteenth century improved methods came into use; the adoption of water-power for driving the bellows, for crushing the charcoal, and for operating the tilt-hammers, had its effect on the development of the iron-smelting industry; higher temperatures obtained and larger masses of ore could now be treated; the iron, produced in larger quantities by improved methods, was perhaps purer and stronger than before.

Greek fire, Gibbon says: "The important secret of compounding and directing this artificial flame was imparted by Callinicus, a native of Heliopolis in Syria, who deserted from the service of the caliph to that of the emperor. The skill of a chemist and engineer was equivalent to the succour of fleets and armies."

For the story of the manner in which its mystery was guarded at Constantinople, of its theft by the Infidel, and of the use he made of it against the Christian chivalry at the crusades, see Chapter LII of *The Decline and Fall of the Roman Empire.*

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In wrought iron, then, a material was available which almost alone was suitable for the manufacture of the more portable sorts of gun. By its use guns could be made strong enough, without being of an excessive weight, to withstand the increasing stresses thrown on them, first, by the use of iron bullets instead of stone, and secondly, by the discovery of an improved gunpowder. Artillery underwent a dual development. On the one hand, for use with the weak cannon powder, was the large stone-throwing ordnance, made of cast bronze or of hooped bars of iron ; on the other, for use with iron shot and a stronger propellant, were various denominations of small portable and semi-portable wrought-iron guns. These two distinct types developed side by side until the middle of the sixteenth century.

The use of iron and lead balls, the superiority of which over balls of stone had doubtless been manifested in former centuries in connection with the projection of Greek fire, was practised by the Florentines soon after the invention of guns themselves. The discovery of "corned" gunpowder took place a century later.

In its original form gunpowder possessed many disadvantages as a propellant. Ground into a fine powder, and composed in the first instance of almost equal proportions of saltpetre, sulphur, and charcoal, it was peculiarly liable to accidental explosion, so that frequently the charcoal was kept separate from the other ingredients and mixed just prior to use. If kept mixed it easily disintegrated, in the shaking of transport, into three strata, the charcoal coming to the top and the sulphur sinking to the bottom. It was intensely hygroscopic, and quickly fouled the barrels of the pieces in which it was used. But, most important of all, the efficiency of its combustion depended to an inconvenient degree upon the density with which, after being ladled into the gun, it was rammed home. The greatest care had to be exercised in ramming. If pressed into too dense a mass the powder largely lost its explosive character ; the flame which ignited the portion nearest the vent could not spread through the mass with sufficient speed ; it quietly petered out. If rammed too loosely, on the other hand, the explosive effect was also lost. A great gain ensued therefore when, in place of the fine or "serpentine" powder, corned powder came to be used, about the middle of the fifteenth century. In this form the powder

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was damped and worked into grains, crushed to the requisite size and sieved for uniformity. These grains were finally glazed to prevent deterioration from the effects of damp; and the resulting powder proved stronger and more efficient in every way than the same mixture in its more primitive form.

Some time was to elapse before guns could be cast of sufficient strength to withstand the force of corned powder. "Chemistry had outrun metallurgy." The larger species of ordnance were restricted to the use of serpentine powder until the middle of the sixteenth century. Nevertheless, cast ordnance as well as the lighter forged iron guns were developed continuously for service in the field. Named after birds and reptiles and clumsily cast of such shapes and weights as pleased the founders' fancy, they were of use chiefly in demolishing by attrition the gates and walls of forts and cities. From the battle of Cressy onward, first in huge carts and then on their own wheeled carriages, they rumble across the pages of European history.

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At sea the evolution of ordnance had to conform, of course, to the progress of naval architecture and the changing nature of the warfare. In the Mediterranean, where the oar-propelled galley remained for centuries the typical fighting ship, the bombard was planted in the bows, shackled to a deck-carriage upon the centre line, to give ahead fire and to supplement the effects of a powerful ram. As the galley developed, the main central gun became flanked by other bow-chasers; while on the beams and poop light wrought-iron breech-loading swivel guns formed a secondary armament whose double function was to repel boarders and to overawe its own slave-crew. In the Atlantic, where the typical fighting vessel was the lofty sailing ship, the same two different types of armament had vogue. But in this case their distribution was different; the sailing ship, with no recourse to oars for manœuvring, could not always ensure an end-on attack or defence, and had to arm herself against an enemy from any quarter. Her freedom from oars, her height, and the invention of the porthole, enabled the early "great ship" to mount a sufficiently distributed all-round armament. While her sides were pierced for ponderous bombards, her poop and forecastle bristled with the same light secondary armament as figured in the Mediterranean galley.

This artillery was almost entirely for defence. Before Elizabethan days (as we have already noted) sea battles were nothing more than hand-to-hand fights; the attacking vessel was laid alongside its enemy, sails were furled, and boarding took place. If, after being swept by spherical shot from the bombards and showers of stones and dice from the mortars and periers, the boarders could carry the waist of the defending ship, they still had to capture the barricaded forecastle and poop, from whose rails a multitude of the smaller ordnance—port-pieces, fowlers, serpentines—were trained upon them and behind whose bulkheads crossbow and harquebuss were plied against them in concealment.

The sixteenth century witnessed the greatest strides in the evolution of sea ordnance. In the Mediterranean the decisive effect of gunfire, proved in the sea fight off Prevesa in the year 1538, was confirmed by the victory of the Christians over the Turks at Lepanto in 1571. In the Atlantic England began her long preparation for securing a sea supremacy and, under the masterful eye of King Henry VIII, adapted more and more powerful guns for service in the royal ships. Of the professional interest which the King took in the development of ordnance there is ample evidence. At the royal word French and Flemish gunfounders were induced to come to England to teach the technique of their craft, and to this puissant prince the Italian savant, Tartaglia, dedicated his classic treatise on the Art of Shooting. England now learnt to found, not only bronze, but *cast-iron* cannon. "Although," says Grose, "artillery was used from the time of King Edward III and purchased from abroad by all our successive Kings, it seems extremely strange, that none of our workmen attempted to cast them, till the reign of King Henry VIII, when in 1521, according to Stowe, or 1535 (Camden says), great brass ordnance, as canons and culverins, were first cast in England by one John Owen, they formerly having been made in other countries." And from Stowe's Chronicle he quotes the following: "The King minding wars with France, made great preparations and provision, as well of munitions and artillery as also of brass ordnance; amongst which at that time one Peter Bawd, a Frenchman born, a gun-founder or maker of great ordnance, and one other alien, called Peter Van Collen, a gunsmith, both the King's feedmen, conferred together, devised and caused to be made, certain mortar pieces, being at the mouth from

11 inches, unto 19 inches wide; for the use whereof, the said Peter and Peter caused to be made certain hollow shot of cast yron, stuffed with fire-works, or wild-fire; whereof the bigger sort for the same had screws of yron to receive a match to carry fire kindled, that the fire-work might be set on fire to break in small pieces the same hollow shot, whereof the smallest piece hitting any man, would kill or spoil him. And after the King's return from Bullen, the said Peter Bawd by himself in the first year of Edward VI did also make certain ordnance of cast yron of diverse sorts and forms, as fawconets, falcons, minions, sakers and other pieces."[1] The casting of iron guns in Germany has been traced back as far as the fourteenth century.

According to another account the first English cast-iron guns were made at Buxted, in Sussex, by one Ralph Hogge in 1543. Peter Bawd, the French founder, was an assistant who had come to this country to teach him the method. But it seems that his connection with Hogge was not of long duration; for, "John Johnson, covenant servant to the said P. Bawd, succeeded and exceeded his master in this his art of casting ordnance, making them cleaner and to better proportion. And his son, Thomas Johnson, a special workman, in and before the year 1595 made 42 cast pieces of great ordnance of iron, for the Earl of Cumberland, weighing 6000 pounds, or three tons a-piece." [2]

The advance made in the power of King Henry's sea ordnance is unmistakably shown from trustworthy documents. There is a continuous progress during the reign, and ships which were rebuilt subsequently carried an armament entirely different from that which they originally had. The *Sovereign*, for instance, built about the year 1488, originally carried one hundred and eighty guns, mostly small serpentines. As rebuilt in A.D. 1509 she carried an armament which included four curtalls, three demi-curtalls, three culverins, two falcons, and eleven heavy iron guns. From an inventory of the armament of the *Henry Grace à Dieu*, of 1514, it appears [3] that that historic ship was then armed with a miscellaneous collection of pieces, comprising 122 iron serpentines, 12 "grete yron gonnes of oone makyng and bygnes," 12 ditto "that come owt of fflaunders," all with separate chambers; 2 "grete

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[1] Grose: *Military Antiquities.*

[2] Hayley's MSS.: quoted by M. A. Lower.

[3] Oppenheim.

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Spanish peces of yron of oone sorte," with chambers; 18 "stone gonnes apon Trotill wheles," with chambers; "ffawcons of Brasse apon Trotill wheles"; one "grete bumberde of Brasse apon iiij trotill wheles"; two "grete culverynes of Brasse apon unshodd wheles"; as well as a "grete curtalle of Brasse upon iiij wheles," a sling, vice pieces, and serpentines of brass on wheels shod with iron. Rebuilt at a later date the *Henry* carried a different armament, which included brass cannons, demi-cannons, culverins, demi-culverins, sakers, and cannon-periers.

The transition of armament is plainly marked for us in the case of the *Mary Rose*, rebuilt in 1536, which nine years later came to an untimely end off Brading. At the time of her oversetting she carried, in fact, both types of ordnance. In the Rotunda at Woolwich are to be seen some of the guns recovered from her wreck: a built-up wrought-iron breech-loading stone-throwing gun on its baulk-of-timber carriage, identical in character with a serpentine illustrated in Napoleon III's *Études sur l'Artillerie* as having been taken by the Swiss from Charles the Bold in A.D. 1476; and a bronze cannon royal (with John Owen's name on it), demi-cannon, culverin, and culverin-bastard, all of them finished specimens of the founder's art, and of an offensive, instead of a merely defensive, value. "The system," says Mr. Oppenheim of this growth of artillery armament, "was extended as the reign progressed, and in 1546 we find comparatively small ships like the *Grand Mistress* carrying two demi-cannon and five culverins, the *Swallow* one demi-cannon and two demi-culverins, out of a total of eight heavy guns; the *Anne Galant* four culverins, one curtall, and two demi-culverins," etc. etc.

What were the dimensions of the various pieces? It is difficult to give an exact answer. Owing to the continuous development of ordnance throughout the century the pieces increased in size while they retained their class-names, and there is a wide variation between the table of ordnance of Tartaglia, for instance, compiled in 1537, and those drawn up by English authors at the beginning of the seventeenth century. Briefly, we may note that pieces could be grouped in four classes: viz. cannons, culverins, periers, and mortars. The cannons were large in calibre and of medium length; the culverins were of great length, to give them high ranging power; the periers, or stone-throwers, were a sort of howitzer;

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and the mortars, named probably from the apothecary's utensil to which they bore a resemblance, were squat pieces used for projecting stones or iron balls at a high elevation. The old stone-throwing serpentine was a gun weighing about 260 pounds, which fired a stone "as big as a swan's egg." The curtall, or curtow, was (according to Mr. Oppenheim) a heavy gun of some 3000 pounds, hitherto only used as a siege-piece on land; "courtaulx" are mentioned by Napoleon III as having been, in A.D. 1498, fifty-pounders weighing 5500 livres. The slings were large breech-loaders, probably of the perier class.

With the adoption of a more powerful armament not only did the old pieces disappear, but a simplification of calibres ensued. France led the way in the standardizing of calibres; about the year 1550 the French king Henri II introduced his six "calibres of France." In the English navy at this period several types were discarded, and a limit was set to the size of the largest ship gun. "The report drawn up in 1559 tells us that there were 264 brass and 48 iron guns, all of calibres down to falconets, on board the ships, and 48 brass and 8 iron in store. . . . The heaviest piece used on shipboard was the culverin of 4500 lbs.; throwing a 17⅓ lb. ball with an extreme range of 2500 paces; the next the demi-cannon weighing 4000 lbs. with a 30⅓ lb. ball and range of 1700 paces; then the demi-culverin of 3400 lbs., a 9⅓ lb. ball and 2500 paces; and the cannon petroe, or perier, of 3000 lbs., 24¼ lb. ball and 1600 paces. There were also sakers, minions, and falconets, but culverins and demi-culverins were the most useful and became the favourite ship guns. A contemporary wrote, 'the founders never cast them so exactly but that they differ two or three cwt. in a piece,' and in a paper of 1564 the average weights of culverins, demi-culverins, and cannon periers are respectively 3300 lbs., 2500 lbs., and 2000 lbs." [1]

So far, cast iron had not come into general use. The large iron guns were built up like the early Flemish bombards; the demi-cannons and culverins were all of brass. At the beginning of Elizabeth's reign there seems to have been an attempt to replace the expensive brass by the cheaper cast iron, but later there was a reversion to brass, and it was not until the following century that cast iron was generally recognized as a material for heavy ordnance, and then only for the

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[1] Oppenheim.

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heaviest types. Some technical considerations may help to indicate the chief factors which determined the material and the dimensions of the Elizabethan ordnance.

Writing in 1628, Robert Norton, in his book *The Gunner*, refers as follows to the early Tudor ordnance. "Gun-founders about 100 or 150 years past," he says, "did use to cast ordnance more poor, weak, and much slenderer fortified than now, both here and in foreign parts: also the rather because saltpetre being either ill or not refined, their sulphur unclarified, their coals not of good wood, or else ill burnt, making therewith also their powder evilly reccipted, slenderly wrought, and altogether uncorned, made it prove to be but weak (in respect of the corned powder used now-a-days), wherefore they also made their ordnance then accordingly (that is much weaker than now). For the powder now being double or treble more than it was in force of rarification and quickness, requireth likewise to encrease the metal twice or thrice more than before for each piece." And, in fact, the weight of cannon increased in the period mentioned from eighty to two hundred times, the weight of culverins from a hundred to three hundred times, the weight of their shot. The slender large-bore built-up guns of the *Henry Grace à Dieu* could only be used with a weak slow-burning powder. At the same time this slow-burning powder required, for its complete combustion, a great length of gun. These guns, such of them as were breech-loaders, must have suffered from the leakage of gas at the joints of their primitive chambers; in the case of the smaller pieces a serious inefficiency was the excessive windage allowed between shot and gun. Until the end of the sixteenth century the windage bore no direct relation to the diameter of the shot or bore of the gun: it was a fixed amount, one quarter of an inch. The effect, therefore, of the leakage of powder gases past the shot, the loss in efficiency of discharge, was greatest in the smallest guns.

The lines along which improvement lay were those which were taken. First, an elimination of the smallest guns. Second, a return to muzzle loading. Third, a strengthening of the powder by corning. Fourth, a further fortifying and a general augmenting of the weight of the cast pieces, which had the double effect of giving the necessary strength to meet the stronger powders coming into use,[1] and of giving the extra

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[1] Corned powder was graded in France in the year 1540 into three sizes by means of sieves which varied with the types of guns for which they were

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mass required to minimize the violence of their recoil. Cast iron could not yet compete with well-found brass for the guns required. Demi-cannon proved too unwieldy, and as Elizabeth's reign progressed, gave place more and more to the long-ranging culverins, demi-culverins, and sakers, "which strained a ship less, were served more quickly and by fewer men, and permitted a heavier broadside in the same deck space."[1] As powder grew stronger the conditions improved; smaller charges were necessary, windage had less effect, and, owing to the quicker combustion, it was possible to shorten the pieces without detracting seriously from their ranging power; and this was done in the Queen's Navy, the guns being thereby made lighter and more easily manipulated, while at the same time their projecting muzzles were less liable to entangle and interfere with the tackles of the sails.[2]

The substitution of the powerful, safe, and easily manipulated demi-cannon and the long-ranging culverin and demi-culverin in place of the old chambered ordnance of the first half of the century made possible a new form of naval warfare. The cannon at last became, in the hands of the Elizabethan seaman, the chief instrument of battle. Off-fighting was now feasible: a mode of action which largely neutralized the effects of an enemy's superiority in size of ship or number of men, and which gave full scope and advantage to superior seamanship. Though no high standard of gunnery efficiency was then possible, yet it was the great superiority of the English gunfire, principally from the demi-culverins, the sakers, and the minions, over that of Spain, which conduced more than any other factor to the dispersal and subsequent flight of the Invincible Armada. The gun was the weapon on which the English seaman had learnt to rely. It was the gun, plied with rapidity just out of pistol-shot of his lofty ships, which in the year 1588 harassed and put to confusion the Spaniard, the haughty fighter who still maintained a quixotic contempt for the use of cannon and esteemed artillery "an ignoble arm."[3] What a volume of fire was poured against him may be seen from a letter written by the admiral, Lord Howard of Effing-

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intended (see Hime: *Origin of Artillery*). By the end of the century the manufacture had evidently improved in this country. "Some do make excellent good corn powder, so fine, that the corns thereof are like thime seed," wrote Thos. Smith in his *Art of Gunnery*, A.D. 1600.

[1] Oppenheim. [2] Bourne: *The Art of Shooting in Great Ordnance*, 1587.

[3] Sir J. K. Laughton: *Armada Papers*, N.R.S.

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ham: "All the world," he writes, "never saw such a force as theirs was; and some Spaniards that we have taken, that were in the fight at Lepanto, do say that the worst of our four fights that we have had with them did exceed far the fight they had there; and they say that at some of our fights we had twenty times as much great shot plied as they had there."

By this time the founding of guns in cast iron had made progress. Cast iron was cheap, and of a greater hardness and endurance than bronze, but more like to crack and fly and endanger the crew, and requiring an enormous expenditure of wood-charcoal for its production. The use of mineral coal for iron smelting was not discovered until the following century, and even then, because of the opposition of the vested interests, it was long before it displaced the use of timber. In the Tudor times the iron and brass foundries were nearly all in the wooded south of England. The rivers of Sussex and Kent had for centuries been dammed to form hammer-ponds, and the sound of the tilt-hammers was heard throughout these counties. To such an extent were the forests depleted of wood to form fuel for the Wealden foundries, that serious inroads were made on the available supplies of shipbuilding timber; legislation was required in Elizabeth's reign to prevent the charcoal-burner from robbing the shipwright of his raw material.

Gun-founding, even in bronze, was still a somewhat primitive art. But, once taught, the English founders soon excelled their teachers; and Norton's eulogy, and the records of foreign efforts to obtain possession of English pieces, bear witness to the superiority of our workmen. The products of the most famous founders of that time in Europe were very imperfect. "Some of their pieces (and not a few) are bored awry, their soul not lying in the midst of the body of metal; some are crooked in their chase, others of unequal bores, some too light towards the breech turn their mouths downwards in their discharge, and so endanger their own vawmures and defences; others are too heavy also in their breach, by placing the trunnions too much afterwards, that coynes can hardly be drawn. . . . Some are come forth of the furnace spongey, or full of honeycombs and flaws, by reason that the metal runneth not fine, or that the moulds are not thoroughly dryed, or well nealed. . . . Yet thus much I dare say to the due commendations of our English gunfounders, that the ordnance which

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they of late years have cast, as well for neatness, as also for reasonable bestowing and disposing of the metal, they have far excelled all the former and foreign aforementioned founders." Norton, a land gunner, was here referring to brass ordnance, alone used on shore.

Perhaps the most interesting witness to the success of the English gunfounders is Sir Walter Raleigh, who in his *Discourses* rebuked the detestable covetousness of those licensed to sell ordnance abroad. So great was the number of pieces exported, that all other nations were equipped with good English artillery for ships and forts and coast defence. "Without which," he remarks, "the Spanish King durst not have dismounted so many pieces of brass in Naples and elsewhere, therewith to arm his great fleet in '88. But it was directly proved in the lower house of parliament of Queen Elizabeth, that there were landed in Naples above 140 culverins English. . . . It is lamentable that so many have been transported into Spain."

In 1589 Lord Buckhurst wrote to the justices of Lewes Rape, complaining of their neglect in permitting the surreptitious export of ordnance. "Their lordships do see the little regard the owners of furnaces and the makers of these pieces have of their bonds, and how it importeth the state that the enemy of her Majesty should not be furnished out of the land with ordnance to annoy us."

It is not improbable, in short, that some of the Armada's cannon had been moulded and poured on English soil.

The imperfection of the sixteenth-century foundry products may be gauged from Bourne's evidence that the use of cartridges was inconvenient because, on account of honeycombs and flaws, "you shall scant get the cartridge home unto the bottom of the piece." On the other hand loading by ladle was still considered dangerous. In his *Art of Gunnery*, of 1627, Thos. Smith, soldier, of Berwick-on-Tweed, warns the gunner always to stand to one side of the mouth of the piece when thrusting home the ladle; otherwise, the charge being ignited by smouldering débris in the cavities of the metal, it takes fire and kills the loader—"as happened in Anno 1573 at the siege of Edinborough Castle, to two experienced gunners."[1]

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[1] Smith demolished, to his own satisfaction, a theory current that some molecular movement of the metal took place at the moment of gunfire. "I asked the opinion of a soldier, who for a trespass committed was enjoined to

At about the same date as Smith's book was written, Sir H. Manwayring, in *The Sea-Man's Dictionary*, described the "arming" of cross-bar shot: i.e. the binding them with oakum, yarn, or cloth, to prevent their ends from catching hold in any flaws during their passage through the gun, which might break it.

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Under the Stuart kings a continuous development of ship armament took place.

This development was not always in the right direction. The Commission of Reform of the year 1618 recorded, as we have already seen, the importance of artillery in naval warfare, but owing to the absence of all system it was long before the principle found effective application. Owing to divided authority, or to a lack of unity in the conception of the fighting ship, a tendency to excess in the number and weight of guns continued to be noticeable, an excess which was to react unfavourably on the performances of our ships both in the seventeenth and eighteenth centuries.

Progress was made in the classification of pieces and in the reduction of the number of different types carried; a change was also made in the forms of the guns, in order to enhance the fighting value of the gun armament in certain circumstances. The great guns were made still shorter than before; the quicker-burning powders now in use allowed this to be done. By which expedient the ratio between gun-weight and weight-of-metal-thrown was reduced; more guns could be carried for a given weight of metal; they could be more easily manipulated; and if they were of small ranging power they yet possessed a power of penetration sufficient for close-quarter fighting. Moreover, the reduction in length enabled an increase in calibre to be made; and this was one of the factors which led to the reintroduction of larger types than had formerly been considered suitable: the cannon-serpentine, the cannon, and even the cannon-royal, with its sixty-six pound shot and its eight thousand pounds of metal.[1]

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ride the canon, who confidently affirmed, he could perceive no quivering of the metal of the piece, but that the air which issued out of the mouth and touch-hole of the piece did somewhat astonish and shake him."

[1] The advantages of large calibres had been appreciated in the previous century. Sir Richard Hawkins, in his *Observations*, printed in 1593, compares the armament of his own ships with that of his Spanish opponents, and says: "Although their artillery were larger, weightier, and many more than

In the Dutch Wars the preponderance in the size and weight of the unit shot lay with the English ships, and was in itself undoubtedly a great advantage in their favour; though complaints were made of the great weight and clumsiness of the pieces, "which caused much of the straining and rolling at sea." Writing of naval ordnance in the year 1690, Sir Cloudesley Shovell recorded that, "our lower-deck guns are too big and the tackles ill fitted with blocks, which makes them work heavy; the Dutch who have light guns have lignum vitæ sheaves. The Dutch guns are seldom larger than twenty-four pounders." By this time, it will be noted, the more scientific nomenclature had come into vogue; the cannon-petro was now known as the 24-pounder, and the heavy lower-deck guns referred to were the old bastard-cannons, known since the reorganization of the Commonwealth navy as 42-pounders.

The founding of guns continued to be, throughout the seventeenth century, an affair of private enterprise. Proof was carried out under the supervision of the Board of Ordnance.

In 1619 a decree was issued that gun-founding was to be confined to Kent and Sussex, that guns were to be landed at or shipped from the Tower Wharf only, and that East Smithfield was to be the one market-place for their sale or purchase. Guns could be proved only in Ratcliff fields, and all pieces were to have on them at least two letters of the founder's name, with the year and the weight of the gun. Exportation was illegal; nevertheless the illicit traffic went on just as in Elizabeth's time. The royal forts themselves were turned into marts for these and other unlawful transactions, and Upnor Castle is described as having been "a staple of stolen goods, a den of thieves, a vent for the transport of ordnance."[1]

In later years proof took place at other government grounds, all within the London area. In Moorfields, according to Stowe, was the Artillery Yard, "whereunto the gunners of the Tower do weekly repair; and there, levelling certain brass pieces of great artillery against a butt of earth made for that purpose, they discharge them for their exercise."[2] Spitalfields also had

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ours, and in truth did pierce with greater violence; yet ours being of greater bore, and carrying a weightier and greater shot, was of more importance and of better effect for sinking and spoiling."

[1] Oppenheim.

[2] A significant view of the attitude of these professionals toward any innovation in gunnery material is afforded by the entry of Mr. Pepys in his diary for the 17th April, 1669.

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its artillery butts. "Where Liverpool-street Station now stands the Tower gunners of Elizabeth's day had their yard, and there discharged great pieces of artillery for exercise, while throughout the seventeenth century guns were both cast and tested in the vicinity, as Gun-street, Fort-street, and Artillery Lane hard by serve to remind us. Finsbury Field, levelled for an archery ground in 1498, passed from the London archers to the London gunners, and, as the Honourable Artillery Company's Ground, survives to carry on the long traditions of the spot."[1]

Under the Commonwealth progress was made in the quality of gunpowder, and improved methods were introduced of testing it for strength and uniformity. This advance had its effect on the guns. Failures were frequent, and, in spite of improved founding, pieces had to be made heavier than before; cast iron in particular was found unequal to withstanding the stresses caused by the improved powders, and this metal came into such disfavour that a whole century elapsed before it was again accepted as suitable by both naval and military artillerists. Founding in bronze had undergone improvement. Malthus, an Englishman who had risen in the French service to be Director of their Artillery,[2] mentions in his *Pratique de la Guerre*, as evidence of this improvement, the fact that in breaking up old pieces lumps of free tin and copper were frequently discovered, whereas in the case of new guns the metal was invariably found well-mixed.

Somewhere between the years 1665 and 1680—presumably later than 1667—the proof of ordnance was transferred from Moorfields to the naval depôt at Woolwich, and the nerves of the metropolis were no longer shaken by the roar of pieces loaded with powder charges equal, for proof, to one-and-a-half times the weight of the shots themselves. A proof-master and "his Majesty's founder of brass and iron ordnance" were instituted to supervise and advise the various contractors. The State did not at first take over the work of casting its own guns. But in 1716 an event occurred which brought about the

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[1] An anonymous writer in the *Pall Mall Gazette*.

[2] Le Sieur Malthus, gentil-homme Anglois, Commissaire Général des Feux et Artifices de l'Artillerie de France, Capitaine General des Sappes et Mines d'icelle & Ingeniéur és Armées du Roy, published his *Pratique de la Guerre* in 1668. This notable but almost-forgotten artillerist introduced the use of mortars and bombs into France, in 1637. He was killed by a musket ball at the siege of Gravelines, as he elevated himself above the rampart of a trench in order to watch the effect of a bomb (St. Remy: *Mémoires*).

formation of the Royal Gun Factory, and the manufacture of both land and sea ordnance by the state. A disastrous accident occurred in the City of London. It happened that, after the peace of Utrecht in 1713, the guns captured by Marlborough from the French had been exhibited outside the Moorfields foundry. Three years later they were still there, and, the national ordnance being much depleted by the late wars, it was resolved to recast these pieces and so utilise their metal. On the appointed date a large concourse of the public attended to witness the operation. Late at night the metal was poured. A big explosion ensued, owing to the use of damp moulds, and a number of people were killed and injured.

To avoid a recurrence of such an accident it was decided that the government should possess a brass foundry of their own. The services of an able foreigner, Andrew Schalk of Douai, were sought, and the Royal Foundry at Woolwich was established with Schalk as master founder. The change was a complete success, and Schalk held the position for the next sixty years. Some of his guns, cast in the year 1742, were raised from the "Royal George" in 1840.[1]

By the middle of the eighteenth century the processes of gunnery had been placed for the first time on a scientific foundation; by whom, and in what manner, we shall describe in a later chapter.

The design of guns had by this time become subject to more scientific consideration than had hitherto been bestowed, and their manufacture had been improved by the Swiss invention of the boring machine, which enabled them to be cast solid instead of being cast hollow on a core. Iron guns came more and more into favour as the century progressed, especially for naval use. The cost of iron was only one-eighth that of brass. The art of casting iron in homogeneous masses had by this time made progress, and though hitherto it had been the custom to make iron ordnance of great thickness and weight, repeated trial proved that they could be made lighter, if required, without undue loss of strength, and that in action they outlasted brass ordnance, which cracked, bent at the muzzle, and wore out at the vent. A well-made iron gun was almost indestructible. At the siege of Belleisle, in the Seven Years' War, the brass guns soon wore out, and had to be

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[1] This account is taken from *Historical Notes on Woolwich*, Lieut. Grover, R.E. (Proc. R.A.I., Vol. VI).

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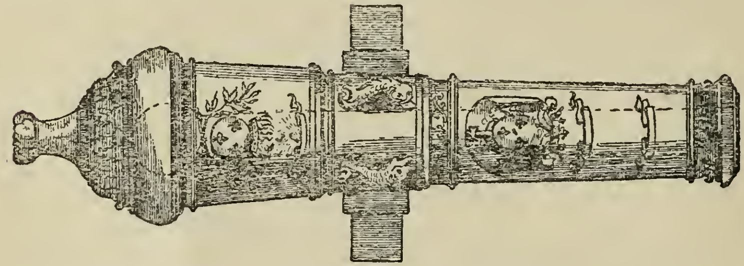
replaced by iron ship guns; and it was long, indeed, before a suitable brass was discovered, which would withstand the repeated fire of large charges without losing its tin-element and degenerating into a spongy and craterous material. Muller, in his *Treatise of Artillery*, of 1768, described how he had seen cast iron at the Carron works so tough that "it would flatten and tear like brass"; and advocated iron guns of a new and light construction to replace Schalk's brass guns forming the armament of the *Royal George*, and give a saving in weight of over a hundred and sixty tons.

In respect of design, the newly acquired knowledge of the true principles governing internal ballistics began gradually, in the latter part of the century, to show its effect. Hitherto, ever since gunpowder had been in military use, pieces had been cast in masses of varying size and shape and ornamented to please the fancy of the founder. Cannon had been made with double or triple reinforces of metal, so that their exterior surface was stepped longitudinally from muzzle to breech. Experience probably pointed out on many occasions the bad design of a piece whose sections showed sudden alterations in shape; but it was not till after the middle of the eighteenth century that this consideration was discussed by a professional. "Since powder acts uniformly and not by starts it is hard to judge from whence this ridiculous custom has arisen. . . . There should be no breakings in the metal." The piece, continues Muller, should be of cylindrical bore, and its outer contour should be a curve slightly concave, corresponding presumably to the curve of the powder pressure. But as this curve would be difficult to find, he recommends a sloping straight line from breech to muzzle as sufficiently exact for practical purposes.



FRENCH TWENTY-FOUR-POUNDER WITH SPHERICAL CHAMBER
From St. Remy's *Mémoires*

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Innumerable experiments were made in the first half of this century with a view to improving the efficiency of combustion in guns, and much argument centred round such subjects as the shape of the chamber and the position of the vent. In France pieces were adopted having spherical chambers: it being proved that, with the charge concentrated in a spherical cavity, as much power could be obtained as from a larger and heavier flush-chambered gun. But such pieces were dangerous. Not only was their recoil so violent as to break their carriages, but many good gunners lost their arms while charging chambers in which smouldering debris lay hidden. The spherical chamber was abandoned.[1]

It may be said that the design and manufacture of guns has now entered the scientific stage. Art there still is, but it lies below the surface. The old "vain ornaments" preserved by tradition are thrown away: the scrolls, mouldings, and excrescences which broke the surface of the metal; the ogees, fillets, and astragals which ran riot over the products of some foundries; the muzzle swells which by their weight caused the chase to droop; the grotesque cascabels. All mouldings, said Muller, should be as plain and simple as possible; the trunnions should be on the axis of the piece; the windage of all types of guns should be smaller, and there should be more moderation in the charges used.

In time all these improvements came. The smooth-bore gun, strengthened and simplified, preserved its establishment in the navy far into the nineteenth century, as will later appear. For the present we must confine ourselves to noting that, in the final stages of its evolution it received improvement in form from two distinguished artillerists whose influence was progressive in the whole realm of gunnery: Generals Congreve[2] and Blomefield.[3] There is yet another eminent officer of this

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[1] Le Blond: *Traité de l'Artillerie*, 1743.

[2] Lieut.-Gen. Sir William Congreve, Bart., was, as Captain Congreve, appointed in 1783 to the control of the Royal Laboratory at Woolwich. Sent in '79 to Plymouth, to examine the gunpowders of H.M. ships in consequence of the complaints of Admiral Barington, he found only four serviceable barrels in the whole fleet. The gross frauds then brought to light led to the formation of the Government establishment at Waltham Abbey. His son was the inventor of the Congreve sight and rocket.

[3] Gen. Sir Thomas Blomefield, Bart., who started his service career as a midshipman, commanded a bomb vessel under Rodney at the bombardment of Havre in 1759, and was present at Quiberon. After varied service abroad he was appointed, in 1780, Inspector of Artillery and of the Brass Foundry. "Never was the need of military supervision over military manufactures more apparent than at this period. The guns supplied to the naval and

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period to whom the navy owes a debt incalculable: Who can assess the value of the work done by General Sir Howard Douglas in his classic treatise on Naval Gunnery?

To the foregoing survey of the evolution of heavy ordnance we now append a few notes on the evolution of the material of purely land artillery: from which it will be seen that, while the intensive competition of great armies resulted in much of this latter evolution originating among the continental powers, the share of this country in initiating improvement was, in the latter years, by no means negligible.

§

It will be noted by the student of European history as significant, that superiority of artillery material has almost invariably marched with national power. Thus in the past the evolution of artillery has been the monopoly of no one nation; it has been progressed by each in turn; each in turn has attained superiority, and each has contributed something of importance to it, in the day of its greatness.

Two ancient and preventable practices seem to have operated in chief measure to retard the progressive development of a mobile land artillery: first, the custom of setting the trunnions of a gun at an appreciable distance below the horizontal plane of the gun-axis; second, the custom of making small pieces relatively longer than those of larger calibre.

The first guns had no trunnions. To obtain the requisite angle of elevation the piece was laid in a dug-out trunk or carriage and this carriage was set on trestles; in which manner, it appears, the English at the siege of Orleans in A.D. 1428 "threw into the town from their bombards large numbers of stones which, flying over the walls, smashed in the roofs of houses."[1] During the fifteenth century trunnions came into use, and the carriages were mounted on wheels. In his *Introduction of Artillery into Switzerland* a French writer, Colonel Massé, has given an account of the early evolution of an artillery of position, as used by the Swiss and their enemies in the fifteenth century. The huge siege bombards, possessed

military forces had degenerated to the lowest point in quality. Bursts were of frequent occurrence, and would doubtless have been much more frequent if the roguery of contractors in gunpowder had not kept pace with the roguery of contractors in guns. . . . From this period dates the high character of British cast iron and brass ordnance."

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[1] Favé.

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by most of the great cities at the end of the fourteenth century, were too cumbrous for transport. Built up of welded and coiled iron, and therefore without trunnions, they were replaced, toward A.D. 1443, by lighter pieces on wheeled carriages. And before the Burgundian War "coulevrines de campagne" were being cast in Switzerland, of bronze, with trunnions to give each piece an elevation independently of its carriage. Relics are still preserved which show the gun-trunnion in its early stages, as embodied in the Burgundian artillery of Charles the Bold. The first method of obtaining elevation for the gun was by hinges or trunnions on the front of the carriage or trunk, in combination with a curved rack erected on the trail for supporting the rear end. Then the trunk disappeared; the trunnions were cast on the gun, whose cascabel was supported by a cross-pin between the flanks of the trail; and then the cross-pin was made removable, and a series of holes was provided for its reception, to give the elevation desired. At first these trunnions were cast level with the gun axis; in Napoleon III's treatise on artillery is a picture of a trunnion gun taken by the Swiss from Charles the Bold in 1476, and another of a cannon of Louis XI, cast in 1478, and in both cases the trunnions are level with the gun axis. But pieces cast later almost invariably had their trunnions set on a level with the bottom of the bore; partly, perhaps, for the insignificant reason given by Norton —that "lying somewhat under the concave cylinder of the bore they will the better support the great weight"—but primarily to ensure a downward pressure on the quoin or trail when discharge took place. The effect of this trivial alteration was enormous. The impulse of the recoil was given a *moment* about the trunnion axis which, as the force of powders increased, produced an increasingly great downward pressure on the trail. Carriages, though made of massive scantlings, frequently broke; nor was it till the latter half of the eighteenth century that the cause was removed, the trunnions being raised nearer the axes of the guns and the carriages being thereby

From Binning's *A Light to the Art of Gunnery*, A.D. 1689 relieved of the excessive cross-strains which they had borne for nearly three hundred years. Muller, in his *Artillery*, refers to the "absurd method" of placing the trunnions so low and, in the year 1768, points out the advantages to be gained by raising them. "Writers do not appear to have had any idea," says Favé, "of the effect which the position of the trunnions had on the stressing of the carriage." Scharnhorst the Prussian gives as an important advantage to be gained by raising the trunnions, the larger wheels which could be employed without adding to the height of the gun above the ground.

Progress was also checked by the great length given to the smaller varieties of cannon. With the fine powder of the Middle Ages a great length of barrel was necessary to ensure complete combustion, and such primitive observations as were made all seemed to prove that, the longer the barrel the greater the range. But with the introduction of corned powder a reduction in length should have been possible. No such change was made. Tradition had consecrated long guns, and official standardization of types afterwards helped to oppose any innovation in this respect until the eighteenth century, with few exceptions.

To Charles V of Spain belongs the credit for the first systematic classification of guns. In his hands artillery had, for the first time, become an efficient instrument of battle in land campaigns, and all Europe saw that, in his batteries of bronze trunnion-guns, on wheeled carriages, firing cast-iron balls against foe or crumbling masonry, a new power had arisen.[1] The emperor, experiencing the inconvenience of a multiplicity of types and calibres, sought to simplify his material. Accordingly, in the year 1544 or shortly before, he approved seven models to which all pieces in use throughout the vast possessions of the Spanish monarchy were thenceforth to conform. These seven types comprised a cannon (a 40-pounder), a cannon-moyen (24-pounder), two 12-pounder culverins, two 6-pounder culverins, and a 3-pounder falcon.

The French soon improved on Charles' example. The oldest patterns of their cannon, according to a table given by St.

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[1] The author of the *Études sur l'Artillerie* places emphasis on the importance of the substitution of cast iron for stone projectiles, as augmenting the power of artillery. Stone balls broke to pieces on impact with masonry, and were of small destructive power except when in large mass, as projected from the largest bombards. He claims the introduction of iron shot, the use of trunnions for elevating, and the standardization of calibres, for the French artillery of Charles VIII, who in 1495 descended on Italy.

Remy in his *Mémoires*, were of a uniform length of ten feet. In A.D. 1550 Henri II issued an edict restricting the number of different calibres to six, named as follows:—

Canon, a 33-pounder, 10½ feet long, weighing 5200 livres, drawn by 21 horses.
Grande coulevrine, a 15-pounder, 11 feet long, weighing 4000 livres, drawn by 17 horses.
Coulevrine bâtarde, a 7-pounder, 9 feet long, weighing 2500 livres, drawn by 11 horses.
Coulevrine moyenne, a 2-pounder, 8½ feet long, weighing 1200 livres, drawn by 4 horses.
Faucon, a 1-pounder, 7½ feet long, weighing 700 livres, drawn by 3 horses.
Fauconneau, a ¾-pounder, 7 feet long, weighing 410 livres, drawn by 2 horses.

These dimensions are only a rough approximation. In the year 1584 two other types, found useful by the Spaniards in the Low Countries, were included—a 12- and a 24-pounder.

The relatively greater lengths of the small pieces will be noted. As it was with the French, so it was with other nations, and the list of Italian ordnance given in Tartaglia's *Art of Shooting* shows a general resemblance to that of Henri II. The desire for a maximum of ranging power, and the necessity of making the smaller pieces long enough to enter the embrasures of fortifications, and strong enough to fire many more rounds than those of the largest size, tended to cause an augmentation in their size and weight; difficulties of transport had an effect in imposing a limit of weight on the largest guns which in the case of the smaller pieces did not operate to the same degree.

Nevertheless, the French possessed, from 1550 onwards, an organized artillery suitable for transport on campaigns. The six calibres were mounted on wheeled carriages, horse-drawn, from which they could be fired; they were moved, muzzles foremost, with their ponderous trails dragging on the ground in rear.

At that point French artillery remained, or with little advance beyond it, until the middle of the eighteenth century. In the Germanic states, on the other hand, important progress was made: by the end of the sixteenth century shorter pieces, shell-fire from mortars, and the use of elevated fire for varying ranges, had been adopted. But the chief centre of artillery progress at the end of the sixteenth century was the Low Countries, then in the thick of their warfare with Spain. "In their glorious struggle for independence their artillery contrived to avail itself of the latest and best theory and practice, to employ cannons and carriages of simplicity and uniformity; and it has endowed the art of war with two inventions of the first order—the hand-grenade and the bomb." [1]

In the first half of the seventeenth century the genius of Gustavus Adolphus gave a new value to land ordnance. He made it mobile. He divided his artillery into two categories, Siege and Field, and for the latter devised the famous light "leather guns" which, operating in mass on certain points, had an important effect on the issue of battles. But after his death at Lützen in 1632 the effort to attain mobility relaxed; an increase in the strength of powders at this time rendered the possibility still more remote; and it was not until the following century that the Prussians, under Frederick the Great, evolved a satisfactory light artillery. Both in Prussia and in Austria great efforts were made, in the middle of the eighteenth century, to evolve a mobile and efficient ordnance. The Seven Years' War found the former state experimenting with pieces varying in weight between eighty and a hundred and fifty times the weight of their ball; and in 1762 a certain French observer, who was destined to become famous as one of the great artillery reformers of all time, wrote letters from Vienna describing the fine qualities of the Austrian service: with its pieces all sixteen calibres in length, all 115 times their balls in weight, all bored to their true nominal dimensions, and firing accurately spherical balls of correct size, with a small windage and a powder-charge of less than one-third the weight of the shot.

In the years immediately following the close of the Seven Years' War the lessons learned at Vienna were translated into practice in France. By 1765 Gribeauval had begun his reorganization of the French material. In order to obtain mobility he made new models of 12, 8, and 4-pounders, very plain, unchambered pieces, each eighteen calibres in length, 150 times its own shot in weight, and firing well-fitting balls with unprecedented precision, with powder-charges of one-third the weight of the balls. Limbers, in the form of small-

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[1] Favé.

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trucked bogies, had been in occasional use ever since the sixteenth century. Gribeauval introduced large-wheeled limbers, and dragged his 12-pounders by six, his 8- and 4-pounders by four horses. From the number of horses, as compared with that of the edict of Henri II, one can measure the progress made in two centuries. The whole of Gribeauval's material was designed to afford rapid transport and rapid and accurate fire; interchangeability of wheels and other parts formed a novel and important element of the standardization which he accomplished. Iron axle-trees, cartridges (used with effect by Gustavus in the preceding century), elevating screws, tangent scales, and other improvements were adopted under his authority. But, "Gribeauval could not force on France the two great inventions of the century—the limber-box and the Horse Artillery." [1]

The horse, or flying, artillery, designed to be attached to, and supported by, cavalry, as field or foot artillery was attached to infantry, was a Prussian invention. It was adopted by France after the outbreak of the Revolution, and almost simultaneously it appeared in the British army.[2]

By the end of the century all the great Powers had adopted Gribeauval's system in most of its important parts: notably in the grouping of artillery into the three categories—siege, field, and coast defence. Progress continued. In the opening years of the next century a new competitor among the Powers began to attract attention by its proficiency. "In the first campaigns of the Revolution the English artillery showed itself less advanced than that of several other powers. But so well did it succeed in ameliorating its condition that when it reappeared on the Continent to take an active part in the Peninsular War it was seen to be itself worthy in its turn to serve as a model."

This is the tribute paid by Colonel Favé.

It is evident from his further remarks that the English artillery surprised its adversaries, not only by its superior mobility, but by the effectiveness of its innovations, two of which, especially, proved to be inventions of the first order—Shrapnel's projectiles and Congreve's war-rockets. France recognized the high efficiency of its opponent artillery, and some years later adopted a material embodying some of its

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[1] Lieut.-Col. Hime, R.A.: *The Progress of Field Artillery.*

[2] Owen: *Lectures on Artillery.*

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most important features. Experiments were made, and comparative trials carried out, with modified English and modified Gribeauval equipments. The former were preferred, and a new series of designs was introduced and approved: this becoming known as "the system of 1827."

Three years later war experience led to investigations in France which caused a revolution in artillery material. In a few years' time smooth-bore cannon were being converted to rifles, for use both on land and sea.

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CHAPTER III

THE STEAM ENGINE

THE greatest of the world's inventions appear to have had a very casual birth. So much an affair of chance has been their first manifestation, that science has not been called in aid; no law can be discerned which might govern the time and sequence of their coming; they seem to have been stumbled on, unpedigreed offspring of accident and time. A monk of Metz discovers gunpowder. "Surely," says Fuller, "ingenuity may seem transposed, and to have crossed her hands, when about the same time a soldier found out printing." "It should seem," writes Lord Bacon, "that hitherto men are rather beholden to a wild goat for surgery, or to a nightingale for music, or to the ibis for some part of physic, or to the pot-lid that flew open for artillery, or generally to chance, or anything else, than to logic for the invention of the Arts and Sciences." So it seemed. And in due time the legend of the pot-lid was woven round the unfortunate Marquis of Worcester, who, tradition had it, made the discovery of the steam engine by observation of the stew-pot in which, when confined a prisoner in the Tower, he was engaged in cooking his dinner. At a later date and in another form the story was connected with James Watt.

In reality, the story of the discovery of the steam engine is far more inspiring. The history of the application of steam to human use is almost the history of science itself; the stages of its development are clearly marked for us; and the large succession of these stages, and the calibre of the minds which contributed to the achievement of the perfected steam engine, are some measure of the essential complexity of what is to-day regarded as a comparatively simple machine. For the steam engine was not the gift of any particular genius or generation; it did not leap from any one man's brain. Some of the greatest names in the history of human knowledge can claim a share in its discovery. From philosopher to scientist, from scientist to engineer the grand idea was carried on, gradually taking more and more concrete form, until finally, in an age when by the diffusion of knowledge the labours of all three were for the first time co-ordinated, it was brought to maturity. A new force of nature was harnessed which wrought a revolution in the civilized world.

An attempt is made in this chapter to chronicle the circumstances under which the successive developments of the steam engine took place. The progress of the scientific ideas which led up to the discovery of the power of steam is traced. The claims of the various inventors chiefly associated with the steam engine are set forth in some detail, not for the difficult and invidious task of assessing their relative merits, but because by the light of these claims and altercations it may be possible to discern, in each case, where the merit lay and to what stage each novelty of idea or detail properly belonged. From this point of view, it is thought, the recital of circumstances which hitherto have been thought so trivial as to be scarcely worthy of record, may be of some suggestive value. The result of the investigation is to make clear the scientific importance of the steam engine: the steam engine regarded, not as the familiar drudge and commonplace servant of to-day, but in all its dignity of a thermodynamic machine, that scientific device which embodied so much of the natural philosophy of the age which first unveiled it—the seventeenth century.

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Before the Christian era steam had been used to do mechanical work. In a treatise, *Pneumatica*, written by Hero of Alexandria about 130 B.C., mention is made of a primitive reaction turbine, which functioned by the reactionary force of steam jets thrown off tangentially from the periphery of a wheel. In the same work another form of heat-engine is described: an apparatus in which, by the expansion from heating of air contained in a spherical vessel, water was expelled from the same vessel to a bucket, where by its weight it gave motion mysteriously to the doors of temples. And evidence exists that in these two forms heat engines were used in later centuries for such trivial purposes as the blowing of organs and the turning of spits. But except in these two primitive forms no progress is recorded for seventeen centuries after the date of Hero's book. The story of the evolution of steam as a motive force really begins, with the story of modern science itself, at the end of the Middle Ages.

With the great revival of learning which took place in Southern Europe in the latter part of the fifteenth century new light came to be thrown on the classical philosophies which still ruled men's minds, and modern science was born. New views on natural phenomena began to irradiate, and, sweeping aside the myths and traditions which surrounded and stifled them, the votaries of the "new science" began to formulate opinions of the boldest and most unorthodox description.[1] The true laws of the equilibrium of fluids, discovered originally by Archimedes, were rediscovered by Stevinus. By the end of the sixteenth century the nature of the physical universe was become a pursuit of the wisest men. To Galileo himself was due, perhaps, the first distinct conception of the power of steam or any other gas to do mechanical work; for "he, the Archimedes of his age, first clearly grasped the idea of force as a mechanical agent, and extended to the external world the conception of the invariability of the relation between cause and effect."[2] To his brilliant pupil Torricelli the questioning world was indebted for the experiments which showed the true nature of the atmosphere, and for the theory he proclaimed that the atmosphere by its own weight exerted its fluid pressure—a theory which Pascal soon confirmed by the famous ascent of his barometer up the Puy-de-Dôme, which demonstrated that the pressure supporting his column of mercury grew less as the ascent proceeded. Giovanni della Porta, in a treatise on pneumatics published in the year 1601, had already made two suggestions of the first importance. Discussing Hero's door-opening apparatus, della Porta showed that steam might be substituted for air as the expanding medium, and that, by condensing steam in a closed vessel, water might be sucked up from a lower level by virtue of the vacuum so formed. And a few years later, in 1615, Solomon de Caus, a French engineer, had come to England with a scheme almost identical with della Porta's, and actually constructed a plant which forced up water to a height by means of steam. Shortly afterwards the "new science" received an accession of interest from the invention, by Otto von Guericke of Magdeburg, of a suction

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[1] Whewell: *History of the Inductive Sciences.*

[2] *Encycl. Brit.*, 11th Edition.

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pump by which the atmospheric air could be abstracted from a closed vessel.

By the middle of this century the learned of all European countries had been attracted by the knowledge gained of the material universe. In England the secrets of science were attacked with enthusiasm under the new strategy of Lord Bacon, enunciated in his *Novum Organum.* The new philosophy was patronised by royalty itself, and studied by a company of brilliant men of whom the leading physicist was Robert Boyle, soon famous for his law connecting the volumes and the pressures of gases. In France, too, a great enthusiasm for science took birth. A group of men, of whom the most eminent was Christian Huyghens, banded themselves together to further scientific inquiry into the phenomena of nature and to demolish the reigning myths and fallacies : they also working admittedly by the experimental method of Bacon.

The time was ripe, however, for wider recognition of these scientists and the grand object of their labours. Within a short time the two groups were both given the charter of their respective countries ; in France they were enrolled as the Royal Academy of Sciences ; in England, as the Royal Society for Improving Natural Knowledge. In other countries societies of a similar kind were formed, but their influence was not comparable with that exerted by the societies of London and Paris. Between these two a correspondence was started which afterwards developed into one of the most famous of publications : the *Philosophical Transactions.* In England, especially, the Royal Society served from its inception as a focus for all the great minds of the day, and in time brought together such men as Newton, Wren, Hooke, Wallis, Boyle—not to mention his majesty King Charles himself ; who, with the best intentions, could not always take seriously the speculations of the savants. " Gresham College he mightily laughed at," noted Mr. Pepys in his diary for the first of February, 1663, " for spending time only in weighing of ayre, and doing nothing else since they sat." A year later Pepys was himself admitted a member of the distinguished company, and found it " a most acceptable thing to hear their discourse, and see their experiments, which were this day on fire, and how it goes out in a place where the air is not free, and sooner out in a place where the ayre is exhausted, which they showed by an engine on purpose."

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In the year 1663, just after the formation of the Royal Society, a small book was published by the Marquis of Worcester, *A Century of the Names and Scantlings of such Inventions as he had tried and perfected.*

Of these inventions one, the sixty-eighth, is thus described :

"An admirable and most forcible way to drive up water by fire, not by drawing or sucking it upwards, for that must be as the Philosopher calleth it, *Intra sphœram activitatis*, which is but at such a distance. But this way hath no bounder, if the vessels be strong enough ; for I have taken a piece of a whole cannon, whereof the end was burst, and filled it three-quarters full of water, stopping and screwing up the broken end, as also the touch-hole ; and making a constant fire under it, within twenty-four hours it burst and made a great crack. So that having a way to make my vessels, so that they are strengthened by the force within them, and the one to fill after the other ; I have seen the water run like a constant fountain-stream forty foot high ; one vessel of water rarified by fire driveth up forty of cold water. And a man that tends the work is but to turn two cocks, that one vessel of water being consumed, another begins to force and refill with cold water, and so successfully, the fire being tended and kept constant, which the selfsame person may likewise abundantly perform in the interim between the necessity of turning the said cocks."

On this evidence the claim is made that the marquis was the original inventor of the steam engine. Is he at all entitled to the honour ? The whole affair is still surrounded with mystery. It is known that he was an enthusiastic student of physical science, and that for years he had working for him a Dutch mechanic, Caspar Kaltoff ; it seems certain that he actually made a water-pumping engine worked by steam, of whose value he was so impressed that he promised to leave the drawings of it to Gresham College and intended to have a model of it buried with him.[1] But neither model nor drawings

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[1] This project, however, is mentioned of an engine called by him "a semi-omnipotent engine," the subject of the 98th invention : "an engine so contrived, that working the *Primum mobile* forward or backward, upward or downward, circularly or cornerwise, to and fro, straight, upright or downright, yet the pretended operation continueth and advanceth, none of the motions above-mentioned hindering, much less stopping the other."

This engine is obviously not the same as that described as the sixty-eighth invention.

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has ever yet been traced. And, considering the social influence of the inventor and the importance of the invention, the silence of his contemporaries on the discovery is strange and inexplicable. He received a patent for some form of water-pumping engine. Distinguished visitors came to Vauxhall to see his engine at work. He numbered among his acquaintances Sir Jonas Moore, Sir Samuel Morland, Flamstead and Evelyn: probably Mr. Pepys, Sir W. Petty, and others of the group of eminent men of his time who were interested in natural science. Yet no trace of his inventions has come down to us. His *Century* was admittedly compiled from memory—"my former notes being lost"—and perhaps it was designedly obscure; science was at that time a hobby of the cultured few, and scientific men loved to mystify each other by the exhibition, without explanation, of paradoxes and toys of their own construction. The marquis, it will be agreed, left valuable hints to later investigators. Whether his claim to have invented the steam engine is sufficiently substantiated, we leave to the opinion of the interested reader, who will find most of the evidence on this subject in Dirck's *Life of the Marquis of Worcester.*

The power of steam to drive water from a lower to a higher level had been shown by Solomon de Caus,[1] who, in his work, *Les Raisons des Forces Mouvantes,* published in A.D. 1615, had described a hot-water fountain operated by heating water in a globe. In Van Etten's *Récreation Mathematique* of 1629 was an experiment, described fifty years later by Nathaniel Nye in his *Art of Gunnery* as a "merry conceit," showing how the force of steam could be used to discharge a cannon. As the century advanced the ornamental was gradually superseded by the utilitarian; the usefulness of steam for draining fens, pumping out mines, was realized; and applications for patents to cover the use of new and carefully guarded inventions began to appear.

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[1] A well-known story, quoted at length in the Memoirs of Sir John Barrow, connected de Caus with the Marquis of Worcester in dramatic fashion. The Marquis was being conducted through the prison of the Bicêtre in Paris when his attention was attracted by the screams of an old madman who had made a wonderful discovery of the power of steam, and who had so importuned Cardinal Richelieu that he had been incarcerated as a nuisance.

"This person," said the insolvent Lord Worcester after conversing with him, "is no madman; and in my country, instead of shutting him up, they would heap riches upon him. In this prison you have buried the greatest genius of your age."

The fable, and its exposure by a French writer, M. Figuier, are described in Dirck's book.

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Gunpowder as a medium was a strong competitor of steam. In 1661 King Charles granted to Sir Samuel Morland, his master of mechanics, " for the space of fourteen years, to have the sole making and use of a new invention of a certain engine lately found out and devised by him, for the raising of water out of any mines, pits, or other places, to any reasonable height, and by the force of air and powder conjointly." What form the engine took is not known ; whether the gunpowder was used to produce a gaseous pressure by which the work was done, or whether its function was to displace air and thus cause a vacuum as its gases cooled. In France, too, efforts were made at this time to produce a gunpowder engine. In 1678 a Jean de Hautefeuille raised water by gunpowder, but authorities differ as to whether he employed a piston—which were then in use as applied to pumps—or whether he burned the powder so that the gases came in actual contact with the water. In the following year an important advance was made. Huyghens constructed an engine having a piston and cylinder, in which gunpowder was used to form a vacuum, the atmospheric pressure providing the positive force to produce motion ; and in 1680 he communicated to the Academy of Sciences a paper entitled, " A new motive power by means of gunpowder and air."

But it was to his brilliant pupil, Denis Papin, that we are indebted for a further step in the materialization of the steam engine. Papin suggested the use of steam for gunpowder.

In 1680 Papin, who like Solomon de Caus had brought his scientific conceptions to England in the hope of their furtherance, was admitted on the recommendation of Boyle to a fellowship of the Royal Society. After a short absence he returned to London in '84 and filled for a time the post of curator to the society, meeting, doubtless, in that capacity the leading scientists of the day and coming in touch with all the practical efforts of English inventors. During his stay here he worked with enthusiasm at the production of a prime mover, and when he left in '87 for a mathematical professorship in Germany he continued there his researches and experienced repeated failures. In a paper published in '88 he showed a clear conception of a reciprocating engine actuated by atmospheric pressure, and in '90 he suggested for the first time the use of steam for forming the vacuum required. As water, he wrote, has elasticity when fire has changed it into vapour, and as cold will condense it again, it should be possible to make engines in which, by the use of heat, water would provide the vacuum which gunpowder had failed to give. This memorable announcement gave a clear direction to the future development of the heat engine. Steam was the medium best suited for utilizing the expansive power of heat generated by the combustion of fuel; steam was the medium which, by its expansive and contractile properties, could be made to impart a movement *de va et vient* to a piston. Though Papin did not succeed in putting his idea into practical form his conception was of great value, and he must be counted as one of the principal contributors to the early development of the steam engine. His life was an accumulation of apparent failures ending in abject poverty. To-day he is honoured by France as the inventor of the steam engine, and at Blois a statue has been erected and a street named to his memory.

Before the end of the century an effective engine had been produced, in England.

In 1698 Thomas Savery, a Devonshire man, obtained a patent for "a new invention for raising of water and occasioning motion to all sorts of millwork by the impellent force of fire." Before the king at Hampton Court a model of this invention was displayed, and the importance of the new discovery was soon realized by the landed classes; for in the following year an act of parliament was passed for the encouragement of the inventor and for his protection in the development of what, it was recognized, was likely to prove of great use to the public. In the same year Savery published a pamphlet called *The Miner's Friend*, and republished it, with additions, in 1702. This pamphlet contained a full and clear description of his engine; but significance has been attached to the omission from it of any claim that it embodied a new idea. The omission may be accidental.

The steam engine, shown in the accompanying illustration, was simply a pump, whose cycle of operations was as follows. Steam, admitted into the top of a closed vessel containing water and acting directly against the water, forced it through a pipe to a level higher than the vessel itself. Then, the vessel being chilled and the steam in it thereby condensed, more water was sucked into the vessel from a lower level to fill the vacuum thus formed; this water was expelled by steam in the same way as before, cocks being manipulated, and, even-

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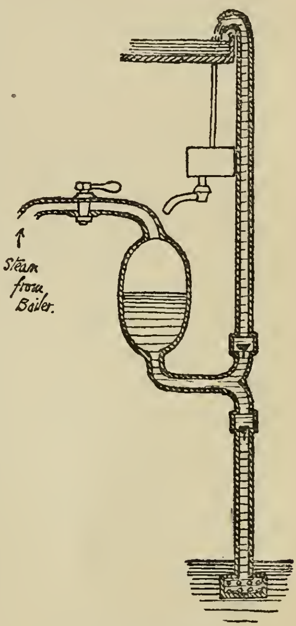
tually, self-acting valves being placed, so as to prevent the water from returning by the way it came. Two chambers were used, operating alternately.



SAVERY'S ENGINE

For this achievement Savery is by many regarded as the first and true inventor. He certainly was the first to make the steam engine a commercial success, and up and down the country it was extensively used for pumping water and for draining mines. By others Savery was regarded as a copyist; and indeed it is difficult to say how far originality should be assigned him. The marquis too had claimed to raise water; his engine had evidently acted with a pair of displacement-chambers, from each of which alternately water was forced by steam while the other vessel was fillng. And if he did not specify or appreciate the effect of the contractile force of the steam when condensed, yet in this respect both inventors had been anticipated by Giovanni della Porta.

The marquis had a violent champion in Dr. Desaguliers, who in his *Experimental Philosophy*, published in 1743, imputed disreputable conduct to the later inventor. "Captain Savery," said the doctor, "having read the Marquis of Worcester's book, was the first who put into practice the raising of water by fire. His engine will easily appear to have been taken from the Marquis of Worcester; though Captain Savery denied it, and the better to conceal the matter, bought all the Marquis of Worcester's books that he could purchase in Pater-Noster Row and elsewhere, and burned them in the presence of the gentleman his friend, who told me this. He said that he found out the power of steam by chance, and invented the following story to persuade people to believe it, viz. that having drunk a flask of Florence at a tavern, and thrown the empty flask upon the fire, he called for a bason of water to wash his hands, and perceiving that the little wine left in the flask had filled the flask with steam, he took the flask by the neck and plunged the mouth of it under the

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surface of the water in the bason, and the water in the bason was immediately driven up into the flask by the pressure of the air. Now, he never made such an experiment then, nor designedly afterwards, which I shall thus prove," etc. etc.

Other writers saw no good reason for depriving the captain of the title of inventor. With reference to the book-burning allegation, the only evidence tending to substantiate it lay in the fact that the book "on a sudden became very scarce, and but few copies of it were afterwards seen, and then only in the libraries of the curious." [1] It has been remarked, also, that Desaguliers was himself to some extent a rival claimant, several improvements, such as the substitution of jet for the original surface condensation being due to him; and that this fact gave a palpable bias to his testimony on the work of others.

In recent years the claims of Savery have been upheld, as against those of the marquis, by a writer who argued, not only that the engine of the marquis had never passed the experimental stage, but that no counter-claim was made by his successors at the time Savery produced his engine and obtained his patent. "Although a patent for ninety-nine years (from 1663 to 1762) was granted the marquis, yet Captain Savery and his successors under his patents which extended for thirty-five years (from 1698 to 1733) compelled every user of Newcomen's and other steam engines to submit to the most grinding terms and no one attempted to plead that Savery's patents were invalidated by the Marquis of Worcester's prior patents." [2]

By the admirers of Papin it has been claimed that it was from him that Savery received his idea. "After having minutely compared Savery's machine," says a biographer of Papin, "one arrives at the conviction that *Savery discovered nothing*. He had borrowed from Solomon de Caus the use of steam as a motive force, perfected by the addition of a second chamber; from Papin, the condensation of the steam. . . . And as for the piston, borrowed ten years later by Newcomen, that was wholly Papin's." [3]

Suppose it true; even so, his countrymen would always think great credit attaches to Savery for his achievement.

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[1] Millington: *Natural Philosophy.*
[2] Sir E. D. Lawrence: *Steam in Relation to Cornwall.*
[3] Enouf: *Papin, sa vie et son œuvre.*

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His engine, though used extensively for lifting water through small distances, was exceedingly wasteful of fuel, nor could it be used conveniently for pumping out mines or for other purposes in which a large lift was required. The lift or "head" was directly proportional to the steam pressure. Efforts to improve the lift by augmenting the steam pressure resulted in endless accidents and discouragement; the solder of the engine melted when steam of a higher pressure was used, the joints blew open and the chambers burst.

Living at Dartmouth, within some fifteen miles of Savery's home, were two men, Newcomen, an ironmonger, and Cawley, a glazier. These two had, doubtless, every opportunity of seeing Savery's engine at work. They appreciated its limitations and defects, and, undertaking the task of improving it, they so transformed the steam engine that within a short time their design had almost entirely superseded the more primitive form. Here, too, it might be said that they invented nothing. The merit of their new machine consisted in the achievement in practical form of ideas which hitherto had had scarcely more than an academic value. The labours of others gave them valuable aid. Newcomen, it is certain, could claim considerable knowledge of science, and though little is known of his personality there is evidence that he had pursued for years the object which he now achieved. He knew of the previous forms of piston engine which had been invented. He had probably read a translation, published in the *Philosophical Transactions*, of Papin's proposal for an atmospheric engine with a vacuum produced by the condensation of steam. He obtained from Savery the idea of a separate boiler, and other details. And where Papin had failed, Newcomen and his partner succeeded. Their Atmospheric Steam Engine, as it was aptly called, was produced in the year 1705, and at once proved its superiority over the old "Miner's Friend." It had assumed an entirely new form. In a large-bore vertical cylinder a brass piston was fitted, with a leather flap round its edge and a layer of water standing on it to form a seal against the passage of steam or air. The top of the cylinder was open to the atmosphere, the bottom was connected by a pipe with a spherical boiler. The piston was suspended by a chain to one end of an overhanging timber beam, which was mounted on a brick structure so as to be capable of oscillating on a gudgeon or axis at its middle. One end of this beam was

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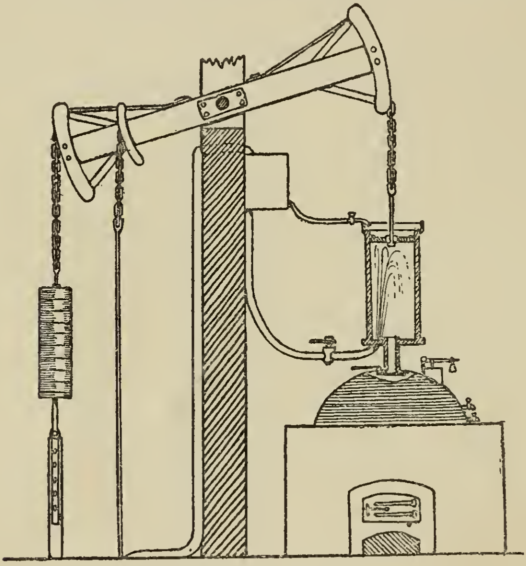
vertically over the piston; at the other end was the bucket of a water-pump, also attached to a crosspiece or "horse-head," by means of a chain or rod. The whole machine formed a huge structure like a pair of scales, one of which (the water-pump) was loaded with weights so as to be slightly heavier than the other (the steam engine).

To work it, steam was generated in the boiler at a pressure slightly greater than atmospheric. By the opening of a cock steam was admitted to the cylinder, below the piston, which was initially at rest in its highest position. The steam having filled the cylinder and expelled nearly all the air, the cock was shut and the cylinder was chilled by an external spray of cold water. Whereupon, as soon as the steam in the cylinder began to condense, the piston, forced down by the now unbalanced atmospheric pressure above it, began to descend. As soon as it had completed its downward stroke steam was again admitted beneath the piston, and, the pressure on the two sides of the piston becoming equal, the piston began to move up again to its original position. And so on.



NEWCOMEN'S ENGINE

This was the original Newcomen engine. Even in this primitive form it far surpassed Savery's in economy of fuel and in safety. It had, too, far greater flexibility in the manner

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in which its power could be applied; it could be used not only to lift a certain volume of water through a relatively small height, but a smaller volume through a greater height: which was a desideratum in the case of deep mines like those of Cornwall. In 1720 an engine was erected at Wheal Fortune mine having a cylinder nearly four feet in diameter and drawing water, at fifteen strokes a minute, from a depth of 180 feet.

Yet it was apparent that the engine was in many respects inefficient. The cocks, for instance, which controlled the motion of the piston had to be opened and shut by a man. Sometimes he let the piston rise too far, in fact, right out of the cylinder; sometimes he let it down too fast, so as to damage the engine. Again, the external spraying of the cylinder at every stroke to induce condensation of the steam within was an obviously clumsy and primitive operation. It was not long before external spraying gave place to internal cooling of the steam by the injection of water; this method being discovered, it is said, as the result of a leaky piston allowing its sealing water to pass, yet giving unaccountably good results. The difficulties with the cocks were overcome by the laziness or initiative of a youth named Humphrey Potter, who attached some strings and catches to the cocks of an engine which he was employed to work at Wolverhampton.[1]

With these improvements the engine remained practically without alteration for the next forty years. Its greatest sphere of usefulness was in the northern coalfields, where cheap and abundant fuel was close at hand. In Cornwall, until by special legislation the duty on seaborne coal was remitted when used for Newcomen's engine, the cost of fuel proved a great obstacle to its use.

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In 1764 James Watt, an instrument maker employed on work for Glasgow College, was given the task of repairing a working model of a Newcomen engine.

A man of serious and philosophical mind, an intimate friend

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[1] On the evidence of a picture purporting to represent the first Newcomen engine, in which mechanisms are shown for operating the cocks automatically, an attempt has been made to prove that the manipulated cocks were a figment and the story of Humphrey Potter a myth. The iconoclast has not been successful. The evidence that the first engines were hand-controlled is very general (see Galloway's *Steam Engine and Its Inventors*).

of Professor Robison, the physicist, and acquainted with the famous Dr. Black of Edinburgh, then in the thick of his researches on the phenomena of latent heat, Watt often discussed with these two scientists the possibility of improving the steam engine; which apparatus was still only employed for the purpose of pumping water, and which was so clumsy and so wasteful of fuel as to be comparatively little used. To this end he was induced to try some experiments on the production and condensation of steam. The results of these, and a knowledge of the newly discovered phenomenon of latent heat,[1] convinced him that the existing cycle of operations in the engine was fundamentally inefficient, and that improvement was to be sought in the engine itself rather than in the boiler, which was the element which was receiving most attention from contemporary investigators.

In particular, he clearly discerned the thermal inefficiency of the Newcomen engine: the waste of heat involved in alternately heating and cooling the large metal cylinder, which absorbed such immense quantities of fuel. Watt's first idea was, to lag the cylinder in wood so as to prevent all outward radiation. But the result of a trial of a lagged cylinder was disappointing. A gain was certainly obtained in that the steam, when admitted to the cylinder, did not require to raise by partial condensation the temperature of the walls; it exerted its expansive force at once and the piston rose. But on the other hand much greater difficulty was experienced in condensing it when a vacuum was required, for the down stroke. Moreover it was observed that an increase in the amount of injection water only made matters worse.

Watt was faced with a dilemma, and he overcame it by a series of studies in the properties of steam which constitute, perhaps, the highest achievement of this workman-philosopher.

Out of all his experiments two conclusions were drawn by him; first, that the lower the temperature of condensation of steam the more perfect the vacuum thereby formed; second, that the temperature of the cylinder should be as nearly as possible equal to that of the steam admitted to it. In Newcomen's engine these two conditions were obviously incom-

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[1] At this time the corpuscular theory of heat still held the field. "Caloric," or the matter of heat, was supposed to be a substance which could be imparted to or abstracted from a body, which had the property of augmenting its bulk, but not its weight, by setting its particles at a greater or less distance from one another.

patible, and the problem was,—how could they be reconciled? Early in 1765, while walking one Sunday afternoon in Glasgow Green the idea flashed upon him of condensing the steam in a separate vessel. The steam was generated in a separate vessel, why not produce the vacuum separately? With a view to trying this effect he placed a hollow air-tight chest beneath the steam cylinder, connected with it by a pipe having a stop-cock in it. This new or lower vessel was immersed in a cistern of cold water. Upon trial being made, it was found that by this simple contrivance as perfect a vacuum as desired was produced; the speed of the engine was greatly increased, the expenditure of fuel radically reduced, the walls of the steam cylinder were maintained at a high and constant temperature, and the whole arrangement promised great success. The new vessel Watt called a Condenser.

Fresh difficulties now arose. As the engine worked, the condenser gradually filled with the condensed steam and had to be emptied periodically. The water in which it was immersed became so hot, by absorbing the heat of the steam, that it frequently required changing. Watt promptly called in aid two new auxiliaries, two organs whose motion was derived from the main beam of the engine: the Air Pump and the Circulating Pump. By these expedients the action of the condenser was rendered satisfactory, and an engine resulted which had a fuel-consumption less than half that of Newcomen's engine.

Much, he saw, yet remained to be done to obtain economical expenditure of steam. In particular the open-topped cylinder, whose walls were chilled at every descent of the piston by contact with atmospheric air, was an obvious source of inefficiency. He therefore determined not to expose the walls to the atmosphere at all, but to enclose all the space above the piston; and, thinking thus, he conceived the idea of replacing the air above the piston by steam, an equally powerful agent. The cylinder he proposed to maintain at a constant high temperature by means of a layer of hot steam with which he encased it, which he called a steam jacket. And so the atmospheric engine as left by Newcomen evolved into the *single-acting steam engine* of Watt;—an engine in which steam was still used below the piston, only to displace air and provide a vacuized space for the downward motion of the piston; but in which steam now acted positively above the

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piston, in lieu of atmospheric air, to drive it down. It was still a sufficiently primitive form of prime mover. The piston was still lifted by the counterweight at the other end of the timber cross-beam ; the engine had not yet developed the organs necessary for producing a satisfactory rotary motion. This step was shortly to follow.

In 1769 Watt obtained his patent for the " double impulse," as it was called ; and by this step, by the transition from a single- to a double-acting engine, the possibilities of such machines for every variety of application first came into general view. This stage of the development showed to the full the ingenuity of Watt's mechanical mind. By the invention of the slide-valve he distributed steam to the top and to the bottom of the cylinder, and in appropriate phase with these actions opened the two ends to the condenser ; so that the piston was actuated positively and by an equal force on both up and down strokes. The chain by which the piston had been suspended was no longer adequate ; it was replaced by a rod. A straight-line motion was required for the top end of the rod ; so he formed a rack, to gear with the circular end or horse-head of the beam. But this noisy mechanism was soon superseded by another contrivance, the beautifully simple " parallel motion," in which two circular motions are combined to produce one which is rectilinear. This was patented in '84.

Four years before this, that ancient mechanism the crank and connecting rod had been applied, together with a flywheel, to transform the reciprocating motion of a steam engine into a rotary motion ; and the non-possession of this invention of James Pickard's proved for a time a stumbling-block to Watt in his further development of his engine. Watt would have nothing to do with it. By now he had joined his fortunes with those of Mr. Boulton, of Soho, Birmingham, a man of great business ability, in conjunction with whom he was engaged in constructing engines in large numbers to suit the varying conditions of the mines in Cornwall and the North. Considerable ingenuity was expended by him in trying to circumvent the troublesome crank of Pickard, and many devices were produced, the most noteworthy being the " sun-and-planet wheels," which enabled him with some sacrifice of simplicity to obtain the rotary motion desired.

Watt seemed to be borne along by the momentum of his

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own discoveries ; every inquiry yielded him valuable reward. For some time he had studied the possibility of reducing the violence with which the piston, now positively steam-driven on both sides, came to the end of its stroke. This problem led him to the discovery of the advantage of using steam expansively : of cutting off the inflow of steam before the piston had travelled more than a fraction of its stroke, and letting its inherent elastic force impel it through the remainder of its journey, the steam meanwhile expanding and thus exerting a continuously decreasing force. Later came the throttle valve, and the centrifugal governor for controlling the speed of rotating engines ; there was no end to his ingenuity. And so complete was his inquiry into the possible sources of improvement of the steam engine, that he even considered means of regulating the force which the piston exerted on the crank throughout its working stroke, a force which was compounded of the steam pressure itself and of the mass-acceleration of the piston and other moving parts.

Another cardinal invention followed : the Indicator. The principle of the indicator is now applied to every form and kind of piston engine. It is a reproduction on a small scale of the essential part of the engine itself ; a small piston, held by a spring and moving in a cylinder connected by a pipe with the cylinder of the engine itself, shows by the degree of compression imparted to the spring the gaseous pressure actually present at any moment in the engine cylinder. By recording the position of the indicator piston on a paper wrapped round a rotating drum whose motion represents the motion of the engine's piston, a diagram is obtained which by its area measures the work done by the steam during the stroke of the engine.

This instrument was designed by Watt to give his firm some standard of work which would serve as a basis for the power of each engine, on which to charge their customers ; their engines being sold by the horse-power. But its usefulness far exceeded the immediate purpose for which it was produced. Its diagram, to the eye of an expert, gave valuable information in respect of the setting of the valves, the tightness of the piston, the dryness of the steam, the degree of vacuum in the condenser, and, generally, of the state of efficiency of the engine. "It would be difficult to exaggerate the part which this little instrument has played in the evolution of the steam engine. The eminently

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philosophic notion of an indicator diagram is fundamental in the theory of thermodynamics ; the instrument itself is to the steam engineer what the stethoscope is to the physician, and more, for with it he not only diagnoses the ailments of a faulty machine, whether in one or another of its organs, but gauges its power in health."[1]

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We have now traced the evolution of the steam engine up to the time when it was first adapted to the propulsion of war-vessels. There we must leave it. In a later chapter we shall consider the evolution of the propelling machinery in its relation, especially, to the military qualities of ships. A few observations will be sufficient to illustrate the conditions, as to design, practice, and material, under which the steam engine made its appearance in the royal navy.

After the death of Watt all improvement of steam machinery was strenuously opposed by the combined force of prejudice and vested interest. The great Watt himself had set his face against the use of high-pressure steam, and, such was the lingering force of his authority, years passed before the general public gave assent to the advances made by his talented successors—Hornblower, Woolf, Evans, and Trevithick. Before the end of the eighteenth century the first steps had been made to use the force of steam for driving ships. Before Trafalgar was fought steam engines had made their appearance in the royal dockyards. Then there was a pause ; and many years passed by before steam propulsion was admitted to be a necessity for certain classes of war-vessels.

An interesting account of the state of design and practice as it existed on ship-board in the year of Queen Victoria's accession is given by Commander Robert Otway, R.N., in his treatise on *Steam Navigation*. Low-pressure principles are still in vogue ; steam is generated still, at a pressure not exceeding three pounds per square inch, in rectangular boilers of various forms according to the fancy of the maker, scarcely two being alike. The engines are also of varying forms, every size, variety, and power being deemed suitable for similar vessels. They are amazingly ponderous : weigh about twelve hundredweight, and the boilers eight hundredweight, to the horse-power. The engines of all makers exhibit the greatest varia-

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[1] *Encycl. Brit.*, Eleventh Edition.

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tions in the relative dimensions of their various parts: one firm embodies a massive frame and light moving rods and shafts, another adopts massive rods and shafts, and supports them within the lightest framework. The author advocates a correct design and a "total dispensation of all superfluous ornament."

Already, however, following the example of the Cornish mines, the builders of steam vessels were at this time beginning to adopt high-pressure steam, generated at a pressure of ten to fifteen pounds per square inch in cylindrical boilers, and working expansively — "doing work in the cylinder by its elasticity alone"—before returning to the jet condenser. This improvement, strenuously opposed by orthodox engineers as being unsafe for ship practice, was introduced first into the Packet Establishment at Falmouth, and then, tardily, into Government steamers. It gave a gain in economy measured by the saving of "thousands of bushels of coal per month." Steam engines working on the low-pressure system used from nine to twelve pounds of coal per hour, for each horse-power. These engines were carried in vessels "built on the scantling of 10-ton brigs," of great draught and of such small coal capacity —about 35 tons, on an average—that when proceeding out of home waters "they were burthened with, at the least, four days' more fuel, *on their decks* (top hamper), in addition to that which already filled up their coal-boxes below." Boilers emitted black clouds of smoke at sea. In harbour the paddle-wheels had to be turned daily, if but a few float-boards only, by the united force of the crew. "Coaling ship" was carried out with the help of convicts from the hulks:—"pampered delinquents," observes the author, "whose very movements are characteristic of their moral dispositions—being thieves of time; for their whole day's duty is not worth an hour's purchase."


CONNECTING ROD

From Otway

In these unattractive circumstances the steam engine, most wonderful contrivance of the brain and hand of man, presented itself for embodiment in the navy, by the personnel of which it was regarded, not without reason, as an unmitigated evil.

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CHAPTER IV

"NEW PRINCIPLES OF GUNNERY"

WE have traced the smooth-bore cannon through the successive stages of its evolution. It is now proposed to give, in the form of a biographical sketch, an account of the inception of scientific methods as applied to its use, and at the same time to pay some tribute to the memory of the man who laid the foundations deep and true of the science of modern gunnery. One man was destined to develop, almost unaided, the principles of gunnery as they are known to-day. This man was a young Quaker of the eighteenth century, Benjamin Robins.

For a variety of reasons his fame and services seem never to have been sufficiently recognized or acknowledged by his own countrymen. To many his name is altogether unknown. To some it is associated solely with the discovery of the ballistic pendulum: the ingenious instrument by which, until the advent of electrical apparatus, the velocities of bullets and cannon balls could be measured with a high degree of accuracy. But the ballistic pendulum was, as we shall see, only one manifestation of his great originating power. The following notes will show to what a high place Robins attained among contemporary thinkers; and demonstrate the extent to which, by happy combination of pure reason and experiment, he influenced the development of artillery and fire-arms. His *New Principles of Gunnery* constituted a great discovery, simple and surprisingly complete. In this work he had not merely to extend or improve upon the inventive work of others; his first task was to expose age-long absurdities and demolish all existing theories; and only then could he replace them by true principles founded on correct mathematical reasoning and confirmed by unwearying experiment with a borrowed cannon or a "good Tower musquet."

Down to the time of Robins, gunnery was still held to be an art and a mystery. The gunner, that honest and godly man,[1] learned in arithmetic and astronomy, was master of a terrible craft;—his saltpetre gathered, it was said, from within vaults, tombs, and other desolate places;—his touchwood made from old toadstools dried over a smoky fire;—himself working unscathed only by grace of St. Barbara, the protectress of all artillerymen. The efficiency of his practice depended overwhelmingly on his own knowledge and on the skill with which he mixed and adjusted his materials. No item in his system was of sealed pattern; every element varied between the widest limits. There were no range-tables. His shots varied in size according to the time they happened to have been in service, to the degree of rusting and flaking which they had suffered, and to their initial variations in manufacture. His piece might be bored taper; if so, and if smaller at the breech end than at the muzzle, there was a good chance of some shot being rammed short of the powder, leaving an air space, so that the gun might burst on discharge; if smaller at the muzzle end the initial windage would be too great, perhaps, to allow of efficient discharge of any shot which could be entered. There was always danger to be apprehended from cracks and flaws.

But the greatest of mysteries was that in which the flight of projectiles was shrouded. At this point gunnery touched one of the oldest and one of the main aspects of natural philosophy.

The Greek philosophers failed, we are told, in spite of their great mental subtlety, to arrive at any true conception of the laws governing the motion of bodies. It was left to the period of the revival of learning which followed the Middle Ages to produce ideas which were in partial conformity with the truth. Galileo and his contemporaries evolved the theory of the parabolic motion of falling bodies and confirmed this brilliant discovery by experiment. Tartaglia sought to apply it to the motion of balls projected from cannon, but was held up by the opposing facts: the initial part of the trajectory was seen to be a straight line in actual practice, and even, perhaps, to have an upward curvature. So new hypotheses were called in aid, and the path of projectiles was assumed to consist of three separate motions: the *motus violentus*, the *motus mixtus*, and the *motus naturalis*. During the *motus violentus* the path of the spherical

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[1] A text-book published a few years before Robins' birth (Binnings' *Light to the Art of Gunnery*, 1689) told how a certain profane and godless gunner, Cornelius Slime, was carried off by the devil before the eyes of the astonished onlookers!

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projectile was assumed to be straight—and this fallacy, we may note in passing, gave rise to the erroneous term "point blank," to designate the distance to which the shot would travel before gravity began to operate; during the *motus naturalis* the ball was assumed to fall along a steep parabola; and during the *motus mixtus*, the path of the trajectory near its summit, the motion was assumed to be a blend of the other two. This theory, though entirely wrong, fitted in well with practical observation; the trajectory of a spherical shot was actually of this form described. But in many respects it had far-reaching and undesirable consequences. Not only did it give rise to the misconception of the *point en blanc*; it tended to emphasize the value of heavy charges and high muzzle velocities while at the same time obscuring other important considerations affecting range.

So the gunner was primed with a false theory of the trajectory. But even this could not be relied on as constant in operation. The ranging of his shot was supposed to be affected by the nature of the intervening ground; shot were thought to range short, for some mysterious reason, when fired over water or across valleys, and the gunner had to correct, as best he could, for the extra-gravitational attraction which water and valleys possessed. In addition to all these bewilderments there was the error produced by the fact that the gun itself was thicker at the breech than at the muzzle, so that the "line of metal" sight was not parallel with the bore: a discrepancy which to the lay mind, and not infrequently to the gunner himself, was a perpetual stumbling-block.

It is not surprising that, in these conditions, the cannon remained a singularly inefficient weapon. Imperfectly bored; discharging a ball of iron or lead whose diameter was so much less than its own bore that the projectile bounded along it and issued from the muzzle in a direction often wildly divergent from that in which the piece had been laid; on land it attained its effects by virtue of the size of the target attacked, or by use of the *ricochet*; at sea it seldom flung its shot at a distant ship, except for the purpose of dismasting, but, aided by tactics, dealt its powerful blows at close quarters, double-shotted and charged lavishly, with terrible effect. It was then that it was most efficient.

Nor is it surprising that, in an atmosphere of ignorance as to the true principles governing the combustion of gunpowder

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and the motion of projectiles, false "systems" flourished. The records of actual firing results were almost non-existent. Practitioners and mathematicians, searching for the law which would give the true trajectories of cannon balls, found that the results of their own experience would not square with any tried combination of mathematical curves. They either gave up the search for a solution, or pretended a knowledge which they were unwilling to reveal.

§

In the year 1707 Robins was born at Bath. Studious and delicate in childhood, he gave early proof of an unusual mathematical ability, and the advice of influential friends who had seen a display of his talents soon confirmed his careful parents in the choice of a profession for him: the teaching of mathematics. Little, indeed, did the devout Quaker couple dream, when the young Benjamin took coach for London with this object in view, that their son was destined soon to be the first artillerist in Europe.

That the choice of a profession was a wise one soon became evident. He was persuaded to study the great scientific writers of all ages—Archimedes, Huyghens, Slusius, Sir James Gregory and Sir Isaac Newton; and these, says his biographer, he readily understood without any assistance. His advance was extraordinarily rapid. When only fifteen years old he aimed so high as to confute the redoubtable John Bernouilli on the collision of bodies. His friends were already the leading mathematicians of the day, and there were many who took a strong interest in the brilliant and attractive lad. He certainly was gifted with qualities making for success; for, we are told, "besides his acquaintance with divers parts of learning, there was in him, to an ingenuous aspect, joined an activity of temper, together with a great facility in expressing his thoughts with clearness, brevity, strength, and elegance."

Robins' mind was of too practical a bent, however, to allow him to stay faithful to pure mathematics; his restless energy required another outlet. Hence he was led to consider those "mechanic arts" that depended on mathematical principles: bridge building, the construction of mills, the draining of fens and the making of harbours. After a while, taking up the controversial pen again, he wrote and published papers by which a great reputation gradually accrued. In 1735 he blew to pieces, with

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a *Discourse on Sir Isaac Newton's Method of Fluxions*, a treatise written against the mathematicians by the Bishop of Cloyne. And shortly after followed further abstruse and controversial studies: on M. Euler's Treatise on Motion, on Dr. Smith's System of Optics, and on Dr. Jurin's Distinct and Indistinct Vision.

His command of language now attracted the attention of certain influential gentlemen who, deploring the waste of such talent on mathematical subjects, persuaded their young acquaintance to try his hand at the writing of political pamphlets: party politics being at that time the absorbing occupation of the population of these islands. His success was great; his writings were much admired. And—significant of the country and the age—friendships and acquaintances were formed by the pamphleteer which were later to be of great value to the rising scientist.

This phase of his activities, fortunately, did not last long. Kindling the lamp of science once more, he now started on the quest which was to make him famous.

For thoughtful men of all ages, as we have already noted, the flight of bodies through air had had an absorbing interest. The subject was one of perennial disputation. The vagaries of projectiles, the laws governing the discharge of balls from cannon, could not fail to arouse the curiosity of an enthusiast like Robins, and he now set himself in earnest to discover them by an examination of existing data, by pure reason, and by actual experiment. Perusal of such books as had been written on the subject soon convinced him of the shallowness of existing theories. Of the English authors scarcely any two agreed with one another, and all of them carped at Tartaglia, the Italian scientist who in the classic book of the sixteenth century tried to uphold Galileo's theory of parabolic motion as applied to military projectiles. But what struck Robins most forcibly about all their writings was the almost entire absence of trial and experiment by which to confirm their dogmatical assertions. This absence of any appeal to experiment was certainly not confined to treatises on gunnery; it was a conspicuous feature of most of the classical attempts to advance the knowledge of physical science. Yet the flight of projectiles was a problem which lent itself with ease to that inductive method of discovering its laws through a careful accumulation of facts. This work had not been done. Of all

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the native writers upon gunnery only four had ventured out of two dimensions; only four had troubled to measure definite ranges. All four asserted the general proposition that the motion of bodies was parabolic. Only one noticed that practice did not support this theory, and he, with misapplied ingenuity, called in aid the traditional hypothesis of a violent, a crooked, and a natural motion. Which wrong hypothesis enabled him, since he could choose for himself the point at which the straight motion ceased, to square all his results with his precious theory.

Leaving the books of the practitioners, Robins had more to learn from the great circle of mathematicians who in the first part of the eighteenth century lent a lustre to European science. The old hypotheses were fast being discarded by them. Newton, in his *Principia*, had investigated the laws of resistance of bodies to motion through the air under gravity, by dropping balls from the cupola of St. Paul's Cathedral; and he believed that the trajectory of a cannon ball differed from the parabola by but a small extent. The problem was at this time under general discussion on the Continent; and led to a collision between the English and the German mathematicians, Newton and Leibnitz being the two protagonists.[1] But, whatever the merits or outcome of the controversy, one thing seems certain. None of the great men of the day understood the very great accession of resistance which a fast-travelling body encountered in cleaving the air, or realized the extent to which the trajectory was affected by this opposing force. It was in fact universally believed and stated, that "*in the case of large shot of metal, whose weight many times surpasses that of air, and whose force is very great, the resistance of air is scarcely discernible, and as such may, in all computations concerning the ranges of great and weighty bombs, be very safely neglected.*"[2]

In 1743 Robins' *New Principles of Gunnery* was read before the Royal Society.

In a short but comprehensive paper which dealt with both internal and external ballistics, with the operation of the propellant in the gun and with the subsequent flight of the projectile, the author enunciated a series of propositions which, founded on known laws of physics and sustained by actual

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[1] Whewell: *Hist. of the Inductive Sciences.*

[2] Dr. Halley: *Phil. Trans.*, 1686.

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experiment, reduced to simple and calculable phenomena the mysteries and anomalies of the art of shooting with great guns. He showed the nature of the combustion of gunpowder, and how to measure the force of the elastic fluid derived from it. He showed, by a curve drawn with the gun axis as a base, the variation of pressure in the gun as the fluid expanded, and the work done on the ball thereby. Producing his ballistic pendulum he showed how, by firing a bullet of known weight into a pendulum of known weight, the velocity of impact could be directly ascertained. This was obviously a very important discovery. For an accurate measurement of the "muzzle velocity" of the bullet discharged from any given piece of ordnance was, and still is, the solution and key to many another problem in connection with it: for instance, the effect of such variable factors as the charge, the windage or the length of gun. In fact, as the author claimed, there followed from the theory thus set out a whole host of deductions of the greatest consequence to the world's knowledge of gunnery. Then, following the projected bullet in its flight, he proceeded to tell of the continuous retardation to which it was subject owing to the air's resistance. He found, he said, that this resistance was vastly greater than had been anticipated. It certainly was not a negligible quantity. The resistance of the air to a twenty-four pound cannon ball, fired with its battering charge of sixteen pounds of powder, was no less than twenty-four times the weight of the ball when it first issued from the piece: a force which sufficiently confuted the theory that the trajectory was a parabola, as it would have been if the shot were fired in vacuo. It was neither a parabola, nor nearly a parabola. In truth it was not a plane curve at all. For under the great force of the air's resistance, added to that of gravity, a ball (he explained) has frequently a double curvature. Instead of travelling in one vertical plane it actually takes an incurvated line sometimes to right, sometimes to left, of the original plane of departure. And the cause of this departure he ascribed to a whirling motion acquired by the ball about an axis during its passage through the gun.

The reading of the paper provoked considerable discussion among the learned Fellows, who found themselves presented with a series of the most novel and unorthodox assertions, not in the form of speculations, but as exact solutions to problems which had been hitherto unsolved; and these were

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presented in the clearest language and were fortified by experiments so careful and so consistent in their results as to leave small room for doubt as to the certainty of the author's theory. Of special interest both to savants and artillerists must have been his account of " a most extraordinary and astonishing increase in the resistance of the air which occurs when the velocity comes to be that of between eleven and twelve hundred feet in one second of time " : a velocity, as he observed, which is equal to that at which sounds are propagated in air. He suggested that perhaps the air, not making its vibrations with sufficient speed to return immediately to the space left in the rear of the ball, left a vacuum behind it which augmented the resistance to its flight. His statement on the deflection of balls, too, excited much comment. And, in order to convince his friends of the reality of this phenomenon, which, though Sir Isaac Newton had himself taken note of it in the case of tennis balls, had never been thoroughly investigated, Robins arranged an ocular demonstration.

One summer afternoon the experiments took place in a shady grove in the Charterhouse garden. Screens—" of finest tissue paper "—were set up at intervals of fifty feet, and a common musket bored for an ounce ball was firmly fixed in a vice so as to fire through the screens. By repeated discharges the various deflections from the original plane of departure were clearly shown ; some of the balls whirled to the right, some to the left of the vertical plane in which the musket lay. But not only was the fact of this deflection established to the satisfaction of the visitors. A simple but dramatic proof was afforded them of the correctness of Robins' surmise that the cause was the whirling of the ball in flight. A musket-barrel was bent so that its last three or four inches pointed to the left of the original plane of flight. The ball when fired would then be expected to be thrown to the left of the original plane. But, said Robins, since in passing through the bent part the ball would be forced to roll upon the right-hand side of the barrel ; and as thereby the left side of the ball would turn up against the air, and would increase the resistance on that side ; then, notwithstanding the bend of the piece to the left, the bullet itself might incurvate towards the right. " And this, upon trial, did most remarkably happen."[1]

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[1] How strange and almost incredible this phenomenon appeared to people long after Robins' time, may be seen from the manner in which Ezekiel Baker,

Robins by now had gained a European reputation. Mathematical controversy and experiments in gunnery continued to occupy his time and absorb his energies, and it was not long before he was again at the rostrum of the Royal Society, uttering his eloquent prediction as to the future of rifled guns. Speaking with all the emphasis at his command he urged on his hearers the importance of applying rifling not only to fire-arms but to heavy ordnance. That State, he said, which first comprehended the advantages of rifled pieces; which first facilitated their construction and armed its armies with them; would by them acquire a superiority which would perhaps fall little short of the wonderful effects formerly produced by the first appearance of fire-arms. His words had little or no effect. Mechanical science was not then equal to the task. A whole century was to elapse before rifled ordnance came into general use. The genius of Whitworth was required to enable the workshops of the world to cope with its refined construction.

Another subject which attracted Robins' attention at this time was fortification, the sister art of gunnery, which now had a vogue as a result of the great continental wars. He was evidently regarded as an authority on the subject, for we find him, in 1747, invited by the Prince of Orange to assist in the defence of Berghen-op-Zoom, then invested and shortly afterwards taken by the French.

Now befell an incident which, besides being a testimony to the versatility of his genius, proved to be of great consequence to him in his study of artillery. In 1740 Mr. Anson (by this time Lord Anson, and at the head of the Admiralty) had set out on his famous voyage to circumnavigate the world. For some time after his return the public had looked forward to an authentic account, on the writing of which the chaplain of the *Centurion*, Mr. Richard Walter, was known to be engaged. Mr. Walter had collected, in the form of a journal, a mass of material in connection with the incidents of the voyage. But on a review of this it was decided that the whole should be rewritten in narrative form by a writer of repute.

one of the principal London gunmakers and the contractor who supplied the rifles with which the Rifle Brigade was equipped in the year 1800, poured gentle sarcasm on the account of this experiment. In his book on *Rifle Guns*, published in 1825, he can only assign the cause of the deflection to "some peculiar enchantment in the air." "Or," he continues, "with all my practice I have yet much to learn in guns, and the effects of powder and wind upon the ball in its flight."

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Robins was approached, and accepted the commission. The material of the chaplain's journal was worked up by him into a narrative, and the book was published in 1748. "It was an immediate success; four large editions were sold in less than a year; and it was translated, with its stirring accounts of perils and successes, into nearly all the languages in Europe." Robins' name did not appear in it, and his share in the authorship is to this day a subject of literary discussion.

The acquaintance with Lord Anson thus formed was of great benefit to him, not only in securing for him the means of varied experiment with all types of guns in use in the royal navy, but by the encouragement which his lordship gave him to publish his opinions even when they were in conflict with the orthodox professional opinion of the day. To this encouragement was due the publication in 1747 of a pamphlet entitled, *A Proposal for increasing the strength of the British Navy, by changing all guns from* 18-*pounders downwards into others of equal weight but of a greater bore;* a paper which, indirectly, had considerable influence on the development of sea ordnance. In the introduction to this paper the author explains that its subject-matter is the result of the speculations and experiments of earlier years; and he describes the incident which at the later date induced its publication. It appears that at the capture of the *Mars*, man-of-war, a manuscript was discovered on board which contained the results and conclusions of some important gunnery trials which the French had been carrying out. This manuscript, being shown to Robins by Lord Anson, was found to contain strong confirmation of his own views both as to the best proportions of guns and the most efficient powder-charges for the same. He had not published these before, he plaintively explains, because, "not being regularly initiated into the profession of artillery, he would be considered a visionary speculatist." But fortified by the French MS. he no longer hesitated to submit his proposal to the public.

Briefly, the paper is an argument for a more efficient disposition of metal in ordnance. Robins states his case in language simple and concise. Large shot, he says, have naturally great advantages in ranging power over small shot; in sea fighting the size of the hole they make and their increased power of penetration gives them a greatly enhanced value. Hence the endeavour made in all cases to arm a vessel with the

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largest cannon she can with safety bear. And hence the necessity for so disposing the weight of metal in a ship's ordnance to the best advantage; all metal not usefully employed in contributing to the strength of the pieces being not only useless but prejudicial to efficiency.

He then proceeds to prove (not very convincingly, it must be admitted) that there is a law of comparison to which the dimensions of all guns should conform, and by which their weights could be calculated. For every pound of bullet there should be allowed a certain weight of metal for the gun. So, taking the service 32-pounder as having the correct proportions, the weight and size of every other piece can be found from this standard. He observes, however, that in actual practice the smaller the gun, the greater its relative weight; the 6-pounder, for example, weighs at least eighteen hundredweight, when by the rule it should weigh ten. The proposal is therefore to utilize the redundant weight of metal by increasing the calibre of the smaller guns. At the same time it is proposed to limit the stress imposed on all guns by reducing the powder-charge to one-third the weight of the bullet, for all calibres; this smaller charge being almost as efficient for ranging as the larger charges used, and infinitely less dangerous to the gun.

The publication of the pamphlet came at an opportune moment. A new spirit was dawning in the navy, a new enthusiasm and search for efficiency were abroad, which in the next half-century were to be rewarded by a succession of well-earned and decisive victories. Interest in the proposed change in armament was widespread, both in and outside the royal service. And a significant commentary on the proposed regulation of powder-charges was supplied, this very year, by Admiral Hawke, who reported that in the fight off Ushant all the breechings of his lower-deck guns broke with the repeated violence of recoil, obliging him to shoot ahead of his opponent while new breechings were being seized.

Some time was to elapse before the arguments of Robins gave signs of bearing fruit. Experiments carried out at Woolwich in the seventies by Dr. Hutton with all the facilities ensured by the patronage of a ducal master-general of ordnance merely extended and confirmed Robins' own results. In '79 the carronade made its appearance, to attest in dramatic fashion the value, at any rate for defensive work, of a large ball, a small charge, and an unusually small windage. As

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offensive armament it represented, of course, the *reductio ad absurdum* of the principles enunciated by Robins; its dominant feature of a ball of maximum volume projected with a minimum velocity was, in the words of an American authority, "manifestly as great an error as the minima masses and the maxima velocities of the long gun system, to which the carronade was thus directly opposed." Nevertheless, the carronade (whose history we deal with in a later chapter) did excellent work. Mounted upon the upper decks and forecastles of merchantmen and the smaller classes of warships, it emphasized, by the powerful and often unexpected blows which it planted in the ribs of such adversaries as ventured within its range, the comparative inefficiency of the smaller types of long gun with which our ships of war were armed. To the clearest-sighted of our naval captains the relative merits and defects of the carronade and the small long gun were evidently clear. In the year 1780 we find Kempenfelt advocating, in a letter to Sir Charles Middleton, a weapon with a little more length and weight than a carronade: something between it and a long gun. Robins' arguments against the still prevalent types of small pieces have proved convincing to him, and he transcribes the whole of the *Proposal* for the consideration of his superior. "Here you have, sir," he writes, "the opinion of the ablest artillery officer in England at that time, and perhaps in Europe."

Once more the versatile and gifted pen was called in aid of politics. In 1749 he was persuaded to write what his biographer describes as a masterpiece of its kind: *An apology for the unfortunate affair at Preston-Pans in Scotland.*[1] But soon an opening worthier of his talents presented itself. The East India Company, whose forts in India were as yet ill-adapted for defence, required the services of an expert in military fortification. An offer was made, and, as Engineer-General to the Company, Robins left England for the East at the end of '49, to the great sorrow of all his acquaintance. They were not to see him again. In the summer of the following year he died of a fever, pen in hand, at work upon his plans in the service of the Company.

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[1] Of the superstitious awe with which an iron field-piece was regarded by the highlanders in '45, and of its small material value in the field, a note will be found in the appendices to Scott's *Waverley.*

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So ended a short, a brilliant, and a very honourable career. Benjamin Robins possessed in an exceptional degree the power, inherent in so many of his countrymen, of applying the truths of science to practical ends. An individualist deriving inspiration from the great masters of the past, he followed the bent of his enthusiasms in whatever direction it might lead him, till ultimately his talents found expression in a field undreamed of by himself or by his early friends. In the realm of gunnery he was an amateur of genius. Partly for that reason, perhaps, his views do not appear to have been considered as authoritative by our own professionals; the prophet had more honour in Berlin, Paris and Washington. Speaking of the rifle, the true principle of which was admittedly established by him, the American artillerist Dahlgren wrote in 1856: "The surprizing neglect which seemed to attend his labours was in nothing more conspicuous than in the history of this weapon. Now that whole armies are to wield the rifled musket with its conical shot, one is surprized at the time which was permitted to elapse since that able experimenter so memorably expressed his convictions before the Royal Society, in 1746."

Of the value of his work to the nation there is now no doubt. Of the man himself an entertaining picture is given in his biography, published, together with his principal papers, by Dr. Hutton, from which many of the foregoing notes have been taken. Among other eminent men who have given their life and labours to the public service, and whose efforts in building up the past greatness of England have been generously acknowledged, let us not forget to honour that distinguished civilian, Benjamin Robins.

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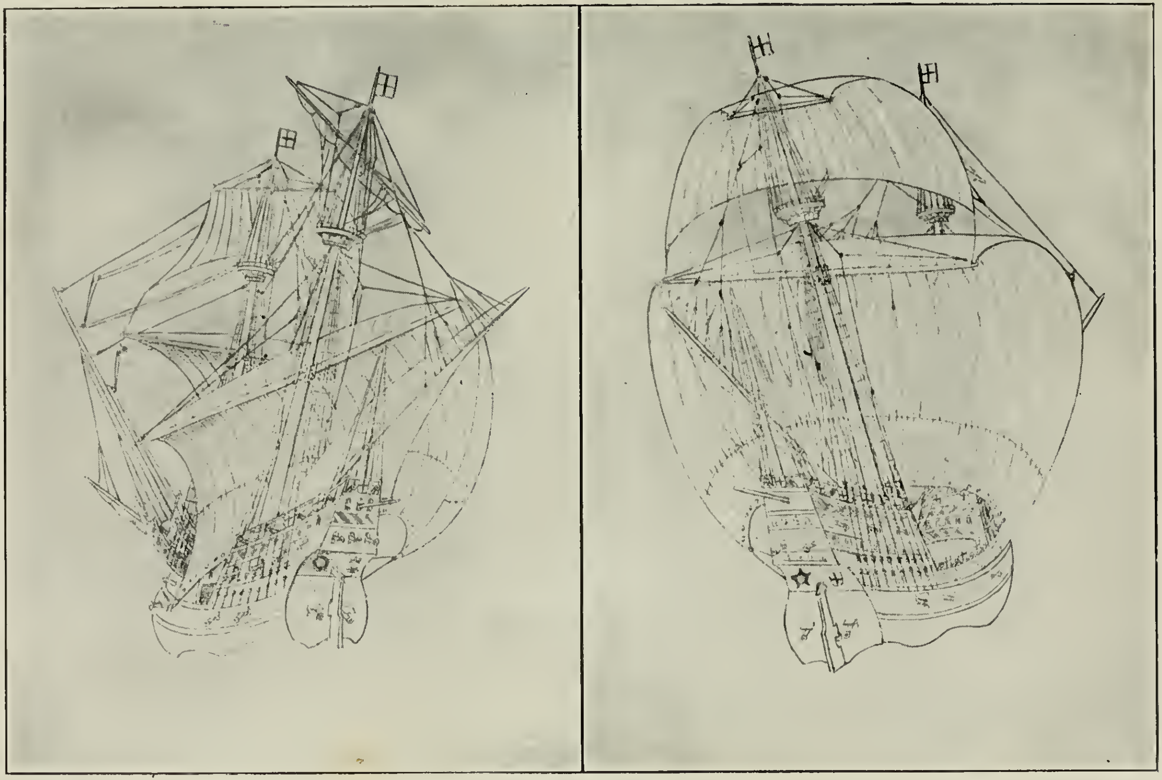

TUDOR SHIPS UNDER SAIL

From the same MS. as plate facing page 60

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CHAPTER V

THE CARRONADE

AT the monthly meeting of the Carron Company, a Scotch iron-founding and shipping firm, which was held in December, 1778, the manager informed the board that, in order to provide armament for some of the Company's sailing packets, he had constructed a very light species of gun, resembling a cohorn, which was much approved by many people who had come on purpose to inspect it. So favourable, indeed, was the impression given by the inspection of this weapon that, with the company's permission, he could receive a great many orders for them. Whereon it was resolved to authorize the manufacture of the new species in quantity; and to call all such guns as should be made by them of this nature, Carronades.

Such were the circumstances in which the carronade first came into use. And the following advertisement, appearing in Edinburgh shortly afterwards, sufficiently explains the incentive for exploiting the new type of ordnance, and the reason of its popularity among shipowners, passengers and crews. "To sail March 5, 1779, the *Glasgow*, Robert Paterson master, mounting fourteen twelve-pounders, and men answerable. . . . N.B.—The Carron vessels are fitted out in the most complete manner for defence at a very considerable expense, and are well provided with small arms. All mariners, recruiting parties, soldiers upon furlow, and all other steerage passengers who have been accustomed to the use of fire-arms, and who will engage in defending themselves, will be accommodated with their passage to and from London, upon satisfying the masters for their provisions, which in no instance shall exceed 10s. 6d. sterling. The Carron vessels sail regularly as usual, without waiting for the convoy."

The carronade was a very short, light, carriage gun of relatively large bore, made to take a standard size of long-gun shot and project it, by means of a small charge of powder,

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against an enemy at close range. Its proprietors soon found a market for the produce of their foundry, not only for merchant ships but for men-of-war. The reputation of the new ordnance quickly spread ; carronades found a place almost immediately among the orthodox armament of the greater number of our fighting ships ; and kept their place till, after a chequered career of half a century, during which they contributed both to victory and to defeat, they were finally discarded from the sea service.

The story of the carronade begins some little time before the meeting of the Carron board in the year 1778. It will be remembered that in 1747 Mr. Benjamin Robins had advocated, in a much-talked-of paper, an increase in the calibre of warships' guns at the expense of their ranging power, and that in support of his argument he had drawn attention to two features of ship actions—first, that the great majority of duels were fought at close quarters ; secondly, that the destructive effect of a cannon-ball against an enemy's hull depended largely on the external dimensions of the ball, the larger of two balls producing an effect altogether out of proportion to the mere difference in size.

However invalid may have been the arguments founded on these assertions—and that there was a serious flaw in them time was to show—there could be no doubt that, so far as considerations of defence were concerned, the conclusions reached were of important value. In the case of a merchant packet defending herself from boarding by a privateer, for example, a light, short-ranging gun throwing a large ball would give far more effective protection than a small-calibre long gun. And if, moreover, the former involved a dead weight less than a quarter, and a personnel less than half, of that involved by the latter, the consideration of its superiority in action was strongly reinforced, in the opinion of shipowners and masters, by less advertised considerations of weight, space, and equipment—very important in their relation to the speed and convenience of the vessel, and hence to all concerned.

So the arguments of Robins, though propounded solely with reference to warships, yet applied with special force to the defensive armament of merchant ships. A conception of this fact led a very able artillerist, General Robert Melville, to propose, in 1774, a short eight-inch gun weighing only thirty-one hundredweight yet firing a nicely fitting sixty-eight pound ball with a charge of only five and a half pounds of powder. This piece he induced the Carron company to cast, appropriately naming it a Smasher. Of all the carronades the Smasher was the prototype. It possessed the special attributes of the carronades in the superlative degree; the carronade was a reproduction, to a convenient scale, of the Smasher. That General Melville was the prime inventor of the new type, has been placed beyond doubt by the inscription on a model subsequently presented to him by the Carron Company. The inscription runs: "Gift of the Carron Company to Lieut.-General Melville, inventor of the Smashers and lesser carronades for solid, ship, shell, and carcass shot, etc. First used against French ships in 1779." [1]

In almost every respect the Smasher was the antithesis of the long gun: the advantages of the one were founded on the shortcomings of the other. For instance, the smallness of the long gun's ball was a feature which, as ships' sides came to be made stronger and thicker, rendered the smaller calibres of long guns of a diminishing value as offensive armament. It was becoming increasingly difficult to sink a ship by gunfire. The round hole made near the enemy's water-line was insufficient in size to have a decisive effect; the fibres of the timber closed round the entering shot and, swelled by sea-water, half closed the hole, leaving the carpenter an easy task to plug the inboard end of it. The large and irregular hole made by a Smasher, on the other hand, the ragged and splintered opening caused by the crashing of the large ball against the frames and timbers, was quite likely to be the cause of a foundering. Again, the high velocity of the long gun's ball, while giving it range and considerable penetrative power, was actually a disadvantage when at close quarters with an enemy. The maximum effect was gained, as every gunner knew, when the ball had just sufficient momentum to enable it to penetrate an opponent's timbers. The result of a high velocity was often

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[1] Mr. Patrick Miller, who is mentioned in a later chapter as builder of the first successful steam-propelled vessel, was also an enthusiastic artillerist. In a memorandum to the Select Committee of the House of Commons, appointed in 1824 to consider the claims of various inventors of steam-vessels, a Mr. Taylor gave the following evidence: "I found him (Mr. Miller) a gentleman of great patriotism, generosity, and philanthropy; and at the same time of a very speculative turn of mind. Before I knew him (1785) he had gone through a very long and expensive course of experiments upon artillery of which the carronade was the result."

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to make a clean hole through a ship without making a splinter or causing her to heel at all. Hence the practice of double-shotting : a system of two units which, as we have just seen, was less likely to prove effective than a system of a larger single unit. On the other hand the Smasher vaunted its low muzzle velocity. As for the relative powder charges, that of the long gun was wastefully large and inefficient, while that of the Smasher was small and very effective. It was in this respect, perhaps, that the Smasher showed itself to the greatest advantage. And as this feature exerted from the first an important influence on all other types of ordnance, we will examine in some detail the means by which its high efficiency was attained.

Apart from the inefficiency inherent in the small-ball-and-big-velocity system the long gun laboured under mechanical disadvantages from which its squat competitor was happily free. In the eighteenth century the state of workshop practice was so primitive as to render impossible any fine measurements of material. Until the time of Whitworth the true plane surface, the true cylinder and the true sphere were unattainable in practice. For this reason a considerable clearance had to be provided between round shot and the bores of the guns for which they were intended ; in other words, the inaccuracies which existed in the dimensions of guns and shots necessitated the provision of a certain " windage." But other considerations had also to be taken into account. The varying temperatures at which shot might require to be used ; the fouling of gun-bores by burnt powder ; the effect of wear and rust on both shot and bore, and especially the effect of rust on the shot carried in ships of war (at first enlarged by the rust and then, the rust flaking or being beaten off with hammers, reduced in size)—all these factors combined to exact such disproportionate windage that, in the best conditions, from one-quarter to one-third of the force of the powder was altogether lost, while, in the worst conditions, as much as one-half of the propulsive force of the powder escaped unused. Not only was a large charge required, therefore, but the range and aim of the loosely fitting shot was often incorrect and incalculable ; the motion of the shot was detrimental to the surface of the bore and the life of the gun ; while the recoil was so boisterous as sometimes to dismount and disable the gun, injure the crew, and even endanger the vessel.

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The inventor of the Smasher, by eliminating this obvious deficiency of the long gun, gave to his weapon not only a direct advantage due to the higher efficiency of the powder-charge, but also several collateral advantages arising from it, such as, economy of powder, ease of recoil, and small stresses upon the mounting and its supporting structure.

It had been laid down by Dr. Hutton in 1775, as one of the chief results of the systematic experiments carried out by him at Woolwich in extension of the inquiries originated by Robins, that if only the windage of guns could be reduced very important advantages would accrue ; among others, a saving of at least one-third of the standard charges of powder would result. General Melville determined to give the Smasher the very minimum of windage necessary to prevent accident. The shortness of the bore favoured such a reduction. The large diameter, though at first it might appear to render necessary a correspondingly large windage, was actually an advantage from this point of view. For, instead of adhering to the orthodox practice with long guns, of making the windage roughly proportional to the diameter of the bore, he gave the Smasher a windage less than that of a much smaller long gun, arguing that though a certain mechanical clearance was necessary, yet the amount of this clearance was in no way dependent on the diameter of the shot or piece. The large size of the Smasher acted therefore to its advantage. The windage space through which the powder gases could escape was very small in relation to the area of the large ball on which they did useful work.

But this divergence from the standard practice would appear to necessitate the provision of special ammunition for use with the Smasher : the nicely fitting sixty-eight pound ball would require to be specially made for it ? And this would surely militate against the general adoption of the Smasher in the public service ? No such difficulty confronted the inventor. For, curiously enough, the principle on which the dimensions of gun-bores and shot were fixed was the reverse of the principle which obtains to-day. Instead of the diameter of the *gun* being of the nominal dimension and the diameter of the shot being equal to that of the gun minus the windage, the diameter of the *shot* was the datum from which the amount of the windage and the calibre of the gun were determined.

So, the size of the shot being fixed, a reduction of windage

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was obtainable in a new design of gun by boring it to a smaller than the standard diameter. And this was what the inventor of the Smasher did. The large ball, in combination with the restricted windage and the small charge of powder, gave the Smasher ballistic results far superior, relatively, to those obtained with the long gun. Its lack of ranging power was admitted. But for close action it was claimed that it would prove an invaluable weapon, especially in the defence of merchant ships.[1] Not only would its large ball make such holes in the light hull of an enemy privateer as would break through his beams and frames and perhaps send all hands to the pumps; but, projected with just sufficient velocity to carry it through an opponent's timbers, it would thereby produce a maximum of splintering effect and put out of action guns, their crews, and perhaps the vessel itself.

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On the lines of the Smasher the "lesser carronades," more convenient in size and more easily worked, were cast, and quickly made a reputation in merchant shipping. The Smasher itself was offered to the admiralty, but was never fitted in a royal ship; though trials were carried out with it later with hollow or cored shot, to ascertain how these lighter balls compared in action with the solid 68-pounders. Meanwhile the Carron Company found a large market for the lighter patterns of carronade; the 24, 18, and 12-pounders were sold in large numbers to private ships and letters-of-marque, and to some of the frigates and smaller ships of the royal navy. The progress of the new ordnance was watched with interest by the board of admiralty. In 1779 we have Sir Charles Douglas writing to Sir Charles Middleton in full accord with his views on the desirability of mounting Carron 12-pounders on the poop of the *Duke*, and suggesting

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[1] On April 20th, 1669, Mr. Pepys recorded in his diary a visit to "the Old Artillery-ground near the Spitalfields" to see a new gun "which, from the shortness and bigness, they do call Punchinello." Tried against a gun of double its own length, weight, and powder-charge, Punchinello shot truer to a mark and was easier to manage and had no greater recoil—to the great regret of the old gunners and officers of the ordnance that were there.

The gallant inventor offered Mr. Pepys a share in the profits; there seemed great promise that the king would favour it for naval use. "And," adds Pepys, "no doubt but it will be of profit to merchantmen and others to have guns of the same form at half the charge."

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24-pounders, three a side, upon her quarter-deck. To the same distinguished correspondent Captain Kempenfelt writes, deploring that no trials have yet been made with carronades. Shortly afterwards the navy board discusses the 68-pound Smasher and desires the master-general of ordnance to make experiment with it. A scale is drawn up by the navy board, moreover, and sanctioned by the admiralty, for arming different rates with 18- and 12-pounder carronades. The larger classes of ships, the first, second, and third rates, have their quarter-decks already filled with guns ; but accommodation is found for a couple of carronades on the forecastles, and for half a dozen on the poop, which for nearly a century past has served chiefly as a roof for the captain's cabin. This is now timbered up and given three pairs of ports, making a total of eight ports for the reception of carronades. In the case of smaller ships less difficulty is experienced. Ports are readily cut in their forecastles and quarter-decks, and in some cases their poops are barricaded, to give accommodation for from four to a dozen carronades.[1]

The new weapon found its way into most of our smaller ships, not always and solely as an addition to the existing long-gun armament, for use in special circumstances, but in many cases in lieu of the long guns of the establishment. The saving in weight and space gained by this substitution made the carronade especially popular in the smaller classes of frigate, the sloops, and brigs ; many of which became almost entirely armed with the type. The weak feature of the carronade, which in the end was to prove fatal to it—its feeble range and penetrating power—was generally overlooked, or accepted as being more than compensated for by its many obvious advantages. The carronade, it was said by many, was the weapon specially suited to the favourite tactics of the British navy—a yard-arm action.

There were others, however, who were inclined to emphasize the disability under which the carronade would lie if the enemy could contrive to avoid closing and keep just out of range. And on this topic, the relative merits of long gun and carronade as armament for the smaller ships, discussion among naval men was frequent and emphatic. The king's service was divided into two schools. The advocates of long guns could quote many a case where, especially in chase, the superior

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[1] James : *Naval History.*

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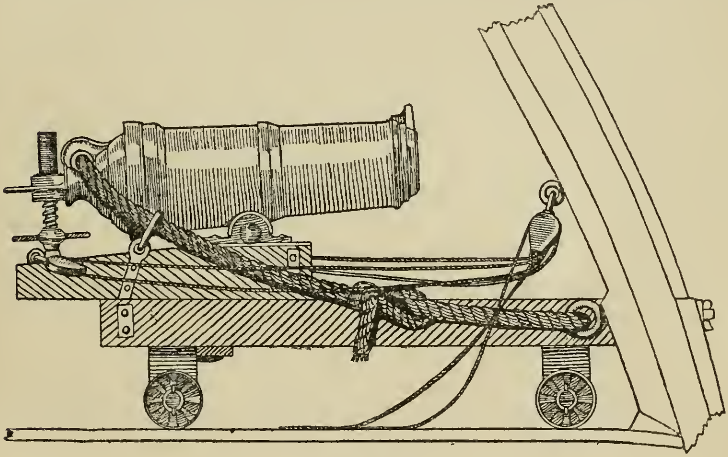
range of the long gun had helped to win the day. The advocates of the carronade replied with recent and conclusive examples of victories won by short-gun ships which had been able to get to grips and quickly neutralize the advantages of a superior enemy armed with long guns. When challenged with the argument that, since the advantages of the carronade entirely disappear at long ranges it is essential that ships armed with them should be exceptionally fast sailers, they replied, that the very lightness of a carronade armament would, other things being equal, give ships so armed the property required. As for out-ranging, they were even ready to back their carronades in that respect, if only they were well charged with powder. It was a matter of faith with many that, in spite of Dr. Hutton's published proof to the contrary, a considerable increase of range could be obtained by the expedient of shortening the gun's recoil ; so that in chase it was a common procedure to lash the breechings of carronades to the ship's timbers, to prevent recoil and to help the shot upon its way.

At first mechanical difficulties occurred in the fitting of the new carronade mountings which, though not due to any defect inherent in the equipments, nevertheless placed them under suspicion in certain quarters. Though the prototype had trunnions like a gun, the carronades afterwards cast were attached by lugs to wooden slides which recoiled on slotted carriages pivoted to the ship's side timbers, the slide being secured to the carriage by a vertical bolt which passed down through the slot. The recoil was limited by breechings ; but as these stretched continuously the bolt eventually brought up with a blow against the end of the slot in the carriage : the bolt broke, and the carronade was disabled. This happened at Praya Bay, where the carronades broke their beds, owing to slack breechings, after a few rounds. Captains complained, too, that the fire of the carronades was a danger to the shrouds and rigging.

In spite of these views the popularity of the new ordnance increased so rapidly that in January, 1781, there were, according to the historian James, 429 ships in the royal navy which mounted carronades. On the merits of these weapons opinion was still very much divided. The board of ordnance was against their adoption ; the navy board gave them a mild approval. In practice considerable discretion appears to have been granted to the commanders of ships in deciding what armament they should actually carry.[1] But the uncertainty of official opinion gave rise to a surprising anomaly: *the carronade, although officially countenanced, was not recognized as part of the orthodox armament of a ship.* What was the cause of this is not now clear. It has been said in explanation, that the carronade formed too fluctuating a basis on which to rate a ship's force; that a long-gun basis afforded a key to the stores and complement of a ship, whereas carronades had little effect on either complement or stores; or that it may have been merely inertia on the part of the navy board. Whatever the cause, the ignoring of the carronade, in all official quotations of ships' armaments, led to great uncertainty and confusion in estimating the relative force of our own and other navies, to suggestions of deception on the part of antagonists, to the bickering of historians and the bewilderment of the respective peoples. This extraordinary circumstance, that carronades with all their alleged advantages were not thought worthy to be ranked among the long guns of a ship, is commented on at length by James. "Whether," he says, "they equalled in calibre the heaviest of these guns, added to their number a full third, or to their power a full half, still they remained as mere a blank in the ship's nominal, or rated force, as the muskets in the arm-chest. On the other hand, the addition of a single



A CARRONADE

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[1] The carrying of *sham* guns among their armament was not unknown in the case of vessels which boasted a reputation for their superior speed and sailing qualities (vide *Bentham Papers*).

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pair of guns of the old construction, to a ship's armament, removed her at once to a higher class and gave her, how novel or inconvenient soever, a new denomination."

While the products of the Carron firm were gaining unexpected success in the defence of merchant shipping, their value in ships of the line was not to remain long in doubt. Some of the heavier carronades had been mounted in the *Formidable*, *Duke*, and other ships, and their presence had a material effect in Admiral Rodney's action of April, 1782. As had been generally recognized, the carronade was especially suited to the British aims and methods of attack—the destruction of the enemy by a yard-arm action. To the French, whose strategy and methods were fundamentally different, its value was less apparent. So that for long this country reaped alone the benefit of its invention; until in somewhat half-hearted way France gradually adopted it, and then mostly in the smaller sizes, and more apparently with a view to defence than for offensive purposes. In the action with de Grasse the carronades of the British fleet operated, in the opening stages, as an additional incentive to the enemy to avoid close quarters. And later, at the in-fighting, their weight of metal contributed in no small degree to the superiority of fire which finally forced him to surrender.

It was later in this same year that the carronade won its most dramatic victory as armament of a small ship. In order to give a thorough trial to the system the navy board had ordered the *Rainbow*, an old 44, to be experimentally armed with large carronades, some of which were of as large a calibre as the original Smasher; by which her broadside weight of metal was almost quadrupled. Thus armed she put to sea and one day fell in with the French frigate *Hébé*, armed with 18-pounder long guns. Luring her enemy to a close-quarter combat, the *Rainbow* suddenly poured into the Frenchman the whole weight of her broadside. The resistance was short, the *Hébé* surrendered, and proved to be a prize of exceptional value as a model for frigate design. The capture was quoted as convincing proof of the value of a carronade armament, and the type continued from this time to grow in popularity, until the termination of the war in 1783 put a stop to further experiments with it.

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Throughout the long war which broke out ten years later the carronade played a considerable part in the succession of duels and actions which had their climax off Trafalgar. It was now generally adopted as a secondary form of armament, captains being permitted, upon application, to vary at discretion the proportion of long-gun to carronade armament which they wished to carry. In the smaller classes especially, a preponderance of carronades was frequently accepted; the accession of force caused by the substitution of small carronades for 6- and 9-pounder long guns in brigs and sloops could hardly be disputed. In ships-of-the-line the larger sizes continued in favour. The French now benefited, too, by their adoption; on more than one occasion their poop and forecastle carronades, loaded with langrage, played havoc with our personnel. Spaniards and Dutchmen did not carry them. How far their absence contributed to their defeats it is not now to inquire; but how the tide of battle would have been affected by them—if the Dutch fleet, for instance, had carried them at Camperdown—may be a not unprofitable speculation.

Early in the war the carronade system was to score its greatest defensive triumph, and this, by a happy coincidence, in the hands of the old *Rainbow's* commander.

The *Glatton*, one of a few East Indiamen which had been bought by the admiralty, was fitted out in 1795 as a ship of war, and left Sheerness in the summer of the following year under the command of Captain Henry Trollope to join a squadron in the North Sea. At her commander's request she was armed with carronades exclusively. She was without ahead or astern fire, without a single long bow or stern chaser; she carried 68-pounder carronades along her sides, whose muzzles were so large that they almost filled the small port-holes of the converted Indiaman and prevented more than a small traverse. Off the Flanders coast she fell in one night with six French frigates, a brig-corvette, and a cutter; and at ten o'clock a close action began. The *Glatton* was engaged by her antagonists on both sides, her yard-arms almost touching those of the enemy. She proved to be a very dangerous foe. Her carronades, skilfully pointed and served by supply parties who worked port and starboard pieces alternately, poured out their heavy missiles at point-blank range. So heavy was her fire that one

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by one the frigates had to haul off, severely damaged, and the *Glatton* was left at last to spend the night repairing her rigging unmolested, but in the expectation that the French commodore would renew the attack in the morning. To her surprise no action was offered. The blows of the 68-pounders had done their work. Followed by the *Glatton* with a "brag countenance," the enemy retired with his squadron in the direction of Flushing.

The action had more than one lesson to teach, however, and no more ships, except small craft, were armed after this upon the model of the *Glatton*.

We must at this point mention an experiment made in the year 1796, at the instance of Sir Samuel Bentham, in the mounting of carronades on a non-recoil system. Sir Samuel, who in the service of Russia had armed long-boats and other craft with ordnance thus mounted, produced arguments before the navy board for attaching carronades rigidly to ships' timbers; so as to allow of no other recoil than that resulting from the elasticity of the carriage and the materials connecting it to the ship. The ordnance board reported against the new idea. Sir Samuel pointed out that the idea was not new. Both the largest and the smallest pieces used on board ship (viz. the mortar and the swivel) had always been mounted on the principle of non-recoil. He showed how bad was the principle of first allowing a gun and its slide or carriage to generate momentum in recoil and then of attempting to absorb that momentum in the small stretch of a breeching-rope. He argued that a rifle held at the shoulder is not allowed to recoil: if it is, the rifleman smarts for it. He instanced the lashing of guns fast to the ship, especially in chase, for the purpose of making them carry farther. No; the novelty consisted in preparing suitable and appropriate fastenings for intermediate sizes of guns between the mortar and the swivel. The adoption of his proposal, he contended, would result in smaller guns' crews, quicker loading, and greater safety.

As a result of these arguments certain sloops designed by him were armed on this principle; and in other cases, notably in the case of the boats used at the siege of Acre, the carronades and smaller types of long gun were successfully mounted and worked without recoil by attaching their carriages to vertical fir posts, built into the hull structures to serve as front pivots. But, generally, the system was found to be impracticable.

The pivots successfully withstood the stresses of carronades fired with normal charges of powder; no permanent injury resulted to the elastic hull structures over which the blows were spread. But the factor of safety allowed by this arrangement was insufficient to cover the wild use of ordnance in emergencies. The regulation of charges and the prevention of double-shotting was difficult in action, and pieces were liable to be over-charged in the excitement of battle in a way which Sir Samuel Bentham had failed to realize. Pivots were broken, ships' structures strained, and the whole system found ill-adapted for warship requirements.

It was not till the war of 1812 that the fatal weakness of the carronade, as primary armament, was fully revealed. The Americans had not developed the carronade policy to the same extent as ourselves, for transatlantic opinion was never at this period enamoured of the short-range gun. Their well-built merchant ships, unhampered by tonnage rules or by the convoy system which had taken so much of the stamina from British shipping, were accustomed to trust to their speed and good seamanship to keep an enemy at a distance. Their frigates, built under less pedantic restrictions as to size and weight, were generally swifter, stouter and more heavily armed than ours. And, though they included carronades among their armament, these were not generally in so large a proportion as in our ships, and in part were represented by a superior type—the colombiad, a hybrid weapon of proportions intermediate between the carronade and the long gun. Our ships often depended heavily upon the carronade element of their armament. Experience was soon to confirm what foresight might, surely, have deduced: namely, that when pitted against an enemy who could choose his range and shoot with tolerable accuracy the carronade would find itself in certain circumstances reduced to absolute impotence.

This was to be the fate and predicament of our ships on Lakes Erie and Ontario, in face of the Americans. "I found it impossible to bring them to close action," the English commodore reported. "We remained in this mortifying situation five hours, having only six guns in all the squadron that would reach the enemy, not a carronade being fired." The same lesson was to be enforced shortly afterwards on the Americans. One of their frigates, the *Essex*, armed almost exclusively with carronades, was fought by an English ship,

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the *Phœbe*, armed with long guns. The *Essex*, it should be noted, possessed the quality essential for a carronade armament, namely, superior speed. But the *Phœbe* fell in with her in circumstances when, owing to damage, her superior speed could not be utilized. The captain of the *Phœbe* was able to choose the range at which the action should be fought. He kept at a "respectful distance": within range of his own long guns and out of range of his opponent's carronades. Both sides fought well, but the result was a foregone conclusion. The *Essex*, disabled and on fire, had to surrender. From that time the carronade was discredited. For some years after the peace it found a place in the armament of all classes of British ships, but it was a fallen favourite. The French commission which visited this country in 1835 reported that, although still accounted part of the regular armament of older ships, the carronade was being replaced to a great extent by light long guns in newer construction. Opinion certainly hardened more and more against the type, and, gradually falling into disuse, it was at last altogether abandoned.

There was a feature of the carronade, however, which if it had been exploited might have made the story of the carronade much longer: might, in fact, have made the carronade the starting-point of the great evolution which ordnance was to undergo in the second quarter of the nineteenth century. We refer to the large area of its bore, as rendering it specially suitable for the projection of hollow spheres charged with powder or combustibles: in short, for shells. Although, as shown by the inscription on the model presented to him, General Melville's invention covered the use of shell and carcass shot, yet there was no general appreciation in this country, at the time of its invention, of the possibilities which the new weapon presented for throwing charges of explosive or combustible matter against the hulls of ships. Empty hollow shot were tried in the original Smasher for comparison against solid shot, in case the latter might prove too heavy;—and these, as was pointed out by an eminent writer on artillery,[1] possessed in an accentuated degree all the disadvantages of the carronade system, their adoption being tantamount to a reversion to the long-exploded granite shot of the medieval ordnance—but the use of *filled* shell in connection with carronades does not appear to have been seriously

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[1] Captain Simmons, R.A.

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considered. The disadvantages of filled shell as compared with solid shot were fairly obvious; their inferiority in range, in penetrative power, in accuracy of flight, their inability to stand double-shotting or battering charges—all these were capable of proof or demonstration. Their destructive effect, both explosive and incendiary, as compared with that of uncharged shot, was surprisingly under-estimated. Had it been otherwise, the carronade principle would have led naturally to the introduction of the shell gun. "The redeeming trait in the project of General Melville," wrote Dahlgren, "the redeeming trait which, if properly appreciated and developed, might have anticipated the Paixhans system by half a century, was hardly thought of. The use of shells was, at best, little more than a vague conception; its formidable powers unrealized, unnoticed, were doomed to lie dormant for nearly half a century after the carronade was invented, despite the evidence of actual trial and service."

In other respects the carronade did good service in the development of naval gunnery. Its introduction raised (as we have seen) the whole question of windage and its effects, and was productive of general improvement in the reduction and regulation of the windage in all types of gun. By it the advantages of quick firing were clearly demonstrated. And by its adoption in the ship-of-the-line it contributed largely to bring about that approach to uniformity of calibre which was so marked a feature of the armament schemes of the first half of the nineteenth century.

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CHAPTER VI

THE TRUCK CARRIAGE

FROM the small truck, *trochos*, or wheel on which it ran, the four-wheeled carriage which served for centuries as a mounting for the long guns of fighting ships has come to be known as a truck carriage : the gun, with trunnions cast upon it, as a truck gun.

Artillery being from the first an affair common, in almost all respects, to land and to sea service, and being applied to ships as the result of its prior development on land, it would be expected that naval practice should in its evolution follow in the wake of that on land. And so it has, in the main, until the time of the Crimean War ; since when, completely revolutionizing and in turn revolutionized by the rapid development of naval architecture and material, it has by far surpassed land practice both in variety and power. But while the wooden ship imposed its limitations no branch of affairs, perhaps, appeared to be more conservative in its practice than naval gunnery. No material seemed less subject to change, no service less inclined to draw lessons from war experience. And in recent years the truck carriage has often been taken as typifying the great lack of progress in all naval material which existed between the sixteenth and the nineteenth centuries.

Whether there was in fact so great a stagnation as is commonly supposed, and to what causes such as existed may have been due, we may discern from an examination of the truck carriage itself and of its development from the earliest known forms of naval gun mounting.

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The first large ordnance to be used on land, having as its object the breaching of walls and gates and the reduction of fortresses, was mounted solidly in the ground in a way which would have been impracticable on board a ship at sea. In

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time, as the energy of discharge increased, this method of embedding the gun in soil grew dangerous: a certain recoil was necessary to absorb and carry off the large stresses which would otherwise have shattered the piece. In time, too, as the power of explosives and the strength of guns increased, their size diminished; cannon, as we have seen, became more portable. No longer embedded in earth or fixed on ponderous trestles, they were transported from place to place on wheeled carriages. And on these carriages, massive enough to stand the shock of discharge and well adapted to allow a certain measure of recoil, the land ordnance were fired with a tolerable degree of safety.

Both of these methods were followed in principle when guns came to be used at sea.

In the early Mediterranean galley the cannon was mounted in a wooden trough placed fore and aft on the deck in the bow of the vessel. The trough was secured to the deck. In rear of the cannon's breech and in contact with it was a massive bitt of timber, worked vertically, which took the force of the recoil. Later, as force of powder increased, this non-recoil system of mounting ordnance failed. The cannon had to be given a certain length of free recoil in order that, by the generation of momentum, the energy which would otherwise be transmitted to the ship in the form of a powerful blow might be safely diverted and more gradually absorbed. Hence free recoil was allowed within certain limits, the cannon being secured with ropes or chains.

But, as had doubtless been found already with land ordnance, the violence of recoil depended largely upon the mass of the recoiling piece; for any given conditions of discharge the heavier the gun, the less violent was its recoil. It was a natural expedient, then, to make the recoiling mass as large as possible. And this could be effected, without the addition of useless and undesirable extra deadweight, by making the wooden trough itself partake of the recoil. The cannon was therefore lashed solidly to the trough, and both gun and trough were left free to recoil in the desired direction. The primitive mounting helped, in short, by augmenting the weight of the recoiling mass, to give a quiet recoil and some degree of control over the piece.

Later, this trough or baulk of timber performed an additional function when used as a mounting for a certain form of gun. When the piece was a breech-loader—like those recovered from

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the wreck of the *Mary Rose*—the trough had at its rear end a massive flange projecting upwards, forming the rear working face for the wedge which secured the removable breech chamber to the gun. "The shot and wadde being first put into the chase," wrote Norton in 1628, "then is the chamber to be firmly wedged into the tayle of the chase and carriage." The mounting was, in fact, an integral part of the gun. In the 8-inch breech-loading equipment of the *Mary Rose* which lies in the museum of the Royal United Service Institution in Whitehall there is evidence of two small rear wheels. Most of these early ship carriages had two wheels, but for the more powerful muzzle-loaders introduced toward the middle of the sixteenth century, four came into favour. With four wheels our timber baulk has become a primitive form of the truck carriage of the succeeding centuries.[1]

But perhaps the truck carriage may more properly be regarded as a derivative of the wheeled mounting on which, as we have seen, land ordnance came eventually to be worked. The ship being a floating fort, the mode of mounting the guns would be that in vogue in forts and garrisons ashore, and the land pieces and their massive carriages would be transferred, without modification, for use on shipboard. How different the conditions under which they worked! The great cannon, whose weight and high-wheeled carriages were positive advantages when firing from land emplacements, suitably inclined, were found to work at great disadvantage under sea conditions. Their great weight strained the decks that bore them, and their wheeled carriages proved difficult to control and even dangerous in any weather which caused a rolling or pitching of the gun platform. With the introduction of portholes their unfitness for ship work was doubtless emphasized; there was neither height nor deck-space enough to accommodate them between decks. Hence the necessity for a form of carriage suitable for the special conditions of sea service, as well as for a size of gun which would be within the capacity of a ship's crew to work. In the early Tudor ships the forms of mounting were various: guns were mounted on two or four-wheeled carriages, or sometimes, especially the large bombards, upon "scaffolds" of timber.[2] By Elizabeth's reign the limit

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[1] The carriage thus formed out of a baulk or trunk appears to have been known as a trunk carriage. Norton describes the cannon-periers as being mounted on "trunk carriages provided with four trucks."

[2] Oppenheim.

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had been set to the size of the gun; the demi-cannon had been found to be the heaviest piece which could be safely mounted, traversed, and discharged. This and the smaller guns which were plied with such effect against the Spanish Armada were mounted on low, wheeled, wooden carriages which were the crude models from which the truck carriage, the finished article of the nineteenth century, was subsequently evolved. Even then the carriages had parts which were similar and similarly named to those of the later truck carriage; they had trunnion-plates and sockets, capsquares, beds, quoins, axletrees, and trucks.[1] On them the various pieces—the demi-cannons, the culverins, the basilisks and sakers—were worked by the nimble and iron-sinewed seamen; run out by tackles through their ports, and traversed by handspikes. Loaded and primed and laboriously fired by means of spluttering linstocks, the guns recoiled upon discharge to a length and in a direction which could not be accurately predicted. The smaller guns, at any rate, had no breechings to restrain them: these ropes being only used for the purpose of securing the guns at sea, and chiefly in foul weather.[2]

On the whole these low sea carriages appear to have proved satisfactory, and their continued use is evidence that they were considered superior to those of the land service pattern. "The fashion of those carriages we use at sea," wrote Sir Henry Manwayring in 1625, "are much better than those of the land; yet the Venetians and others use the other in their shipping." In essentials the carriage remained the same from Elizabeth to Victoria. Surviving many attempts at its supercession in favour of mechanically complicated forms of mounting, it kept its place in naval favour for a surprising length of time; challenging with its primitive simplicity all the elaborate mechanisms which pitted themselves against it.

An illuminating passage from Sir Jonas Moore's treatise on

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[1] It was evidently a practice at this period to vary the diameter of the trucks to suit the ship's structure and the height of the gun-ports. "Be careful," says Bourne in 1587, "that the trucks be not too high, for if the trucks be too high, then it will keep the carriage that it will not go close against the ship's side. . . . And the truck being very high, it is not a small thing under a truck that will stay it, etc. etc. And also, if that the truck be too high, it will cause the piece to have the greater reverse or recoil. Therefore, the lower that the trucks be, it is the better."

Bourne also mentions, in the same book, the *Art of Shooting in Great Ordnance*, as a curious invention of a "high Dutchman" a gun mounting so devised as to allow the piece to rotate through 180° about its trunnions for loading.

[2] Manwayring: *Sea-Man's Dictionary.*

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artillery, written in 1689 and copied from the *Hydrographie* of the Abbé Fournier, shows at a glance the manner in which the armament of small Mediterranean craft of that period was disposed, and the method on which the guns were mounted. "At sea the ordnance are mounted upon small carriages, and upon four and sometimes two low wheels without any iron work. Each galley carries ordinarily nine pieces of ordnance in its prow or chase, of which the greatest, and that which delivers his shot just over the very stem, and lies just in the middle, is called the Corsiere or 'cannon of course' or 'chase cannon,' which in time of fight doth the most effectual service. It carries generally a shot of thirty-three or forty pounds weight, and are generally very long pieces. It recoils all along the middle of the galley to the mast, where they place some soft substance to hinder its farther recoil, that it might not endamage the mast. Next to this Corsiere are placed two Minions on each side, which carries a five or six-pound ball; and next to these are the Petrieroes, which are loaded with stone-shot to shoot near at hand. Thirdly, there are some small pieces, which are open at the breech, and called Petrieroes a Braga, and are charged with a moveable chamber loaded with base and bar shot, to murder near at hand. And the furthest from the Corsiere are the Harquebuss a Croc, which are charged with small cross-bar shot, to cut sails and rigging. All these small pieces are mounted on strong pins of iron having rings, in which are placed the trunnions with a socket, so that they are easily turned to any quarter.

"All the guns are mounted upon wheels and carriages; moreover the Petrieroes, which are planted in the forecastle and quarter to defend the prow and stern, are mounted upon strong pins of iron without any reverse; the greatest pieces of battery are planted the lowest, just above the surface of the water, the smallest in the waist and steerage, and with the Petrieroes in quarter-deck and forecastle. Upon the sea, to load great ordnance they never load with a ladle, but make use of cartridges, as well for expedition as security in not firing the powder, which in time of fight is in a continual motion."

Before passing to a consideration of the truck carriage in detail there is an important circumstance to be noted with regard to the conditions under which its design and supply to the naval service were regulated. It is a remarkable fact that, during almost the whole of what may be called the truck carriage era, the arming of ships with ordnance, the supply of the requisite guns and their carriages, the design of the guns and their mode of mounting, was no part of a naval officer's affair. The Board of Ordnance had control both of land and of sea artillery. From the death of Sir William Wynter onwards the mastership of the ordnance by sea was absorbed into the mastership of the ordnance by land. From this arrangement, as may be imagined, many inconveniences arose, and many efforts were made at various times to disjoin the offices and to place the armament of ships under naval control. For, apart from the fact that at an early date the ordnance office acquired "an unenviable reputation for sloth and incapacity,"[1] the interests of the sea service were almost bound to suffer under such a system. And in fact the inconvenience suffered by the navy, through the delays and friction resulting from the system whereby all dealings with guns and their mountings and ammunition were the work of military officials, was notorious. The anomalous arrangement survived, in spite of the efforts of reformers, till far into the nineteenth century. Probably the Board of Ordnance argued honestly against reintroducing a dual control for land and sea artillery material. They had, at any rate, strong interests in favour of the status quo. For, writing in the year 1660, Sir William Slingsby noted regretfully that "the masters of the ordnance of England, having been ever since of great quality and interest, would never suffer such a collop to be cut out of their employment."

The arming of ships, therefore, apart from the original assignment of the armament, remained in the province of the military authorities.

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An examination of the design of the perfected truck carriage and a glance at the records of its performances in action show that the advocates of rival gun mountings were not altogether incorrect in their contention that the manner in which the broadside armament of our ships was mounted was wrong in principle and unsatisfactory in actual detail. The many defects of the truck carriage were indeed only too obvious.

In the first place, the breechings were so reeved that the force sustained by them in opposition to the recoil of the gun tended inevitably to cause the piece to jump. The reaction of

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[1] Oppenheim.

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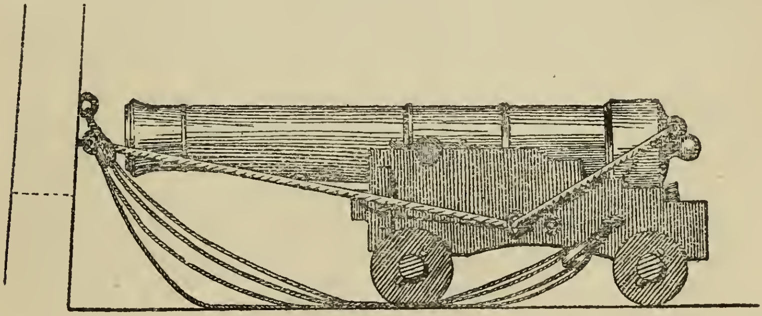
the breeching acted along lines below the level of the gun-axis; the breeching therefore exerted a lifting force which, instead of pressing down all of the four trucks upon the deck and thus deadening the recoil, tended to raise the fore trucks in the air and reduce the friction of the carriage upon the deck. The larger the gun and the higher the gun-axis above the trucks, the greater was this tendency of the gun to lift and overturn. If the rear trucks, about which the gun and carriage tended to revolve, had been set at some distance in rear of the centre of gravity of the equipment, it would have been rendered thereby more stable. But space did not permit of this. And actually they were so placed that, when discharge was most violent, the weight of the equipment was scarcely sufficient to oppose effectively the tendency to jump. Again, the anchoring of the breeching to two points in the ship's frames, one on either side of the gun, was wrong and liable to have serious consequences. For with this arrangement not only had the breeching to be continuously "middled" as the gun shifted its bearing, but even when accurately adjusted the "legs" of the breeching bore an unequal strain when the gun was fired off the beam. In other words, the horizontal angles subtended between the gun-axis, when off the beam, and the two lines of the breeching were unequal; one side of the breeching took more of the blow of gunfire than the other; and not infrequently the gun carriage was thrown round violently out of the line of recoil, with damage to the equipment and injury to the crew.

The design of the carriage was in no way influenced, apparently, by a desire to obtain a minimum area of port opening in combination with a maximum traverse of the gun. For the broad span of the front part of the carriage soon caused the gun to be "wooded" when slewed off the beam. And a further disadvantage of this broad span was in the effect it had of automatically bringing the gun right abeam every time it was hauled out after loading: the front span of the carriage coming square with the timbers of the port-sill.

As for the system of recoil, while the recoiling of the carriage with the gun had an advantage in reducing the stresses brought on the hull structure, yet this arrangement had the correlative disadvantage that the carriage as well as the gun had to be hauled out again. And, as regards safety, it is a matter for surprise that the system of checking recoil by means of large ropes—of absorbing the momentum of a heavy gun and its carriage in a distance corresponding to the stretch of the breechings under their suddenly applied load—was not far more injurious than experience proved to be the case. Even so, the results obtained from it were far from satisfactory. "It is a lamentable truth"—we quote Sir William Congreve, writing in 1811—"that numbers of men are constantly maimed, one way or another, by the recoiling of the heavy ordnance used on board ships of war. Most of the damage is done by the random recoil of the carriage which, moving with the gun along no certain path, is much affected by the motion of the vessel and the inequalities of the deck. It is difficult to know, within a few feet, to where the carriage will come, and the greatest watchfulness is necessary on all hands to prevent accidents." This refers, observe, to the truck gun under control. How terrible an uncontrolled gun could be, may be read in the pages of Victor Hugo's *Quatre-Vingt-Treize*, of which romance the breaking loose of a piece on the gun-deck of a frigate forms a central incident. It was conjectured that the old *Victory*, Admiral Balchen's flagship which went down off the Casquets in 1744, "mouse and man," was lost through the breaking loose of her great guns in a gale.[1]



A TRUCK GUN

The accessories of the truck carriage were a source of frequent accident. The attachment of breechings and tackles to the ship's side often involved disablement in action, the numerous bolts being driven in as missiles among the crew, who were also in danger of having their limbs caught up in the maze of ropes and trappings with which the deck round the gun was encumbered. Considered as a mechanism the

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[1] Hutchinson: *Naval Architecture.*

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whole gun-equipment was a rude and primitive affair; the clumsy carriage run out to battery by laborious tackles, the cast-iron gun laid by a simple wedge, the whole equipment traversed by prising round with handspikes—by exactly the same process, it has been remarked, as that by which the savage moved a log in the beginning of the world.

Why, then, did the truck carriage maintain its long supremacy? The answer is, that with all its acknowledged defects it had merits which universally recommended it, while its successive rivals exhibited defects or disadvantages sufficient to prevent their adoption to its own exclusion. It was a case, in fact, of the survival of the fittest. And if we examine its various features in the light of the records of its performances in action (the truck carriage appears in the background of most of our naval letters and biographies), we shall understand why it was not easily displaced from favour with generation after generation of our officers and seamen.

In the first place the truck carriage, a simple structure of resilient elm, with bed, cheek-plates, and trunnions strongly fitted together and secured by iron bolts, was better adapted than any other form for the prevention of excessive stresses, resulting from the shock of recoil, on either gun or ship's structure. By the expedient of allowing the whole gun equipment to recoil freely across the deck, by allowing the energy of recoil to assume the form of kinetic energy given to the gun and carriage, the violent reactionary stresses due to the sudden combustion of the gunpowder were safely diverted from the ship's structure, which was thus relieved of nearly the whole of the firing stresses. Moreover, by allowing the gun to recoil readily under the influence of the powder-gases the gun itself was saved from excessive stresses which would otherwise have shattered it. From this point of view the weight of the carriage, relatively to that of the gun, was of considerable importance. If the carriage had been at all too heavy it would not have yielded sufficiently under the blow of the gun, and, howsoever strongly made, would eventually have been destroyed, if it had not by its inertia caused the gun to break; if too light, the violence of the recoil would have torn loose the breechings. Actually, and as the result of a process of trial-and-error continuously carried on, the weight of the finally evolved elm carriage was so nicely adapted to that of its gun that a recoil of the most suitable proportions was generally obtained, a free yet not too boisterous run back. This, of course, upon an even keel. Conditions varied when the guns were at sea upon a moving platform. With the ship heeled under a strong wind the weather guns were often fired with difficulty owing to the violence of the recoil. On the other hand the listing of the ship when attacking an enemy from windward favoured the lee guns by providing a natural ramp up which they smoothly recoiled and down which they ran by gravity to battery, as in a shore emplacement. Of which advantage, as we know, British sea tactics made full use at every opportunity.

It was strong, simple, and self-contained. Metal carriages, whose claims were periodically under examination, proved brittle, too rigid, heavy, and dangerous from their liability to splinter. Gunslides, traverses, or structures laid on the deck to form a definite path for the recoil of the gun (such as the Swedish ships of Chapman's time, for example, carried) were disliked on account of their complication, the deck-space occupied, and the difficulty which their use entailed of keeping the deck under the gun dry and free from rotting; though beds laid so as to raise the guns to the level of the ports were sometimes fitted, and were indeed a necessity in the earlier days owing to the large sheer and camber given to the decks. The use of compressors, or of adjustable friction devices, in any form, for limiting the recoil, was objected to on account of the possibilities which they presented for accident owing to the forgetfulness of an excited crew. The truck carriage, being self-contained and independent of external adjustment, was safe in this respect.

The four wood trucks were of the correct form and size to give the results required. The resistance of a truck to rolling depends largely upon the relative diameters of itself and its axle. It was thus possible, by making gun-carriage trucks of small diameter and their axles relatively large, to obtain the following effect: on gunfire the carriage started from rest suddenly, the trucks skidding on the deck without rotating and thus checking by their friction the first violent motion of recoil; during the latter phase of the recoil the trucks rotated, and the carriage ran smoothly back until checked by the breechings.

The friction of the trucks on the deck was also affected, however, by another feature of the design: the position of

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the trunnions relatively to the axis of the gun. How important was this position as influencing the history of land artillery, we have already seen. Truck guns were nearly always "quarter-hung," or cast with their trunnions slightly below their axis, so as to cause the breech to exert a downward pressure on firing, and thus augment the friction of the rear trucks on the deck and check the recoil. The position of the trunnions was studied from yet another point of view: namely, to give the minimum of jump to the gun and ensure a smooth start to the recoil. With this object they were so placed that the two ends of the gun were not equally balanced about the trunnion axis, but a preponderance of about one-twentieth of the weight of the gun was given to the breech-end, thus bringing a slight pressure, due to deadweight alone, upon the quoin.

As for this quoin or primitive wedge by which the gun was roughly laid, this had a great advantage over the screw (which gained a footing, as an alternative, when the carronade came into use) in that it allowed of rapid changes of elevation of the gun. Hence, though the quoin was liable to jump from its bed on gunfire and do injury to the crew, it kept its place as an accessory almost as long as the truck carriage itself survived.

There was one advantage possessed by the truck carriage which was perhaps the most important of all: its superior transportability. The gun equipment was easily transferable, and what this meant to the seaman may be gathered from the accounts of the way in which, in sailing-ship days, ships' armaments were continually being shifted. The armament, we have noted, was not embodied, as it is to-day, as an integral part of the design of the ship. The guns and their carriages were in the nature of stock articles, which could be changed in size, number and position according to the whim of the captain or the service of the ship. And there was every reason why all parties concerned, and especially the ordnance people, should tend to standardize the forms of guns and carriages, to keep them self-contained and as independent as possible of the special requirements of individual ships or positions. The shifting of guns was constantly going on in a commissioned ship. At sea they were lashed against the sides so as to leave as clear a deck as possible. In chase a shifting of guns, among other heavy weights, was resorted to in order that the vessel should not lose way by plunging heavily. If she set sail on a long voyage some of the guns were struck down into the hold, to stiffen her and give her an increased stability. And on her return to harbour the guns might be removed for examination and repair by the ordnance officials, the ship being laid alongside a sheer hulk for the purpose. In the days before the sheathing of ships' bottoms was successfully practised, and in the absence of docks, it was constantly necessary to careen ships for the repair of their ground-timbers, for the cleaning of their sides and the caulking of their seams. This, again, necessitated a shifting or complete removal of most of their stores and ordnance. Great advantages were offered, therefore, from having gun-carriages compact, self-contained, and capable of being quickly removed from one place to another.

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Having inspected the truck carriage in some detail, let us now briefly glance at the development of its use which took place in the last hundred years of its service, between the middle of the eighteenth and the middle of the nineteenth centuries.

The stream of improvement in naval gunnery began to flow strongly under the administration of Lord Anson. New methods of firing, experiments with priming tubes to replace the primitive powder horns and trains of vent powder, and gun locks to replace the dangerous and unreliable slow match and linstock,[1] were under trial in the fleets commanded by Admiral Hawke, but with results not altogether satisfactory. The locks supplied were lacking in mechanical precision, and the tubes—"very pernicious things" they were voted—were apt to fly out and wound the men. But that the unsatisfactory results obtained were not due to defects inherent in the new devices was soon clearly proved. Twenty years later an eminent gunnery officer, Sir Charles Douglas, by perseverance and an

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[1] In the margin of the copy of *The Art of Gunnery*, Thos. Smith, A.D. 1600, in the library of the R.U.S.I. in Whitehall, is the following note, written in legible seventeenth-century script: "Some make a device to discharge at a distance by a long string, fixed to a device like a cock for a gun with a flint or like a musket cock with a match."

In the same work are instructions as to firing in a wind, when the train of powder might be blown from the vent before the linstock could be applied. The gunner was to form a clay rampart, a sort of tinker's dam, on the metal of the piece on the windward side of the touch-hole.

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enthusiastic attention to mechanical detail, succeeded in making both locks and priming tubes a practical success, greatly enhancing by their aid the rate and effectiveness of fire of the great guns. Flint-locks of his own design he bought and fitted to the guns of his ship at his private expense. Flannel-bottomed cartridges, to replace the parchment-covered cartridges which had caused so much fouling, and goose-quill priming tubes, were provided by him, and to him is certainly due the credit for initiating the series of improvements in material which, trivial as they may seem in detail, yet in the aggregate had the effect of placing our gunnery at a relatively high level in the ensuing wars.

In addition to introducing improvements in methods of firing, Sir Charles Douglas did much to improve the efficiency of the truck carriages themselves. On his appointment to the *Duke* in 1779 he at once began to put his schemes in hand. To ease the recoil of the guns and to save their breechings he devised and fitted steel springs in some way to the latter; with such surprising good effect (he reported) that even with a restricted length of recoil no breeching, not even that of a 32-pounder weather gun double-shotted and fired over a slippery deck, was ever known to break. The recoil he further eased by loading the truck carriage with shot, which he slung on it, thereby augmenting the recoiling mass. He also proposed and tried another apparatus having the same effect: suspended weights, secured to the carriage by ropes reeved through fairleads, which on recoil the gun was made to lift. Which weights also had an effect in helping to run the gun out again which he calculated to be equal to that of two extra men on the tackles.

Perhaps the principal improvements due to Sir Charles Douglas were those which had as their object the firing of ships' guns on other bearings than right abeam. He realized the importance of possessing a large arc of training for his guns; and with this object he cleared away all possible obstructions on the gun decks of the *Duke*, removing and modifying knees, standards and pillars to allow his guns to be pointed a full four points before and abaft the beam: a degree of obliquity hitherto unknown in the navy for broadside armament. To traverse the carriages quickly to the required line of bearing he had eyebolts fitted in line between the guns for attachment to the tackles; and to shorten and control the recoil and thus allow of firing on an extreme bearing in a confined space, and also to improve the rate of fire, he shod the carriage-trucks with wedges designed to act as drags. "We now dare to fire our guns without running them out," he wrote to Lord Barham, "and so as to admit of the ports being shut, with certain impunity, even to the obliquity of three points before or abaft the beam. A wedge properly adapted is placed behind each truck, to make up for the reduction of space to recoil in, in firing to windward or in rolling weather. The gun first ascends the wedges by rotation, and when stopped, performs the remainder of her recoil as a sledge, so feebly as scarce to bring her breeching tight. The bottoms of the wedges, to augment their friction against the deck, are pinked, tarred, and rubbed with very rough sand or with coarse coal dust. This method has also, I hear, been adopted in the *Union*."

It was also adopted in the *Formidable*, in which ship Sir Charles fought as first captain to Admiral Rodney in the great fight which took place three years after the above was written. At the Battle of the Saints not a single goose-quill failed in the *Formidable*, nor did a gun require to be wormed so long as the flannel-bottomed cartridges held out. Of the hundred and twenty-six locks fitted in the *Duke*, only one failed; with this exception a single Kentish black flint served for each gun throughout the whole engagement. The oblique fire which our ships were enabled to employ so shattered the enemy by the unexpectedly rapid and concentrated fire poured into him, that victory was not left long in doubt; the toll of his killed and wounded was enormous. The *Duke*, it was reckoned, fired twice as many effective shots as would have been possible under the old system. The *Formidable* reported that two, and sometimes three, broadsides were fired at every passing Frenchman before he could bring a gun to bear in reply.[1] If all the ships of the fleet, it was said, had been able to use their guns as they were used in these two, very few of the enemy would have escaped. The advantage accruing to the British fleets from the improvements initiated and developed by Sir Charles Douglas and other captains of his time was palpable and undisputed. It is possible, however, that the total effect produced by all these developments in gunnery material, both

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[1] On this Sir John Laughton remarked: "The exercise, so born, continued as long as the old men-of-war and the old guns—'Ships passing on opposite tacks; three rounds of quick firing'" (*Barham Papers*, N.R. Soc.);

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in this action and in those of the following war, may have been insufficiently emphasized by historians ?

It is to the war which broke out with the United States of America in 1812 that we must turn to see the truck equipment working at its highest point of efficiency. By this time the advantage of gun-sights[1] for giving accuracy of aim has been seized by a few individual officers, and sights of various patterns have been fitted by enthusiasts. No official encouragement is given, however, to experiments with sights and scales and disparting devices, and once again it is left to private initiative and expense to make a further advance toward efficiency. Applications for gun-sights are rejected during the war on the ground that these novelties are "not according to the regulation of the Service."[2]

These are the circumstances in which a certain vessel in the royal navy exhibits such a superiority in gunnery over her contemporaries as to render her conspicuous at the time and, for several decades afterwards, the accepted model by which all such as care may measure themselves.

The *Shannon*, nominally a 38-gun frigate, carried twenty-eight 18-pounder long guns on her gun deck and fourteen carronades, 32-pounders, upon her quarter-deck and forecastle ; in addition to four long 9-pounders. She was commanded by Captain Philip Broke, whose fame as a gallant commander is secure for all time but whose attainments in the realm of gunnery have been less widely appreciated. Captain Broke, possessing a keen insight into the possibilities of the *Shannon's* armament, set himself to organize, from the first day of his ship's memorable commission, her crew and material for the day of battle. No other ship of the time was so highly organized. For all the guns sighting arrangements were

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[1] A form of sight for use with ordnance was described by Nathaniel Nye, in his *Art of Gunnery*, of 1674. It consisted of a lute-string and a movable bead, with a scale opposite the latter graduated in degrees and inches.

[2] In Lloyd and Hadcock's *Artillery* an extract from a letter written in 1801 by Lord Nelson relative to a proposal to use gun-sights at sea is given. The letter is unfavourable to the invention on the ground that, as ships should always be at such close quarters with their enemies that missing becomes impossible, such appliances would be superfluous. But in this connection the observation is made that, with the degree of accuracy of guns up to the nineteenth century a rough "line of metal" aim was probably all that was justified, in the matter of sighting. In other words, with one element of the system (the gun) so very inaccurate, nothing was to be gained by increasing the accuracy of another element (the sight) to a disproportionate degree. With increasing accuracy of the gun, increasing accuracy of sight was called for.

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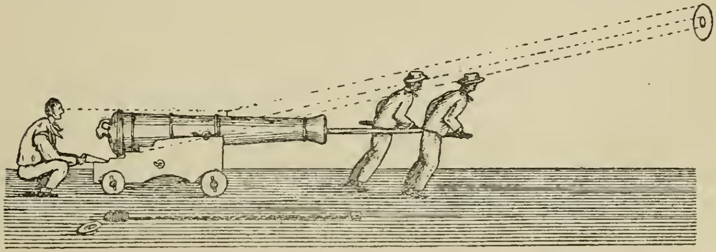
provided by him. To each gun-carriage side-scales of his own design were attached, marked with a scale of degrees and showing by means of a plumb-bob the actual heel of the ship; so that every gun could be laid by word of command at any desired angle of elevation. For giving all guns a correct bearing a circle was inscribed on the deck round every gun-port, degrees being represented by grooves cut in the planks and inlaid with white putty; by which device concentration of fire of a whole battery was rendered possible, the sheer of the ship being compensated for by cutting down the carriages and adjusting them with spirit-levels.

Beside these improvements applied to his material—steps which seem simple and obvious to-day, but which were far-sighted strides in 1812—the training of his personnel was a matter to which he paid unremitting attention. His gunners were carefully taught the mysteries of the dispart. Gun drill was made as realistic as possible and prizes were given out of his private purse for the winners of the various competitions. Often a beef cask, with a piece of canvas four feet square attached to it, was thrown overboard as a target, the ship being laid to some three hundred yards away from it. The captain's log was full of such entries as: "Seamen at target," "fixed and corrected nine-pounder sights," "mids at target and carronade," "swivels in maintop," "practised with musket," "exercised at the great guns," etc. etc. Systematic instruction in working the guns, fixing sights and reading scales, was carried out. And a method of practising gun-laying, which later came to be used in other ships from the example set by the *Shannon*, is illustrated by the accompanying sketch. A gun was taken onto the quarter-deck and secured; a spar was placed in its muzzle with a handspike lashed



METHOD OF GUN-EXERCISE IN H.M.S. "SHANNON"
From a pamphlet by Captain S. J. Pechell, R.N.

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across it; and then two men surged the gun by means of the handspike to imitate the rolling of the ship, while the captain of the gun, crouching behind it, looked along his line of sight for the target (a disc placed in the forepart of the ship) and threw in the quoin when he had taken aim.

With such a training did the captain of the *Shannon* prepare for the duel which fortune was to give him with the *Chesapeake*. The pick of the British fleets was to meet an American of average efficiency. Superiority of gunnery would have decided that famous action in favour of the former, it may safely be said, whatever the conditions in which it had been fought. At long range the deliberate and practised aim of the *Shannon's* 18-pounders would have overborne even the good individual shooting of an American crew. At night or in foggy weather or in a choppy sea the *Shannon's* arrangements for firing on a given bearing and at a given elevation would have given her the superiority. As it happened, the combined and correct fire at pistol range, of long gun and carronade—the long gun, double-shotted, searching the *Chesapeake's* decks with ball and grape, the carronade splintering her light fir-lined sides and spreading death and destruction among the crew—quickly secured a victory, and showed the naval world the value of high ideals in the technique of gunnery.

In the *Shannon* we have the high-water mark of smooth-bore gunnery. From that time onward, in spite of the precedents which her captain created, little appears to have been done in the way of extending his methods or of applying his improvements to the armament of the navy generally. As a consequence, relatively to the continuously improving defensive efficiency of the ships themselves there was an actual decline in the efficiency of the truck gun after the American War: a decline which culminated in Navarino. It was a time when "new-fangled notions," developments of method and material, were viewed with strong suspicion, even with resentment, by many of the most influential of naval officers. In the case of the truck gun, strong prejudices reacted against the general introduction of such refinements as had admittedly been found effective in exceptional cases, and the demand still went up for everything in connection with gunnery to be "coarsely simple." To many it doubtless seemed impolitic, to say the least, that anything should be done in the way of mechanical development which would have the effect of substituting pure

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skill for the physical force and endurance, in the exertion of which the British seaman so obviously excelled. The truck gun was merely the rough medium by which this physical superiority gained the desired end, and it had been proved well suited to the English genius. Nothing more was asked than a rough equality of weapons. The arguments used against such finesse in gunnery as that used by the commander of the *Shannon* were much the same, it may be imagined, as those used at an earlier date (and with better reason) to prohibit the use of the mechanically worked crossbow in favour of the simple longbow, strung by the athletic arm of the English archer.

That little was done for years to improve the truck gun equipment, is evident from a letter, written in 1825 by Captain S. J. Pechell and addressed to the Commander-in-Chief of the Mediterranean squadron, deploring the defective equipment of ships' guns. Even at this date, it appears, few of the guns were properly disparted, few had sights or scales fitted to them. No arrangements had yet been generally adapted for permitting horizontal, or what Captain Broke had called "blindfold" firing; or for laying all the guns together by word of command. The truck carriages still gave insufficient depression, preventing a ship from firing her weather guns at point-blank when listed more than four degrees. The quantity of powder and shot allowed for exercise only amounted to one shot for each captain of a gun in seven months. No instruction was given in sighting or fixing sights, no system of instruction in principles was followed. And once again, as in the seventeenth century, the disadvantage under which naval gunnery laboured by reason of the dual control in all matters pertaining to the ordnance was strongly felt. "It is singular," wrote Captain Pechell, "that the arming of a ship is the only part of her equipment which has not the superintendence of a Naval Officer. We have no sea Officer at the Ordnance to arrange and decide upon the proper equipment of Ships of War; or to carry into effect any improvement which experience might suggest. It is in this way that everything relating to the Ordnance on board a Man of War has remained nearly in the same state for the last thirty years; and is the only department (I mean the naval part of it) that has not profited by experience or encouraged Officers to communicate information. Much might be done now that the Marine Artillery are stationed at Portsmouth. At present it is not even generally known that

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a manual exercise exists. . . . If some such system were adopted, we should no longer consider the length of an action at its principal merit; the *Chesapeake* was beat in eleven minutes!"

Captain Pechell was a firm believer in the desirability of developing to its utmost British material. He had an enthusiastic belief, moreover, in the possibilities of his personnel; and stated his conviction that officers were only too anxious to be given the chance of instruction, prophesying an emulation among them and as great a desire to be distinguished "in gunnery as in Seamanship." His advocacy of a system of gunnery training bore fruit later in the establishment of the *Excellent* at Portsmouth. The scheme for the development of a corps of scientific naval officers, which had been foreshadowed by Sir Howard Douglas in his classic treatise on Naval Gunnery and which was formulated later in detail by Captain Pechell, was one of the reforms brought to maturity by Sir James Graham in the year 1832.

Through all the subsequent changes of armament up to the Crimean War, from solid shot to shell-fire, the truck carriage maintained its place of favour. In 1811 Colonel (afterwards Sir William) Congreve had published a treatise demonstrating the defects of the truck carriage and proposing in its place a far more scientific and ingenious form of mounting. It lacked, however, some of the characteristics which, as we have seen, gave value to the old truck carriage. Except where special conditions gave additional value to its rival, the truck carriage kept its place. In 1820 an iron carriage was tried officially, for 24-pounders, but gave unsatisfactory results. In 1829 the Marshall carriage was tried, offering important advantages over the standard pattern. Its main feature was a narrow fore-carriage separate from the recoiling rear portion, this fore-carriage being pivoted to a socket in the centre of the gun-port. But still the truck carriage survived the very favourable reports given on its latest rival.

As concentration of fire became developed new fittings such as directing bars, breast chocks and training racers made their appearance and were embodied in its design. As the power of guns and the energy requiring to be absorbed on recoil increased, the rear trucks disappeared and gave place, in the two-truck Marsilly carriage, to flat chocks which by the friction of their broad surfaces against the deck helped more

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than trucks to deaden the motion of the carriage. The quoin, perfected by the addition of a graduated scale marked to show the elevation corresponding to each of its positions, gave place at length to various mechanical forms of elevating gear. The elm body was replaced by iron plates bolted and riveted together. And then at length, with the continuous growth of gun-energy, the forces of recoil became so great that the ordinary carriage constrained by rope breechings could no longer cope with them. The friction of wood rear-chocks against the deck was replaced by the friction of vertical iron plates, attached to the carriage, against similar plates attached to a slide interposed between carriage and deck, and automatically compressed: the invention, it is said, of Admiral Sir Thomas Hardy. The truck carriage, as it had been known for centuries, had at last been left behind in the evolution of naval artillery.

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With the advent of modern gun mountings the old anomaly of the divided responsibility of War Office and Admiralty became unbearable; the necessity for a close adaptation of each gun to its ship-position, for careful co-ordination of the work of artillerist, engineer and shipbuilder, produced a crisis which had important effects on future naval administration. A single paragraph will suffice to show the position as it presented itself in the early 'sixties. "There were a thousand points of possible collision," wrote the biographer of Captain Cooper Key, the captain of the *Excellent*, "as it became more and more certain that gun carriages, instead of being loose movable structures capable of being used in any port, were henceforth to be fixed in the particular port which was adapted for them, with special pivoting bolts and deck racers—all part of the ship's structure. Where the War Office work began and the Controller's ended in these cases, no one knew, but the captain of the *Excellent* came in as one interfering between a married pair, and was misunderstood and condemned on both sides."

In 1866 the solution was found. Captain Cooper Key was appointed to the Admiralty as Director-General of Naval Ordnance.

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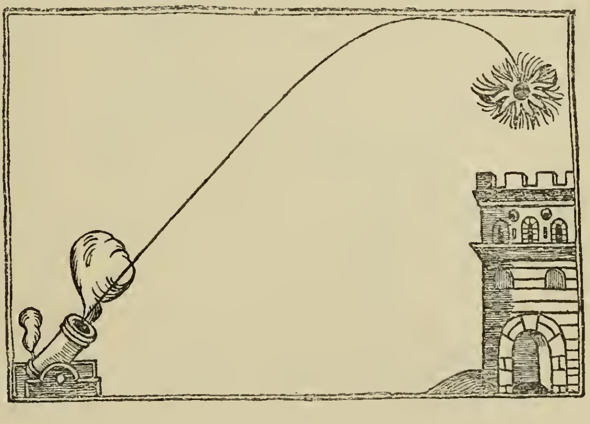
CHAPTER VII

THE SHELL GUN

THE chief function of land artillery in its earlier days was the destruction of material. The huge engines of the ancients were of value in effecting from a safe distance what the tortoise and the battering-ram could only do at close quarters: the breaching of walls and the battering-in of gates, doors and bulwarks. After the invention of gunpowder the use of artillery remained, we have seen, substantially the same. Apart from the moral effect on horse and man of the "monstrous roare of noise" when in defence, the offensive object of ordnance was almost entirely the breaching of the enemy's works. The guns were literally "pieces of battery," doing their slow work by the momentum of their large projectiles.

Thus considered, artillery was not a very effective instrument. And, just as in earlier times it had been sought to supplement mere impact by other effects—by the throwing into besieged fortresses of quicklime, for instance, "dead horses and other carrion,"—so, after the arrival of gunpowder, endeavour was made to substitute incendiarism or explosion for the relatively ineffective method of impact. The use of grenades, hand-thrown, was discovered. And then followed, as a matter of course, their adaptation to the mortars already in use for the projection of stones and other solid material. These mortars, as in the case of the early cannon, were at first made of an inconveniently large size; and, also as in the case of cannon, they came later to be cast of more moderate proportions to facilitate their transport and thus render them more serviceable for operations in the field. Artillery was now devoting its attention to the personnel. The result of this evolution was the howitzer, a weapon whose value to land armies was greatly enhanced by the discovery, by Marshal Vauban at the end of the seventeenth century, of the efficacy of the *ricochet.* Under this system the fuzed bomb or grenade, instead of being projected from a mortar set at a high elevation, to describe a lofty and almost parabolic trajectory, was discharged from a howitzer at a sufficiently low elevation to cause it to strike the ground some distance short of its objective, whence it proceeded, leaping and finally rolling along the ground till it came to its target, where it exploded.

So far shell fire had developed on land. In sea warfare the solid cannon ball remained the orthodox missile; the use of explosive or incendiary shells was deemed so dangerous a practice as to forbid its acceptance by the great maritime powers, save in exceptional cases, until the nineteenth century. Toward the end of the eighteenth century serious consideration was given, by France especially, to the possibilities of shell fire. Frenchmen felt restless and dissatisfied with the conditions in which they were waging war with England. Sea ordnance, which in the past had wrought so much by the destruction of personnel, was becoming increasingly impotent, not only against personnel but against ships themselves. Trafalgar came as a proof of this, when not a single ship was sunk by gunfire. Sea fighting was again resolving itself into a straightforward physical struggle between the guns' crews of the opposing fleets, in which struggle the victory went by attrition to the side which plied its guns with the greatest rapidity and perseverance. Élan, enthusiasm, science, the mental alertness of the individual, were bound to be overborne in such a case by superior endurance, physique, coolness, and sound workmanship. Both sides had a profound belief in the



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superiority of their personnel in hand-to-hand conflict. Where fighting was, as in the earliest days of the rival navies, " man to man, lance to lance, arrow to arrow, stone to stone," success depended entirely upon courage and physical strength; and in such cases, says Nicolas, the English were almost always victorious. If, stated a French writer, sea actions could be decided by hand-to-hand combat the arms of France would triumph. But sea fights were in fact almost solely a matter of artillery. If only the conditions of battle could be altered; if only the forces of incendiarism or explosion could be summoned to put the enemy ships-of-the-line in jeopardy, a short cut to victory might be found or, at any rate, the superiority of England in material might be seriously depreciated.

Some time was to elapse, however, before France was to see even the partial consummation of this fervent desire.

While the use of grenades, bombs, carcasses and other explosive and incendiary missiles had been recognized on land for centuries, an event occurred in the year 1788 which, coming to the ears of Europe, should have had considerable effect in turning the thoughts of artillerists to the possibilities of their use at sea. In that year, some sixty-five years before the action off Sinope, a Deptford shipwright who had risen to high service under the Russian government fitted out for his employers a flotilla of long-boats for an attack upon a Turkish squadron. These long-boats Sir Samuel Bentham—he was the ex-shipwright—armed with brass ordnance mounted on his favourite non-recoil system, and for them he requisitioned a large supply of shells, carcasses and solid shot. At the mouth of the Liman river in the Sea of Azov the Russians, with these insignificant war vessels, attacked a very superior force of Turkish ships, and gained a complete victory. The effect of the shells, fired at close range into the Turkish ships, was startling and impressive. Great holes were torn in the sides of the vessels, and fires were started which, in a favouring medium of dry timber and paint and pitch, rapidly spread and caused the squadron's destruction.

No evidence can be quoted, it must be admitted, to show that contemporary opinion realized how portentous was this sea action; no stress is laid on the event in histories relating to that time. Nor does another event which occurred at this period appear to have caused the notice it deserved: the firing, at the suggestion of a Captain Mercier, 35th Regiment, of mortar shells from the British long 24-pounders, from Gibraltar into the Spanish lines.[1] Nor was Lieutenant Shrapnel's contemporaneous invention,[2] of a shell containing case shot explodable by a small bursting charge, developed or the possible adaptation of its use for sea warfare fully appreciated. Or, if authority did discern the eventual effect of these innovations, a wholesome dread of their extension and development in naval warfare appears to have dictated a policy of calculated conservatism in respect of them, a suppression of all ideas and experiments which had in view any intensifying or improvement of our artillery methods. "So long as foreign powers did not innovate by improving their guns, by extending the use of carronades and, above all, by projecting shells horizontally from shipping; so long it was our interest not to set the example of any improvement in naval ordnance—the value of our immense material might otherwise be depreciated. Many of the defects which were known to exist, so long as

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[1] In Vol. IV of the *Proceedings of the Royal Artillery Institution*, in an article by General Lefroy, an order is quoted showing that trials were made of firing shells horizontally by the Royal Artillery in Canada in 1776. The author also shows that the trials made by the French in 1784–6 were brought to the notice of Lord Nelson.

In Vol. V is the following extract: "Experiments were made on Acton Common in 1760, to fire coehorn and royal shells from 12- and 24-pounders, in order to be applied to the sea service; but as the shells were found frequently to burst in the guns, it was thought too hazardous to introduce them on board ships of war."

[2] The first public demonstration was given by Lieut. Shrapnel, R.A., before the G.O.C., Gibraltar, in the year 1787.

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they were common to all navies, operated to the advantage of Great Britain."[1]

Apart from this consideration, however, it is remarkable how small a value was set by English opinion, even at a late date, upon explosive as compared with solid projectiles. The obvious disadvantages of hollow spherical shell—their smaller range, more devious flight and less penetrative power—were emphasized; their admittedly greater destructive effect (even taking into account the small bursting charges deemed suitable for use with them) was rated at a surprisingly low figure.

The French, on the other hand, showed great eagerness to explore the possibilities of shell fire in fighting ships. Addicted to science, they searched unceasingly throughout the revolutionary wars for some development of naval material which would neutralize the obvious and ever-increasing superiority of the British navy under existing conditions, even if it might not actually incline the balance of power in their favour. To this end they courted the use of incendiary projectiles. Our own authorities, partly from a lively apprehension of the danger believed to be inherent in their carriage and use in wooden ships and partly from a feeling of moral revulsion against the employment of what they genuinely believed to be an unfair and unchivalrous agency, limited the use of fuzed shells, carcasses and other fireworks as much as possible to small bomb vessels of special construction—and inferior morals. But in ships-of-the-line the use of such missiles was strongly deprecated by naval opinion, and even the use of hand-grenades in the tops was forbidden by some captains. Time justified this cautious attitude. The French suffered for the precipitancy with which they adopted inflammatory agents; fires and explosions were frequent in their fleets; the history of their navy in these wars—" la longue et funeste guerre de la Révolution "—is lit up from time to time with the conflagrations of their finest ships, prey to the improperly controlled chemical forces of their own adoption. One example alone need be cited: the *Orient* at the battle of the Nile. Even if the French flagship was not set on fire by their direct agency, small doubt exists that the spread of the fire which broke out in her was accelerated by the presence of the combustibles which, in common with most of the French ships, she carried. Throughout the wars fuzed shells, carcasses, stinkpots, port-

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[1] Simmons: *Effect of Heavy Ordnance*, 1837.

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fires, proved far more terrible to friend than foe. And the foe doubtless felt confirmed and fortified in his opinions that such substances were quite unsuitable for carriage in warships. As to the ethics of explosives even the French themselves seem to have been doubtful. For, shortly after the battle in Aboukir Bay, some of their officers accused an English captain of having been so "unfair" as to use shells: an audacious manœuvre on their part, for, on some of the shells in question being produced and the gunner questioned as to whence they came, "to the confusion of the accusers, he related that they were found on board the *Spartiate*, one of the ships captured on the first of August!"[1]

Continuous trials were carried out in France with shells fired from guns. In 1798, following a series of successful experiments, trials were prosecuted at Meudon by a special commission, who caused 24- and 36-pound shells to be fired at a target representing a ship-of-the-line, at ranges of 400 and 600 yards. The results were impressive, and the report rendered to Bonaparte such as to confirm his personal conviction in the value of shell fire. Less than a year later, we may note in passing, the Consul was himself the target of shell fire: being subjected, at the siege of Acre, to the unpleasant attentions of a 68-pounder carronade from the English fleet. In 1804, with the avowed object of keeping our cruisers at a distance, he had long howitzers cast and placed for the defence of Toulon and other ports. And hardly a year passed but some trial was made of horizontal fire of shells from guns and mortars.

Of the two great maritime powers, Britain had contributed more, perhaps, towards the building up by actual practice of the system of artillery which was shortly to come into vogue. Shell fire from mortars had been used with far more effect by her forces than by those of her great enemy. The invention of the carronade was in itself almost a solution; and, though it did not lead directly to the shell gun, yet it undoubtedly induced the weapon which most strongly resembled it: the medium ship-gun, as designed by Congreve and Blomefield, which was something between the carronade and the long gun, and which for a time was mounted in our two-decked ships for the purpose of preserving unity of calibre.

But the French, free from the bias against change of method

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[1] James: *Naval History.*

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and material which operated in this country, seized on the possibilities of existing elements, and combined them in such a way as to form a complete solution of the shell-fire problem. To General Paixhans, the eminent officer of artillery, the credit for this solution is undoubtedly due.

§

The experiments of M. Paixhans, carried out in order to confirm the theories on which his new system was founded, extended over several years and resulted in the publication of two books—the *Nouvelle Force Maritime et Artillerie*, 1822, and *Expériences faites sur une Arme Nouvelle*, 1825.

In these works[1] the author developed in detail the scheme of ship armament which was to win adoption, in the course of time, in the French navy ; whereby our own authorities were also gradually forced to abandon methods and standards of force by which the British navy had grown great. Two principles formed the basis of this scheme :—(1) unity of calibre, embodying the maximum simplification of means ; (2) shell fire, embodying the maximum augmentation of effect.

On these two principles M. Paixhans reared and elaborated in minutest detail the revolutionary system with which his name is associated. No new element or discovery was necessary for giving effect to his designs. Indeed he expressly disclaimed having introduced any novelty : " Nous n'avons donc rien inventé, rien innové, et presque rien changé ; nous avons seulement réuni des élémens épars, auxquels il suffisait de donner, avec un peu d'attention, la grandeur et les proportions convenables, pour atteindre le but important que nous étions proposé." It may be said, in fact, that unity of calibre had been an ideal sought for years before M. Paixhans' time ; while shell fire, the New Arm of 1822, was almost the logical consequence of Robins' discoveries in the principles of gunnery, extended as they were by the researches of Doctors Hutton and Gregory. In particular, mention is made by M. Paixhans himself of two of the results brought out by Dr. Hutton's experiments : one, that the length of the bore of a gun has but a small effect upon the range of its projectile, the range varying

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[1] A short review of both books is given in the *Papers on Naval Architecture*, edited by Morgan and Creuze, 1829.

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as the fifth root of the length; two, that the muzzle velocity may be considered to be independent of the weight of the gun.

As to the lack of novelty of shell fire on ship-board, M. Paixhans gives a significant extract from French naval annals. In 1690, it appears, a M. Deschiens had invented a means of firing bombs from long guns horizontally, instead of parabolically as from mortars. This secret was of great use to him; for, falling in with four English ships at sea, he so surprised them by this new invention that, fearful of being set on fire, they drew off and did not attempt to renew battle. This same French captain at a later date attacked two Dutch ships more than a match for him, and, by means of these horizontally fired bombs, sank one and disabled the other. But M. Deschiens died and his secret with him; though, as M. Paixhans remarks, this "secret" would have been easy to find if anyone had looked for it.

A whole chapter of *The Genuine Use and Effects of the Gunne*, written by Robert Anderson and published at London in 1674, concerns "the shooting of Granados out of Long Gunnes."

Briefly, the grand idea of M. Paixhans consisted in the establishment of a fleet of steam vessels armed with guns designed to project charged shells horizontally at considerable velocities. But as this consummation could only be attained by degrees, he proposed that in the meantime the existing French fleet should be re-armed in such a way as to give to each ship a maximum of force combined with unity of calibre. This part of his scheme was applicable to solid shot (*boulets massifs*) as well as to shell (*boulets creux*). But the former he considered too ineffectual for use in future sea engagements. Although they might be the most suitable projectiles for the destruction of land works, the breaching of ramparts and the battering of stone walls, yet hollow shot, filled with powder and other combustible material, were far better adapted to rend and set fire to defences of wood, impregnated with tar, and, in time of action, replete with every species of inflammable substance, and crowded with combatants. No, M. Paixhans hoped to make solid shots entirely obsolete, by adopting, in combination with small steam vessels, or, for the present, in combination with the existing fleets of sailing ships, an ordnance specially dedicated to shell fire, and to shell fire alone. By its means the enormous superiority of Great Britain would be effectually eliminated, or transferred into the

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hands of France; her material would be rendered suddenly obsolete, her maritime power would shrivel; and the power of France would be augmented to such a degree that the defeat of these islands might at last be encompassed.

Such was the amiable intention of M. Paixhans.

The arguments which he employed in favour of his revolutionary proposals are of sufficient interest and importance, perhaps, to merit consideration. The past histories of the two navies showed, he argued, that the introduction of improvement or of innovation into either navy was shortly afterwards followed by its introduction into the other; so that there was never any important change in the relative naval strength of the two nations. It followed, therefore, that the only means by which power could be wrested from the possessor of it, must be such a change of system as would render useless the existing means by which that power was sustained. How could this be accomplished? Foreign nations had always felt the innate strength of England, residing in the race of splendid seamen (a highly specialized profession) who formed so great a part of her population. France especially had felt her own weakness in not possessing a reserve, a nursery of seamen, such as England had. If only seamanship could be discounted——! M. Paixhans proceeded to show that the coming of the steamer was itself an event which would go a long way to discount a superiority in seamanship. The accursed English "devil boat,"[1] which had begun to spread its pall of smoke over all the northern waters, might be, in truth, a potent friend to France. Steam vessels required only a small and unskilled personnel to man them, instead of prime seamen. Steam vessels could always outstrip sailing ships, and thus could choose their own range and accept or decline battle as occasion required. Moreover, the effect of shell fire would be to upset completely the balance of power existing between big ships and little ships, as such. Instead of size being a measure of power, it would be a measure of vulnerability. The larger the ship the more she would be endangered. Costly three-deckers would cease to exist, and in their place small steam vessels, fast and heavily armed, easily manœuvred and perhaps encased in armour, would hold power. Thus the great obstacle to the acquirement by France of a large naval force—the necessity for a numerous and experienced personnel—would be easily

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[1] See Hugo's *Toilers of the Sea.*

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removed. In short, the adoption of his scheme would in any case be most favourable to France. Even if it were simultaneously adopted by Great Britain its adoption would at least ensure that in future the naval power of the two states would be in proportion to the strength of their *whole* population, instead of only that part of it familiarized with maritime affairs.

Considering first the conversion of the existing French navy, he examined and enlarged upon the various inefficiencies inherent in the usual disposition of ship armaments; in the manner in which the unit and the number of units of artillery force were selected for any individual design of ship; in the variety of the units, and in the lack of system observed in the various proportions between the gun, the charge and the projectile. He observed that the constant tendency of development, both in the French and in the English navy, was in the replacing of smaller by greater calibres, by which process the diversity of calibres was diminished and the effective force of the armament increased. Continuing this process, it appeared that the ideal armament would be reached, the maximum degree of force would be attained, when unity of calibre was achieved. When the calibre of the largest-sized cannon carried on the principal gun deck of ships-of-the-line was adopted as the sole calibre used, the maximum of force would be attained: the greatest possible destructive effect combined with the greatest possible simplification of means. These remarks applied equally to a solid shot and to a shell gun armament. If for some reason it were decided not to adopt shell fire, nevertheless it would be of advantage to re-arm the French sailing fleets on this principle, with guns of one calibre.

M. Paixhans proposed as the unit the French 36-pounder. He explained the advantages to be derived from arming existing ships-of-the-line with 36-pounders all of the same calibre but of different weights on the respective decks. The guns on different decks would take different charges and would therefore project the shot with different muzzle velocities. They would be disposed, the heaviest on the lower deck; a lighter type (reamed out from 24-pounders) on the main deck; still lighter guns on the upper deck, and 36-pounder carronades on the quarter-deck and forecastle would complete the armament.

The employment of solid shot was not favoured by him, however, and he claimed the results of various trials as showing the

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superior offensive value of shells, when compared with solid shot. Comparing a solid shot and a shell of the same external dimensions discharged with the same muzzle velocity, the former, he said, had only the advantage in superior range and penetrative power. The latter, while having a range greater than those at which sea actions were invariably fought and sufficient penetrative power to effect a lodgment in a ship's timbers, required less powder to propel it, a lighter and therefore more rapidly worked gun from which to discharge it, and it had a destructive effect enormously greater than that of the solid ball.

The complete proposal therefore involved the adoption of shell guns exclusively, new guns being made and old guns being reamed out as necessary to enable each ship to carry pieces of one calibre alone. The calibre proposed as unit was the long French 48-pounder. And, as an example of the way in which M. Paixhans would convert armaments, the case of the French 74-gun ship is here taken. This, with an existing armament of :—

28 36-pounders,
30 18-pounders,
14 6-pounders,
14 6-pounder carronades,

a total of 86 pieces throwing 2250 pounds of solid shot, he would convert into a ship armed with :—

28 48-pounders (reamed from 36-pounders),
30 48-pounders (of same weight as 18-pounders),
28 48-pounder carronades ;

eighty-six pieces throwing 3010 pounds of charged shell weighing 35 pounds each.

For the new shell gun he proposed a design of iron howitzer in which the distribution of metal was so adjusted as to give a sufficient factor of safety at every section, while at the same time allowing the total weight of the piece to be reduced to a minimum. This *canon-à-bombe* was to be mounted on a stable form of carriage, made without trucks but fitted with running-out rollers and directing bars to control the line of fire and the direction of recoil.

To those who were inclined to regard with feelings of horror this new use of explosive missiles, this progress in the art of destruction, the inventor put the question, whether experience had not proved that the perfection of arms had not had the effect of making warfare actually less bloody; whether it was not a fact worth consideration, that, while in days of old the destruction and loss of life in battles was enormous, the loss of English seamen by gunfire in the numerous combats of three long and bitter wars of recent times amounted to less than five thousand killed. And would not, therefore, further development of arms be a positive benefit to humanity?[1]

One other feature was put forward to complete this scheme of re-armament, the importance of which it is unnecessary to emphasize. M. Paixhans explored the possibility, by the sacrifice of a tier or more of guns, of rendering all classes of ships invulnerable by casing their sides with iron plates. Although rejected at the time, and as the result of trials which he himself carried out, this suggestion was destined to be carried into effect in startling fashion some thirty years later: with what consequences to naval architecture we shall presently see. In connection with the scheme of re-armament outlined by M. Paixhans in 1822 the suggestion was important in that there was implied in it an admission of one of the two weak features of the inventor's system. The shell gun would lose its superiority over the shot gun, and might indeed be reduced to absolute impotence if, in imitation of France, the enemy also cased his ships of war with iron. The solid shot gun would once again have the advantage; in fact, that very equilibrium of relative values which M. Paixhans was endeavouring to destroy would once more obtain between the navies of the two rival powers.

For this reason, presumably, and because the shell gun system contained, though in a less degree, the disability inherent in the carronade system—inferior ranging power, enabling a clever opponent armed with long solid shot guns to fight at a range which was too great for shell—the Paixhans scheme was not adopted in its entirety by the French government of the time. But the principle of unity of calibre was

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[1] "As for guns," wrote Fuller in his *Worthies of England*, comparing the relative merits of the inventions of printing and gunpowder, "it cannot be denied, that though most behold them as instruments of cruelty; partly, because subjecting valour to chance; partly, because guns give no quarter (which the sword sometimes doth); yet it will appear that, since their invention, Victory hath not stood so long a neuter, and hath been determined with the loss of fewer lives."

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acclaimed and approved almost immediately, applied to solid shot guns. The French 30-pounder was chosen as the unit. In 1829 guns of this calibre, made on several different models to suit the various decks and classes of ship, were mounted in their fleets.[1]

In the meantime M. Paixhans had made further progress toward perfecting the details of his shell gun system. A *canon-obusier* of 80 pounds was made to his design, a chambered howitzer of the same weight (about 72 hundredweight) as the French 36-pounder truck gun and of 22 centimetres calibre. This was designed to project a hollow shell of the same size as the French 80-pound solid shot, but weighing, when its cavity was filled with a charge of 4 pounds of powder, 56 pounds French (62½ pounds English). The shell gun itself was of a distinctive shape. The characteristics of short chase, large bore, a chamber, a small propelling charge, and a scientific elimination of all useless metal, resulted in a form of ordnance quite different from that of the long-accepted smooth-bore cannon. It was easily recognizable by its straight muzzle, smooth lines and the absence of the usual ornaments and reinforcing rings. When, eventually, the New Arm was adopted by other powers, their shell guns too, though independently evolved, were found to exhibit the same external features: the features of what came to be known universally as a "Paixhans gun."

The terrific effect of charged shell, fired from this form of gun with sufficient velocity to find a lodgment in a ship's timbers, was demonstrated at Brest in 1821 and 1824; in the latter trials the target being a frigate, the *Pacificateur*, moored in the roadstead. High range and accurate shooting were obtained. The incendiary effect of the shell was prodigious: so impressive, indeed, that in spite of a strong opinion in the French navy against further carriage of bombs in ships-of-the-line, the Commission recommended "that *canons-à-bombe* be adopted, even in ships-of-the-line, but in small numbers."

But though the principle of the shell gun was accepted by experts, public opinion was not yet ready for the change. The Commission had shown a sage circumspection in regard to the

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[1] At a later date this reduction in number of types of ordnance was extended to cover land artillery. In '62 the French brought down the number of different calibres to four: one for the field, one for the siege, and two (the 30- and 50-pounders) for the navy.

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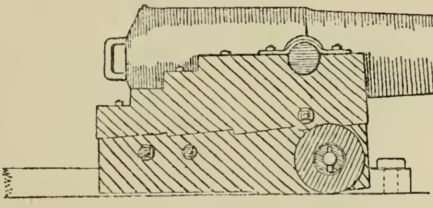
extent of the change proposed; but public opinion was not yet satisfied that the new arm was sufficiently safe. The scheme suffered a long postponement. In the meantime several further trials were held. The design of the piece was again modified; a larger chamber was arranged and a support was cast, at the commencement of the chase, for carrying a sight. Tests *à outrance* were made to find what maximum charge such a shell gun would safely stand; and at last, in 1837, the principle of shell fire was accepted by the government, the Paixhans gun being assigned a place in the prescribed armament of the fleets of France. To the impairment of the unity-of-calibre principle, lately achieved, shell guns of 22 centimetres were admitted as part-armament of ships the greater number of whose pieces were 30-pounders firing solid shot.



A PAIXHANS GUN

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In England the arguments in favour of a new and more scientific adjustment of ship armament had not until this date been clearly formulated. Of the tendency to a single calibre there certainly had been many demonstrations in the last decades of the eighteenth century: a tendency favoured by the replacement of the smaller long guns of the fleet by carronades. Sir Howard Douglas, in his *Naval Gunnery*, the first edition of which was published in 1820, had demonstrated the advantages of large calibre, the inefficiency of random broadsides, and the high importance of the deliberate aim of single guns. And in 1825, before the French began to remodel their ordnance, Colonel Munro, of the Royal Artillery, submitted his project to the naval authorities of arming our ships solely with 32-pounders, of different classes and weights to suit the various circumstances. But no radical revision of armament was made in the British navy until some years after

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the French had made the great stride of 1829, already described.

Unity of calibre, then, was no novel idea on the part of M. Paixhans. "No project," says Dahlgren—"no project has proved more attractive to naval men than that of having a uniform calibre throughout the entire fleet. It has been proposed from time to time without success, until adopted for the French navy in 1829.

"In the promptness with which the example was followed by England and the United States, may be recognized the general convictions of the profession in regard to the serious mischief inseparable from the chaos of calibres that prevailed, and the urgent necessity for some measure that would simplify the complex economy of naval ordnance.

"In a three-decker might be witnessed the extreme phase of the evil: long 32-pounders, 18-pounders, and carronades, requiring three sizes of shot and four classes of full charge, with as many reduces as caprice might suggest. All this variety of supply was to be distinguished and selected in the magazines and shot-lockers—circulated with perfect exactness in the confusion and obscurity of the lower passages, to a particular hatchway, then up to the deck where was placed the gun for which each charge or shot was designed: and this was to be accomplished, not with the composure, deliberation, and attention that the nature of the operation itself demanded, but amid all the excitement and hot haste of battle."[1]

The plans of M. Paixhans, in particular those for the adoption of shell fire on a large scale, were viewed with much misgiving in this country. But, as already noted, Great Britain moved very cautiously in the counter-measures which she took in view of the policy then under review in France. It is probable that the publication, in 1828, of a memoir by Captain F. A. Hastings, R.N., commanding the Greek steam vessel of war *Karteria*, had great effect in encouraging the authorities to countenance shell fire. From this memoir it appears that Captain Hastings was led, by arguments similar to those which influenced M. Paixhans, to consider the possibilities of discharging at an enemy something more devastating in effect than the solid sphere of iron in general use. His navy was inferior in numbers to possible rivals; he expressed the opinion that this inferiority might be nullified by the use of

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[1] Dahlgren: *Shells and Shell-Guns*, 1856.

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shell, but he "got well laughed at for his pains." Soon afterwards, however, he came across Paixhans' work. Acting on his ideas, he applied shell fire with great success in action, and at once became an enthusiastic advocate of the new arm. One great objection to its adoption he almost laid to rest: the increased danger due to the carriage of shells. He denied that there was any increased danger. On the contrary, he considered charged shells less dangerous than powder in cartridges, if properly packed. They were less dangerous, he argued, because their use involved bigger and therefore fewer guns than an ordinary ship would carry. Therefore there was less confusion in action, less jostling, more working spaces, and fewer cartridges and projectiles to be handled. In support of his opinion he could point to an entire absence of accidents during his commission in the *Karteria.*

In 1829 a general increase of calibre was obtained by the inexpensive expedient of boring out guns to their next larger calibre; in which operation the opportunity was taken to arrange for a reduced allowance of windage for the guns thus altered, and thus to secure a double gain, of increased calibre and improved discharge. Experiments were made with shell fire *à la Paixhans.* Tentative designs of shell gun were produced by the ordnance department, and guns of 8-inch, 10-inch and 12-inch calibre were made; one of which, an 8-inch, mounted in H.M.S. *Phœnix,* made very effective shooting at San Sebastian in the year '36 and gave thereby an advertisement to shell fire.

And then, in 1837, came the French decision to adopt a shell gun armament generally.

The result was a complete and corresponding reorganization of British ship armament.[1] By 1839, the authorities being at last convinced of the necessity of meeting the French innovations with similar innovations on our part, Colonel Munro's proposal of 1825 had been adopted, and various classes of ship were equipped with six different patterns of 32-pounder long gun. With these were associated, in small numbers, 8-inch shell guns of fifty-three and sixty-five hundredweight. Thus this country by a single move countered the two moves made

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[1] By this time Denmark, Holland, Russia and Sweden had all recognized the possibilities of shell guns, and had adopted them in greater or less degree. By this time, too, France actually possessed more steam war-vessels than we had ourselves.

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by France in '29 and '37 respectively, and denied to M. Paixhans, for a while at any rate, any considerable change in the relative strength of the two navies. As in the French navy, shell fire was only introduced as an auxiliary to the solid shot. Thus the great ideal of unity-of-calibre, so long sought and at last almost attained, was found incompatible with the other ideal, shell fire; and was therefore sacrificed. No doubt was felt, at this time, as to the necessity for two types of gun. The superior power of shells was dreaded, suspected, half-acknowledged; but the superior range and penetration of solid shot fired from long guns made the latter indispensable to ships' equipment. So shell and large-bore shot guns were mounted in ships side by side. Old guns and carronades were "scrapped" in large numbers to give place to the new ordnance; and an official announcement was made, in justification of the Admiralty policy, that "the changes were not made until they had been adopted by foreign powers."

§

Shell fire was at last accepted. The perils associated with the carriage of shells in wooden ships were found to have been exaggerated; experience soon confirmed that, if special precautions were taken, no danger was inherent in their use.

Even after its introduction into our fleets the shell gun was regarded by many as of doubtful value. For some years previously the opponents of shells had agitated the question of a compromise: viz. the use of hollow shot uncharged, instead of solid balls. And when M. Paixhans had published his great scheme they had held that more advantages would have been offered by it if he had stopped short at charging the shot with powder, and had advocated merely hollow shot, which by their larger size would give the advantages of heavier calibre. But the argument for hollow shot was finally demolished in 1837 by a writer whose views carried great influence. Incorrectly attributing to M. Paixhans himself the proposal to use them, Captain Simmons, R.A. proved clearly and conclusively their comparative uselessness. The adoption of hollow shot, he showed,[1] would be tantamount to a reversion to the use of stone or granite projectiles; it mattered little, for practical purposes, what the projectile be formed of, so that

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[1] Simmons: *Effects of Heavy Ordnance.*

its density be what was desired : whether hollow iron or solid granite. Except the Turks, who still guarded the Dardanelles with granite-firing cannon, all nations had abandoned granite in favour of the heaviest metals, and no one questioned the vast improvement thereby obtained, " except the inventors of the carronade and the promoters of this same system, improved by M. Paixhans." As a matter of fact the carronade was designed for the special circumstances in which hollow shot were not without value. And M. Paixhans, as we know, never intended to forego the use of a charge of powder in the cavity of his *boulet creux*. But the arguments of Simmons sufficed to kill the advocacy of hollow, uncharged shot.

Doubt was cast, too, on the capacity of the shell gun to project its shells to a sufficient range and with sufficient striking velocity in action. In the case of the first shell guns cast, a strict limitation had to be placed on the powder-charges which could safely be used ; and this involved a limitation of range, apart from the reduction due to the lower specific gravity of the projectile. Both French and English shell guns suffered in this respect. For this reason they had been deemed by the French specially suited for use in steam vessels, which could by their locomotive power attain the desired range. But, it was said, steam gives the power of avoiding, as well as of closing to action ; and steam, it was foreseen, was a giant which would one day haul even ships-of-the-line into position for battle. Might not future actions be fought at considerable ranges ? And for close-quarter work, could not our powerful long guns, double-shotted, be used with greater effect than shell guns ?

Then, again, the flight of shells was not nearly so certain as that of solid shot. The effects of eccentricity, which in the case of solid shot had always militated against accurate shooting, were in the case of shells considerably enhanced. The varying thickness of the shell, the lack of homogeneity of the metal, the presence of the protruding fuze, all tended to produce eccentricity and give a bias. The centre of gravity of a shell was seldom at its centre of figure ; and this eccentricity was the cause of deviations in flight, in range and direction, which made the trajectory of a shell not easily predictable. Savants and artillerists, both here and in other countries, discussed for years these deviations, and on the relationship between range and eccentricity numbers of trials

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were made and theories were propounded. Which is the more strange, seeing that Robins had placed on record an almost complete solution. Briefly, the effect of eccentricity may be explained as follows. Just as a stick held vertically by a thread receives, when struck at a point in it other than the centre of percussion, a tendency to motion not only of translation but also of rotation round that centre of percussion ; so a spherical shell whose centre of gravity lies away from its centre of figure receives, from the pressure of the powder gases acting at its centre of figure, a rotary motion about its centre of gravity in addition to a motion along the bore. If the centre of gravity lies below the centre of figure this rotary motion is in such a direction that, as the shell approaches the muzzle, points on its upper surface are moving towards the muzzle, points on the lower part are moving inwards. And this rotation, maintained during flight, has the effect—as was demonstrated by Robins with the musket ball—of giving the sphere a vertical deviation in a downward direction ; i.e. of reducing its range.

It follows, then, that an artificial increase of range could be obtained by placing the sphere with its centre of gravity *above* the centre of figure ? This is precisely what was done ; and by many a measured eccentricity was considered a desideratum, as giving a higher range than could be obtained without it. With such a system, however, the deviations still remained large and flights still more irregular. And the best opinion held that the most satisfactory solution lay in reducing the errors of flight as far as possible by the use of perfectly concentric shells. This ideal was difficult of attainment. Sir Howard Douglas has described at length experiments with shells the axis of whose eccentricity was found by floating them in mercury : experiments which revealed that not one shell in a hundred of those supplied was perfectly balanced. For this reason misgiving was felt as to the effectiveness of shell fire when carried out at considerable ranges against solid shot, and efforts were continuously made to correct all shell before issue.

Nor were the Americans inclined to view the shell gun with much favour ; remembering, doubtless, what they owed to their long and powerful guns when they were opposed to our light guns and carronades in the war of '12 and '13. America was more cautious even than this country. But in '41 the 8-inch shell gun appeared in American ships as an auxiliary to the long guns : four or so on each gun deck. And four years later the types of guns in their ships were limited to 8-inch shell guns, in combination with 32-pounder long guns of various patterns; in fact, their system of armament was assimilated to that of the French and British.

Whatever the relative value of shell and solid shot might be, experience showed that increase in size favoured the former. Though medium-sized solid shot might be more efficient than medium-sized shells, yet it was widely accepted that large solid shot would probably be of less value than large shell. Strong tendencies were at work, making for such increase in the size of artillery. It was in 1837 that a writer already quoted showed the direction in which the arguments of M. Paixhans were leading. Citing Sir Howard Douglas on the advantages of large calibre and the inefficiency of random broadsides, Captain Simmons put forward the argument that, if these statements were accepted, it followed that all ships of war should be armed with a few long guns of the maximum calibre and giving the maximum muzzle energy which the ship could safely carry, with other guns on other decks of the same calibre but of varying weight and range. "Instead of determining the armament of a ship from the length of her decks and crowding as many guns together as possible; determining the number by the extent of the battery, and subjecting their nature to their number—making, in fact, the weight and type of gun depend, not on the service demanded, but on the quotient arising from dividing the total deck-weight by the number, previously fixed on; it might be safer to place on board a few of the most powerful guns which her construction would admit, and then regulate the total number carried by their aggregate weight—making the *number* and not the *nature* of the guns depend on what is inevitably fixed: the capacity of the vessel?"

The English writer went farther than M. Paixhans had gone. His argument foreshadowed the evolution which was so largely influenced by the coming of the steam vessel, with its large paddle-wheels and small crew, and with its deck space necessitating the concentration of its armament into a few guns of the largest calibre; it foreshadowed the supersession of the broadside by the pivot gun, and the enormous expansion in the size of ordnance which took place after the Crimean War.

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The evolution of the shell gun was at this partial stage when the Crimean War broke out. In 1854 both types of projectiles were still struggling for ascendancy, though large shell guns were by this time acknowledged as the superior armament for steam vessels. Both friend and foe were now literally "stormed at by shot and shell"—of which the shell proved on the whole the more effective missile. No decisive superiority could be claimed, however, by one type over the other; and, as we shall see later in surveying the evolution of the ironclad, it was only gradually that the inherent superiority of the shell gun came to be recognized.

Soon after the close of the war a new step in the evolution of armament made its supremacy decisive. The rifled cannon at last materialized. The cylinder superseded the sphere. The increase in volume gained by the adoption of this form of projectile, and the enhanced range and striking velocity which it was possible to impart to it, set all doubts at rest as to the military value of the *Arme Nouvelle.*

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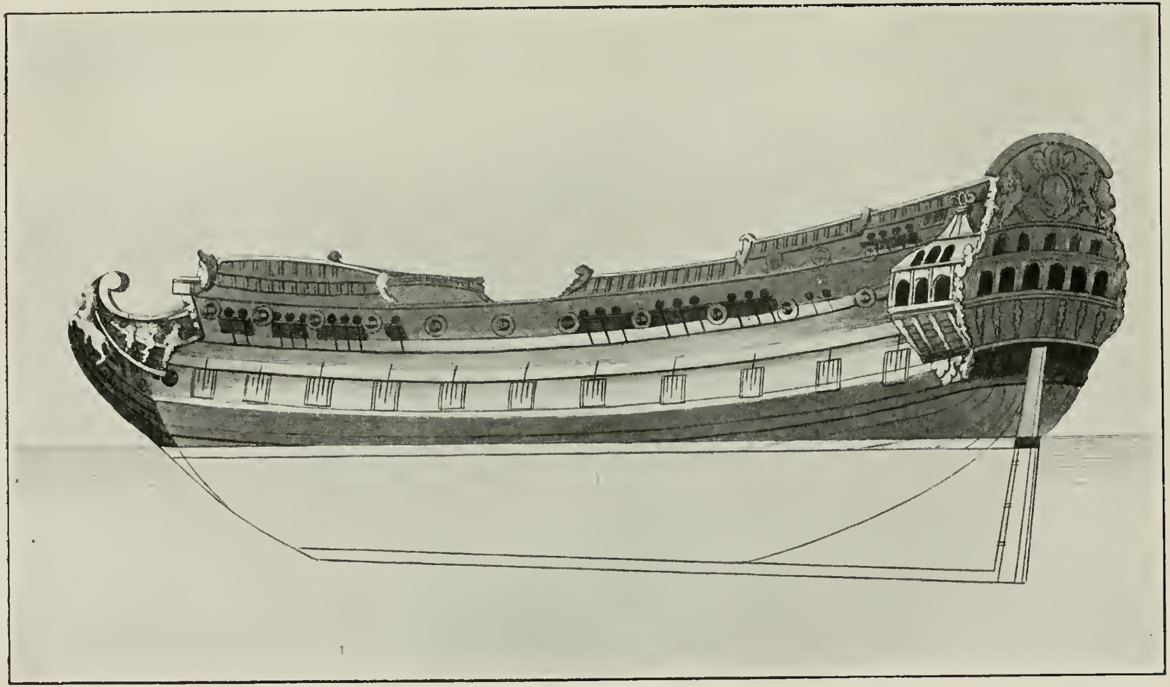

THE *SPEAKER*, A SECOND-RATE OF THE COMMONWEALTH

From Fincham's *Naval Architecture*

To face page 180

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CHAPTER VIII

THE RIFLED GUN

WHILE the evolution of smooth-bore ordnance owed little if anything to the prior development of small arms, the evolution of rifled ordnance which took place in the middle of the nineteenth century followed closely on that of rifling as applied to the musket. Experience with the rifled musket supplied the information necessary for the application of rifling on the larger scale. In tracing the development of rifled ordnance, therefore, the development of the rifled musket must first be considered : the two evolutions are historically linked together. In this chapter an endeavour is made to trace these two evolutions in their natural sequence, and to describe the circumstances in which each took place, the objects aimed at, the difficulties encountered and the results achieved. We shall see how the smooth-bore musket was replaced by the rifle firing a spherical ball ; how the spherical ball gave place, in the course of time, to an elongated bullet ; and how, when the elongated bullet had been evolved, the principle of the rifle was extended to field and to heavy ordnance. A complete survey of the whole process can be obtained only by stepping back, past the days of the primitive rifled fire-arm, to the age when the longbow was still " the surety, safeguard, and continual defence of this realm of England and an inestimable dread and terror to the enemies of the same."

§

The might of England, avouches the historian, stood upon archers. The prowess of the archer, the dreadful precision of the longbow, and the athletic arm by which it was strung, form the constant and animated theme of ancient British story. In battle and the chase, we are told, the power of the archers always prevailed, and the attainment of that power was an

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object of incessant anxiety, in all ranks of people, from their earliest infancy. The longbow was thus, as described in the above-quoted act of Henry VIII, a continual defence of the realm. Over all other countries England had this advantage, that against the exigencies of war she had, not only her race of splendid seamen, but armies of the most skilful archers in the world. In peace she was thus well prepared. Good use was made by legislation to maintain the skill and stimulate the ardour of the bowmen, and the statute book bears witness, reign after reign, to the importance attached to archery from its military aspect. At one time every man between the ages of fifteen and sixty had to possess a bow equal in length to his own height. Every township had to maintain its butts, each saint's day had its shooting competition. The churchyard yew gave its wood for staves, the geese on the green their best wing feathers; and a goose's head was the orthodox and inconspicuous target. No man under the age of twenty-four was allowed to shoot at any standing mark, and none over that age at any mark of eleven score yards or under. Restraint was laid on the exercise of sports which might interfere with archery, and when the mechanically strung crossbow was introduced its use was forbidden except under special conditions.[1] Honours and prizes were awarded the best marksmen. The range and accuracy achieved by them was without doubt prodigious. Much of their power lay in their strength of arm; but one of the chief secrets of their craft lay in the way in which they set their arrow-feathers at the requisite angle to give the arrows a spin which would ensure a long, a true and a steady flight.

With the advent of gunpowder the shooting competitions declined. An embargo was put on fire-arms; instead of being pressed to possess them the people were forbidden their use except under conditions. The military character became a separate order in society. Encouragement was no longer given to the individual to own and master the unwieldy fire-arm. The English peasant, enthusiasm evaporating as his skill declined, no longer gave the State the military value which his forefathers possessed. The clumsy mechanism of the English musket, the uncertainty of its action (especially in wet

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[1] The crossbow was looked upon as a weapon unworthy of a brave man; a prejudice which afterwards prevailed with respect to fire-arms (Hallam: *Middle Ages*).

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weather), its slow rate of fire, its gross inaccuracy, and its inability to penetrate armour under all conditions, were factors which kept fire-arms for long years in disfavour in this country.

Abroad, on the other hand, the development of fire-arms was actually encouraged and skill in their use patronised. The rivalry which already existed with bow and arrow was extended to the new medium, and in Sweden and Switzerland, Germany and France, shooting competitions continued in vogue and proficiency with musket and arquebus was honoured and substantially rewarded. In Switzerland and Southern Germany especially, shooting was very popular. The character of the people, their skill in making delicate mechanisms, the nature of the country, all tended to promote an interest in musketry which did not exist among our own people. As a result England has little to claim in the early stages of the development of portable fire-arms.

During the fourteenth and fifteenth centuries smooth-bore weapons firing spherical lead balls were the only kind known and used. But in the early part of the sixteenth century a development took place which was to prove of the first importance to fire-arms; which was to make the primitive weapon in the course of time "the most beautiful, and at the same time the most deadly instrument of warfare ever devised by the ingenuity of man." The value of rifling was discovered.

How, when, or where this discovery was first made, appears to have defied the researches of investigators. As to the manner in which the development took place and the effects which it was intended to produce by its means there is an assortment of evidence; and this is so various and so interesting as bearing on the action of the rifle and its evolution, that we reproduce it in some detail. On one point there appears to be small doubt: *The earliest rifling had no twist in it.*

"It seems to have been generally accepted by writers on the subject," says the author of *The Book of the Rifle*, "that the earliest barrels had straight grooves, the object of which was to give a space into which the fouling of previous shots might stow itself without obstructing the process of loading with a well-fitting ball, and that spiral grooving was merely an accidental variation of this, afterwards found to possess special advantages." Nevertheless, he himself inclines to the opinion that the straight groove was not necessarily a prior form of the spiral. The collections in museums contain examples of spiral

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grooving older than the oldest straight-grooved barrels. In any case, it is antecedently more probable, he considers, that the spiral grooving was not a variation of the straight groove, but that it was " a deliberate attempt to find a means of giving to the bullet the spiral spin which was well known as having a steadying effect on the javelin, or on the arrow or bolt discharged from the bow."[1]

But in this view he is in a minority. Whereas the invention of helical grooving is generally attributed to Augustin Kutter, a gunmaker of Nuremburg who died in A.D. 1630, straight grooving had been known since 1480, and is ascribed to one Gaspard Zöllner, a gunmaker of Vienna. " Smooth-bore guns," says Schmidt,[1] " had the disadvantage of fouling, and with the poor powder could only be recharged by leaving a comparatively large space between the ball and the barrel. This windage prejudiced straight shooting. To overcome this deficiency the practice was adopted of cutting grooves, more or less numerous, in the barrel, and in wrapping the ball in a rag greased with suet. In this way the windage was reduced, and as the greased rag cleaned the barrel, the weapon could be recharged for a large number of rounds. At first these grooves were made straight."

A theory propounded in a well-known treatise published in the year 1808, entitled *Scloppetaria*, was to the effect that grooving had its origin in the habit which the early huntsman had of gnawing or biting the balls before putting them into the piece, with a view to causing the wound inflicted by them to be rendered more severe. This habit gave rise to the idea that the barrel itself might be made to do the work of jagging or indenting the bullet. " These grooved or sulcated barrels appear to be of great antiquity, and are said to have existed in Russia long before their introduction among the civilized nations of the south."

According to Hans Busk, straight grooving was adopted for the reason given by Schmidt: i.e., purely for the purpose of facilitating loading, and for assisting to dislodge the products of combustion left in the bore. " No doubt the adoption of this plan was calculated to increase the efficiency and accuracy of the arm from the steadiness it imparted to the bullet in its passage through the barrel."

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[1] The Hon. T. F. Fremantle: *The Book of the Rifle.*

[2] *Le Développement des Armes à Feu*, 1870.

And that is a view which, it is suggested, might be expanded to give a motive or combination of motives which may well have operated to induce the early gunmakers to cut grooves in their musket-barrels. Thus: the variations in the flight of spherical lead balls fired from smooth-bore guns were chiefly due (though these causes were not clearly appreciated till a much later date) to the incalculable effect of windage and to the varying axis about which spin took place. If by any means windage could be reduced, and if the ball could be made to assume a central position in the bore and spin about a definite axis in its flight, a large increase in accuracy would be attained. Suppose, for instance, a single groove or gutter were filed along the barrel parallel with its axis. The effect surely would be, by creating a rush of powder-gases along this groove, to cause the ball, under the tangential impulse of the gases, to rotate always in the same plane as it passed through the bore. And thus by the cutting of this single groove a uniformity of flight of the ball would be attained which was unattainable without the groove. The same effect, in fact, was produced by Robins when he bent the musket barrel. He demonstrated that the result was to make the ball roll on a definite part of the barrel and thus to deviate during flight in a definite direction. He might have shewn, as another result of his experiment, that by giving the ball a uniform spin he had endowed it with a regularity of flight, or accuracy, many times greater than it before possessed.

Or suppose that, instead of one groove, two or more grooves were filed in the same way. While the above advantage derived from the single groove would be less fully obtained, another would result. By providing a space on each side into which fouling might spread, and into which the plastic metal of the ball might be intruded by the pressure of the ramrod, their presence would certainly allow of a tight-fitting ball being used. The loss in efficiency of discharge due to friction between ball and barrel would be more than compensated for by the annihilation of windage.[1]

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[1] In this aspect of the origin of the grooves there is a curious analogy between the rifle-barrel and the drill used in machine tools. In the primitive drill the shank is appreciably less in diameter than the hole cut by the drill, so that the drillings can easily work their way out of the hole. When, however, it was desired to make the shank almost of the same diameter as the hole, so as to form a guide, it was necessary to flute it with two grooves or more to allow the drillings to get away. In the course of its evolution these grooves became spiral.

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Suppose, however, that the grooves were augmented in number until they became a series of triangular serrations all round the interior of the barrel. The value of this formation might lie, not so much in the grooves, as in the ends or points of the serrations which supported the ball and held it in a central position on the true axis of the gun. In short, the prime idea of the gunmaker may have been, not so much the provision of grooves, as the provision of internal ribs for holding the ball truly in the musket.

Whatever the cause or motive which led to its adoption, the rifling of musket barrels became a common practice in the sixteenth century. Two significant quotations will suffice to show the period of the invention. The first is an edict issued by the Swiss Government in 1563 :

> "For the last few years the art of cutting grooves in the chambers of the guns has been introduced with the object of increasing the accuracy of fire ; the disadvantage resulting therefrom to the common marksmen has sown discord among them. In ordinary shooting matches marksmen are therefore forbidden under a penalty of £10 to provide themselves with rifled arms. Everyone is nevertheless permitted to rifle his military weapon and to compete with marksmen armed with similar weapons for special prizes."[1]

The second is a recipe from a book by Sir Hugh Plat, written in 1594.

> "How to make a pistol whose barrel is two feet in length to deliver a bullet point blank at eight score. A pistol of the aforesaid length and being of petronel bore, or a bore higher, having eight gutters somewhat deep in the inside of the barrel, and the bullet a thought bigger than the bore, and is rammed in at the first three or four inches at the least, and after driven down with the skowring-stick, will deliver his bullet at such distance."

So at some date not long after that at which straight grooving was put into common practice, the evolution of the rifle made a further advance by the introduction of spiral grooving. This gave all the advantages of the straight grooving, and in addition, spin in a definite plane to a definite

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[1] Quoted in *The Book of the Rifle* from Schmidt's *Armes à Feu Portatives*, 1889.

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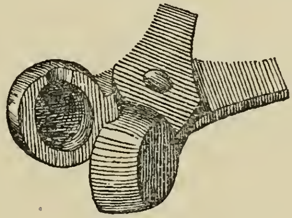
degree; so that it entirely superseded straight grooving in all countries where fire-arms were in common use. Experience amply confirmed the superiority of the twisted rifling. With the accession of accuracy the skill of the marksman naturally increased, enthusiasm grew, and the shooting competitions gained in popularity and importance. "Le goût de tir des armes rayées de précision est poussé jusqu'à la passion: passion qui excite l'amour-propre en ne laissant pas à la maladresse l'excuse si facile de l'imperfection inévitable de l'arme à canon lisse."[1]

Yet in spite of improvements the rifled musket remained unrecognized as a military weapon for another two hundred years. Its use was confined to sporting purposes; though far less in common use than the smooth-bore it became, for its increased accuracy, the favourite weapon of the deer-stalker and the chamois hunter. In England it was little known before the nineteenth century; and when, in 1746, Robins made his famous prophecy, the possibilities inherent in rifled fire-arms, even such as were then in existence, were unrealized by the people of this country.



BULLET MOULD

It is to be noted that it was only in increased accuracy of flight that the rifled gun had a superiority over the smooth-bore; no increase in ranging power was possessed by it. And yet this claim is constantly made by old writers, that, probably (as they say) owing to the fact that increased resistance of the ball to initial motion gave time for all the charge to be thoroughly ignited, the rifled gun carried further than the smooth-bore. As a fact, the contrary was true; other things being equal, the range of the rifle was actually less than that of the smooth-bore. The explanation of the paradox was given by Robins. "It is not surprising," he said, "that those

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[1] Delvigne: *Notice historique des armes rayées.*

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habituated to the use of rifled pieces gave way to prepossessions like these ; for they found that with them they could fire at a mark with tolerable success, though it were placed at three or four times the distance to which the ordinary pieces were supposed to reach : and therefore as they were ignorant of the true cause of this variation . . . it was not unnatural for them to imagine, that the superiority in the effect of rifled pieces was owing either to a more violent impulse at first, or to a more easy passage through the air." The true value of the spiral grooving resided, of course, in the spinning motion which it gave the ball. By making this spin uniform two variable factors determining the trajectory were thereby transformed into constants : first, the effect just mentioned, the influence of the varying resistance of the air on the parts of the ball which met it at different speeds, some parts moving forward relatively to its centre and some parts retreating ; secondly, the effect of eccentricity of mass and irregularity of exterior surface, which were both almost nullified by the rotation. The importance of this second effect may not at first sight be apparent. It must be remembered, however, that the balls used in those days were of the roughest description ; cast in hand moulds, "drawn" in cooling to such an extent that in a large proportion an actual cavity was left in their interior, which could be revealed only by cutting them open ; their burrs removed with pincers, their surface rough and broken, their shape distorted by the ramrod's blows.

The superiority of the rifle in accuracy was generally admitted ; and this advantage not only counterbalanced such deficiency in ranging power as may have accrued from the use of grooving, but actually led to a general but mistaken belief that the rifle carried farther than the smooth-bore. The reverse was the case. Moreover, it was not safe to use with a rifle the very large charges of powder which could be used with safety with a smooth-bore musket. On account of the resistance to motion of the ball which had been forced by ramrod, sometimes even by mallet, down the grooved barrel of the rifle, high chamber pressures resulted, and not infrequently the barrels burst. Hence in spite of the thicker metal of which they were generally made, rifles could only be used with moderate charges, and so could not compete on equal terms, in this respect, with the smooth-bores for superiority of range.

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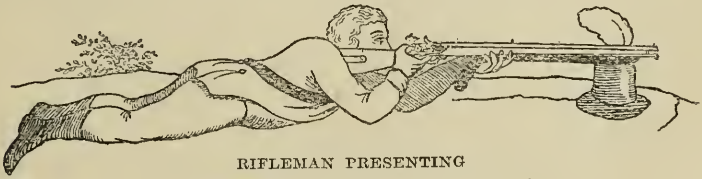
Toward the end of the eighteenth century events occurred which drew attention to the utility of the rifle for military purposes. In spite of its slow rate of fire—to load it carefully took from one and a half to two minutes—it showed itself to be a very effective weapon in the hands of French tirailleurs, Swiss, Austrian, and Tyrolese *Jägers*, Hottentots and American Indians. In the War of Independence the superior accuracy of their rifles, and their capacity for hitting at ranges beyond the 200 yards which were about the limit of the smooth-bore musket, placed the American backwoodsmen at such an advantage over the British troops that riflemen were recruited on the Continent and sent across the Atlantic to counter them. New military tactics came into vogue at this time, their inception influenced by the gradual improvement in fire-arms and artillery. Bodies of riflemen, "a light erratic force concealing itself with facility and forming an ambuscade at will," were formed in the continental armies to act in concert with the masses of infantry as skirmishers or sharp-shooters, their object being to surprise and demoralize the enemy by the accuracy of their long-range shooting. Rifles were now looked on, too, as the natural counterpart of the new flying or horse artillery, "which, from the rapidity of its motions, the execution of cannon-shot in all situations, appears to be the effects of little less than magic."[1]



RIFLEMAN PRESENTING
(From Ezekiel Baker's *Rifled Guns*, A.D. 1813.)

In 1800 a rifle corps was raised by the British government from the old 95th Regiment. As the result of competitive trials the rifle made by Ezekiel Baker, a gunmaker of Whitechapel, was adopted: taking spherical balls of twenty to the pound, and having a barrel 30 inches long, rifled with two grooves twisted one-quarter of a turn. This degree of twist was certainly much less than that used in French, German and American rifles, which as a rule had three-quarters or a whole turn in them; but Baker found that so great a twist

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[1] Beaufoy: *Scloppetaria*.

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caused stripping of the balls; so, as the accuracy of the lower twist was as great as that of the higher up to a range of 300 yards, and as it required a relatively smaller charge, gave smaller chamber pressures and caused less fouling of the barrel than its competitors, it was accepted. There was a strong opinion at the time in favour of the larger twist as universally used by the more expert foreign marksmen; and this opinion was justified by experience.[1] The quarter-turn twist might give sufficient accuracy at low ranges, but as the skill of the riflemen increased longer ranges were attempted; and then it was found that sufficient accuracy was unattainable with the approved weapon. Rifles having a larger twist were therefore made by rival gunmakers and, the results of shooting matches giving incontestable evidence of their superiority, a demand arose for their supply to the army riflemen. Accordingly in 1839 the Brunswick rifle was adopted for the British army. The new weapon had two deep grooves twisted a whole turn in the length of the barrel, in which grooves studs, cast on the ball and designed to prevent stripping, were made to engage.

This was the last stage of the evolution of the rifle firing a spherical ball. So long as the spherical ball was retained, spiral grooving offered relatively small advantages over straight grooving; straight grooving offered small advantages over the best smooth-bore muskets. The tedious loading of these rifles and the inefficiency of the system by which windage was eliminated by the force of ramming, are sufficiently set forth by the various writers on early fire-arms; and there is small wonder that the value of rifles as military weapons was seriously questioned by the highest professional opinion of the time. The charge of powder had to be carefully varied according to the state of the weather and the foulness of the piece. Care had to be taken that all the grains of the charge poured into it went to the breech end and did not stick to the sides of the barrel. Patches of leather or fustian were carried, in which the ball was wrapped on loading, to absorb windage, lubricate the rifling, and prevent the "leading" of the barrel and the

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[1] A paragraph in Beaufoy's *Scloppetaria* (1808) shows the complete misconception under which its author laboured as to the function of rifling. Just as the air turns a windmill or a shuttlecock (he says), so, after an indented ball quits its rifled barrel the air, forced spirally along its grooves, will cause the ball to turn. In short, he regarded the spiral grooves of a barrel as being of no further utility, with respect to the generating of the rotary motion, than as an easy way of giving the ball the requisite indentations.

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wear which would ensue if a naked ball were used. "Place the ball," says Ezekiel Baker, "upon the greased patch with the neck or castable, where it is cut off from the moulds, downwards, as generally there is a small hole or cavity in it, which would gather the air in its flight." The ball, a good tight fit, had to be rammed, in its surrounding patch, right down to the powder: for, if not rammed properly home, an air-space would be left and the barrel would perhaps burst on discharge; at the least, would give an inaccurate flight to the ball. If the barrel were at all worn, double or treble patches were necessary. To loosen the filth which collected in the barrel, and which sometimes prevented the ball from being either rammed or withdrawn, water had to be poured down; not infrequently urine was used.

All sizes and shapes of groove were given to the early rifle, and their number depended largely upon caprice or superstition. Seven, for instance, was a number frequently chosen on account of its mystic properties; in *Scloppetaria* an attempt is made to prove that an odd number has an advantage over an even. So, also, various degrees of twist were used. But in respect of this the evolution followed a definite course. The pitch of the twist necessarily bore a certain relationship to muzzle velocity. With the earliest rifles a fairly rapid twist was given, being rendered possible by the small muzzle velocities employed, and indeed being rendered necessary to ensure stability to the flight of the ball. Then, with the endeavours made, at the end of the eighteenth century, to use higher charges and thereby to extend their range, higher muzzle velocities came into use, and the danger of stripping was then only prevented by the use of low twists. Special devices enabled a return to be made, in the Brunswick and other patterns, to the more rapid twists originally used.

Whatever devices were adopted to prevent stripping, however perfect the design and material of the equipment employed, two factors stood in the way of any further advance in the evolution of the rifle firing the spherical ball. First, the unsuitability of the sphere itself for projection through a resisting medium, by reason of the large surface which it offered to the air's resistance and the relatively small mass by means of which it could maintain its flight. Second, the gyroscopic action of the spinning sphere, which limited its effective range in a manner which was probably unrealized

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until after it had been completely superseded. The sphere, unlike the elongated bullet, which always keeps its axis approximately tangential to its trajectory, maintained throughout flight its spin on its original axis. This did not matter much when ranges were short and trajectories flat; but as greater ranges and loftier trajectories came into use the effect on accuracy of aim became very important. During its descent through the latter part of the trajectory the rifle ball rotated in a plane no longer normal to its direction of flight; "it tended more and more to roll upon the air, and deviated considerably."[1]

§

The old Brown Bess, the ¾-inch smooth-bore musket which our armies carried at Waterloo, in the Peninsula, and even at the Crimea, differed in no great respect from the muskets borne by British troops at Ramillies, whose inefficiency was such that it was seriously questioned whether, without the invention of the bayonet, they would have permanently superseded the crossbow of the Middle Ages. The inefficiency of Brown Bess was indeed remarkable. Its standard of accuracy was so low that a trained marksman could only depend on putting one shot in twenty into an eighteen-foot square target at two hundred yards, at which range it was supposed to be effective. Its windage was so great that bullets flew wild from the muzzle; and it is not very surprising that, armed with such a weapon, our infantry should often have been impelled "to resort to the strong and certain thrust of the bayonet, rather than rely for their safety on the chance performances of the clumsy and capricious Brown Bess." Writers on fire-arms are able to give dozens of tragic and laughable instances of its erratic shooting. In the Kaffir war, for example, our troops had to expend no fewer than eighty thousand rounds to kill or cripple some twenty-five naked savages. After Waterloo a musket was sent down to Woolwich, to ascertain whether its ball would penetrate a French cuirass at two hundred yards' range. The cuirass was mounted on a pole, the musket aligned and held firmly in a vice; but it was found impossible to secure a hit until, at last, a random shot fired by one of the officers present did take effect! Nevertheless, Brown Bess remained in favour for a number of years after Waterloo. It had a flat and raking

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[1] Fremantle: *The Book of the Rifle.*

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trajectory, owing to the very high muzzle velocity imparted to it by the large charge of powder used; from its great windage it loaded easily; and, although rather too heavy for long marches, it was strong enough to bear any amount of hard usage.[1]

So long as the rifle used a spherical ball it could not claim to rival Brown Bess for general service. As soon as the elongated projectile was developed the supersession of the smooth-bore was a matter of time alone. It is strange, however, in view of the enthusiasm of the Victorian rifleman and the ease with which the fire-arm lent itself to novel experiments, that the evolution of the elongated projectile covered so long a period as it did.

Apart from the fact that cylindrical bars and shot had often been fired from ordnance, it was known that Benjamin Robins himself had tried the experiment of firing egg-shaped projectiles from a rifle with a certain amount of success. The inefficiency of the loose sphere, in the case of the smooth-bore, and of the tightly rammed sphere, in the case of the rifle, were both recognized in the early days of the century. And, while no solution could be found, the problem was generally agreed to be: how to drop the projectile loosely down the barrel, and tighten it so as to absorb the windage when already there.

Two or three English inventors made proposals. In 1823 a Captain Norton, of the 34th Regiment, submitted an elongated projectile with a base hollowed out in such a way as to expand automatically when the pressure of the powder-gas came on it, and thus seal the bore. The idea came to him from an examination of the arrow used by the natives of Southern India with their blow-tube: an examination which revealed that the base of the arrow was formed of elastic lotus-pith, which by its expansion against the cylindrical surface of the tube prevented the escape of air past it. In 1836 Mr. Greener submitted a pointed bullet having a cylindrical cavity in its base in which a conical plug was fixed, expanding the base by a wedging action when under the pressure of the powder gases.[2] Had either of these ideas been considered with the attention which it deserved, the development of the rifle in this country

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[1] Captain A. Walker: *The Rifle*, 1864.

[2] At the beginning of the century Ezekiel Baker had noted that "a wadding in the shape of an acorn cup placed on the powder, and the ball put on the top of the cup, will expand the cup and fill the bore—and of course the windage will be much diminished."

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might have been more rapid than it was. "By blindly rejecting both of these inventions the authorities deprived England of the honour of having initiated the greatest improvement in small arms."

It was in France that the elongated projectile waged an eventually successful struggle against the spherical ball, its ancient rival. The French, troubled by the superiority of their Arab enemies in shooting at long range, founded a School of Musketry at Vincennes. In 1828 Captain Delvigne, a distinguished staff officer of that school, established the two main principles on which all succeeding inventors were obliged to rely: one, that in muzzle-loading rifles the projectile must slip down the barrel with a certain windage, so as to admit of easy loading; two, that only elongated projectiles were suited to modern rifles.

Before coming to these two conclusions Delvigne had made important efforts to render the spherical ball as efficient as possible. He had, in particular, proposed to make that part of the barrel near the breech which formed the powder-chamber of slightly smaller diameter than the rest of the barrel; so that a spherical ball, rammed down on it, became indented against its ledge and flattened sufficiently to fill the rifling grooves. By this device quick loading was obtained and the accuracy of aim, it was found, was doubled. Certain practical disadvantages, however, were associated with it: the chamber fouled rapidly, and the ball was frequently distorted and jagged by over-ramming. So in '33 the Delvigne system, as it was called, was modified by the wrapping of the ball in a greased patch and the attaching of the patch to a "sabot" or wad of wood which was interposed between the ball and the shoulders of the powder-chamber. Rifles thus loaded did good work in Algeria in '38.

In the meantime Delvigne, admittedly inspired by the writings of Robins, was urging on the authorities the superiority of the elongated ball. He was insistent on the advantages which would accrue from augmenting the mass of the projectile while at the same time making it present to the air during flight its smallest surface. The shape he proposed was that of the present-day rifle bullet, considerably shortened: a bullet with a flat base, cylindrical sides and ogival head, somewhat resembling the form which had been proposed by Sir Isaac Newton as a "solid of least resistance." After a succession of

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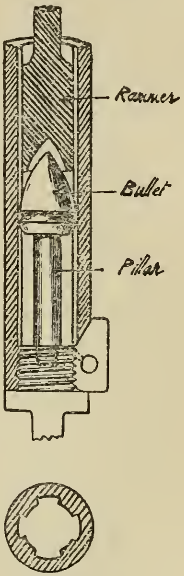
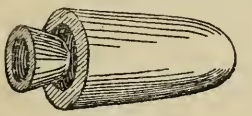
disappointments and refusals, the inventor had the satisfaction of seeing his bullet accepted. Its advantages over the spherical ball had been made manifest on the proving-ground. It was accepted in combination with the *carabine à tige*, a rifle invented by a Colonel Thouvenin, in which the Delvigne shouldered chamber was replaced by a small central pillar or anvil, projecting from the breech-end of the bore, against which the bullet was rammed. The powder, when poured into the barrel, collected in the annular space around the pillar. By this arrangement the necessity for the sabot was obviated and the charge of powder, protected by the pillar, was not in danger of being crushed or mealed. In '46 the new bullet proved its high accuracy and ranging power on active service in Algeria. But the pillar was found liable to bend and distort; and the difficulty in keeping the space round it free from fouling proved to be another of its inherent disadvantages.



"CARABINE À TIGE"

And then in '49 the Minié compound bullet, self-expanding, of the same shape as the Delvigne and utilizing the same principle of an expansive bore as that embodied in Greener's bullet, was produced. The full value of the rifle was at last obtained. By virtue of the elongated bullet the mass of the projectile could be increased to a large extent without any increase in the cross-sectional area exposed to air resistance. With such a projectile, impelled by a charge whose combustive effect could be accurately gauged owing to the absence of all windage losses, great speed and accuracy were possible. As to power, the only limit imposed was the strength of the barrel and the capacity of the marksman to withstand the reactionary blow due to the projectile's momentum. But now, not only was rifling advantageous: with the elongated bullet rifling was an absolute necessity. "Rotation," it was said, "is the soul of the bullet." Rotation was necessary to impart stability, and to keep the projectile, by virtue of the initial



MINIÉ BULLET

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spin acquired, true in its flight throughout the whole trajectory.

In England, where the two-grooved Brunswick still marked the limit of development, the discovery of the Minié weapon and its powers occasioned misgiving and surprise.[1] In '51 some Minié rifles were purchased and issued, as a temporary expedient, to our army. And, interest in the question now becoming general,[2] it was resolved to take under government control the future manufacture of military small arms. A commission of officers visited America for the purpose of inspecting the ingenious tools and appliances known to be employed there in the manufacture of rifles; and the features of the various European and American weapons were seriously studied. A government factory was established at Enfield, and with the products of this factory certain of our regiments were armed for service when the Crimean War broke out. The Enfield rifle, as it was called, combined the best features of the Minié with those of other types. It had a three-grooved barrel with a half-turn twist in its length of 39 inches. It was ·577 inch in the bore, and fired a bullet whose recessed base was filled with a boxwood instead of an iron cup or plug.

The nation soon obtained value from the new development. The efficiency of the Enfield rifle at the Alma and at Inkerman was attested by the correspondent of *The Times*, who reported that "it smote the enemy like a destroying angel." Three years later the Indian Mutiny afforded a still more conclusive proof of the value of this weapon. Though, from the greased cartridges which were used, it served as one of the pretexts for the mutiny, it proved in the sequel a powerful military instrument, and demonstrated both to friend and foe its superiority over the smooth-bore musket with which the rebels

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[1] Mention must be made of an important prior development of the elongated bullet which had been carried out by General Jacob in India, quite independently of French research. General Jacob conducted, in an altogether scientific manner, experiments the successful results of which were communicated by him to the home government on more than one occasion. The importance of his discoveries remained unrecognized, and the value of his improvements was lost to this country.

[2] In military circles the possibilities of the invasion of this country had for some time been under discussion, in view of the increasingly aggressive temper of the French. Interest in national defence became general with the warning letter of the Duke of Wellington which appeared in *The Times* on the 9th January, 1847. In '51 was held the Great Exhibition, and for a time opinion was less agitated. The Exhibition, it was thought and hoped by numbers of people, would inaugurate the millennium.

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were armed. In fact, with the adoption of the Enfield rifle, England found herself in advance even of France; the French, partly perhaps from motives of economy, partly from a desire for symmetry, had retained in their Minié rifle the same calibre as that of their old smooth-bore: indeed, the greater part of the French army rifles were merely converted smooth-bores. In the Enfield a wise reduction of calibre had been made; whereby, while the weight of the rifle was reduced, its strength and the size of the permissible charges, and therefore the range and penetrating power of the projectile were all considerably augmented.

Having once gained the lead, England now took another rapid move forward in the development of the rifle. Though the new standards set by the Enfield were high, expert opinion aimed at something still higher; the Enfield gave variations in range and direction which could not be accounted for by errors in manufacture, nor did the range and penetrative power of the bullet come up to expectations. In these circumstances the government sought the advice of a man whose name was destined to loom large in the story of the subsequent development of ordnance: Mr. Whitworth. Mr. Whitworth was described as the greatest mechanical genius in Europe at that time. Certain it is that, although in the realm of ordnance his name may have been overshadowed to a certain extent by that of his great rival, yet on the broad ground of the influence his inventions exerted on the progress of mechanical science generally, his fame now grows with time. He it was who first swept away the medieval conception of measurement which hitherto had obtained in factories and workshops, and introduced a scientific precision into the manufacture of machines and mechanisms. The true plane surface, as we know it to-day, was unattained before his time; and his contemporaries marvelled at plates of metal prepared by him of so true a surface that, by their mere adhesion, one could be lifted by means of the other. The micrometer was a similar revelation. Men whose minimum of size had hitherto been the thickness of a chalk-line or a simple fraction of an inch, were taught by him to measure the inch to its ten-thousandth part, and even to gauge the expansion of a rod caused by the warmth imparted by the contact of a finger.

Such was the man who made modern artillery possible. To Mr. Whitworth, who knew nothing himself of guns or of

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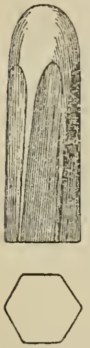
gun-making, the government went for advice on the shortcomings of the Enfield rifle. At their request he promptly began an analytical inquiry into the principles underlying the action of rifles and the flight of their projectiles, resolved and urged to discover the secret of the very partial success so far attained. The results of this inquiry, published in '57, had a great influence on the future of rifled fire-arms and ordnance. Briefly, he discovered that the amount of twist hitherto given to the rifling of gun-barrels had been wholly insufficient to maintain the projectile in its true direction during flight; the weight of the projectile, relatively to its diameter, had been insufficient to give it the necessary momentum to sustain its velocity against the resistance of the air; lastly, the accuracy of manufacture of rifles had been inadequate to the ensuring of a good fit of the bullet in the bore. To prove the truth of these assertions a Whitworth rifle was produced by him which gave better results than any other hitherto made. The form of rifling which the inventor adopted was considered objectionable, and the rifle itself, with its polygonal barrel, was not approved by the authorities; but, instead, the valuable results of Whitworth's experiments were embodied in the Enfield, to its obvious improvement.



WHITWORTH RIFLE BULLET

The muzzle-loading rifle had now reached the limit of its development. The rifle was the accepted arm of all the great military powers. But in the case of one of them, Prussia, the principle of breech-loading was already in favour, and it was not long before the progress in mechanical science enabled this principle to prove its superiority over the ancient principle of muzzle-loading. Although in the Prussian needle-gun great difficulties were encountered; although in service its reputation suffered from such defects as the rusting of the needles which pierced the percussion cartridges, the failure of springs, the escape of gases at the breech; yet it was recognized that none of these defects was necessarily inherent in the breech-loading system, and its merits were admitted. With the breech-loader a greater rapidity of fire was always attainable, there was less difficulty in preventing fouling, and, above all, there was the certainty that the powder-charge would be fired to its last effective grain.

In 1864 breech-loading rifles were recommended for the

British army, and shortly afterwards they were introduced in the form of converted Enfields.

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We have seen how the development of field ordnance stimulated the development of the rifle. In turn the attainment of superior range and accuracy by rifled small arms led directly to a corresponding development of field ordnance, designed to recover the loss of its ascendancy. In France, where the logical consequences of the progress in small arms were officially noted on several occasions, Napoleon III, himself an authority on artillery, took the initiative to restore field ordnance to its former relative position. It was in the Crimean War that the enhanced effects of rifle regiments were first seriously felt. Convinced by the protraction of the operations before Sebastopol of the inadequacy of smooth-bore guns, the Emperor caused bronze pieces to be rifled, and these, being sent to Algeria on active service, gave conclusive proof of their increased efficiency. On report of which, all the bronze field pieces in the French army were rifled in accordance with the plans which a M. Treuille de Beaulieu had submitted in 1842, viz. with six shallow rounded grooves in which engaged zinc studs carried on two bands formed on the cylindrical projectile. The gain in power obtained by rifling ordnance was greater even than that obtained from rifling as applied to small arms. For not only did rifling confer the advantages of a more massive projectile more suitably shaped for flight through a resisting medium, but it allowed a large increase in the number of balls which could be discharged in the form of case or shrapnel, and a large increase in the powder-charge which could be carried inside a common shell. An advantage was also gained in respect of that important detail, the fusee or fuze ; the rotation of the projectile about a definite axis made it possible to use fuses whose action depended on one definite part of the projectile coming first in contact with the ground or target.[1] All these advantages were found to be present in the French field pieces when rifled on the above

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[1] This advantage of the rifled gun had been fully appreciated by Captain Norton. As early as 1832 he had conducted trials with one-pounder rifled cannon, to confirm his belief that the projectile would maintain its rotation during flight and hit the target point-first (*Journal of R.U.S.I.*, 1837).

plan. "And thus," said an English writer, "at slight expense but too late for use in the Crimean War, France was put in possession of an artillery which, consuming its usual powder and using either round ball or elongated projectiles, proved of immense value in the war against Austria in 1856, when, at Magenta and at Solferino, the case shot from their rifled field-pieces ploughed through the distant masses of opposing infantry and decimated the cavalry as they formed for the attack."[1]

In England an almost simultaneous development took place, but on entirely different lines. Let us tell it in the words of Sir Emerson Tennant:

"The fate of the battle of Inkerman in November, 1854, was decided by two eighteen-pounder guns which by almost superhuman efforts were got up late into the field, and these, by their superior range, were effectual in silencing the Russian fire. Mr. William Armstrong was amongst those who perceived that another such emergency could only be met by imparting to field-guns the accuracy and range of the rifle; and that the impediment of weight must be removed by substituting forged instead of cast-iron guns. With his earliest design for the realization of this conception, he waited on the Secretary for War in December, 1854, to propose the enlargement of the rifle musket to the standard of a field gun, and to substitute elongated projectiles of lead instead of balls of cast iron. Encouraged by the Duke of Newcastle, he put together his first wrought-iron gun in the spring of 1855."[2]

The manufacture of this gun marked a new era in ordnance. Repeated trials followed its completion; with the result that in 1858 the Armstrong gun was officially adopted for service in the field,—the epoch-making Armstrong gun: a tube made of wrought-iron bar coiled in a closed helix and welded at a white heat into a solid mass; turned to a true cylinder and reinforced by outer tubes shrunk on to it; rifled with a large number of grooves; breech-loading, a powerful screw holding a sliding vent-piece tightly against the face of the breech; firing a lead-coated projectile in whose plastic covering the rifling engaged as soon as it started its passage through the bore; and mounted on a field-carriage in such a way that the gun

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[1] Commander R. A. E. Scott, R.N.: *Journal of R.U.S.I.*, Vol. VI, 1862.

[2] Tennant: *The Story of the Guns.* This book gives in detail the controversy which arose between the advocates of the Armstrong and the Whitworth systems.

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could recoil up an inclined slide and return by gravity, and in such a way that its motion both for elevating and for traversing was under the accurate control given by screw gearing.

The coming of the Armstrong gun at once revolutionized artillery practice and material in this country. The sum of all the improvements embodied in it was so great that existing material scarcely bore comparison with it. Its accuracy as compared with that of the smooth-bore field piece which it displaced was stated in parliament to be in the ratio of fifty-seven to one. And the effect of its inventor's achievement was, "that from being the rudest of weapons, artillery has been advanced to be nearly on a par mechanically with the steam engine or the power-loom; and it differs as essentially from the old cast-iron tube dignified with the name of a gun, as the railway train of the present day differs from the stage-coach of our forefathers."[1] A revolutionary invention it certainly was. Yet, like most revolutionary inventions, it relied for its grand effect more on the aggregate effect of the small improvements in its various elements than on the materialization of some new-born idea. The building up of guns in coils was not a new discovery, polygroove rifling was already in use abroad, breech-loading, lead-coated projectiles, elevating screws—all had been known for years. Nor does this fact detract in the least from the fame of Mr. Armstrong in this connection. His greatness lay, surely, in the insight and initiative with which he made use of known forms and combinations, summoning to his aid the new powers placed at his disposal by Whitworth, Nasmyth, Bessemer and their contemporaries in order to evolve a system incomparably superior to anything hitherto achieved.

In England, too, an independent development was at the same time taking place in yet another direction. Mr. Whitworth, having satisfactorily established the principles governing the design of rifles, felt confident of extending them to field and heavy ordnance. Adhering to the muzzle-loading principle and to his hexagonal form of rifling he manufactured, between the years 1854 and 1857, several guns which fired projectiles of from six to twenty-four pounds' weight with great accuracy and to ranges greater than any yet attained. Events occurred which caused him to be given every encouragement by the

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[1] *Edinburgh Review*, 1859. Quoted by Sir E. Tennant.

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government. The attitude of the French in these years was suspicious and unfriendly. Schemes of invasion were openly discussed in their press, and war vessels of various types equipped with armour plate were designed and actually built. Reports of their plans, following closely on the exposures of the Crimean War and the Indian Mutiny, rendered the country increasingly restless and apprehensive as to the value of our offensive and defensive armaments. And then, although the new Armstrong gun was acclaimed as eminently suited for service in the field, doubts had been cast as to whether the principles of its design could be applied satisfactorily to the heaviest ordnance. Other rifled artillery had certainly failed to give the results expected from it. The Lancaster rifled gun, a muzzle-loading gun with a twisted bore of a slightly oval section, had failed lamentably at the Crimea owing to the tendency, according to one account, of the oval projectile to wedge itself against the slightly larger oval of the bore ; according to another account, owing to the flames from the powder gases penetrating the interior of the welded shells which had been supplied for it. The breech-loading ordnance of Cavalli had failed the Italians. In Sweden several accidents had occurred with Wahrendorf's breech-loading pieces. The French system, which had been copied by the majority of the powers, was that which appeared to be giving the least unsatisfactory results.

In these circumstances every encouragement was given Mr. Whitworth to develop ordnance on his own lines. In '58 a committee on rifled guns was appointed by parliament to examine and report on the relative merits of the various systems in use. The committee quickly set to work. No difficulty was found in eliminating all but two, on which attention was soon concentrated : the Armstrong and the Whitworth. The result of the final investigation was a report in favour of the Armstrong gun, which, as we have already seen, was adopted in the same year for field service. Mr. Armstrong, who had handed over his rights in the gun for the benefit of the nation, was knighted and his services were subsidized for the improvement of rifled ordnance generally. The title of "Engineer to the War Department" was conferred on him, and later he received the further appointment of "Superintendent of the Royal Gun Factory" at Woolwich.

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The revolution in field guns was closely followed by a corresponding revolution in heavy ordnance. The experience of the Crimean War proved two things: that the development of the shell gun necessitated the provision of armour to protect the flanks of warships; and that the development of armour necessitated a heavy ordnance of a greater power than existing smooth-bore cannon. The shell gun, in fact, induced a rifled ordnance.

The French, who had already found a cheap and sufficiently effective rifled field artillery in the conversion of their smoothbores on the de Beaulieu principle, merely had to extend this conversion to their heavier pieces. By 1860 they had converted their 30- and 50-pounder cannon in this way, thus enabling them to be used for the discharge of either spherical or elongated projectiles.

Britain, on the other hand, found herself committed to an entirely new and experimental system which could not be applied to existing ordnance; a large outlay of money was thereby involved for new plant and guns; our vast establishment of smooth-bore cast-iron cannon was in danger of being reduced to scrap material. At the same time doubts were expressed whether this new system, whose success as applied to medium pieces was generally admitted, would be found satisfactory when applied to the largest size of ordnance. It was natural, then, that great interest should be centred in what was regarded as a less experimental alternative to the Armstrong system, in case the latter failed. The results obtained by Mr. Whitworth in the manufacture of solid cannon, rifled hexagonally, muzzle-loading and capable of firing hexagonal bolts or, in emergency, spherical balls, were such as to give promise of competing successfully with those obtained from the ordnance officially patronized. To the public the simplicity of his system strongly appealed. Mr. Whitworth himself, far from being deterred by the decision given in favour of his rival, was now an enthusiastic exponent of the constructive principles which he had made his own. Trial succeeded trial, piece after piece was made and tested to destruction. By 1860 a very successful ordnance was evolved at Manchester by him: guns made of homogeneous iron,

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forged in large masses, and formed of cylindrical tubes forced one over another by means of a known hydraulic pressure—not, as in the Armstrong system, by heating and shrinking. And on the sands at Southport a series of public trials were carried out with these guns, the results of which proved a great advertisement for the Whitworth system. The accuracy of flight of the projectiles was unprecedented, and all records in ranging power were broken by one of the pieces, a 3-pounder, which threw a shot to a distance of 9,688 yards ![1]

Even if the new Whitworth system were adopted, the utilization of the old smooth-bore cannon which formed the existing national armament of ships and fortresses was not secured. Neither the Armstrong nor the Whitworth system provided an expedient for converting to rifled ordnance the thousands of cast-iron guns in which the défence of the country was invested. Efforts were therefore made to reinforce the old pieces so that, when rifled, they would be sufficiently strong to withstand the greater stresses entailed. Greater stresses in the metal, due to higher chamber pressures of the powder gases, were almost a necessary concomitant of rifling. For, apart from the increase in the size and mass of the projectile and its greater initial resistance to motion, pressures tended to increase in a greater ratio than the size of the pieces them-

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[1] The sudden and extraordinary development of rifled ordnance which now took place had a revolutionary effect not only on naval architecture and gunnery but on land fortification. In '59 Sir William Armstrong, giving evidence before a committee appointed by the War Secretary, stated that he could attain with a specially constructed gun a range of five miles. The statement made a sensation ; for in the presence of such a gun most of the existing defences of our dockyards and depôts were almost useless. A Commission on National Defence was formed. It reported that new fortifications were necessary for our principal arsenals, the fleet alone being insufficient for the defence of ports. "The introduction of steam," stated the report, "may operate to our disadvantage in diminishing to some extent the value of superior seamanship ; the practice of firing shells horizontally, and the enormous extent to which the power and accuracy of aim of artillery have been increased, lead to the conclusion that after an action even a victorious fleet would be more seriously crippled and therefore a longer time unfit for service." Thus the command of the Channel might be temporarily lost. As steam facilitated invasion, the immediate fortification of vital points on the South Coast was considered necessary. In short, faith in the mobile fleet was temporarily abandoned.

The recommendations of the Commission were carried out almost in their entirety. In the case of Portsmouth, for instance, the reinforcement of the Hilsea Lines, decided on only two years previously, was suspended in favour of a defence of far greater radius—a circle of forts some of which were designed to prevent an enemy from gaining possession, from the land side, of Portsdown Hill, a ridge less than five miles from the Dockyard and therefore a position from which, with the new artillery, the Dockyard could be bombarded. A similar girdle of defences was given to Plymouth.

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selves; the mass of the projectile increased as the cube, the propulsive force of the gases as the square, of the diameter of the bore; hence to attain a given velocity, the larger the bore the higher the pressure required to propel it with a given type of powder,—other things being equal. No limit, therefore, could be assigned to the strength and power required of heavy ordnance. Moreover a struggle had begun in '59, with the building of the *Gloire* and *Warrior*, which was already foreshadowing tremendous developments both of guns and of armour.

The experiences of America in this connection were not encouraging. The civil war served as an incentive to the Americans to rifle all their large calibre guns as quickly as possible. In '62 large numbers of cast-iron cannon were rifled and reinforced by external hoops of iron. The results were deplorable. A great number of pieces burst; and experience made it clear that "a gun made up of a single homogeneous casting soon reaches a limit of resistance to internal pressure beyond which the addition of extra metal has little or no effect." Two improvements must be mentioned as having more than a passing effect on the progress of ordnance in America: first, the adoption of compressed and perforated powder which, by prolonging the combustion period, caused a more even distribution of stresses over all sections of the barrel; second, the casting of guns hollow and the chilling of their interiors, so as to form on the inside of the piece a hardened stratum on which the outer parts of the casting contracted as they slowly cooled, thus giving it support. But in spite of these inventions it became apparent that cast iron was in its nature unsuited as a material for rifled ordnance.

In England a safer method of conversion was followed. Guns were bored out, on a scheme proposed in '63 by Major Palliser, and accurately turned tubes of coiled wrought iron were fitted in them, which were afterwards rifled. The resulting pieces consisted, then, of a wrought-iron inner tube, supported by a surrounding cast-iron jacket against which, on firing, the inner tube expanded. Thus converted, the old smooth-bores were enabled to develop an energy far in excess of their original limit, and so to prolong for some years their period of usefulness.

The conversion of the cast-iron guns was seen to be only a temporary expedient. Just as the smooth-bore cannon,

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after a last effort to overcome iron plates with spherical solid shot of the largest calibre, withdrew from the competition; so, as the thickness of armour increased, the converted cast-iron cannon, with its special armour-piercing shot of chilled iron, soon reached the limit of its power and gave place to the rifled artillery of wrought iron or steel.

And now, rifled ordnance having definitely supplanted the smooth-bore, a new struggle arose between the various systems of gunmaking, and more especially between the two rival methods of loading: by the breech and by the muzzle. The prognostications of those who had doubted whether the latter method was suitable for large ordnance were seen to be partially justified. Other nations had already relapsed into muzzle-loading, impressed by the complexity and weakness of the breech-loading systems of Cavalli, Wahrendorf and other inventors. Besides ourselves only the Prussians, the originators of the breech-loading rifled musket in its modern form, continued to trust in breech-loading ordnance. The Italians, following the example of the French and Americans, abandoned the system. "Thus," said an English authority in '62, "while, after more than four centuries of trial, other nations were giving up the moveable breech, . . . we are still going from plan to plan in the hope of effecting what will, even if successful in closing the breech, be scarcely safe with the heavy charges necessary for smashing armour plates."[1]

In the following year, '63, the committee appointed to carry out the competitive trials between Whitworth and Armstrong guns, reported that the many-grooved system of rifling, with its lead-coated projectiles and complicated breech-loading arrangements, entailing the use of tin caps for obturation and lubricators for the rifling grooves, was far inferior for the general purposes of war to both of the muzzle-loading systems tried. This view received early and practical confirmation from a report sent to the Admiralty by Vice-Admiral Sir Augustus Kuper, after the bombardment of Kagosima. In that action several accidents occurred owing to the Armstrong guns being fired with their breech-blocks not properly screwed up. The guns were accordingly withdrawn from service and replaced by muzzle-loaders. In 1864 England reverted definitely to muzzle-loading ordnance, which, in the face of violent controversy and in spite of the gradual reconversion

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[1] Commander R. A. E. Scott, R.N.

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of her rivals to the breech-loading principle, she maintained for the next fifteen years. Whitworth's system was adopted in the main, but the hexagonal form of bore and projectile was avoided. Studded projectiles were approved, the pieces being rifled with a few broad shallow grooves not unlike those used by the French. England at last possessed a muzzle-loading sea ordnance, characterized by ease and rapidity of loading, accuracy, cheapness, and capacity for firing, in emergency, spherical shot as well as rifled projectiles.

What was the effect of this retrogression upon the status of our naval armaments?

It seems frequently to have been held that, in view of the eventual victory of the breech-loading gun, the policy of reverting to muzzle-loading was wrong, and that this country was thereby placed at a serious disadvantage to her rivals. Several good reasons existed, however, for the preference given to muzzle-loading ordnance at that time. The accidents with removable breeches had been numerous and demoralizing. Muzzle-loading guns, besides the advantages which they possessed of strength, solidity and simplicity of construction, offered important advantages in ease and rapidity of loading—particularly in the case of turret or barbette guns, where "outside loading" was a great convenience. On the other hand the principal deficiency of the muzzle-loader, namely, the large windage required with studded projectiles, was now eliminated by the invention of the cupped "gas check," a copper disc attached to the rear of the projectile which, on discharge, expanded automatically and sealed the bore.

Expert opinion confirmed the wisdom of the government policy. Experience, in the Franco-Prussian war and elsewhere, confirmed the views of the experts. "Reviewing the action of the artillerists who decided to adopt muzzle-loaders, with the greater experience we now possess it seems that they were right in their decision at the time it was first made; but there was too much hesitation in coming back to breech-loaders when new discoveries and great progress in powder quite altered conditions."[1] In fact, once having abandoned the disparaged system, the country was with difficulty persuaded by the professionals to retrace its steps. In the end, ordnance followed small arms; the researches of Captain Noble at Elswick proved conclusively to the world at large the

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[1] Lloyd and Hadcock.

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necessity for a reversion to breech-loading; and in 1880 the muzzle-loading gun was finally superseded by a greatly improved form of breech-loader.

In 1880 the state of knowledge and the conditions under which ordnance was manufactured were certainly altered from those of '64. The struggle between guns and armour begun with the *Gloire* and *Warrior* had continued. In the presence of the new powers of mechanical science, artillerists and shipbuilders had sought to plumb the possibilities of offensive and defensive elements in warship design. Guns influenced armour, armour reacted on guns; both revolutionized contemporary naval architecture. It was in the effort to aggrandize the power of guns that Noble discovered that, with the existing powders and with the short muzzle-loading gun, a natural limit of power was soon reached. Better results could only be obtained, he showed, by the adoption of slow-burning powder and a longer gun; by the avoidance of the sudden high chamber pressure which resulted from the small-grained powder, and the substitution for it of a chamber pressure which would rise gradually to a safe maximum and then suffer only a gradual reduction as the gases expanded behind the moving projectile. The work done by the gases on the projectile could by this means be enormously increased. But, for this result, larger powder-charges were required; and these larger charges of slow-burning powder were found to require much larger chambers than those embodied in existing guns; in short, the new conditions called for a new shape of gun. Long guns, having powder chambers of larger diameter than that of the bore, were necessary, and these could not conveniently be made muzzle-loading.

So a return to the breech-loading ordnance became inevitable, and the change was made. The old Armstrong moveable vent-piece was avoided, however, in the new designs; of the two alternative breech-closing systems in use, viz. the wedge system of Krupp and the "interrupted screw" system of the French, the latter was adopted. A steel tube, rifled on the polygroove system, formed the body of the piece, and this was strengthened by hoops of iron or steel shrunk on its exterior. The new gun yielded a very great increase of power. Muzzle-loading guns were at once displaced, in the projected programme of new battleships, for the new type of ordnance, and a further series of revolutionary changes in ship arma-

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ment at once took place. Other nations had already augmented the length and power of their guns. By the adoption of the improved breech-loading ordnance, Great Britain, who for the last few years had been falling behind her rivals, not only drew level with them but definitely took the lead in the power of her heavy ordnance : a lead which from that time to this she has successfully maintained.

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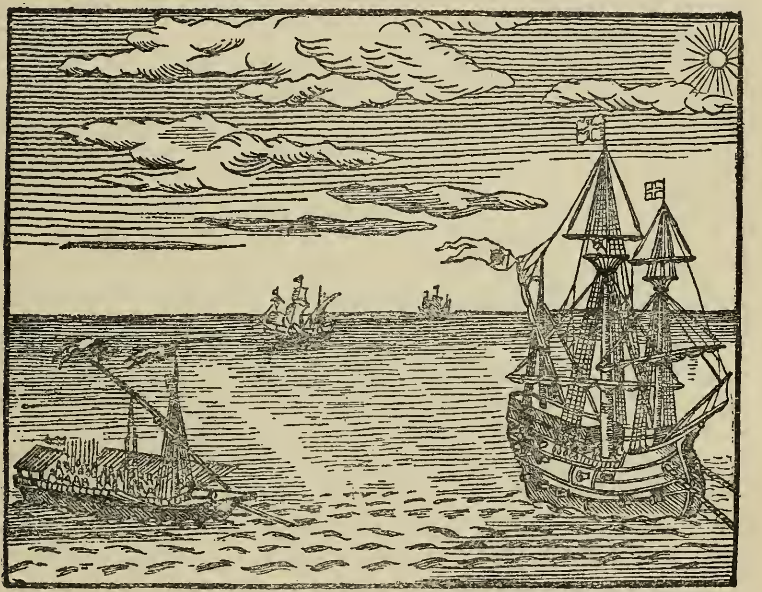
CHAPTER IX

PROPELLING MACHINERY

NO aspect of old naval warfare is so difficult for the modern reader to visualize, perhaps, as that which displays the essential weakness of the sailing warship: its impotence in a calm. It was a creature requiring for its activities two elements, air and water. Ruffle the sea with a breeze, and the sailing ship had power of motion towards most of the points of the compass; withdraw the winds, and she lay glued to the smooth water or rolling dangerously in the heavy swell, without power either of turning or translation. For centuries this weakness told heavily against her and in favour of the oar-propelled vessel, particularly in certain latitudes. Through many years, indeed, the two types held ascendancy each in its own waters; in the smooth stretches of the Mediterranean the oar-driven galley, light, swift, and using its sharp ram or bow-cannon as chief means of offence or defence, was a deadly danger to the becalmed sailing ship; in the rougher north Atlantic the sailing ship, strong, heavy, capacious, and armed for attack and defence only along its sides, proved far too fast and powerful for the oar-driven rival. Progress—increase of size, improvement in artillery, the development of the science of navigation—favoured the sailing ship, so that there came at last the day when, even in the Mediterranean, she attained ascendancy over the galley. But always there was this inherent weakness: in a dead calm the sailing ship lay open to attack from a quarter where her defence lay bare. Ninety-nine times out of a hundred, perhaps, she could move sufficiently to beat off her attacker by bringing her broadsides to bear. The hundredth, she lay at the mercy of her adversary, who could, by choosing his range and quarter of attack, make her temporary inferiority the occasion of defeat. For this military reason many attempts were made to supplement sails with oars. But oars and sails were incompatible. They were often seen together in early times, but with progress the use of one became more and more irreconcilable with the use of the other. The Tudor galleasse, though possessing in our northern waters many advantages over the galley type, had the defects inherent in the compromise, and gave place in a short time to the high-charged "great ship" propelled by sails alone. The sailing ship was by that time strong and powerful enough to risk the one-in-a-hundred chance of being attacked by oared galleys in a stark calm.



SHIP AND GALLEY
(From Tartagliá's *Arte of Shooting*, English Ed., A.D. 1588.)

It was only when the first steam vessels plied English waters that the old weakness became apparent again. It was then seriously urged that the ship-of-the-line should carry oars once more, against the attack of small steamers converging on her from a weakly defended quarter.

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The oar was in many ways an objectionable form of power. It was very vulnerable, its presence made manœuvring at

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close quarters risky and difficult; and apart from the necessity, on which the galley service was based, of a large supply of slave-labour for working them, oars and the rowers absorbed a large proportion of the available inboard space, to the detriment both of artillery and merchandise.

Many attempts were therefore made, not only to substitute animals for men, for the work of propulsion, but to apply power in a manner more suitable than by the primitive method of levers: oars or sweeps. The paddlewheel was thought of at a very early date; a Roman army is said to have been transported into Sicily by boats propelled by wheels moved by oxen, and in many old military treatises the substitution of wheels for oars is mentioned.[1] In 1588 Ramelli, engineer-in-ordinary to the French king, published a book in which was sketched an amphibious vehicle propelled by hand-worked paddlewheels: "une sorte de canot automobile blindé et percé de meurtrières pour les arquesbusiers." In 1619 Torelli, Governor of Malta, fitted a ship with paddles, and in it passed through the Straits of Messina against the tide. But Richelieu, to whom he offered his invention, was not impressed with its value.[2] Before this, Blasco de Garoy, a Spanish captain, had exhibited to the Emperor Charles V, in 1543, an engine by which ships of the largest size could be propelled in a calm: an arrangement of hand-operated paddlewheels.

In Bourne's *Inventions and Devices*, published in 1578, is the first mention of paddlewheels (so far as we know) in any English book. By the placing of certain wheels on the outside of the boat, he says, and "so turning the wheels by some provision," the boat may be made to go. And then he proceeds to mention the inversion of the paddlewheel, or the paddlewheel which is driven, as distinguished from the paddlewheel which drives. "They make a watermill in a boat, for when that it rideth at an anker, the tide or stream will turn the wheels with great force, and these mills are used in France," etc. It is possible, indeed, that this was the prior form, and that the earliest paddlewheel was a mill and not primarily a means of propelling the vessel.

Early in the seventeenth century the mechanical sciences began to develop rapidly and as the century advanced the flood of patents for the propulsion of ships increased. "To

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[1] Woodcroft: *Steam Navigation*, 1848.

[2] de la Roncière: *La Marine Française.*

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make boats, ships, and barges to go against the wind and tide"; "the drawing and working of barges and other vessels without the use of horses"; "for making vessels to navigate in a straight line with all winds though contrary"; these are some of the patents granted, the details of which are not known. At last the ingenious Marquis of Worcester, who in 1663 was granted a patent for his steam engine, also obtained a patent for an invention for propelling a vessel against wind and stream. It has sometimes been inferred that this invention was connected in some way with the steam engine, and the claim has been made that the Marquis was one of the first authors of steam propulsion. This is not so. Contained in the description of the ship-propelling invention are two statements which dispose completely of the theory that steam was the motive force; first, that the "force of the wind or stream causeth its (the engine's) motion"; secondly, that "the more rapid the stream, the faster it (the vessel) advances against it." From this it appears that the Marquis intended to utilize the watermill as described by Bourne. From a study of the description of the apparatus it has been concluded that "a rope fastened at one end up the stream, and at the other to the axis of waterwheels lying across the boat, and dipping into the water so as to be turned by the wheels, would fulfil the conditions proposed of advancing the boat faster, the more rapid the stream; and when at anchor such wheels might have been applied to other purposes."[1] If this reconstruction is correct, the scope of the propelling device was very limited.

In Bushnell's *Compleat Shipwright*, published in 1678, a proposal was made for working oars by pivoting them at the vessel's side and connecting their inboard ends by longitudinal rods operated by cranks geared to a centre-line capstan. But the disadvantages of oars so used must have been apparent, and there is no evidence that this invention was ever put into practice. The obvious alternative was the paddlewheel, and though that device had been known and used in a primitive form long before the seventeenth century, it was continually being reinvented (especially in the 'nineties) and tried by inventors in various countries. Denis Papin turned his original mind to the solution of this problem. A paper on the subject written by him in Germany in 1690 is of interest. Discussing the use of oars from ships' sides he notes that, "Common oars

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[1] Woodcroft: *Steam Navigation.*

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could not be conveniently used in this way, and it would be necessary to use for this purpose those of a rotary construction, such as I remember to have seen at London. They were affixed to a machine made by direction of Prince Rupert, and were set in motion by horses, so as to produce a much greater velocity than could be given by sixteen watermen to the Royal Barge." Papin, who had suggested the atmospheric steam engine, also suggested the possible application of steam to propulsion. But it was left to others to achieve what he had to propose. His talent, it has been said, lay rather in speculations on ingenious combinations, than in the mechanical power of carrying them into execution on a great scale. In 1708 he laid before the Royal Society, accompanied by a letter of recommendation from Leibnitz, a definite proposal for a boat " to be moved with oars by heat . . . by an engine after the manner that has been practised at Cassel." What form this engine was to take, and how the power was to be transmitted to the oars, is still a matter of conjecture. Only this is known, that the proposal was considered in detail by the president, Sir Isaac Newton, and that on his advice no further action was taken.[1]

In France it has been widely claimed that Papin actually engined a boat and propelled it over the waters of the Weser by the force of steam. His biographer states that on the 24th September, 1707, Papin " embarquait sur le premier bateau à vapeur toute sa fortune."[2] But the statement is not correct. The misconception, like that which assigned to the Marquis of Worcester the invention of a steam-propelled vessel, was doubtless due to the fact that the inventor was known to be engaged in the study of the steam engine and of ship-propelling mechanism. The two things, though distinct in themselves, were readily combined in the minds of his admirers. It is generally agreed to-day, we think, even by his own countrymen, that Papin, though he may claim the honour of having first suggested the application of steam to ship propulsion, never himself achieved a practical success.

In the meantime Savery in England had produced his successful engine. In his case, too, the claim has been made that he first proposed steam propulsion for ships. But in his *Miner's Friend* this able mechanician showed that he recognized

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[1] Rigaud: *Early Proposals for Steam Navigation.*

[2] Enouf: *Papin; Sa Vie et Son Œuvre.*

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the limited application of his steam engine. "I believe," he says, "it may be made very *useful* to ships, but I dare not meddle with that matter; and leave it to the judgment of those who are the best judges of maritime affairs." But in propulsion by hand-operated paddlewheels Savery was an enthusiastic believer. In 1698 he had published, in a book bearing the title, "*Navigation Improv'd: Or the Art of Rowing Ships of all Rates, in Calms, with a more easy, swift, and steady Motion than Oars can,*" a description of a mechanism consisting of paddlewheels formed of oars fitted radially to drumheads which were mounted on the two ends of an iron bar placed horizontally across the ship. This bar was geared by mortice wheels with another bar mounted vertically as the axis of a capstan; rotation of the capstan was thus transmitted to the paddlewheels. Savery fitted this mechanism to a wherry and carried out successful trials on the Thames before thousands of people. But the Navy Board would not consider it. They had incurred a loss, it appeared, on a horse tow-vessel which had been in use at Chatham a few years previously: a vessel which towed the greatest ships with the help of four, six, or eight horses, and which, incidentally, may have influenced Savery in adopting the term "horse power" as the unit of work for his steam engine. The sanguine inventor made great efforts to interest the authorities, but without avail; the Surveyor rejected the proposal. So in an angry mood Savery published his book, with a description of his mechanism and an account of his efforts to interest the authorities, to show how one man's humour had obstructed his engine. "You see, Reader, what to trust to," he concluded, "though you have found out an improvement as great to shipping as turning to windward, or the compass; unless you can sit round the green table in Crutched Friars, your invention is damned of course."

The first detailed scheme for applying steam-power to ship propulsion was contained in the patent of Jonathan Hulls, in 1736. Though great credit is generally given to this inventor (who has even been dubbed the father of steam navigation), it does not appear that in reality he contributed much to the advancement of the problem; which was, indeed, still waiting on the development of the steam engine. Hulls' notion, explained in a pamphlet which he published in 1737, was to connect the piston of a Newcomen engine by a rope gearing

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with some wheels mounted in the waist of the vessel, which wheels oscillated as the piston moved up and down. These wheels were in turn connected by rope gearing with a large fan-wheel mounted in a frame rigged out over the vessel's stern, the fans in their lowest position dipping into the water. The oscillating motion of the inboard wheels was converted into a continuous ahead motion of the fan-wheel by means of a ratchet. With this machinery he designed to tow ships in harbours and rivers. It must, however, be remarked that the invention was never more than a paper project; and that if Hulls had tried to translate his ideas into three dimensions he would have encountered, in all probability, insuperable practical difficulties. One very original suggestion of his certainly deserves notice; as a special case he proposed that when the tow-boat was used in shallow rivers two cranks, fitted to the axis of his driving wheels, should operate two long poles of sufficient length to reach the bottom of the river; these trailing poles, moving alternately forward, would propel the vessel. Here is an early application of the crank. But in this case it will be noted that the crank is driven, and that it converts a rotary into a reciprocating motion; in short, it is an inversion of the driving crank which, as applied to the steam engine, was not invented till some years later.

As before remarked, the whole problem of steam propulsion waited upon the development of the steam engine. In the meantime the application of convenient forms of man power received considerable study, especially in France. In Bouguer's *Traité du Navire* the problem was investigated of propulsion by blades or panels, hinged, and folding when not in use against the vessel's sides; and in 1753 the prize offered by the Academy of Sciences for an essay on the subject was won by Daniel Bernouilli, for a plan on those lines. Euler proposed paddlewheels on a transverse shaft geared like Savery's, by mortice wheels to a multiple capstan. Variations of this method were proposed by other writers and inventors, and some of the best intellects in France attacked the problem. But nothing definite resulted. The most valuable result of the discussion was the conclusion drawn by M. Gautier, a professor of mathematics at Nancy, that the strength of the crew was not sufficient to give any great velocity to a ship. He proposed, therefore, as the only means of attaining that object, the

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employment of a steam engine, and pointed out several ways in which it might be applied to produce a rotary motion.[1]

In the course of time the problem marched forward to a solution. The first great improvement in the steam engine which rendered it adaptable to marine use was the invention by Watt of the "double impulse"; the second, Pickard's invention of the crank and connecting-rod. By virtue of these two developments the steam engine was made capable of imparting to a shaft a continuous rotary motion without the medium of noisy, brittle or inefficient gearing. As soon as engines having this power were placed on the public market attempts were made to mount them in boats and larger vessels; steam navigation was discerned as a possibility.

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Of the many efforts which were made at the end of the eighteenth century to apply steam power to the propulsion of ships a striking feature is their complete independence from each other and from the results of prior experience and research. Little information is available as to the results of various experiments which were known to be carried on in France at this time, and, with all respect, it is improbable that they contributed in any way to the subsequent evolution of the steam vessel. The Abbé Darnal in 1781, M. de Jouffroi in 1782, and M. Desblancs in 1802 and 1803, proposed or constructed steamboats. M. de Jouffroi is said to have made several successful attempts on the Saone at Lyons; but the intervention of the Revolution put an end to his undertakings.

In Britain a successful attempt to apply the steam engine to the paddlewheel was made in 1788. In that year three men, combining initiative, financial resource, and a large measure of engineering ingenuity, proved the possibility of steam propulsion in an experiment singularly complete and of singularly little effect on subsequent progress. In the summer of '87 a wealthy and inventive banker, Mr. Patrick Miller of Dalswinton, Edinburgh, had been making experiments in the Firth of Forth with a double vessel of his own invention, sixty feet long, which, when wind failed for sailing, was set in motion by two paddlewheels. These paddlewheels were fitted between the two hulls of the vessel and were worked by men, by means

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[1] Quoted in Fincham's *Naval Architecture.*

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of a geared capstan. Miller believed that a boat furnished with paddlewheels and worked manually would be of great advantage for working in shallow rivers and canals. But the result of a sailing race between his boat and a custom-house wherry of Leith, in which his own sails were supplemented by the labours of four men at the wheels, convinced him that man-power was insufficient. His sons' tutor, a Mr. Taylor, suggested the application of a steam engine. And being acquainted with an engineer named Symington, Taylor prevailed on his patron to engage him to mount a one-horse-power engine in a double pleasure boat, upon the lake at Dalswinton. The experiment was a complete success. "The vessel moved delightfully, and notwithstanding the smallness of the cylinder (4 inches diameter), at the rate of 5 miles an hour. After amusing ourselves a few days the engine was removed and carried into the house, where it remained as a piece of ornamental furniture for a number of years."[1] Determined to pursue the experiment, Miller ordered a replica of the original engine on a larger scale, and this engine, with a cylinder of 18 inches diameter, was erected at Carron and fitted to a larger boat. This also was successful. But no further trials were made after '89 ; for Patrick Miller, who had spent a large sum in order to establish the feasibility of the invention, decided to close his investigations, and to turn to other pursuits.

No further attempt was made in Great Britain until 1801, when Lord Dundas engaged Symington to make a series of experiments on the substitution of steam power for horse towage of barges on the Forth and Clyde canal: experiments which resulted in the *Charlotte Dundas*. In this celebrated vessel a double-acting Watt engine, with its 22-inch diameter cylinder mounted horizontally on the deck, actuated, through a simple connecting-rod and a crank with a 4-foot throw, a paddlewheel which was carried in a centre-line recess at the stern. In March, '03, Symington in the *Charlotte Dundas* towed two 70-ton vessels nineteen miles against a strong head wind in six hours. Success seemed assured to him. His reputation was already high, and now an invitation came from the Duke of Bridgewater for eight similar tow-boats to ply on his canal. But the inventor's hopes were disappointed. The Duke died suddenly, and the governing body of the Forth

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[1] Mr. Taylor's evidence to Select Committee, 1824. Quoted in Woodcroft's *Steam Navigation.*

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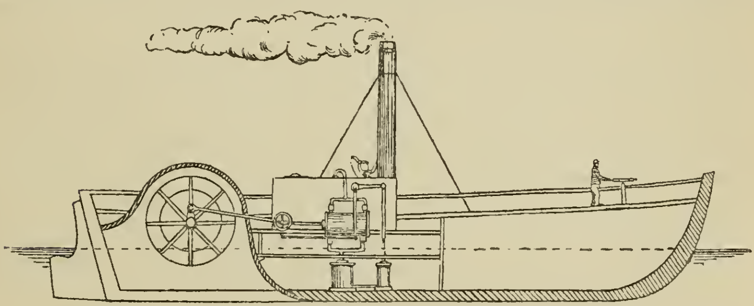
and Clyde canal vetoed the further use of steam vessels for fear of the damage the waves might cause the banks. Other bodies took the same view, and thus came to an end an important passage in the history of steam navigation. It is remarkable, considering the efforts which had been made by inventors from the sixteenth century onwards to improve on oar-propulsion for military purposes, that Miller, Symington, and their friends do not seem to have envisaged any use for steamboats other than as tugs on canals. It is remarkable that in the presence of this initial success neither the government nor the public showed any realization of the possibilities which it unfolded; that no attempt was made by commercial enterprise—even if, in the realm of naval strategy, such an innovation was regarded as impolitic or impracticable[1]—to develop its advantages and to secure an undisputed lead in the new application of steam power.



THE "CHARLOTTE DUNDAS"
(From Fincham.)

It was in America that the most persistent and continuous development took place, quite independently of efforts elsewhere and almost contemporaneously with those above described. America, whose geographical conditions made water transport relatively far more important than it was in Great Britain, lent a ready ear to the schemes of inventors. In

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[1] Miller is said to have approached the Admiralty twice upon the subject, and certainly he was keenly interested in naval affairs. A generous tribute has been paid him by a friend whose name is honoured in our naval annals: "I was unwearied," says John Clerk of Eldin in the preface of his Essay on Naval Tactics, published in 1804, "in my attention to the many valuable experiments of the ingenious and liberal-minded Mr. Patrick Miller of Dalswinton; to whom, whether in shipbuilding or in constructing artillery, both musketry and great guns, his country is more indebted than has hitherto been properly acknowledged."

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1784 James Rumsey, and shortly afterwards John Fitch, had already laid plans before General Washington for the propulsion of boats by steam.

John Fitch, whose original idea was a steamboat propelled by means of an endless chain of flat boards, afterwards experimented with an arrangement, "borrowed no doubt from the action of Indians in a canoe," of paddles held vertically in frames mounted along the sides of the boat and operated by cranks. In 1786 a boat thus equipped made a successful trial on the Delaware, and in the following year a larger boat, fitted with a horizontal double-acting engine with a 12-inch cylinder and a 3-foot stroke, giving motion to six paddles on each side, was publicly tried on the same river. The speed attained was very small. At last in 1790, still protected by a patent which granted him a temporary monopoly in steamboat building, Fitch succeeded in building a boat which was an undisputed mechanical success. Discarding the paddle-frame and adopting a beam engine to drive paddle-boards at the stern, he produced a steamboat which, after being tested and credited with eight knots' speed on a measured mile in front of Water Street, Philadelphia, in the presence of the governor and council of Pennsylvania, ran two or three thousand miles as a passenger boat on the Delaware before being dismantled. It was a considerable achievement. But the excessive weight and space absorbed by the machinery prevented the boat from being a financial success; and, after a journey to France, then distracted by the Revolution, Fitch returned home to America and ended his days a disappointed and a broken man. Nevertheless, the work he did was of service to others. He proved that the ponderous nature of the machinery was the greatest obstacle to the propulsion of small craft by steam, and from his failure deduced the conclusion, on which later inventors were able to build, that the solution of the problem lay in the *scale:* that, "it would be much easier to carry a first-rate man-of-war by steam at an equal rate than a small boat."[1]

James Rumsey, a Virginian, carried out in 1775 the first practical trials of water-jet propulsion, a small boat of his plying the Potomac at a small speed by means of a steam pump which sucked in water at the bow and threw it out at the stern. But as he felt himself obstructed in further experiments by the

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[1] Dickinson: *Robert Fulton, Engineer and Artist.*

patent rights which had been given his rival Fitch he came to England; where, financed by a wealthy compatriot and aided by James Watt himself, he produced in '93 a boat which on the Thames attained a speed of over four knots. Unfortunately Rumsey died in the middle of his experiments.

An individual of extraordinary qualities had now turned his attention to the problem of steam propulsion. In that same year a young American artist, Robert Fulton, who had come to England to work under the guidance of his countryman Benjamin West, wrote to Lord Stanhope informing him of a plan which he had formed for moving ships by steam. Lord Stanhope, well known as a scientific inventor, had recently been experimenting with a vessel fitted with a 12-horse-power engine of Boulton and Watt's working a propeller which operated like the foot of an aquatic bird. A correspondence ensued. Fulton, whose self-confidence equalled his originality, illustrated by drawings and diagrams his ideas on the subject. At first, he said, he thought of applying the force of an engine to an oar or paddle which, hinged on the counter at the stern, by a reciprocating motion would urge the vessel ahead. But on experimenting with a clockwork model he ound that, though the boat sprang forward, the return stroke of the paddle interfered with the continuity of the motion. "I then endeavoured," he wrote, "to give it a circular motion, which I effected by applying two paddles on an axis. Then the boat moved by jerks; there was too great a space between the strokes. I then applied three paddles, forming an equilateral triangle to which I gave a circular motion." These paddles he proposed to place in cast-iron wheels one on each side of the boat and mounted on the same shaft at some height over the waterline, so that each wheel would "answer as a fly and brace to the perpendicular oars." And he stated that he found, from his experiments with models, that three or six oars gave better results than any other number. From which it is clear that the paddlewheel was evolved by Fulton from the simple paddle ndependently of suggestion received from previous inventors.

Some time was to elapse before the results of his experiments were utilized. Attracted by the boom in canal construction then in vogue Fulton devoted his mind to that ubject; though in this connection the idea of steam-propelled boats still occupied him, as is shown by a letter he wrote in '94 o Messrs. Boulton and Watt, asking for an estimate of costs

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and dimensions of "an engine with a rotative movement of the purchase of 3 or 4 horses which is designed to be placed in a boat." From England he went to Paris, to try his fortune at half a dozen projects. In '98 he was experimenting on the Seine with a screw propeller—"a fly of four parts similar to that of a smoke-jack," which gave promising results. This screw propeller, however, was as yet unrecognized as the propulsive medium of the future. It had already been patented in England by Bramah in 1785—"a wheel with inclined fans, or wings, similar to the fly of a smoke-jack or the vertical sails of a windmill"; and, hand-operated, it had actually been used in America in 1776 by Bushnell in connection with his submarine. But in 1802 Fulton had decided against the screw, and in favour of the paddlewheel.

It was in this year that an introduction to an influential compatriot, himself an experimenter in steam propulsion, gave Fulton the opportunity to display his talents to their mutual advantage. Chancellor Livingston, U.S. Minister to France, was aware of the enormous advantages which would accrue to America (and to the happy inventor) if steam propulsion could be achieved economically. With Fulton's aid he decided on building an experimental steam vessel in France, with a view to transferring to America for commercial enterprise the perfected results of their labour. A partnership was formed, the work proceeded; but the experimental steamboat, whose scantlings were unequal to supporting the weight of the 8-horse-power machinery placed on board, sank at her moorings in a storm. A second boat, stronger and bigger, attained complete success. Fulton promptly wrote to Messrs. Boulton and Watt asking them to export to America a 24-horse-power engine complete with all accessories, in accordance with his sketches; and with a brass air-pump suitable for working in salt water. Then, going himself to England, he visited Messrs. Boulton and Watt and gleaned what information he could as to the properties of their machinery; studied the newly published results of Colonel Beaufoy's experiments on ship form and fluid resistance; and journeyed to Scotland to visit Symington and see the famous *Charlotte Dundas*.

Armed with this knowledge, with all the experience of Rumsey and Fitch, and with the data from his own trials, Fulton brought to a successful solution the problem of steam propulsion on a commercial scale. It has been remarked that there was no element in the *Clermont* or her successors so original in conception that it would entitle Fulton to be regarded as the inventor of steam navigation. Nor did he himself claim to be such. He was successful in fitting together the elements, the inventions of others. Science is measurement, and Fulton applied his data and measured with great insight, adapting his elements in the right manner and proportion to form an efficient whole. "He was the first to treat the elementary factors in steamship design—dimensions, form, horse-power, speed, etc.—in a scientific spirit ; to him belongs the credit of having coupled the boat and engine as a working unit." From Fitch he had learned the economy of size, and the advantages of enlarging the scale of operations ; from Beaufoy, the importance of a fair underwater form, with a sharp bow and stern. From Symington, who generously took him for a trip in the *Charlotte Dundas*, he could not fail to have gleaned much practical advice and information ; it is remarkable, in this connection, that, after a sight of Symington's horizontal cylinder with its simple connecting-rod drive to the stern wheel, he should have adhered to the vertical cylinder and the bell-crank or beam for the transmission of the force : an initial divergence which was perpetuated, and which became the hall-mark distinguishing American from English practice for some years to come. Most of his knowledge he gained by his activities in England, and many writers have contested a claim—which so far as is known was never made by him—to the invention of the steamship. His achievements were well defined and legitimately executed, and the remarkable insight and initiative which he displayed in adapting the labours of others to serve his own utilitarian ends cannot, surely, deserve the opprobrium cast on them by some of the nineteenth-century writers. Prometheus, it is said, stole fire from heaven. Fulton bought his in the open market ; obtaining his engine in Soho and his boiler in Smithfield he transported them across the Atlantic, and in 1807 produced the *Clermont*.

The *Clermont*, a flat-bottomed wall-sided craft 166 feet in length and only 18 feet in beam, steamed at a speed of five knots from New York to Albany, in August, 1807 ; to the suprise of thousands of spectators who knew her as "Fulton's folly," and whose shouts of derision gave place to silence, and then to a chorus of applause and congratulation. Many of the

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inhabitants of the banks of the Hudson had never heard even of an engine, much less of a steamboat. "A monster moving on the waters, defying the winds and tide, and breathing flames and smoke! The first steamboat used dry pine wood for fuel, which sends forth a column of ignited vapour many feet above the flue, and, whenever the fire is stirred, a galaxy of sparks fly off which, in the night, have a very brilliant and beautiful appearance."[1] The *Clermont* was followed by others, each an improvement on the last; until in 1816, so rapid was the process of evolution, the *Chancellor Livingston* was built, ship-shaped, with figure-head and fine bows, faired sides and tapering stern, with engines of 75-horse-power and with promenade decks and accommodation for 120 passengers. Certain characteristics now showed themselves in all American construction. The engines were mounted with cylinders vertical, their rods actuating large overhead beams which transmitted the force of the steam to the paddlewheels. The boats were made very broad to give the necessary stability, the machinery being carried high; and to reduce their under-water resistance as much as possible their bodies were made full near the water-line and lean below. For the same reason, and since the principal weights were concentrated amidships, fine forward and after bodies were given them; a rising floor, and a deep draught if necessary. The position of the paddlewheels was limited by that of the engine. Experience showed that where two paddles on each side were used their relative position had to be adjusted nicely, otherwise the rear paddles, acting on accelerated water, might actually be a disadvantage. Much difficulty was caused with accidents to paddles; on the Mississippi the wheels were generally mounted astern, where they were protected from floating logs of timber. In some cases double hulls were built, with the paddlewheels between them; but owing to the rush of water on which they acted these wheels were not very efficient.[2]

Fulton had so far built steam vessels only for commercial traffic. He now came near to revolutionizing naval warfare with them. In 1813, in the middle of the war with this country, he presented to the President his plan for a steam-propelled armoured warship for coast defence, a design of an invulnerable

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[1] Colden: *Life of Fulton.*

[2] *M. Marestier's Report on Steam Navigation in the U.S.A.* (Morgan and Creuze, 1826).

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THE *COMET* OF 1812
From an oil painting in the South Kensington Museum

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vessel of thirty guns, twin-hulled, with a 120-horse-power engine in one hull, a boiler in the other, and a single paddlewheel in a space between the two; double-ended, flat-bottomed, and protected by a belt of solid timber 58 inches thick. Her armament was to consist, in addition to thirty 32-pounders, of submarine guns or columbiads, carried at each end and firing 100-pound projectiles below the water-line. Named the *Demologos,* this monstrous vessel was nearly completed when the war came to an end. It was too late for use. The treaty of Ghent being signed, interest in armaments immediately evaporated. Nevertheless, in the following year a trial of the *Demologos* was carried out, which showed that a speed of five and a half knots could be attained with her. The *Demologos,* now renamed the *Fulton,* served no useful purpose. She was laid up in Brooklyn Navy Yard, and many years elapsed before steam war vessels were built again in America.

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In the meantime progress had been made on this side of the Atlantic. Stimulated by Fulton's commercial successes, Thomas Bell of Helensburgh built in 1812 a vessel of thirty tons' burden named the *Comet,* successfully propelled by a 3-horse-power engine which worked a paddlewheel on each beam. This "handsome vessel" was intended to ply between Glasgow and Greenock, to sail by the power of wind, air, and steam; and so it did, with fair financial success, with a square sail triced to the top of a tall smoke-stack: the first passenger steamer to ply in European waters. Shortly afterwards steam vessels were built which pushed out to the open sea. In 1815 the *Argyle,* built on the Clyde and renamed *Thames* on being purchased by a London company, made a voyage from Greenock to London which was the subject of much comment. On making the Cornish coast after a stormy run south, boats were seen by those on board making towards her with all possible speed in the belief that she was on fire! All the rocks commanding St. Ives were covered with spectators as she entered the harbour, and the aspect of the vessel, we are told, "appeared to occasion as much surprise amongst the inhabitants, as the ships of Captain Cook must have produced on his first appearance among the islands of the South Seas." Next

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day the *Thames*, her 9-foot paddlewheels driven by a 16-horse-power engine, reached Plymouth, where the crews of all the vessels in the Sound filled the rigging, and the harbour-master was "struck with astonishment." From Plymouth she steamed to Portsmouth, making the passage in twenty-three hours. So great was the swarm of vessels that crowded round her, that the port admiral was asked to send a guard to preserve order. She steamed into harbour, with wind and tide, at from twelve to fourteen knots. A court-martial was sitting in the *Gladiator* frigate, but the whole court except the president adjourned to inspect the strange visitor. Next day the port admiral sent off a guard and band; and soon afterwards he followed, accompanied by three admirals, eighteen post captains, and a large number of ladies.[1]

The success of the *Thames* led to the immediate building of other and larger steamers. In '17 the son of James Watt purchased a 94-foot boat, the *Caledonia*, fitted her with 28-horse-power machinery driving 10-foot paddlewheels, and for a pleasure trip proceeded in her up the Rhine as far as Coblentz. From this time onwards steam navigation for commercial purposes progressed rapidly. In 1818 a steamboat made regular voyages at sea; the *Rob Roy*, 90 tons, built by Denny of Dumbarton, with engines of 30 horse-power made by Napier, plied regularly between Holyhead and Dublin. In the same year the *Savannah*, a ship of 350 tons' burden built and fitted with auxiliary steam machinery at New York, crossed the Atlantic, partly under steam; her paddlewheels with their cast-iron frame and axletree successfully withstanding heavy weather. In '21 the postmaster-general introduced a steam service for the mails at Dover and Holyhead; and in the following year there were steamboats running between London and Leith, and other seaports. The experience of the Holyhead packets was of special value, as it proved that steam vessels could go to sea in weather which would keep sailing vessels in harbour. Soon after this the question was raised of employing steam power to shorten the passage between England and the East, as well as of the navigation by steam of the great Indian rivers. Steam superseded sails in the government mail service between Falmouth, Malta and Corfu; everywhere commercial enterprise was planning new lines of steamships and new possibilities of ocean travel. In '25 a

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[1] *Fraser's Magazine*, 1848.

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barque belonging to Mr. Pelham, afterwards Earl of Yarborough, was fitted with steam machinery as an auxiliary and made the voyage to India. The plash of the paddlewheel was then heard for the first time in Oriental waters.

By this time the great question of steam as applied to naval ends had arrived to agitate the Admiralty.

In '22 M. Paixhans discharged his revolutionary treatise at the French nation, advocating, with a wealth of argument, a navy of steam-propelled warships armed with a few shell guns. Six years later a warning echo reverberated through Whitehall. Captain Sir John Ross published a volume on "Steam Navigation, with a System of the Naval Tactics peculiar to it," in which, though his name was not mentioned, the arguments of M. Paixhans were set forth from an opposite point of view. The two books, starting with the same arguments, arrived at diametrically opposite conclusions. While Paixhans claimed that steam power offered important advantages to France, the English writer reached the gratifying conclusion that the change which steam would effect in naval affairs might be rendered favourable to this country. For coast defence alone steam vessels would be invaluable. The colonies would be safer from piracy. Passages, at present difficult or dangerous, would be made with speed and safety. Incidentally, an entirely new system of tactics would be evolved by the coming of steam; each ship-of-the-line would be escorted by a steam vessel, to tow her into position, and concentration of force would be obtained by such means as, harnessing two steamers to one sailing ship, so as to tow one half of the fleet to a position of vantage over the enemy. After the main action the steamers would themselves attack each other; and so on. Both French and English writers agreed that there would be a reversion to the ancient warfare of the galleys; the steamer, whose paddlewheels lent themselves readily to a pivot gun armament and to great powers of manœuvring, would always attack like a bull, facing the enemy, its bows presenting one or more large and well-protected cannon. Sir John Ross regarded the steamer, however, essentially as an auxiliary. M. Paixhans took a more sanguine view. "At this moment," he wrote in May, '22, "the English admiralty are building two steam vessels, each of thirty horsepower, one at Portsmouth and one at Plymouth, for tugging sailing ships held up by contrary winds. They commence by

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being the servitors of the ships-of-the-line; but it is their destiny to become their masters."[1]

But the views of Sir John Ross did not find favour at the Admiralty. In the presence of the revolution the authorities continued to steer a policy of passive resistance to all changes and methods which might have the effect of depreciating existing naval material; and Lord Melville himself penned, as a reply to the Colonial Office to a request for a steam mail service between two Mediterranean ports, the principle which guided the Board. They felt it their bounden duty (he wrote in 1828) to discourage, to the utmost of their ability, the employment of steam vessels, as they considered that the introduction of steam was calculated to strike a fatal blow at the naval supremacy of the Empire.[2] [3]

So far, then, new methods of propulsion had not been greeted with enthusiasm. Yet to the First Lord himself was due the utilization of steam for minor purposes in the navy. In spite of the non-success of Lord Stanhope's experimental "ambi-navigator" ship in 1795, Lord Melville in 1815 caused the three-masted schooner *Congo*, designed for a surveying expedition to the river of that name, to be fitted with paddle-wheels and machinery by Boulton and Watt, expressly to try it in a ship-of-war. This machinery was so large and ponderous that, not only did it usurp one-third of the space aboard the ship, but brought her down so deep as only to give four knots through the water. It was all removed again before she sailed, and sent to Chatham for use in the dockyard. In the following year we find Mr. Brunel in correspondence with his lordship on the question of steam navigation. Brunel wrote quoting evidence to the effect that paddlewheels could be made

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[1] In his book *On Naval Warfare with Steam*, published thirty years later, Sir Howard Douglas set out more clearly the case for the strenuous development of steam navigation by this country, and exposed one of the chief flaws in M. Paixhans' argument. At that date it was still the all-but-universal opinion in foreign countries that the introduction of steam had rendered superiority in seamanship of comparatively little importance in naval warfare. Sir Howard Douglas showed that English superiority had spread to machine design, construction and manipulation, and that if this country chose to exert itself it could maintain its lead.

It is curious to note that not one of these three writers emphasises the main disability under which France has actually suffered, viz. the unsuitability of French coal as warship fuel and the distance of her iron and coal mines from her chief shipbuilding centres.

[2] Briggs: *Naval Administrations.*

[3] A steam paddle-boat, named the *Lord Melville* in honour of the descendant of Charlotte Dundas, was then plying regularly between London Bridge and Calais.

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of sufficient strength and stiffness to withstand the violence of seas and gales ; to which Lord Melville replied that the Board deemed it unnecessary to enter, at that time, into the question of steam navigation generally, but desired his views on the application of steam to the towing of ships-of-war out of harbour against contrary winds and tides : which would be a matter of great advantage to his Majesty's service. Brunel answered recommending that the steamer *Regent*, plying between Margate and London, be chartered during the winter and employed on this work, as a particular experiment.

"From this period may be dated the introduction of steam navigation into the English navy. Lord Melville was now so fully convinced of the great utility which the naval service would derive from it, that he ordered a small vessel to be built at Deptford, by Mr. Oliver Lang, to be called the *Comet*, of the burthen of 238 tons, and to have engines of 80 horse-power. She was built accordingly and ready for sea in 1822."[1] As a matter of fact, the first steamer actually brought into H.M. service was the *Monkey*, built at Rotherhithe in 1821 ; and she was followed by the more powerful *Sprightly*, built at Blackwall by Messrs. Wigram and Green in '23. Gradually the use of these paddlewheel tugs extended, their tonnage and horse-power increased, and the Surveyor of the Navy and his master shipwrights began to divert their talents to a consideration of the small steamers.

For the reason stated by Lord Melville, steamers were at this time tolerated only for towing and other subsidiary duties ; authority poured cold water on the idea of utilizing them as ships-of-war ; and if steam could have been dispensed with altogether, everyone would have been the better pleased.

Even at this period the idea of using manual labour, applied in an effective manner, for towing and bringing into position sailing warships had not been altogether abandoned. In 1802 the transport *Doncaster* had been propelled at a slow speed in Malta harbour by the invention of a Mr. Shorter : a screw propeller rigged over the stern. In 1820 experiments were made at Portsmouth with paddlewheels manually worked, and in '29 Captain C. Napier took his ship *Galatea* out of Portsmouth Harbour by use of paddlewheels geared to winches

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[1] *Memoirs of Sir John Barrow, Bart.*

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which were worked by the crew. One hundred and thirty men were able to give her a speed of 2½ knots, while the full crew of a hundred and ninety produced a speed of three. After this doubtful success another trial was held—a race between the *Galatea*, propelled by paddles, and the *Briton*, towed by boats—which *Galatea* won. Captain Napier's paddlewheels afterwards did good work for his ship in other quarters of the world.[1] Nothing resulted, however, from his initiative in this connection ; only was emphasized the enormous superiority of steam-propelled vessels as tugs, in which capacity they had already made their appearance, and from which they were destined to evolve, in the next decade, into fighting vessels of considerable force.

By 1830 steam navigation had made significant strides along the lines of commercial development. In that year a service of steam mail boats started to run at regular intervals between Falmouth and Corfu, covering the distance in about one-fourth of the time which had been taken by the sailing packets ; a Dutch government steamer, the *Curaçoa*, built in England, had since '27 been running between Holland and the East Indies ; and already the Indian Government had built an armed steamer, designed as the forerunner of others which were to connect Bombay with Suez and thus to place India in more direct communication with England.

The navy was still represented only by paddle-tugs. With a change of administration, however, came a change in Admiralty policy. The new Board took a distinctly progressive view. It was agreed that, if foreign powers initiated the building of steam war-vessels, this country must build as well, and not only as well but better : a policy tersely summed up by Admiral Sir T. M. Hardy in his saying, " Happen what will, England must take the lead." Certain objections to steam vessels as naval units which had hitherto held a vogue were now seen to be ill-founded or baseless. In particular it was discovered, not without surprise to many, that steamers could be manœuvred without difficulty. A paddlewheel steamer, the *Medea*, gained her commander considerable credit from the skill with which she was navigated from the Thames into the basin at Woolwich dockyard, which proved that steamers could be steered and manœuvred better than

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[1] Williams : *Life of Sir Charles Napier.*

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sailing ships. In '33 the construction of steamers was placed in the hands of the Surveyor.[1]

But small progress was made. One reason alleged was that the shape of hull which the Surveyor had made peculiarly his own was ill-adapted for steam machinery. "Nothing more unpropitious," observed a later writer, "for Sir William Symond's mode of construction than the introduction of steam can be conceived. His sharp bottoms were the very worst possible for the reception of engines; his broad beam and short length the most unfavourable qualities that could be devised for steam propulsion. As much as he could, he adhered to his principles. . . . Rather than yield to the demands of the new power, he sacrificed the armaments of his vessels, kept down the size of their engines, and recklessly exposed the machinery to shot should they go into action."[2] There doubtless was something in this criticism. And yet, as we have seen, experience in America led to a form of hull for paddle steamers in many respects approaching that condemned as being favoured by the Surveyor!

Another and more valid reason for the slow progress made lay in the inherent unsuitability of the paddlewheel steamer as a substitute for the large sailing warship. Not only did the paddlewheels offer a large and vulnerable surface to destruction by enemy shot, but the wheels and their machinery could not be embodied in a ship design without interference with its sails and sailing qualities and, still more, without serious sacrifice of broadside armament. The machinery monopolized a large section of the midship space, the huge wheels covered the sides and interfered with the training of those guns for which room remained. The problem of arming steam-vessels was novel and difficult of solution. The guns must be few and therefore powerful. Hence it appeared that paddlewheel steamers, notwithstanding the advantages they possessed of speed and certainty of motion, could only sustain a small concentrated armament, consisting of the heaviest and most

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[1] In 1835 a new department, of Royal Naval Engineers, was formed: to consist of technically trained men to manage the machinery of steam vessels. A uniform button was designed for them, and they were given the rank of Warrant Officers. Up to this time the machinery had been in charge of men who, for the most part, were "mere labourers"; and, commanding officers being ignorant of mechanical engineering, extensive fraud and waste had been practised, especially in connection with the refitting of vessels by contractors (Otway: *Steam Navigation*).

[2] Reed: *On the Modifications to H.M. Ships in the XIXth century.*

powerful ordnance: guns of large calibre, which possessed large power of offence at ranges where the broadside cannon would be deprived of much of their efficiency. Hence in '31 a 10-inch shell gun of 84 hundredweight was expressly designed and cast for this purpose; and all the classes of steamers in early use in the navy were armed with it until, in '41, it was displaced by the 68-pounder pivot gun, which then became the principal pivot gun of the service. Thus the development of paddlewheel machinery reacted on the development of artillery. The steamer was a stimulus to the development of large ordnance worked on the pivot system. And this form of armament in turn influenced the form of the ship. The main weights—those of the propelling machinery—were already concentrated in the waist of the vessel, and it was now possible so to place the few pivot guns that the ends of the vessel were left very lightly loaded. Thus it was possible to give unprecedentedly fine lines to the new steamers, a sharp and lengthened bow and a well-tapered run: an improved form of body by the use of which high speeds were obtained. In the case of commercial steamships the advantages of fine lines had already been recognized, and their designers had been free to give them a form which would allow of a high speed being attained; but in the case of war vessels designed to carry a broadside armament the limitations imposed by the heavily weighted ends had hitherto prevented other than bluff bows and sterns being given them. But now the subject of ship form came under general consideration, and the new conditions led to a more serious study of the laws governing the motion of bodies through water.

Year after year the size of steamers grew.[1] And as with size the cost of construction and maintenance increased, the question pressed itself more and more clearly—what was the naval utility of such expensive and lightly armed vessels? Numerous attempts were made to produce a form of paddlewheel steamer which would carry a broadside armament comparable with that which a sailing vessel of the same burthen

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[1] The strategic value of steam power in warfare was first demonstrated by Lord John Hay in '36. In the operations on the North Coast of Spain "the opportune arrival of a reinforcement of fifteen hundred fresh troops from Santander, by one steamer alone, despatched the previous day from San Sebastian, a distance of a hundred miles, for that express purpose, gave a decisive and important turn to the transactions of that day" (Otway: *Steam Navigation*).

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would bear. In 1843 the *Penelope*, 46 guns, was cut in halves at Chatham and lengthened by the addition of about 65 feet, in which space engines of 650 horse-power were installed. But the extra displacement failed to compensate for the weight of the machinery ; the altered vessel drew more water than had been anticipated and, though various alterations were made to minimize the effects of this, the experiment was not a success and was not repeated. In '45 a steam frigate called the *Odin* was built by order of the Board. "The results aimed at in constructing this ship were—capability of carrying broadside armament ; diminished rolling, in comparison with any war steamers then built ; and less draught of water in relation to the size. These objects were accomplished ; but as the position of the machinery and boilers is partially above the water-line, and the propellers are exposed to danger in broadside fighting, the ship is necessarily imperfect in these two conditions, as well as in the position of the sails ; for in this case the proper place of the mainmast was occupied by the boilers, and consequently the centre of effort of the wind on the sails is in a wrong place."[1] In the same year the *Sidon* was laid down, the design being on the lines of the *Odin* but modified in accordance with the ideas of Sir Charles Napier : with greater depth of hold and with machinery below the water-line. Iron tanks were placed in the hold for carrying the coals ; by filling these with water when empty the steamer was kept at a more or less constant draught, a matter of considerable importance to the efficient working of the paddle-wheels. In other respects, however, the *Sidon* was unsatisfactory. She was so crank that the addition of ballast and a modification of her armament were necessary. Her engines were cramped, her boilers of insufficient power and of unsuitable design, and her coal capacity too small to give her a useful radius of action. For the attainment of all the properties specified it was subsequently calculated and shown that a much larger displacement was necessary. Just as Fitch had discovered and Fulton had discerned, increase in scale reduced many of the difficulties encountered in designing heavily weighted steam vessels. Hence the success of the *Terrible*. In the case of the *Terrible*, a large paddlewheel frigate of 1,850 tons and 800 horse-power built in 1845, it was clear that an increase of size had given a partial solution to the problem of

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[1] Fincham.

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designing a war-vessel with heavy and spacious propelling machinery, with adequate armament, and with full sail-power and all the properties of a sailing ship.

Still the steam war-vessel was not satisfactory. Her machinery usurped the weight and space required for armament, her cumbrous paddlewheels were far too exposed to damage by shot or shell. And how to surmount these difficulties and reconcile the conflicting requirements of artillery and motive power, was a problem which cost the country years of unsuccessful experiments and millions of money. "It was," said Dahlgren, "the riddle of the day."

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The problem was solved by the adoption of the screw propeller.

Since Archimedes' day the screw had been known in the form of a pump, and in two familiar objects—the smoke-jack and the windmill—the principle of the driven screw had been for centuries widely employed. In connection with ship propulsion the screw appears to have been tried at an early date, like the Marquis of Worcester's water-wheel, in the form of a mill. Among the machines and inventions approved by the Royal Academy of Sciences of Paris between the years 1727 and 1731 is one described as a screw, suspended in a framework between two boats, which when acted upon by the current was intended to warp the vessels upstream, the motion of the screw being transmitted to a winch barrel on which a tow-rope was wound. But so far as is known no attempt had been made at this date to use the screw directly as a propeller. In 1768 its use in this form was suggested in a work entitled *Théorie de la Vis d'Archimede.*[1] And shortly after, as we have already seen, Bramah in England and Bushnell in America

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[1] The author of this work, M. Paucton, in addition to discussing the possibility of replacing the oar by the screw, threw out the suggestion of its use for aerial flight. "Je sçais qu'on ne peut guère manquer de faire rire, en voulant donner des aîles à un homme. Je sçais que plusieurs personnes, qui ont osé prendre l'effor dans les airs, n'ont pas eu un meilleur succès que l'imprudent Icare." Nevertheless, it is incontestable that a man can lift more than his weight. And if he were to employ his full force on a machine which could act on air as does the screw, it would lift him by its aid through the air as it will propel him through the water.

M. Paucton hastened to calm the incredulous reader by assuring him with an affectation of levity that he was not really serious. "Il est permis de s'égayer quelquefois."

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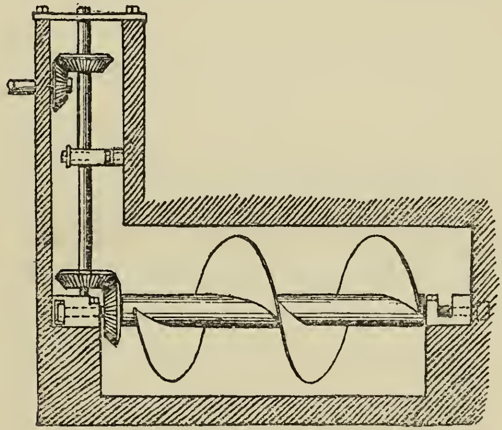
had patented, and the latter had actually put into use, the screw as a means of propelling vessels through water. We have seen, too, that Fulton successfully adapted the screw propeller, on a small scale, in one of his experimental steamboats. Sporadic attempts were made in the early days of the nineteenth century both in this country and in America to drive ships by means of screws, both manually and by the medium of steam, some of which were attended with a certain measure of success.[1] Yet some time was to elapse before screw propulsion gained recognition. Doubt as to the efficiency of a screw's action, ignorance as to the shape of the vessel required and as to the best position for the propeller, difficulty in accommodating the early long-stroke steam engine to drive direct an under-water propeller shaft; inertia, prejudice and vested interest, all seem to have played a part in delaying the adoption of what, when it did come, was acknowledged to be the only suitable form of steam propulsion for war vessels.



PETTIT SMITH'S PROPELLER

In 1825 a premium was offered by the Admiralty for the best plan of propelling vessels without paddlewheels; and a plan proposed by Commander S. Brown, R.N., was deemed sufficiently promising for trial: a two-bladed screw propeller placed at the bow of a vessel and actuated by a 12-horse-power engine. But though exhibiting advantages this form of the invention did not survive.

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[1] A full account of these is given in Bourne's *Treatise on the Screw Propeller*.

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The history of the screw-propeller may be said to date from 1836. In that year two capable inventors obtained patents: Mr. Francis Pettit Smith and Captain Ericsson. So little attention had, up to that time, been given to the subject that the two proposals "were presented to the public in the character of novelties, and as such they were regarded by the few who had curiosity enough to look at them." Smith's patents were for the application of the screw to propel steam vessels by fixing it in a recess or open space formed in the deadwood; and, says Fincham, "the striking and peculiar merit of Mr. Smith's plan appears to consist, *chiefly*, in his having chosen the right position for it to work in." Trials were carried out with Smith's propeller in a 6-ton boat on the City and Paddington canal, and then between Blackwall and Folkestone, with encouraging success; the boat, encountering heavy weather off the Foreland, demonstrated the advantage derived from the absence of paddlewheels, and showed the new form of propelling machinery to place no limitations on her qualities as a sailing vessel. She returned to Blackwall, having run over 400 miles at a mean speed of 8 knots.

Captain Ericsson, a Swedish army officer who had come to London and established himself as a civil engineer, had a contemporary success with a boat fitted with two large-bladed propellers each 5 feet 3 inches in diameter. So successful was he, indeed, that he invited the Board of Admiralty to take a trip in tow of his novel craft; a trip which had important and unexpected results on the subsequent progress of steam navigation. One summer day in '37 the Admiralty barge, in which were the Surveyor and three other members of the Board, was towed by Ericsson's screw steamer from Somerset House to Limehouse and back at a speed of 10 knots. The demonstration was a complete success, and the inventor anticipated some further patronage of his invention. But to his chagrin nothing was asked of him, and to his amazement he was subsequently informed that the proposal to propel warships by means of a screw had been pronounced impracticable. Never, perhaps, in the whole history of mechanical progress has so signally wrong a decision been made, never has expert opinion been so mistaken. Engineers and shipbuilders all failed to realize the possibilities of the screw. The naval authorities who, in the face of their personal experience, dismissed the project as impracticable (owing to some anticipated difficulties in steering ships fitted with screws) merely expressed the unanimous opinion of the time. "The engineering corps of the empire were arrayed in opposition to it, alleging that it was constructed on erroneous principles, and full of practical defects, and regarding its failure as too certain to authorize any speculations even of its success. The plan was specially submitted to many distinguished engineers, and was publicly discussed in the scientific journals; and there was no one but the inventor who refused to acquiesce in the truth of the numerous demonstrations, proving the vast loss of mechanical power which must attend this proposed substitute for the old-fashioned paddlewheel."[1] Yet in five years' time steamers designed for paddlewheels were being converted to carry screws, and a great screw-propelled liner, the *Great Britain*, had been launched for the Atlantic traffic!

It was in America, we have seen, that progress in steam navigation was of the greatest interest to the public, and it was by Americans that the disabilities of the paddlewheel were most keenly appreciated. Two witnesses of the trial of Ericsson's boat saw and admitted the advantages of the new method: Mr. Ogden, an engineer who had been U.S. consul at Liverpool for some years, and Captain Stockton, U.S.N. The latter appreciated the military advantages of screw propulsion and was soon its enthusiastic advocate. Under his influence and encouragement Ericsson threw up his engagements in London and went to America. "We'll make your name ring on the Delaware," said Captain Stockton to him at a dinner in his honour given at Greenwich. The prediction was fulfilled. In the course of time Ericsson saw his propeller applied on a large scale, not only to mercantile craft but in the American navy. Early in '37 Captain Stockton had ordered an iron vessel to be built by Messrs. Laird, of Birkenhead, and fitted with a screw. In the following year she was launched, and in the spring of '40, after giving demonstration on the Thames of the great towing power of her propeller, she left for America for service as a tug on the big rivers. On this work one of the great advantages of the screw was realized: the immunity with which the screw vessel could work in drift ice, when paddlewheel steamers were perforce laid up.

In the meantime, fortunately, Pettit Smith's successes had not been without their effect on opinion in this country. A

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[1] Weale: *Papers on Engineering.*

company was formed to exploit the screw, and a vessel, the *Archimedes*, was built amid a strange chorus of detraction, opposition and ridicule. She made her trials in October, '39. Her propeller was at first in the form of a complete convolution of a helical screw of 8-foot pitch and of 5 foot 9 inches diameter ; but subsequently this blade was replaced by two, each of which formed half a convolution, with the two halves set at right angles to one another. Comparative trials were ordered by the Admiralty in the following year to test the merits of the *Archimedes*' screw as compared with the ordinary paddle-wheels applied to her Majesty's mail packets on the Dover station. The results were inconclusive.[1] But a subsequent voyage round the coasts of Great Britain, during which the machinery of the *Archimedes* was laid open to the inspection of the general public, and a later voyage from Plymouth to Oporto which recreated a new record for a steam passage, went far to establish in public estimation the merits of the new propeller. But generally the invention was discouraged. Prejudice and vested interests, rather than a reasoned conservation, seem to have operated to oppose its progress. "A striking instance of prevailing disinclination to the screw propeller was shown on the issue of a new edition of the *Encyclopædia Britannica*, in which the article on steam navigation contained no notice whatever of the subject."

But in spite of all prepossessions against it the screw had won a decisive victory over its rival. So striking were the results recorded by the *Archimedes*, that a decision was made in December, 1840, to change the *Great Britain*, an Atlantic liner then under construction, from paddlewheel to screw propulsion. In two ways she was a gigantic experiment : she was the first large ship to be built of iron, and it was now proposed to fit her with a screw. Mr. Brunel took all the responsibility for advising the adoption of both these revolutionary features ; the result was a splendid testimony to his scientific judgment, boldness of enterprise, and "confident reliance on deductions from facts ascertained on a small scale."

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[1] The *Archimedes*, with a 3-foot stroke engine which worked at 27 strokes per minute, was run against the *Widgeon*, the fastest paddlewheel steamer on the Dover station. Two points of importance were noted by the Admiralty representatives with reference to the propelling machinery of the *Archimedes* : the objectionable noise made by the spur-wheels, and their liability to damage and derangement. As, however, Mr. Smith proposed to obviate this objection "by substituting spiral gearing in lieu of the cogs" the representatives did not lay stress on these disadvantages.

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Before the completion of the *Great Britain* the Admiralty had initiated experiments which were to furnish important information as to the power and efficiency of the screw propeller in its various forms, and to settle beyond cavil the question of its superiority over the paddlewheel for the propulsion of warships. The sloop *Rattler*, 888 tons and 200 horse-power, was fitted with screw machinery. Several forms of screw were tried during the winter of 1843–4. First the screw as used in the *Archimedes* was fitted: a screw of 9-foot diameter, 11-foot pitch, and of 5½ feet length, consisting of two half-convolutions of a blade upon its axis. Then a screw was tried of the same diameter and pitch but of only 4-foot length; and then the length was again reduced to 3 feet. The effect of cutting down the length was to give an increase of efficiency.[1] The screw was again shortened by 2 feet, and finally to 1 foot 3 inches; with each reduction in length the slip diminished and the propulsive efficiency increased. Various other forms of screws were tried, and it was shown that Pettit Smith's short two-bladed propeller was on the whole the most efficient.

The best form of screw having been determined, it still remained to compare the screw propeller with the paddle-wheel. Accordingly the *Alecto*, a paddlewheel sloop of similar lines to the *Rattler*, was selected as the protagonist of the older form of propulsion, while the *Rattler* herself represented the screw. Naval opinion was still completely divided on the great question, while in the competing sloops the utmost emulation existed, each captain advocating his own type of propeller. The speed trials took place, and showed the *Rattler* to have an undoubted advantage. The paddlewheel, however, laid claim to a superiority in towing power. So a further competition was ordered, as realistic as any, perhaps, in the history of applied science: nothing less than a tug-of-war between Paddle and Screw, those two contending forms of steam propulsion! Lashed stern to stern and both steaming ahead full power, one evening in the spring of '45 the two steamers struggled for mastery. And as *Rattler* slowly but surely pulled

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[1] A similar paradox was accidentally revealed in the case of the paddle-wheel. It was at first thought that, the broader the floats the greater would be the pull. A certain steam vessel, however, being found to have too much beam to allow her to pass into a lock, was altered by having her floats and paddle-boxes made narrower. It was found that her speed had thereby been improved (Otway).

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over *Alecto*, the question which had been for years so hotly debated was settled; the superiority of the screw was demonstrated. With the adoption of the screw the problem of disposing the armament was settled. The broadsides and the spaces between decks were once more free to the guns along the entire length; moreover the action of the screw was in complete harmony with that of the sails. With the screw as an auxiliary to sail power, and subsequently with the screw as sole means of propulsion, a change came over the character of the pivot armament. Whereas with the paddlewheel the pivot gun was the chief means of offence, when the screw was introduced the broadside was restored, and though the heavy pivot guns were retained (steam and the pivot gun had become associated ideas), yet by their comparatively limited numbers they became a subordinate element in the total armament.

External affairs now lent a spur to screw propulsion. In '44 the French navy came under the reforming power of the ambitious Prince de Joinville, and from this year onwards the attitude of France to this country became increasingly hostile and menacing. The thoughts of the French were turned toward their navy. No sooner had de Joinville been placed in command than schemes of invasion were bruited in this country; and the public viewed with some alarm the altered problems of defence imposed on our fleets by the presence in the enemy's ports of a steam-propelled navy. Sanguine French patriots sought to profit by the advent of the new power. A pamphlet appeared in Paris claiming to prove that the establishment of steam navigation afforded France the very means by which she could regain her former level of naval strength. The writer, using the same arguments as Colonel Paixhans had used in '22, reviewed the effect of steam power on the rival navies, and pointed to the Duke of Wellington's warnings in parliament of the defencelessness of the English coasts and to his statement that if Napoleon had possessed steam power he would have achieved invasion. These cries of alarm, said the writer, should trace for France her line of policy. She should emulate the wise development of steam propulsion as practised by Great Britain. "We think, England acts; we discuss theories, she pursues application. She creates with activity a redoubtable steam force and reduces the number of her sailing ships, whose impotence she recognizes. . . . Sailing vessels have lost their main power; the employment of

RATTLER VERSUS *ALECTO*

From an aquatint in the South Kensington Museum

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steamers has reduced them to the subaltern position of the siege artillery in a land army." The writer praised English policy in the matter of steam development : its wise caution, its reasoned continuity. There had admittedly been some costly deceptions. Nevertheless the method was to be commended, and France should proceed in a similar manner : by a succession of sample units while steam was still in the experimental stage, by far-sighted single strides, and then by bold and rapid construction of a steam navy which would compete on more even terms with that of her hereditary rival.[1]

Faced with the probability that our rivals would pursue some such progressive and challenging policy as outlined by the pamphleteer, the Admiralty acted rapidly. Before the *Rattler* trials were complete a decision was made favourable to the screw propeller, and an order was made for its wide application to warships built and building. It was resolved, on the advice of Sir Charles Napier, that the screw should be regarded solely as an auxiliary to, and in no way as in competition with, sail power. The *Arrogant* was laid down, the first frigate built for auxiliary steam power ; and screws driven by engines of small horse-power were subsequently fitted to other ships with varying degrees of success.

Two important features were specified for all : the machinery was required to be wholly below the water-line, and the screw had to be unshippable. Engines were now required for Block Ships and for sea-going vessels. So the principal engineers of the country were called together and were asked to produce engines in accordance with the bare requirements given them. A variety of designs resulted. From the experience obtained with this machinery two important conclusions were quickly drawn : firstly, that gearing might be altogether dispensed with ; secondly, that no complex contrivance was necessary for altering the pitch to enable engines to work advantageously under varying conditions, the efficiency of the screw varying very little whether part of the ship's velocity were due to sail power or whether it were wholly due to the screw.[2]

And here it may not be amiss to note, in relation to a nation's fighting power, the significant position assumed by naval material. In land warfare a rude measure of force could always

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[1] Note sur l'État des Forces Navales de la France, 1844.

[2] Parliamentary Report on Screw Propulsion in H.M. Navy, 1850.

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be obtained by a mere counting of heads. At sea man was in future to act, almost entirely, through the medium of the machine.

However we may have deserved the eulogy of the French writer in respect of developing the paddlewheel war steamer, the development of screw propulsion in the next decade was marked by a succession of failures and a large outlay of money on useless conversions and on new construction of poor fighting value, most of which could have been avoided. Had our methods been less tentative and more truly scientific the gain would have been undoubtedly very great ; we should have laid our plans on a firmer basis and arrived at our end, full screw power, by a far less circuitous route than that actually taken. In this respect France had the advantage of us.

Although a decision had been made to maintain the full sail power of our ships and install screw machinery only as an auxiliary motive power, attempts were naturally made to augment so far as possible the power exerted by the screw; and within a short time new ships were being fitted with machinery of high power, in an endeavour to make the screw a primary means of propulsion. The results were disappointing. As the power increased difficulties thickened. The weight of the machinery grew to be excessive, the economy of the comparatively fast-running and short-stroke engines proved to be low, and the propulsive efficiency of the screws themselves grew unaccountably smaller and smaller. So poor were the results obtained, indeed, that in the case of a certain ship it was demonstrated that, by taking out the high-power machinery and substituting smaller engines an actual gain in speed was obtained, with the reduced displacement. The first screw ship in which an attempt was made to obtain full power with the screw was the *Dauntless*, of 1846. Although a frigate of beautiful lines she was considered a comparative failure. It was agreed that, equipped with paddlewheels and armed with guns of larger calibre, she would have constituted a faster and more powerful warship than, with her 580-horse-power engines, her 10 knots of speed, and her 32-pounder guns, she actually was.

Part of the trouble was due to the unsuitability of our ships' lines for screw propulsion. It has already been noted that, owing to the carriage of heavy weights at their extremities, war vessels were always given very full bows and sterns. In

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the case of the *Rattler*, whose records served as a criterion for later designs of screw ships, the lines of the stern were unusually fine: partly, no doubt, in imitation of the *Archimedes*. Also, since it had been necessary to allow space enough for a long screw to be carried (a screw of a complete convolution was thought possible) the *Rattler's* short screw as finally adopted worked at some distance aft of the deadwood, and thus suffered no retarding influence from it when under way. But in the case of later ships these advantages did not obtain. They were built with the usual "square tuck," a bluff form of stern which prevented a free flow of water into the space ahead of the propeller and thus detracted from its efficiency. It was not appreciated at this time that, for efficient action, the screw propeller demands to be supplied with a body of unbroken, non-eddying water for it to act upon, which with the square-cut stern is not obtained. At low speeds, and in the ship to which the screw was fitted as an auxiliary, the effect of the square tuck was not marked. But as power and speed increased its effect became more and more evident; the increase in power gave no proportionate increase in speed; and many, ignorant of the cause, surmised that there was a limit to the power which could be transmitted by a screw and that this limit had already been reached. The inefficiency of the square tuck was exposed by trials carried out in H.M.S. *Dwarf* at Chatham. As a result of these, future new and converted ships were given as fine a stern as possible.

For several years, however, the policy of the Admiralty remained the same: the screw was regarded solely as an auxiliary. The French, on the other hand, took a less compromising line of action. After waiting for some time and watching our long series of experiments, they convened in 1849 a grand *Enquête Parliamentaire:* a commission which, primed with the latest information as to British naval material, was to decide on what basis of size, number, armament and means of propulsion future French warships should be built. For two years the commission sat sifting evidence. And then it recommended screw propulsion of the highest power for all new ships, as well as the conversion of some existing classes to auxiliary screw power. England had fitted her ships with screws capable of giving them small speed; France must fit hers with screws of greater power. Speed, said the commission, is an element of power. Superior speed is the only means by

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which the English can be fought with a good chance of success. Sails must be secondary, therefore, and full reliance must be placed on the screw. The recommendations of the commission were duly realized. In the following years a powerful force of fast screw battleships, frigates, transports, and despatch boats was constructed which by '58 had brought the aggregate of the horse-power of the French fleet almost to a level with that of England.

When the Crimean War brought the two navies together as allies in '54 the full effect of the new policy of the French had not yet been made apparent. Some apprehension existed in this country as to the adequacy and efficiency of our navy, when compared directly with that of France. But from then onwards this country became aware of the increasing hostility of the French public and government; speeches were made, and letters appeared in the press of both countries, which tended to fan the flames of fear and suspicion.[1] It was not till '58, however, that general attention was drawn to the great strides which the French navy had made in recent years, and to the skilful way in which its position, relative to that of its great rival, had been improved. An article entitled "The Navies of England and France" appeared in the *Conversations Lexicon* of Leipsic, and caused a great sensation. Reprinted in book form, with a long analysis and with a mass of information about the French, English and other navies and arsenals,[2] this notorious article brought apprehension to a head. Though written by no friendly critic, it was in most respects an accurate presentment of the respective navies and of their condition. The analysis of Hans Busk, while ostensibly exposing its bias and its inaccuracies, in effect confirmed the main contentions of the German article; in addition his book gave in spectacular columns a summary of the units of the rival navies, which gave food for thought. The article itself professed to show how much France had benefited by the bold and scientific manner in which she had handled the problem of naval construction since the coming of steam. Other factors were discussed, the forms of ships, the Paixhans system of armament, problems of

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[1] Sir Howard Douglas was instrumental in bringing to the notice of the Government the aggressive aims implied by the *Enquête Parlementaire*: His notes were printed confidentially in '53 at the press of the Foreign Office. Vide his *Defence of England*, published in 1860.

[2] *The Navies of the World.* Hans Busk, M.A., 1859.

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manning and of education ; but the factor which had caused the greatest accession of strength to France, by her wise divergence from the English policy, was (according to the critic) steam propulsion. In the case of paddlewheel steamers England, by her unscientific and ruinous experiments, had squandered millions of money and produced a series of crank and inefficient war vessels. In the case of screw ships England's waste of exertions and money was even more surprising ; the building of new ships and the conversion of others was carried out at an enormous cost with many galling disappointments. The French, on the other hand, took longer to consider the principle of the screw, but then, when their more scientific constructors had completed their investigations and analysed the new power, they acted thoroughly and without delay. From all of which the German critic inferred that England had good reason to watch with anxious eye the significant development of strength on the part of her neighbours across the Channel. "We must pronounce," he concluded, "that with a nearly equal amount of *matériel*, the French navy surpasses the English in capacity and in command of men. France need feel no hesitation in placing herself in comparison with England. . . . Never was the policy of England so yielding and considerate towards France as at the present day. And then, with respect to the vexed question of the invasion, it is certain that Napoleon III has the means of effecting it with greater ease and far greater chance of success than his uncle."

The means was steam power. But the much-talked-of invasion was never to be attempted. Other events intervened, other developments took place, which reduced the tension between the two great naval powers and removed for an indefinite time the danger, which the Leipsic article disinterestedly pointed out, of war under novel and unprecedentedly terrible conditions : with shell guns and wooden unarmoured steam warships.

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CHAPTER X

THE IRONCLAD

THE year 1860 marks the most dramatic, swift, and far-reaching change which has ever befallen war material: the supersession of the wooden ship-of-the-line by the modern battleship in its earliest form. What were the causes, suddenly realized or acknowledged, which impelled this revolutionary change, and what were the circumstances which moulded the new form of naval construction? This final chapter will attempt to show. Before descending to a detailed examination of this evolution, however, let us trace out the most striking features of the transition; their measure of accuracy can be estimated by the light of the subsequent narration of progress.

In the first place, then, we remark that, potentially, from the time when shell-throwing ordnance was introduced into the French, and then as a counter-measure into our own fleet, unarmoured wooden ships were doomed. Strange it seems that so long a time elapsed before this fact was realized; though it is true that with spherical shells and small explosive charges the destructive effects of shell fire were not greatly superior to those of solid shot, that fuzes were unreliable, that trials of artillery against material were rarely resorted to, and that, moreover, no opportunity occurred between 1822 and the outbreak of the Crimean War to demonstrate in actual sea-fighting such superiority as actually existed. Implicit trust was placed in our fine sailing ships. So long as solid shot were used, indeed, these timber-built ships were admirably suited for the line of battle; as size and strength increased and as our methods of construction improved the ship gained an increasing advantage over the gun, defence increasingly mastered attack, to such a degree that by the end of the long wars with France the ship-of-the-line had become almost unsinkable by gun-fire. But so soon as shell guns were established—even with spherical

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shells fired from smooth-bore ordnance—wooden ships loomed easy targets for destruction. For a long time this disquieting conclusion was ignored or boldly denied ; expert opinion with sagacity turned a blind eye to the portentous evidence presented to it of the power of shell. War came, but even then the full possibilities of shell fire were not developed. Enough proof was given, however, to show that in the special circumstances of that war unarmoured ships were of small value against shell fire. Armour was accordingly requisitioned, and, some few years after the war, was applied to seagoing warships.

Another development now took place. At this period when disruptive and incendiary shell was proving itself a more powerful agent than solid shot of equal size, both shell and shot gained an enhanced value from the application of rifling to ordnance ; moreover, ordnance itself was developing so quickly that each year saw an appreciable increase in the unit of artillery force. This variation in the unit profoundly affected naval architecture. No longer was there a unit of standard and unchanging value, which, when multiplied by a certain number, conveyed a measure of a ship's offensive power. No longer was the size of a ship a rough measure of its fighting strength ; by concentrating power in a few guns, offensive strength could be correspondingly concentrated, if desired, in a small vessel. On the other hand, in view of the sudden accession of offensive strength, the defensive capacities of a ship remaining as before, it was now true that size had become an element of danger, diminutiveness of safety. Hence warships, which had for centuries triumphed in the moral and physical effect of their height and size, suddenly sought to shrink, to render themselves inconspicuous, to take the first step towards total invisibility.

An effect of the same development—of the increasing size of the unit gun, and therefore of the decreasing number of units which a ship could carry—was the mounting of every big gun so as to command as large an arc of fire as possible.

As the final development we note that the steam engine, in endowing the warship with motions far more variable, certain and controlled than those of the sailing ship, called forth tactical ideas quite different, in many respects, from those which governed sea actions in the canvas period. The warship itself is the embodiment of tactical ideas. Hence the design of

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the steam-propelled warship evolved along a different line from that of the sailing ship.

By the effect and interaction of these developments a complete revolution was compassed in naval architecture ; by the progress of artillery and the steam engine, and by the improvement in mechanical processes in general, an entirely new unit of naval force was evolved from the old sailing ship : the mastless, turreted ironclad of the late 'sixties, the precursor of the modern battleship.

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No sooner had the shell gun given proofs of its destructive powers than experiments on the penetrative power of projectiles began to assume importance, and as early as 1838 trials were being made at Portsmouth against a hulk, the result of which, confirming the experiments made by the French with the *Pacificateur* some sixteen years previously, demonstrated the far-reaching effects of explosive shell against a ship's side-timbers. Four years later the prime minister was apprised from New York that the Americans had discovered a suitable and adequate protection for ships' sides; iron plates of three-eighths of an inch in thickness, riveted together to form a compound 6-inch plate, were alleged to have been found ball-proof. On receipt of which intelligence the Admiralty instructed Sir Thomas Hastings, captain of the *Excellent*, to confirm or disprove by actual trial. Trial was made, but it was reported that no protection was afforded by such plates against the fire of 8-inch shell or 32-pounder shot, even at 200 yards' range. No defensive remedy could be devised against shell fire, and the only counter-measures deemed practical were of an offensive nature, viz. to mount shell guns as powerful as those of the enemy, and to keep him at a distance by the employment of large and far-ranging solid-shot ordnance.

In the meantime iron, which was not acceptable as a protection, had been accepted as a constructive material for ships. For some years it had been increasingly used for mercantile shipping with satisfactory results. The scarcity of timber and its cost, as well as the positive advantages to be obtained from the use of the much stronger and more plentiful material, had decided the Admiralty in '43 to build iron warships. Some small vessels were built and, in spite of adverse criticism and alarming prediction, acquitted themselves admirably on service. In '46 it was resolved, however, to put iron to the test of artillery. An iron steamboat, the *Ruby*, was used as a target by the *Excellent* gunners, and the results were unfavourable; the stopping power of the thin metal was small, and the balls which went clean through the near side wrought extensive damage on the opposite plates. In '49 trials were made with stouter plates with more promising results: a report favourable to iron as a protection for topsides was made. But in '51, as the result of elaborate trials made against a "mock up" of the side of the *Simoon*, the previous conclusions were reversed. Iron was condemned altogether as unsuitable for ships of war. "The shot and shell," reported Captain Chads, "on striking are shivered into innumerable pieces, passing on as a cloud of langrage with great velocity," and working great destruction among the crew. Nor was a combination of wood and iron any better. In fact the report claimed that, as regards the suitability or the unsuitability of iron, these experiments might be deemed to set the question at rest. The experience of the French had apparently been somewhat similar to our own. In both countries the use of iron for warships received a sudden check and, in England at any rate, the idea of unarmoured wood was once again accepted. In both countries the opinion was widely held that iron was unsuitable either for construction or protection, and that the view of General Paixhans, that vessels might be made proof even against shells by being "cuirassées en fer," was preposterous and impracticable.[1]

Potentially, as it now seems, wooden sailing ships were so weak in defensive qualities that the new artillery, if only it could be adequately protected, had them at its mercy. Actually it required the rude test of war to establish the unpalatable truth. In November, 1853, such proof was given. At Sinope a squadron of Turkish frigates armed with solid-shot guns was almost blown out of the water by shell fire from a powerful Russian squadron; the latter were practically uninjured, while the Turkish fleet was set on fire and a terrible mortality inflicted among the crews in a short time. General Paixhans, who had lived to see his invention fulfil in actual warfare his early predictions, was able to emphasize, in the columns of

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[1] The details of these trials against iron plate will be found in Sir Howard Douglas' *Naval Gunnery*, third and subsequent editions.

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the official *Moniteur*, the arguments against large ships and the advantages which would accrue to France especially by the subdivision of force and the substitution of small protected steamers armed with heavy guns for the existing wooden ships-of-the-line. The concentrated fire of a few such steamers would overpower the radiating fire of the largest three-decker.

The type of naval warfare imposed on the allies in the Crimean War lent special force to Paixhans' arguments. For the attack of fortresses and coasts whose waters were exceptionally shallow it was at any rate clear that the orthodox form of warship, unarmoured, of large size and of deep draught, was of very limited value. Some special form was necessary ; France made a rapid decision. Napoleon III issued an order for the construction of a flotilla of floating batteries, light-draught vessels capable of carrying heavy shell guns and of being covered with iron armour strong enough to resist not only solid shot but the effects of explosive shell.

The idea of armouring ships was, of course, not novel. Armour of sorts had been utilized from antiquity ; in the days when the shields of the men-at-arms were ranged along the bulwarks of the war galleys ; in the Tudor days when the waists of ships were protected by high elm "blinders," and when Andrea Doria's carrack was so sheathed with lead and bolted with brass that "it was impossible to sink her though all the artillery of a fleet were fired against her." In the eighteenth century the French themselves had attempted to clothe floating batteries with armour, not indeed against shells but against red-hot shot. In 1782 they had devised, for the attack on Gibraltar, six wooden floating batteries which, with their armament, were protected by a belt of sand enclosed in cork and kept moist with sea water. But this experience had been disastrous. The sand-drenching apparatus failed to act, and the batteries were almost totally destroyed by fire.

But now, although experiments with iron-plated ships had been the reverse of satisfactory, data were to hand which showed that, if used in sufficient thickness, iron plates *were* capable of withstanding the disruptive effects of shell. At Vincennes trials had been made, between 1851 and 1854, with various thicknesses and dispositions of iron ; with plates four to five and a half inches thick, with compound plates, and with

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plates supported on a hard wood lining eighteen inches thick; of all of which the thick simple plates had proved the most effective. So the five floating batteries ordered for work in the Crimea were covered with 4-inch iron plates backed by a thick lining. Sixty-four feet long, 42 feet in beam, drawing about 18 feet of water, armed with sixteen 56-pounder shell guns and equipped with auxiliary steam machinery for manœuvring, their construction was hastened with all possible speed. By October, '55, three of them, the *Dévastation*, *Tonnante*, and *Lave*, had joined the allied flags, and on the 17th of that month they took a principal part in the bombardment of Kinburn. Their success was complete. Although repeatedly hit their iron plates were only dented by the Russian shot and shell. "Everything," reported the French commander-in-chief, "may be expected from these formidable engines of war." Once again the arguments of Paixhans for armoured war vessels had been justified; the experience gained with iron armour at Kinburn confirmed that gained with shell guns at Sinope. France at once proceeded to apply these lessons to the improvement of her navy proper.

In England, on the other hand, no great impression was created either by shells or by iron protection. A comfortable faith in our fleets of timber-built ships persisted; and, with regard to policy, as it had been with shell guns, and with steam propulsion, so it appeared to be with armour; the national desire was to avoid for as long a time as possible all change which would have the effect of depreciating the value of our well-tried material. At the same time it is remarkable how small an effect was conveyed to expert opinion, both here and in America, by the events of the Crimean War. In the years immediately following the war some notable technical works were published: Dahlgren's *Shell and Shell Guns*, Read's *Modifications to Ships of the Royal Navy*, Grantham's *Iron Shipbuilding*, Sir Howard Douglas' *Naval Warfare with Steam*, and Hans Busk's *Navies of the World*. From these works and from the press and parliamentary discussions of the day it is evident that, outside France, the impressions created were vague and conflicting. The main lesson conveyed was the great tactical value of steam propulsion. The reports laid no emphasis on shells, and so scanty was the information concerning them that it was very difficult to appraise their value. Their effect at Sinope was disguised by the overwhelming superiority of the Russian force, which rendered the result of the action a foregone conclusion; on another occasion (at Sebastopol) shells fired at long range were reported to have failed to penetrate or embed themselves in a ship's timbers. Commander Dahlgren was uncertain, in the absence of fuller information, whether shells had justified their advocates or not. Nor was Grantham impressed by the French floating batteries. "One only of these vessels," he incorrectly says, "was thus engaged, but then not under circumstances that gave any good proof of their efficiency, as the fire was distant and not very heavy."

So no violent change in our naval material followed as the immediate result of the war. Only in the matter of light-draught gunboats and batteries tardy action was forced on the authorities by public opinion. Although iron had been condemned for warship construction iron ships had been built in the years preceding the war in considerable numbers for foreign governments; the firms of Laird and Scott Russell had built in 1850 powerful light-draught gunboats for Russia, and in the same year Russia had ordered from a Thames firm an iron gunboat whose novel design had been brought to the notice of the Admiralty. But these craft were intended for the defence of shallow waters, and nothing analogous to them was considered necessary for the British navy. The exigencies of the war demonstrated in the course of time the value of these light-draught vessels. Still there was long hesitation; though the French government pressed on us their advantages, and presented our minister with the plans of their own floating batteries. The disappointment of the Baltic expedition, however, and the realization that the powerful British fleet which in the summer of '54 had set out to reduce Cronstadt had done nothing but prove the inherent unsuitability of large ships-of-the-line for the attack of fortresses in shallow waters, gave rise to a loud demand in the press that gunboats should be built. Several were accordingly laid down. The first of these were found to be too deep, but others of lighter draught were designed and by the autumn of '55 sixteen were ready; and these, together with some dockyard lighters which had been fitted as mortar vessels, joined a flotilla of French floating batteries in the Baltic and effectually bombarded Sveaborg. As the war progressed the value of ironclad gunboats became more fully appreciated. A large number was ordered, but most of them were only completed in time to fire a grand salute in honour of the proclamation of peace.[1]

Apart from the building of these gunboats innovation was avoided. Unarmoured wooden ships, equipped with a mixed armament of shot and shell guns, continued to be launched and passed into commission, and it was only after France had constructed, at Toulon in '58, an iron-encased frigate, that England unwillingly followed suit, convinced at last that a reconstruction of her materials could no longer be averted.

La Gloire, the iron-belted frigate, was the direct result of the lessons gained from the floating batteries in the Russian war. After Kinburn the French naval authorities took up the study of how to apply armour to sea-going ships. Was it possible to embody in a fighting unit sea-going capacity, high speed, great offensive power, in addition to the defensive qualities possessed by the slow, unwieldy batteries? Could such a weight as iron armour would entail be embodied in a ship design without loss of other important qualities? It was concluded that, while it would be impossible to cover the sides completely, it would be possible to protect the surfaces near the water-line, under cover of which all the ships' vital parts could be secreted. A great increase in defensive power would thus be obtained. Before developing a plan in detail it was decided to carry out further armour trials, and solid iron plates of 4½ inches thickness were fired at with English 68-pounders and French 50-pounders, with solid balls and with charged shells. The results were satisfactory, so these plates were adopted as the standard of armour protection. To the design of M. Dupuy de Lôme the first ironclad frigate was constructed from a fine two-decked ship, the *Napoleon*, which was cut down, lengthened, and armoured from stem to stern. The result was the celebrated *Gloire*. She was followed shortly

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[1] The rapid construction of over two hundred gunboats and their steam machinery revealed the enormous industrial capacity of this country, and constituted a feat of which the whole nation was rightly proud. For instance of successful organization, Messrs. Penn of Greenwich contracted to build eighty sets of main engines in three months—a proposition ridiculed as impossible. By the rapid distribution of duplicate patterns throughout the country the resources of all the greatest firms were utilized, and the contract was fulfilled almost to the day!

Some seven or eight years later, when the building of ironclads was being debated in parliament, the government was able to recall this achievement as an argument for not building too many ships of a new and probably transitional type. If we liked, it was said, we could soon produce a fleet of ironclads far greater than all the other Powers of Europe besides.

afterwards by two sister vessels. And then, in order to obtain a direct comparison between timber-built and iron ships, an armoured *iron* frigate, the *Couronne*, was also built. The three wooden ships were given a complete belt round the water-line of 4½ inches of iron; the *Couronne* had compound armour—3-inch and 1½-inch iron plates separated from each other and from the iron stem-plating by wood lining 6 inches in thickness. The armament of all four frigates consisted of thirty-six 50-pounder shell guns, carried low. They were given yacht masts and equipped with propelling machinery designed to give them 12 knots speed.

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The naval position of England at this time was the reverse of satisfactory. Comparing the material resources of the two great maritime rivals, it came to be noted with surprise that France, taking advantage of the development of steam propulsion during the decade, had actually drawn level with England in the numbers of steam warships available and in their aggregate motive horse-power. The French had submitted to great financial outlay on account of their navy. In this country a reaction, following the large and partially ineffective expenditure incurred in the Crimean War, had dried up the sources of supplies and stunted constructional development; there was little to show for the money spent on such works as the enlargement of docks and on the extensive new factories and docks established at Sheerness and Keyham. Apprehension was widespread when the intelligence of the building of the iron-sided ships was received, and this apprehension developed when whispers reached Westminster of a huge prospective programme meditated by France. To allay the panic a parliamentary committee was formed to inquire into the relative strength of the two navies; and their report, published in January, 1859, made bad reading. Comparing the steam navies—for, the committee reported, sailing ships could not be opposed to steamships with any chance of success—France and England each had afloat the same number of line-of-battle ships, viz. twenty-nine; and as regards frigates France had thirty-four to England's twenty-six! This did not include the four *frégates blindées* laid down by France, which would be substitutes for line-of-battle ships,

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which were being built with the scantling of three-deckers, and which were to be armed with thirty-six heavy guns, most of them 50-pounders throwing an 80-pound hollow percussion shell. "So convinced do naval men seem to be in France," note the committee, "of the irresistible qualities of these ships, that they are of opinion that no more ships-of-the-line will be laid down, and that in ten years that class of vessel will have become obsolete." The position is bad enough; yet so bewildered are our experts by the radical developments of the rival navy, so difficult appears the problem of countering the French designs by any new and well-studied procedure, that all that the committee can recommend is the accelerated conversion of our remaining sailing ships to steam. The committee realize that naval architecture, and still more naval artillery, is in a state of transition, and that the late invention of Armstrong's gun "may possibly affect even the size and structure of ships of war."

It is not possible, however, for a country desirous of maintaining its maritime supremacy to wait upon perfection in the manner implied as the policy of the parliamentary committee. Some drastic and immediate action was necessary, to redress the advantage accruing to France from the possession of the *Gloire* and her sister frigates. Such action was duly taken; but before proceeding to examine this action it will be necessary to revert for a moment to a consideration of iron. We have already sketched the evolution of iron as a protective covering for warships; we must now glance back and briefly trace its progress as a constructive material.

Iron vessels had appeared on the canals of England in the latter part of the eighteenth century. In 1815 a pleasure boat of that material had sailed on the River Mersey, attracting crowds of people whose credulity had been severely strained by the statement that an iron ship would float. Admiral Napier had manifested an early interest in iron ships; in 1820, in partnership with a Mr. Manby, he had constructed the first iron steamer, the *Aaron Manby*, and navigated it from London up the Seine to Paris, where in '22 it attracted considerable attention. From this date onwards iron vessels increased in number. In '39 the *Nemesis* and *Phlegethon* were built by Mr. Laird for the East India Company, and in the China war of '42 these gunboats played a conspicuous and significant part. The grounding of the *Nemesis* in '40 on the rocks off Scilly afforded early evidence of the value of watertight bulkheads (a Chinese invention) when embodied in an iron hull.

As the size of ships increased, the disabilities attaching to the use of timber became more and more evident. Though braced internally by an elaborate system of iron straps, knees, and nutted bolts in iron or copper, the large timber-built ship, considered as a structure, was fundamentally weak ; in fact the presence of the straps and ties contributed in no small degree to its inability to withstand continuous stress. The fastenings did not accord with the materials which they fastened together, and the wood was relatively so soft that when a severe strain arose a general yielding took place, the boltheads sinking into the wood and causing it to give way to the pressure thrown locally upon it. As tonnage increased the metal fastenings grew more and more conspicuous, the ship became a composite structure of wood and iron, with the result that uniformity of elasticity and strength was lost and the stresses, instead of being distributed throughout the structure, tended to become localized at certain points. "The metallic fastenings of a timber-built ship act to accelerate her destruction so soon as the close connection of the several parts is at all diminished." So in 1840 wrote Augustin Creuze, a graduate of the disbanded school of naval architecture and one of the most gifted and eminent men of his profession at that day.

Iron ships, on the other hand, were found to be well adapted to withstand the racking stresses, the localized loads and the vibrations which were introduced by steam machinery ; they were lighter than wooden ships, more capacious, more easily shaped to give the fine lines necessary for speed, cheaper and immeasurably stronger. In course of time the objections to them gradually vanished ; by aid of the scientists the derangement of their compasses was overcome, the dangers from lightning were obviated, and the extent of the fouling to which their surfaces were liable was kept within limits. In course of time, in spite of natural preference and vested interest, and since the advantages of iron were confirmed by continuous experience, wood became almost entirely superseded by the metal for large mercantile construction. But in the case of warships, as we have seen, insuperable objections seemed to prohibit the change of material. No sooner had a step been

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taken by the Admiralty, in the ordering of a group of iron paddlewheel frigates in '43, than an outcry arose; the wooden walls of England were in danger, the opponents of iron declared, and iron ships were wholly unsuitable for warlike purposes. More were ordered in '46. Sir Charles Napier, whose opinion naturally carried great weight with the public, led the opposition, and when, in '49, the artillery trial demonstrated the dangerous effects of shot and shell on thin iron plates, the advocates of iron were fain to admit the error of their opinions. The iron frigates were struck from the establishment and transformed—such of them as were completed—into unarmed transports.

As experience with iron ships accumulated, the feeling grew in certain quarters that the artillery trials, the results of which had been claimed as being decisive proof of the unsuitability of iron for warships, might not have been the last word upon the subject. The events of the Crimean War tended to emphasize the doubt and uncertainty. A few there were who saw in that war clear proofs of the superiority of iron over wood; who argued that, though iron had proved to be dangerous in the form of thin plates in certain circumstances, yet it had shown itself to be impervious both to shot and shell, and indeed an indispensable defence in certain circumstances when applied in sufficient thickness; that thicker plates than those condemned as dangerous might therefore prove to be a great protection against shell fire; and that, even as regards thin plates, the splintering effect of shell against these was small, from all accounts, compared with the *incendiary* effect of shell against timber. And in what other respects were the advantages of iron contested?

But, acting upon expert advice and influence, doubtless, by the remembrance of the *Birkenhead* and *Simoon* fiasco, the government still felt unable to sanction the use of iron, and it was not until news of the laying down of the *Gloire* reached England that a decision was made to adopt the new material, both as armour and for the hulls of warships.

The high protagonist of timber-built ships, it was shortly afterwards revealed, was Sir Howard Douglas: the most strenuous advocate of iron was John Scott Russell. For years, it appeared, Sir Howard had been the influential and successful adviser of the government against the adoption of iron. "I was consulted by Sir Robert Peel," he wrote in 1860, "on his

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accession to the government, as to the use and efficiency of a certain half-dozen iron frigates, two of which were finished, and four constructing by contract. I stated in reply that vessels wholly constructed of iron were utterly unfit for all the purposes of war, whether armed or as transports for the conveyance of troops." In the same paper he stated the arguments on which he had tendered this advice; and these arguments appeared so fallacious, and the facts on which they were based so disputable, as to seem to call for some reply from the builders of iron ships. Sir Howard had certainly strayed far from science in his unsupported statements as to the calamitous effects of iron if used for warships; and unfortunately he had allowed himself to stigmatize the *Great Eastern*, as representative of iron ships generally, as "an awful roller," and as never having attained anything like her calculated speed. Scott Russell made a violent reply. "After establishing that Sir H. Douglas's conclusions are the reverse of the truth," he began, "I shall proceed to establish that the future navy of England must be an iron navy. That its construction must be founded on facts and principles, which Sir H. Douglas's writings ignore, and his deductions contradict; and I believe I shall prove that if iron ships had been introduced at the time when Sir Howard says he sedulously and systematically opposed their introduction, the money which has been spent on a wooden fleet about to become valueless would have given England a fleet greatly more powerful than the combined navies of the world."[1]

It may be conceded that in this public argument Scott Russell had the advantage: the architect of the *Great Eastern* had little difficulty in confuting the views of the artillerist. But by this time the battle between wood and iron had been fought and won. The Board of Admiralty, influenced by the arguments of Scott Russell and their own constructors, and in the presence of gigantic achievements in the form of iron-built liners, felt unable to agree with Sir Howard in his continued advocacy of timber; Sir John Pakington expressed his personal doubts to him in a correspondence. Expert opinion, naval officers and architects, leaned more and more in the direction of the new material, and, early in 1859, the decision was made to build an armoured frigate *of iron*. It was a momentous decision. The "wooden walls" had crumbled at

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[1] J. Scott Russell: *The Fleet of the Future: Iron or Wood?* 1861.

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last, and iron had won acceptance as alone able to cope with the new forces brought into existence by the progress of artillery and steam machinery. The opponents of iron could not sustain for long their arguments in favour of timber; experience was accumulating against them, and it was necessary to accept defeat. Chief among them was Sir Howard Douglas. There is, surely, something pathetic in the episode of his long-continued struggle against radical change; something tragic in the spectacle of this scientist, whose labours had done more, perhaps, than any other man's for the efficiency of the nineteenth-century navy, in his old age casting the great weight of his influence unwittingly against the navy's interest? How gamely the old general fought for his convictions is told us by his biographer, who with a natural warmth denounced the fierce criticism which Scott Russell had directed against a veteran of eighty-five winters, devoting his last hours to the service of his country. "His resistance to armour ships bore him down, his arguments met with unbelief, or elicited taunts, and ceased to influence the public. 'All that I have said about armour ships will prove correct,' he remarked, twenty-four hours before his death, toward the end of '61. 'How little do they know of the undeveloped power of artillery!'"

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In June, 1859, some months before the launching of the *Gloire*, the reply was given: the *Warrior* was laid down. Up to this time the initiative, in the slow evolution of naval material, had rested mainly with France. From this moment England, having taken up the challenge, assumed the initiative and its responsibilities; and from now onwards, in spite of false moves, failures, and ineffective expenditures of money and labour, she regained more and more surely the preponderance in naval strength which she had possessed of old. At last a scientific era of naval architecture had opened. Up to this time the design and construction of warships had been treated as a mere craft: a craft hampered, moreover, by absence of method, reluctance to adopt new views, limitations as to size, interference and ever-varying decisions as to such factors as the extent of sail-power or the number of guns to be carried. By the official acceptance of scientific methods this was largely changed. By the raising of the old office of Surveyor to the

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dignity of Controller of the Navy, by the institution of a new school of naval architecture to take the place of that suppressed in 1832 (whose most eminent graduates, fittingly enough, were the chief witnesses against the debased state and management of naval construction as it was prior to 1860), by utilizing the services of men trained in mathematics, the effect on naval architecture soon became apparent. Originality had scope, forethought and cleverness had full play; men of considerable technical knowledge were pressed into service, who proved well able to cope with the new developments.

The outcome of this new orientation was the *Warrior.* It is usual to think of her as similar to the *Gloire;* like her she was designed to resist the 68-pounder unit of artillery, like her she carried a belt of iron armour 4½ inches thick, and was equipped with steam machinery to give her a high speed. Yet in important respects she differed from her French rival.

Firstly, her size in relation to her armament caused general surprise. Admittedly the policy of restricting dimensions, pursued with such rigour from the seventeenth to the beginning of the nineteenth century, had operated to the detriment of our naval construction; admittedly the long and fine-shaped sailing vessels built during recent years were greatly superior to those of the older models; yet no reason presented itself for building a ship, of armament equal to that of the 5000-ton French frigate, which would displace over 9000 tons. Were not cost and tonnage directly related, and was there some real necessity forcing us to build ships of so large a size? Was it true that the basins at Portsmouth would require to be enlarged to take such a ship, and that her draught would be such that she could only be docked at certain tides? The question was debated vigorously by the Board itself. Three considerations, according to an authoritative statement made to parliament, prompted the decision to depart widely from the design adopted by the French: considerations one or more of which have influenced all subsequent construction in this country. Firstly, the world-wide duties of the British navy demanded a type of ship capable of making long and distant voyages either with steam or sail: in short, a fully rigged ship, a good sailer, and at the same time one with sufficient carrying capacity to enable her to keep the seas for a long time. Secondly, to ensure good sailing qualities and to avoid a defect which had been experienced in our own ships

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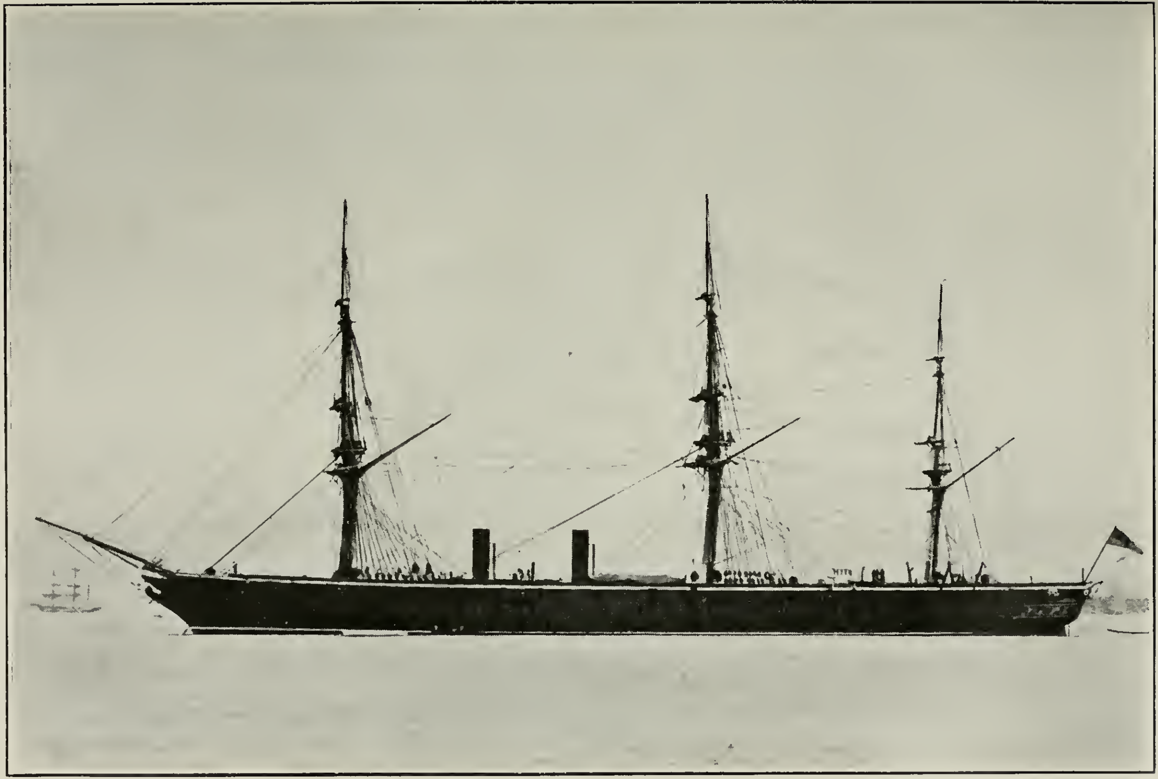

THE *WARRIOR*

From a photograph in the possession of Dr. Oscar Parkes, O.B.E.

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fitted with heavy pivot guns, and which was predicted in the case of the *Gloire*, the extremities must be as lightly loaded as possible, and not weighed down with heavy armour. Thirdly—and this was more or less special to the period—since artillery was already in a state of rapid transition to higher power, any protective armour approved must sooner or later be insufficient and require to be augmented. These conditions, and the advantages which increase of length were known to give in reducing the propeller power necessary to obtain a certain speed, governed the specifications to which the *Warrior* was built. She was given a length of 380 feet, machinery for a speed of nearly 14 knots, full canvas, telescopic funnels, and water-line armour over her central parts: the ends being left unarmoured, but subdivided by watertight compartments. Of her forty-eight smooth-bore guns, twenty-six were behind armour and twelve were outside of the protective belt; the remaining ten were mounted on the upper deck, also without protection.

In another respect the *Warrior* bore witness to the foresight of the Board. Hidden behind, and altogether disguised by, the shapely bow with its surmounting figure-head, was a stout iron ram-stem, worked to the knee and side-plates of the bow: an inconspicuous but significant feature. Ever since steamers had been established in the navy the possibilities of ramming had been discussed. The revolution in tactics resulting from the introduction of steam as motive power had been examined by authorities such as Bowles and Moorson, Douglas, Dahlgren and Labrousse, and all of them saw in the new conditions an opening for the use of the ram. In '44 Captain Labrousse had suggested strengthening the bows of wooden ships for this purpose, and in England Admiral Sartorius had become the advocate of a special type of warship built expressly to ram. The circumstances of the naval warfare of the Crimea, in which slow-moving steamers operated in restricted waters, had displayed to naval men the advantages to be obtained from actual collision—from the use of their ship itself as a projectile against the enemy's hull. In the case of the *Warrior* an additional argument was now to hand for providing a ram. The use of iron as armour had restored the equilibrium between defence and attack which had been disturbed by the adoption of shell fire; nay more, it had actually turned the scale against artillery, the 68-pounder being unable to penetrate the armour

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of the ship in which it was carried. For this reason, that for the moment armour had the ascendancy over the gun, a ram was considered to be necessary as an additional means of offence; and a ram was accordingly embodied in the *Warrior*, to the strength of which her converging iron-plate structure aptly contributed.

And now, leaving the *Warrior* for a moment, it will be convenient to glance ahead and note the part played by the ram and the value set upon it in connection with later types of warships.

In 1860 no doubt was felt but that ramming would play a very important part in future warfare. The experiences of the American Civil War of '62 seemed to supply a perfect confirmation of this opinion. "We fought the *Merrimac* for more than three hours this forenoon," wrote the engineer of the *Monitor* to John Ericsson, "and sent her back to Norfolk in a sinking condition. Ironclad against ironclad, we manœuvred about the bay here (Hampton Roads), and went at each other with mutual fierceness. . . . We were struck twenty-two times, the pilot house twice, the turret nine times, the side armour eight times, deck three times. . . . She tried to run us down and sink us, as she did the *Cumberland* yesterday, but she got the worst of it. Her bow passed over our deck, and our sharp upper-edged side cut through the light iron shoe upon her stem, and well into her oak. She will not try that again. She gave us a tremendous thump but did not injure us in the least. . . . The turret is a splendid structure. . . ."

On the preceding day the iron-covered *Merrimac* had sunk the wooden sailing ship *Cumberland* by ram alone, without the aid of artillery, the shots from her victim's guns glancing off her iron casing "like hailstones off a tin roof." She had then opened on the wooden *Congress* with shell fire, and in a short time the crowded decks of that ship had been reduced to a shambles. Then she had fought the inconclusive duel with the armoured *Monitor*. What lessons were at length driven home by these three single actions! What a novel warfare did they not foretell! The helplessness of the wooden ship when attacked by an ironclad was apparent, the terrific effects of shell fire were once again conclusively proved. The value of thick armour was once more shown, but, above all, the power of the ram, the new *arme blanche* of sea warfare, seemed to be indisputably demonstrated. On both sides of the Atlantic a revision of values took place: the wooden navies of the world

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sank into insignificance, the *Warrior* and her type were seen to be the main support and measure of each nation's naval power. "The man who goes into action in a wooden ship is a fool," Sir John Hay was quoted as saying, "and the man who sends him there is a villain." The ocean-sceptre of Britain was broken, thought an American writer forgetful of the limitations of monitors, by the blow which crushed the sides of the *Cumberland* and *Congress.*

Four years later the battle of Lissa, in which the ironclad squadrons of Austria and Italy were engaged with one another, gave confirmation that the lessons of Hampton Roads were also applicable to blue-water actions. "Full speed. Ironclads rush against the enemy and sink him," was the signal made by the Austrian admiral, Tegetthof. The ram was his chief weapon of offence, the gun being a useful auxiliary in gaining him the victory; gunfire, by disabling the steering gear of the *Ré d'Italia*, making her an easy prey for the ram of his flagship, *Ferdinand Max.*

Of all the factors influencing the evolution of naval material, the experiences and records of actual warfare are naturally considered to carry the greatest weight in council: they are, indeed, the only data whose acceptance is indisputable. The claims and achievements put forward in time of peace, however their excellence may have been attested by the most realistic experiments, are all referred to actual war for trial, and are accepted only in so far as they fit in with war experience. But sea actions between ironclads have been few and far between. It has been the more difficult, therefore, to draw from them the true lessons conveyed; the fixed points have been insufficient in number, so to speak, to allow of the true curve of progress being traced. Not only has this insufficiency been evident, but the restriction in the area of war experience has had another harmful effect, in that undue weight has been given to each individual experience. Difficult as it always is to strip each experience of its special circumstances and deduce from it the correct conclusion, errors have undoubtedly been made; and these errors have had a prominence which would not have been theirs if the number of experiences had been greater. On the other hand, an altogether insufficient weight has commonly been given to the experiences of peace-time.

These remarks find one application in the ram, and in the value placed upon it in the 'sixties and 'seventies. During

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this period artillery was undergoing a continuous and rapid improvement, eventually turning the scales against defensive armour; steam power was expanding and the manœuvring capacities of ships were being extended, so as to make ramming an operation more and more difficult to perform. Yet faith in the ram grew rather than decreased, influenced almost entirely by the evidence of the two sea-actions.

What was the actual experience of ramming gained in peace-time? In '68 Admiral Warden, commanding the Channel Fleet, reported: "So long as a ship has good way on her, and a good command of steam to increase her speed at pleasure, that ship cannot be what is called 'rammed'; she cannot even be struck to any purpose so long as she has room, and is properly handled. The use of ships as rams, it appears to me, will only be called into play after an action has commenced, when ships, of necessity, are reduced to a low rate of speed—probably their lowest." As time progressed the chances of ramming certainly grew less. Yet Lissa and Hampton Roads continued to influence opinion to such a degree, as to lead to a glorification of ram tactics; in the press, and in the technical institutions which had now come into being, the ram retained a lustre which it no longer deserved. So long as artillery was feeble and gunnery of low efficiency, and so long as speeds of ships were slow and manœuvring power restricted, the ram was of great potential value. As these conditions changed, the value of the ram declined. But for a time it was actually in question which of the two forms of power, the steam engine or the gun, would ultimately exert the greater influence as a weapon in action. The subject of a Prize Essay for 1872 was, "The Manœuvres and System of Tactics which Fleets of Ships should adopt, to develop the powers of the Ram, Heavy Artillery, Torpedoes, etc., in an action in the open sea"; and it was the opinion of the prize-winner, Commander G. H. Noel, that the ram was at that time fast supplanting the gun in importance. "The serious part of a future naval attack," wrote Captain Colomb, in *Lessons from Lissa*, "does not appear to be the guns, but the rams." And the French Admiral Touchard described the ram as "the principal weapon in naval combats—the *ultima ratio* of maritime warfare." "There is a new warfare," said Scott Russell in 1870. "It is no longer, Lay her alongside, but, Give her the stem, which will be the order of battle." And he predicted fleets of high-speed vessels, equipped with powerful rams and twin-screw engines, in which both guns and armour were merely of secondary importance. And writers on tactics discerned future squadrons in action charging each other after the manner of heavy cavalry.

The evolution of artillery falsified these expectations. With the growing advantage of artillery over the defence, and with the coming of the torpedo, fighting ranges increased and the use of the ram declined. With greater speeds and greater ranges the possibility of ramming became (as might be deduced mathematically) a diminishing ratio; before the end of the century it was sufficiently clear, and was confirmed by actual warfare, that the ram formed but a very secondary factor of a warship's offensive power. But for some years ramming, and "bows-on" fighting in which ramming was intended to play an important part, influenced to a great extent the designs of warships.

So much for the ram, first fitted in the *Warrior*. In her sister ship the ram was less pronounced and, before Hampton Roads had drawn attention to its possibilities, it was even in question to renounce it altogether. In the case of the *Warrior* the heavy figure-head so overhung the ram that many were dubious whether the latter would seriously damage an enemy; and, moreover, the wisdom of driving a fully rigged ship against another vessel, and risking the dismantling of her masts and rigging, was widely doubted. In other respects, except for her armour belt and for the material of which she was built, that vessel was not radically different from her predecessors; the first of iron-built ironclads was a handsome screw frigate not unlike previous British ships of her type, from whom she was lineally descended.

Although on the whole she was a conspicuous success, it was soon apparent that the great length of the *Warrior* tended to make her difficult to manœuvre: in fact, made her deficient in that very quality—handiness—which was indispensable to her effective use as a ram. And this unhandiness was accentuated in the *Minotaur* class which was begun in 1861. These ships were given a belt an inch thicker than that of the *Warrior*, and, partial protection being considered objectionable, especially as leaving exposed the steering gear and a portion of the gun armament, the belt was made continuous over the whole length of the ship. This length, owing to the extra

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weight of the armour, was 400 feet: 20 feet greater than that of the *Warrior* and a hundred greater than that of the longest timber-built ships. At first, five masts were fitted, in order to obtain a large sail-area while at the same time keeping the size of each sail within desirable limits; but these were afterwards reduced to three. Sail power and steam machinery were seen to be an imperfect combination in so large a vessel. The *Minotaur* class proved to be costly, unhandy and vulnerable ships, and signalled a return to smaller dimensions. It was found possible to design ships equally fast and equally well armed and protected, by the use of fuller lines and less length and an increased engine power. "Increased manœuvring power and reduction in prime cost," wrote the designer of the new type, "more than make amends for the moderate addition to the steam power."[1]

Here we may briefly note the conversion of the timber-built fleet. In '57 Captain Moorsom had submitted a scheme of cutting down ships to a short height above the water-line and using the weight thus gained to provide an armour belt. Sir Charles Napier had advocated a similar policy in parliament. As soon as the necessity for armour was accepted this policy was adopted; not only were the resources of the private shipyards bent to the building of a fleet of new iron warships, but the best of the old navy was metamorphized in the royal dockyards by the process of the *razee*: the cutting down of two-deckers and their conversion into iron-belted frigates. By these exertions France was soon outstripped in the struggle. For a long time she clung to wooden ships, though in '62 she adopted iron for upper works; and of such ships, of wooden bottoms but of iron above the water-line, she built a fleet "possessing only one possible merit—uniformity; which the new English construction lacked." The combination of heavy steam machinery and wooden hulls was the cause of continuous difficulties; the growth of artillery rendered the ships obsolete almost before they were built.

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By the time the *Warrior* and her sister ships were afloat the great struggle between armour and artillery was well in

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[1] Reed: *Our Ironclad Ships.*

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progress. It was a struggle which was to lead to unsuspected developments in naval architecture.

For the moment, and in the presence of the new iron-built ironclads, the gun was at its lowest point of effectiveness. But rifling had conferred new powers on it, and the greatest efforts were being put forth to improve its position. As it grew rapidly in size and power, naval experts were faced with a succession of problems of extraordinary difficulty. Two things were in question: both the type and the disposition of gun best suited for a warship's armament.

With regard to type, the adoption of armour inevitably gave a set-back to the value of the shell gun. Shells, which would rend and set on fire a wooden ship, would not pierce armour or inflame iron plates; of which facts Hampton Roads afforded a demonstration. It seemed clear also from that incident, to experts in this country and in France, that no extension of the Paixhans principle was likely to compete with armour in the future. The system of shell fire of General Paixhans, like the shot system of the inventor of the carronade, had relied on low muzzle velocities and curved trajectories, to effect its purpose. His shells were for lodgment rather than penetration, and did not gain their effect by their kinetic energy; and in view of this their inventor had himself conceived the use of iron armour as the very means whereby they might be countered. Nevertheless the Americans had been strongly attracted by the Paixhans principle, and with their Dahlgrens and Columbiads had extended it in practice to embrace the use of guns of the largest calibres. The action between the *Monitor* and the *Merrimac* did nothing to shake their faith in this class of ordnance. Subsequent experiments appeared to confirm the national predilection; and one of their writers, in giving credit to the navy chiefs for adhering to the principle of the large smooth-bore gun, recorded that the small-bore-and-high-velocity theory had received its quietus by the utter demolition of a 6-inch plate by a ball from a 15-inch gun at Washington in February, 1864.[1] In France and England it was held, and held rightly, that high velocities were necessary for the attack of armour.

If shell guns were of small value, what was suitable? Were the old spherical solid shot still capable of beating the defence?

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[1] Boynton: *The Navies of England, France, America, and Russia. New York, '65*:

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A serious effort was made in this country to bring them to do it. The Armstrong rifled breech-loading guns recently adopted had been proving defective and indifferent on service; a return was wisely made to muzzle-loading; and it was in question also to revert to spherical shot and shell. Spherical shot of hardest steel were tried by the *Excellent*, in the hope that they would penetrate 4½-inch plates. Experimental guns were also made, in 1864, to discharge 100-pound balls with charges of 25 pounds of powder; guns so heavy (6½ tons) that it was doubted at the time whether they could be efficiently worked on the broadside of a rolling ship. Should not increased power be obtained by persevering with rifled guns? The advantages possessed by the rifled gun in ranging power, accuracy, capacity of shell, were admitted; nevertheless the navy as a whole favoured the smooth-bore, with its simplicity, rapidity of fire, strength, and greater initial velocity, and thought that, at close ranges, the 100-pounder 6½-ton smooth-bore gun was the best and most suitable weapon for the service. But the rifled gun was advancing rapidly. "By May, 1864, the 7-inch muzzle-loading rifled shunt gun of 6½ tons had been tried in the *Excellent*, and had a good deal shaken the position of the smooth-bore. Captain Key reported that it was more than equal to naval requirements. . . . It was admirably adapted for the naval service."[1] This fired a projectile 115 pounds in weight. By June of the following year the target of 9-inch plate representing the side of the *Hercules* had beaten the latest Armstrong achievement, a 12½-ton 300-pounder. And on this pretext, and judging the defensive power of the whole ship by the defensive power of the thickest patch of its armour, a still more powerful gun was demanded for the navy by the inventor and by the press: a 25-ton 600-pounder.

So rapidly the power of ordnance grew. It has been observed that of this feverish evolution of armour and artillery the circumstances were doubly remarkable. Firstly, no foreign pressure existed which called for such overleaping and experimental advances. The Americans still clung to their smooth-bore system; the French, who like us had adopted breech-loading guns, retained the system in their service and suffered for some years from its continuous inefficiency. Secondly, the navy was itself "unwillingly dragged into the cul-de-sac of

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[1] Colomb: *Memoirs of Sir Cooper Key.*

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experimental construction induced by the clamour of public opinion." The type, the size of the gun which was to be embodied in our latest warships, was decided mainly by forces outside the navy, and changed from year to year. Naval architecture changed with it. The adoption of the succession of increasingly powerful rifled guns set experts at their wit's ends devising warships suitable for carrying them; entailed continuous alterations both in the armaments of new ships and in the design of the new ships themselves; but also, as it happened, had the effect of giving this country a mastery over naval material which it has never since surrendered.

The type having been decided for each individual vessel, there remained the question of the disposition of the armament.

Two main considerations guided the evolution of the ironclads of this period in respect of the disposition of their guns: one mainly tactical, the other mainly constructive. It appears probable that, from the date of Trafalgar onward, the limitations of merely broadside fire had been realized; that the end-on attack, such as had obtained in the supreme actions fought by Nelson and Rodney, had shown the weakness of the broadside ship in ahead fire and had made obvious the anomaly that, in all ships-of-the-line, the course of the ship, the direction in which the attack was made, was the very direction in which gunfire was least powerful, if not altogether non-existent. With the coming of steam and the consequent growth of the ram and ramming tactics, this anomaly was more and more apparent; and from the *Warrior* onwards each new type presented an enhanced effort to provide, particularly, ahead fire. The growth of the gun materially assisted this effort. Ahead fire increased, between the years 1860 and 1880, from zero to a large proportion of the total fire. The broadside ship was for a time abandoned.

The constructive consideration was the requirement of a protected armament capable of the maximum effective fire in all directions. In the first half of the century an increased effectiveness had been obtained, with the old-fashioned truck guns, by adaptation of the ports or by use of specially designed carriages, to permit of as large an arc of training as possible. Even so the arc through which guns could be fired was small, and in the case of the 68-pounder of the *Warrior* was only thirty degrees before and abaft the beam. The

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demand for greater utility was emphasized when, with the increase in size of the unit gun, the number of pieces carried by each ship was diminished.

How, then, having regard to these two considerations, should a warship's guns be disposed? Various methods were adopted. In the first instance, it was seen to be possible to augment the ahead fire of a ship, and to give a wide sweep of training to some of her guns, by indenting the sides; by so shaping the ship's side-plating as to allow guns mounted in the forward part to fire in the direction of the ship's longitudinal axis. At first, slight use was made of this method: with the fine lines given to iron ships it appeared practicable in only a small degree. Moreover, it was objected to as causing a "funnelling" effect to the path of fragments of enemy shell or shot; it was found that shrapnel shell, fired at indented embrasures at Shoebury, broke up, and the number of balls which entered the portholes was ten times the number which entered similar portholes on a straight side. But, after the *Minotaur* class, less length and greater beam were given to ships, and recessed ports and indented sides therefore became more feasible.

As guns increased in weight and individual importance the advantages of concentration became apparent. It was now undoubtedly desirable to protect *all* the guns; yet, if they had been strung out along the whole length of the ship, the weight, both of the guns and their protective armour, would prove to be an excessive burden to the ship. Hence the advantage of the *central battery*. By concentrating the guns into a central area, an armoured box amidships, the weight of armour necessary to protect them could be kept within reasonable limits, protection was afforded not only to the guns but to the vital parts of the ship, while at the same time the extremities were left lightly loaded. The complete water-line belt of armour was retained, but, both in the French and in the English navy, the system of complete protection as embodied in the *Gloire* and *Warrior* was given up.

This device of the central battery was at first used solely for broadside guns. But the desire for ahead fire from behind armour soon caused the adaptation of the battery to allow it. Ports were cut in the two transverse bulkheads, the ship's sides were indented, suitable gun-mountings were provided whereby some of the battery guns could be shifted from one

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porthole to another; and in this way it was secured that a fair proportion of the armament could be fired either on the beam or parallel with the keel-line of the ship. A power of offence was given in all directions, and no "point of impunity" existed.

Ingenious were the arrangements resorted to, to obtain the maximum effect from the new medium-sized artillery which superseded the original truck-guns of the *Warrior* and former warships. The armoured boxes, instead of being made with their sides respectively parallel, and at right angles, to the sides of the ship, were sometimes set diagonally, with their sides at forty-five degrees with fore-and-aft. Sometimes they were octagonal, sometimes with curved bulkheads, sometimes two batteries were superposed one on the other; but always the desire was to utilize each gun over as large as possible an arc of fire, and always the tendency was to augment the ahead fire. The central battery formed a powerful citadel covering the whole beam of the ship amidships. The guns of this citadel, by the power of manœuvring given by the adoption of twin-screw propelling machinery, could, it was argued, be brought to bear in any direction desired. Of all directions, "right ahead" was considered to be of the greatest importance. End-on fighting, it was assumed, would always be resorted to in future; and it was the power of keeping the ship end-on to the enemy which was the great military advantage conferred by twin screws.

A further step in the direction of giving to each gun a large arc of fire was taken in the introduction of the sponson. By means of this circular platform, projecting from the vessel's side, a gun could be carried so as to fire through an arc of 180 degrees. The same system obtained largely in the French ships of this period; by mounting guns in overhung circular turntables, one at each corner of the central battery *en caponière*, a large effective arc was obtained for them.

Only one step more was necessary: that which would allow each gun to command the whole sweep of the horizon, and to be available for duty upon either beam and any bearing: the adoption of the *centre-line turret*. But before tracing the evolution of the turret, let us recapitulate the typical ships built between 1860 and 1873 which composed our central-battery fleet.

The germ of the central-battery idea may be seen, perhaps,

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in the belted *Minotaur*, in which, in order to allow the chase guns to be fought from behind armour, a transverse armour bulkhead was worked, at a distance of some 25 feet aft of the bow. Had foreign influence not exerted itself it may be supposed with reason that from the *Minotaur* the central battery would have been evolved. However this may be, the evolution was hastened by French initiative; for in each of the two wooden ships *Magenta* and *Solferino*, laid down in '59, was found a complete two-decked central battery whose whole depth was faced with armour for the protection of fifty-two 5-ton cannon, the rest of the ship's water-line being protected by an armour belt much narrower than that of the *Gloire*. In imitation of this plan our own designs were prepared; and gradually, and only by a series of steps, we achieved what our rivals had obtained in a single stride.

In '63 Sir Edward Reed, at that time Mr. Reed, one of the graduates of the school which in '48 had been established at Portsmouth Dockyard, was appointed to the office of Chief Constructor of the Navy. Possessed of broad and original views and gifted to an unusual degree in the arts of exposition and argument, he made himself responsible for designs of warships differing widely from their large and unwieldy precursors. The first of these was the *Bellerophon*, a short and easily manœuvred, fully rigged belt-and-battery ship, carrying ten 12-ton Armstrong guns for broadside fire in the battery, and two 6-ton guns for ahead fire in a small armoured battery in the bows. Not only in the disposition of her armament was the *Bellerophon* different from all former ships. She was a radical departure from existing practice in many important respects. Constructionally, she was built on a new "bracket-frame" system designed to give great girder strength for small expenditure of weight, already in vogue for mercantile shipping. The use of watertight compartments was extended as a defence against an enemy ram, the system of double bottoms was extended as a consequence of the introduction of the torpedo. A powerful ram was carried, but the bow took a new form; a U- instead of a V-section was adopted in order to give buoyancy and thus minimize the tendency to plunge which was inherent in a fine-bowed ship; the section near the water-line being fined away so as to form a cut-water. Steel was largely used instead of iron, with a consequent saving of weight. A novel trim was given her—six feet by the stern—

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to give a deep immersion for the powerful screw and to assist the ship in turning quickly on her heel under the action of the balanced rudder ; an adjustment which experience showed to have a detrimental effect on the propulsive efficiency.

Next came the *Enterprise*, a still smaller ship. In the *Bellerophon*, as we have seen, there was no bow fire possible from the central battery ; in the *Enterprise* this was obtained by piercing the athwartship bulkheads of the battery with ports, and substituting movable for fixed bulwarks. The same arrangement was developed in the *Pallas* and *Penelope*, in which ships the arc of fire of the corner guns of the battery was further extended by the device of indented sides. Then came the *Hercules*, generally like the *Bellerophon* but with indented sides and, as a novelty, alternative ports in the battery armour by means of which the corner guns could be trained, on revolving platforms, to fire either on the beam or nearly in line with the keel ; a system which presented an obvious disadvantage in requiring twelve ports for eight guns. In the *Kaiser* class, designed by Sir Edward Reed shortly afterwards for the German government, this disadvantage was obviated by the expedient of forming ports in facets of the battery set at forty-five degrees with the keel-line, and by muzzle-pivoting guns.

Both in the *Bellerophon* and the *Hercules* axial fire had only been obtained by the provision of special batteries, at the bow and stern, of partially protected guns. Now, this accumulation of weight at the extremities was a feature viewed with disfavour by naval opinion ; moreover, these bow batteries did not meet the ever-growing demand for a considerable ahead fire. So in the *Sultan*, which carried a central-battery armament similar to that of the *Hercules*, an upper deck armoured battery was embodied, superposed on the after end of the main deck battery and carrying guns which gave both astern and beam fire ; while, for bow fire, two 12-ton guns were mounted in the forecastle, but without any protection.

The central-battery system had now to sustain the greatest attack that had yet been made upon it by the advocates of centre-line turrets. The position of the central-battery school was already somewhat shaken ; ordnance had grown to a weight and power which justified the main argument of the turret advocates ; Lissa had just shown the importance of being able to concentrate on any one bearing a maximum of

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offensive power. Controversy raged hotly on the relative merits of turret and central battery.

In these circumstances the Admiralty in '68 determined to consider both types, with a view to embodying the best arrangement in the new class of vessels then projected. The principal shipbuilders of the country were invited to compete, and were presented with specifications for a first-class warship so widely drawn as to leave them the greatest latitude in design. Of the seven designs submitted, three were of the central-battery type, three were turret ships, and one a compound of the two. After comparison with an Admiralty design produced by Sir Edward Reed, it was decided to adopt this in preference to those of the private firms, and to build a whole class of six ships to it. The result was the *Audacious* class—of which the best-remembered are the *Iron Duke* and the ill-fated *Vanguard.* In this class a strong all-round fire was obtained by arranging two central batteries of the same size, one on the main and one on the upper deck. The main deck battery had only broadside ports for its six 12-ton guns, each gun training thirty degrees before and abaft the beam ; the upper deck battery had four guns of the same calibre mounted at ports cut in armour facets at forty-five degrees with the keel-line, and training through ninety degrees. To allow axial fire from these guns the upper battery was made to project slightly, sponson fashion, over the sides of the ship, and the bulwarks forward and aft of the battery were set slightly back toward the centre line to enable the guns to fire past them.

A final stage in the evolution of the central-battery ship was attained in the *Alexandra,* laid down in '72. The type had proved tenacious of life, and, for masted vessels, still held its own up to this point against the turret system. The design for the *Alexandra* gave as complete an all-round fire as was attainable in a central-battery ironclad ; for the first time, it was said, we really had a masted ship with satisfactory all-round fire. Generally like the *Audacious* class, the *Alexandra* possessed an advantage in that the two forward guns of the upper deck battery were 25 ton instead of 18 ton, and in having, in addition to the six broadside guns of the main deck battery, two additional 18-ton guns mounted so as to be capable of firing nearly ahead and on the beam as well. Designed to fulfil the requirements of "end-on" fighting, she made a heavy sacrifice of broadside fire to obtain a maximum

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of bow fire; and at a later date, when a different valuation had come to be placed on axial fire, this sacrifice was noted against her. "She could only take her place at a disadvantage in any form of battle which was suited to the armaments of the ironclads that had gone before her."[1] Nevertheless she was a formidable vessel. Defensively, too, she was pronounced to be conspicuously successful; her armour belt, which attained a thickness of 12 inches at the water-line amidships, was carried down at the bow to cover and strengthen the stem, and to protect the vessel from a raking fire. For the protection of the stern against a raking fire, an armour bulkhead was worked across the after part, extending to a depth of 6 feet below the water-line.

The *Alexandra* was the last of the purely "central battery" ships.[2] By the time she was launched experience had set the seal of approval on another type, to the evolution of which we must now revert.

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It is difficult to trace to its source the invention of the armoured gun-turret. The inventive Ericsson is said to have envisaged at an early age the idea of a protected gun carried on a mobile raft, "an idea probably inspired by his river-rafts in Sweden"; and it is known that at a later date he planned in detail a primitive monitor, the design of which at the outbreak of the Crimean War he offered to Napoleon III. Perhaps the idea, which M. Paixhans first developed in public, of applying iron armour to a sea-going ship, induced the idea of a pivot-gun protected by an armour shield. A protected armament was found, as we have seen, in the French batteries built for the assault of Kinburn: the armoured vessel and the armoured gun were first embodied in the same unit; and though these units were the first to be tried in actual war, yet some years previously, in 1842 or thereabouts, a Mr. Stevens of New York had proposed and made an armoured floating battery. But in neither of these instances was the gun in a turret. The turret

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[1] Colomb: *Memoirs of Sir Cooper Key.*

[2] In parenthesis, for she is of no special interest as a type, we may note here the *Temeraire*, built at Chatham and completed in 1877: a compromise between the central-battery and the turret ship. Generally like the *Alexandra* in disposition of armament, she carried in addition, in order to give all-round fire, two open barbettes, one at each end of the upper deck, each containing a 25-ton gun hydraulically operated.

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idea, like so many other inventions, had an independent development in Europe and in America. In each case war supplied the incentive. In America, in '62, Ericsson himself produced in a national emergency the *Monitor*, the low, shallow-draft armoured vessel carrying two 11-inch Dahlgren guns in a steam-rotated turret which served to counter the Southern *Merrimac*, the rasée with the fixed penthouse armour roof over its guns which the Confederates had built by the light of French experience.

The *Monitor*, both in design and in the circumstances of its production, was a great achievement ; its success gave sanction to the revolving turret as a form of structure by means of which a big gun could be carried and trained. Nevertheless it is doubtful whether it influenced to an appreciable degree the evolution of the sea-going turret ship on this side of the Atlantic. Already, when the *Monitor* fought her action with the *Merrimac*, the turret had been adopted in coast-defence ships ordered for European powers ; and, dramatic though it was, the incident of Hampton Roads afforded merely a confirmation of the effectiveness of the turret form of gun mounting. It was to an episode of the Crimean War that the development of the sea-going turret ship was directly due.

In the Sea of Azov, in the spring of 1855, Commander Cowper Coles, of H.M. steamer *Stromboli*, constructed in a single night, of barrels, spars and boards, a raft capable of bearing heavy artillery, which he named the *Lady Nancy* ; by means of which he brought within range and destroyed by shell fire the Russian stores at Taganrog.

The naval operations of this war had drawn general attention to the special problems in connection with the navigation of shallow waters by vessels with a heavy armament, and Commander Coles' exploit immediately excited official interest. Models of armed rafts were submitted by him for Admiralty inspection, and shortly afterwards he was himself ordered home to give advice upon the requirements of this form of construction : in connection with which the necessity for armour protection for the gun or guns was a point early insisted on by him. In that same year he sketched a design for a belted shallow-draught vessel for the attack of stationary forts which he equipped with guns of the heaviest pattern, each working in a fixed hemispherical shield. From the fixed shield to a revolving turret was a small step. In a short time Com-

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mander Coles made himself the enthusiastic exponent of armour-protected guns, mounted in cupolas or turrets on or near the centre-line of a ship so as to give a command over nearly the whole sweep of the horizon. By such a system, he argued, a vessel could be endowed with a concentrated offensive power on any bearing unapproachable by broadside armament, however designed; all guns were effective on almost any bearing without diverting the ship, their force required no evolution to elicit, existing as it did when the ship was at anchor, in dry dock or on a constant course. The height of the turrets gave them a plunging fire, an effect particularly useful now that ships' sides were armoured and their decks alone remained penetrable.

His advocacy of the turret system, aided by the technical assistance of Mr. Brunel, made a deep impression on a large section of the public and gained the interest of the Prince Consort. He did not profess the technical knowledge of a shipbuilder or designer; but in his insistence on the advantages to be derived from the method of mounting guns on the centre-line he wielded arguments of great natural force, and enlisted in his favour the professional sympathies of eminent builders and naval men. In 1860 he produced before the newly founded Institution of Naval Architects a plan of a sea-going ship carrying nine turrets, seven on the centre-line and two off-set so as to allow ahead fire from three turrets. In the following year he wrote to the Admiralty undertaking to prove that a vessel could be built on his principle of armament 100 feet shorter than the *Warrior* and in all military respects her superior: "I will guarantee to disable and capture her in an hour; she shall draw four foot less water, require only half the crew, and cost the country for building at least £100,000 less. I am ready to stand or fall on these assertions."

Such a pronouncement could not be lightly passed over. Moreover, coast-defence vessels embodying the turret system—light-draught vessels characterized by small tonnage, small cost and indifferent sea-going qualities, in combination with massive protection and a large offensive armament—were already being built by the private firms of this country for various foreign powers. In '61, for instance, Denmark had ordered the *Rolf Krake*, a turret gunboat carrying a 4½-inch belt and four 68-pounder guns, a pair in each of two armoured turrets; which three years later proved her value in action

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against a nominally superior force. Prussia had ordered her first ironclad, a turret ship. Holland, Italy, Brazil, Russia—all were known to be purchasing coast-defence vessels of the turret type. And two sea-going turret ships which had been ordered by the American Confederates, and which were building in this country—the *Wyvern* and *Scorpion*—had been seized and purchased by our government.

In these circumstances the Admiralty, though there was a preponderance of official opinion against the idea, resolved to countenance the turret system and give it a trial. The *Royal Sovereign* was cut down from a three-decker of 120 guns, armoured with a 5½-inch belt and a 1-inch deck, and equipped with four turrets carrying a total of five 12½-ton guns—two in the foremost and one in the remaining turrets. At the same time the *Prince Albert*, also a four-turret ship, was laid down by the firm of Samuda to an Admiralty order. These ships were a distinct success so far as the armament was concerned. They were certainly not ocean-going ships. There were many faults and undesirable features to be found in them. But the disposition of the armament was found satisfactory, and the captain of the *Royal Sovereign* reported most favourably of his ship, describing her as the most formidable man-of-war; "her handiness, speed, weight of broadside, and the small target she offers, increase tenfold her powers of assault and retreat."

Time, and the progress of artillery, were on the side of Captain Cowper Coles. He saw, and the Admiralty advisers felt, that although it was possible to work existing guns on the broadside, yet increase in the size and weight of guns would sooner or later necessitate the mounting of them on accurately balanced turntables secured by central pivots on the centre-line. Only by such a method could the largest gun be worked and the full weight of metal be poured, as required, on either broadside. In fact the turret, the original object of which was purely defensive, was now regarded from a quite different point of view: as a convenient device by which guns of the highest calibre could be carried and worked. Was complicated machinery objected to? The common winch, the rack and pinion, were in constant use on every railway turntable, nor had the American turrets ever failed in action or caused a loss of confidence in their reliability. Reliance upon a central pivot was disliked? Yet the pivot was already in use for holding

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the broadside guns of our ironclads—a mere bolt 4 inches in diameter and itself exposed to gunfire.[1]

The Admiralty constructors were insistent on the practical difficulties which lay in the way of designing a satisfactory sea-going turret ship. The advantages which had been claimed for turrets were obvious, said Sir Edward Reed; the larger and heavier the individual gun, the greater the gain of mounting it in a turret. But enthusiastic advocates of this method lost sight of the fact that turrets were incompatible with masts and sails, and with the forecastle and high freeboard necessary for good sea-going qualities. At that time, 1865, it was possible to protect and work eight of the largest guns, mounted on the broadside, with as little expenditure of weight as would be required to mount four of the guns two in a turret on the centre-line; while in the latter case they could only fire in two different directions at the same time, whereas in the former they could fire in eight.

In order to allow both sides in the controversy to come to grips with the practical difficulties, a committee was formed at the Admiralty in May, '65, and Captain Coles was asked to produce a turret-ship design by the aid of a draughtsman and with the drawings of the *Pallas* for guidance. His design, a vessel showing two 600-pounders each mounted in a centre-line cupola, was not considered suitable. So the Board resolved to build a ship to Sir Edward Reed's design—a fully rigged and masted, high-freeboard ship, with an armour belt and protected bow and stern batteries, and with two centre-line turrets amidships mounted over a central battery, each carrying two 25-ton 600-pounder guns. This was the *Monarch*. She was the first truly ocean-going turret ship, and her performances at sea in '69 in company with central-battery ships like the *Bellerophon* and *Hercules* proved her to be a valuable and efficient unit; by this experiment it was demonstrated, said Mr. Brassey, "that it was practicable to design a thoroughly seaworthy turret ship, although for sea-going purposes a central battery presents great advantages over the turret system."

In the meantime Captain Coles had protested vigorously against the design of the *Monarch* as representative of his

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[1] The freedom of the *Royal Sovereign's* turrets from any liability to jam was demonstrated at Portsmouth by subjecting them to the impact of projectiles fired from the 12-ton guns of the *Bellerophon*.

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system. The plan was not his; the turrets were mounted so high that there was a large area to protect and the ship, unlike the low-freeboard ships of his own design, presented a large target. But his chief objection was, that the presence of a forecastle and an armoured bow battery annihilated the whole advantage of turret guns by preventing ahead fire from them. After protracted negotiations he obtained Admiralty permission to have a ship built to satisfy his own views and independently of criticism from Admiralty officials. In '69 the *Captain*, built by Messrs. Laird to his drawings, was launched at Birkenhead. The *Captain*, although generally similar to the *Monarch* (the growth of artillery limited the number of the turrets to two), differed from her in one important respect: her designed freeboard was only 8 feet as compared with 14; and, by some error in calculation, this dimension proved to be only 6 feet when the vessel was in sea-going trim. This low freeboard, in conjunction with her large sail-area, produced a condition of instability at large angles of heel which led to disaster and sealed the doom of the fully rigged turret ship.

Even in the *Captain* ahead fire was not found possible. In the original plans she had the low freeboard favoured by her designer; but in the later plans poops and forecastles were added to give the necessary sea-going qualities, and ahead fire was thereby sacrificed. Complete mastage was given her: iron masts in the form of tripods to avoid the use of shrouds and to give as clear an arc of fire as possible. The rigging was all stopped short at, and worked from, a narrow flying deck which was built above the turrets. This flying deck provided a working space for the crew, who in a moderately rough sea would not be able to make use of the low upper deck.

On the night of September 6th, 1870, the *Captain* capsized in a heavy sea off C. Finisterre. In St. Paul's Cathedral the memorial brass, erected in commemoration of this disaster, records that the *Captain* was built in deference to public opinion expressed in parliament and through other channels, and in opposition to the views and opinions of the Controller and his department; and that the evidence all tended to show that they generally disapproved of her construction.

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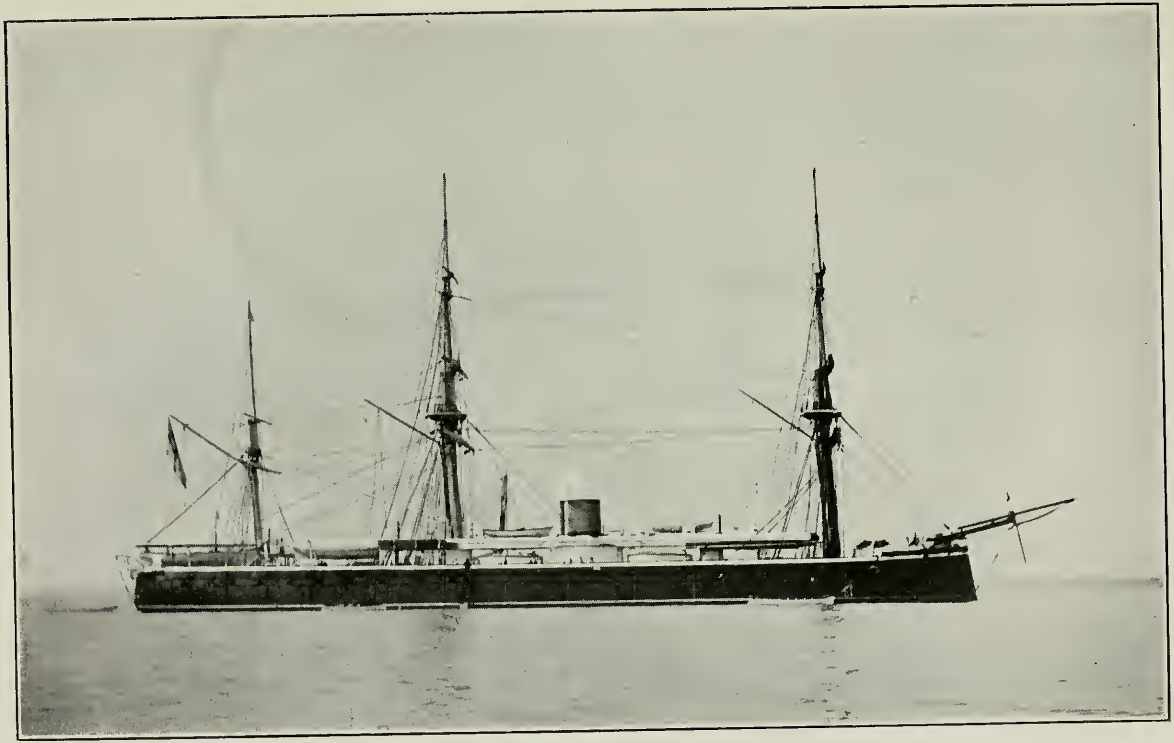

THE *MONARCH*

From a photograph by Symonds, Portsmouth

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The difficulty of combining the turret system with a full rig of masts and sails had for a long time been recognized. Some eighteen months before the loss of the *Captain*, the Admiralty, in the presence of the increasing efficiency of steam machinery, had decided to construct a mastless sea-going turret ship.

American experience greatly influenced this decision. In America, where the principle of machinery for propulsion and for working the guns had been accepted with a greater readiness than in Europe, the line of development had been more direct. From the original *Monitor* a whole series of derivatives had been produced, and from coast-defence vessels of a single turret advance had been made to ocean-going mastless turret ships of low freeboard, carrying the largest smooth-bore guns. These ocean monitors, lacking though they did some features which were considered indispensable in British warships, yet exerted an undoubted influence upon our own construction. Weakly designed in many respects, with small fuel capacity, and unsteady as gun platforms, they were regarded by some writers as the true progenitors of the class of warship which now superseded the masted vessels of the 'sixties.

The problem of the naval architect henceforth was greatly simplified. Masts and sails, which had in the past proved such an embarrassment, were now frankly abandoned, with the result that a thousand difficulties which had beset the designer of the turret ship were swept away. No longer had the stability curve to conform to the conflicting requirements of the sailing vessel and the gun platform. The large weight gained by dispensing with masts and sails could be embodied as an addition to the armament or to the fuel carried. The single screw, which in the case of a ship intended to use sails had been almost a necessity, could be replaced by twin screws of greater power; and the change would remove the liability of complete disablement, and give a number of constructive advantages which it is unnecessary to enumerate. Indeed, it may be said conversely, that the adoption of twin screws so improved the reliability of the propelling machinery as to make practicable the abandonment of masts and sails.

In April, 1869, the *Devastation* was commenced. Designed by Sir Edward Reed, she "forestalled, rather than profited

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by, the dreadful lesson of the *Captain* and by her success gave proof of the judgment and initiative of the Board and their adviser." Sir Edward Reed had recognized, more fully than his critics, the conflicting elements inherent in the rigged turret ship. And it is significant that, just at a time when the assured success of the *Monarch* must have been a gratification to her designer, he should record: "My clear and strong conviction at the moment of writing these lines [March 31st, 1869] is that no satisfactorily designed turret ship with rigging has yet been built, or even laid down."

The *Devastation* design was a development of those of some previous mastless turret ships, the *Cerberus*, the *Hotspur*, and the *Glatton* class, which had embodied Sir Edward Reed's ideas as to the requirements of coast-service vessels. At first given four 25-ton guns, the *Devastation* was ultimately armed with four M.L. guns each weighing 35 tons and carried in turrets on the centre-line, one at each end of a central breastwork, 150 feet in length, built round the funnels.

This central breastwork, raised above the upper deck and armoured along its sides with 10-inch steel, supported the two turrets and enabled the guns to be carried at a desirable height above the water-line. The upper deck itself was low. The sides, up to its level, were protected by a complete belt of armour 8 inches in thickness.

The abolition of masts and rigging had a striking effect on the design. Compared with the *Monarch*, of nearly the same tonnage, she carried heavier guns, double the weight of armour, double the amount of fuel, and required little more than half the crew to work her.

The loss of the *Captain*, confirming the doubts which experts had expressed as to the seaworthiness of rigged turret ships, caused an alarm for the safety of all turret ships, built and building. In the public mind, in consequence of the reported shortcomings of the American monitors and the known deficiencies of our coast-defence vessels, the belief was growing that the turret system was inherently unsafe. It was believed, also, that mastless ships, having no spread of sail to steady their motion, would be liable to excessive and dangerous rolling. To allay the uneasiness as to the safety of the *Devastation* and her type a Committee on Designs was formed. The Committee, composed of some of the most eminent of naval architects and officers, made a report in the spring of '71

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which, though it met with considerable opposition from one school, nevertheless "formed the groundwork upon which the English Admiralty determined to construct their policy for the future." The Committee pronounced altogether against fully rigged ships for the line of battle; it was impossible, in their opinion, to combine in the same vessel great offensive and defensive power and a full spread of canvas. They considered the *Devastation* class as the most suitable type of armoured ship for future service, and found them to have sufficient stability for safety and to be in almost all respects a satisfactory design of warship. As regards the *Devastation* herself they recommended some minor alterations, the effect of which was to improve the stability of the ship and to give greater accommodation for the crew. The main alteration consisted in the carrying up of the ship's sides amidships to the level of the central breastwork, and in continuing the breastwork deck outward to the sides, to form unarmoured side superstructures.

Besides the *Devastation*, two others of the type were laid down shortly afterwards, the *Thunderer* and the *Dreadnought*. The three ships differed from each other slightly in dimensions, but embodied the same characteristic features. Of chief interest is the transition of the unarmoured side superstructures, in the *Devastation*, to an armoured central battery of the same width as the ship, in the *Dreadnought*. The influence of Sir Edward Reed, who had now given place to Mr. Nathaniel Barnaby as Chief Constructor at the Admiralty, was apparent in this evolution. In '73 he stated publicly his objections to the carrying up of the *Devastation's* sides, and pictured a shell entering the unarmoured superstructure and blowing up all the light iron structure in front of the guns. The result was seen in the *Dreadnought*, in which the breastwork was made a continuation of the ship's side and armoured. More freeboard was also given to the forecastle and the after deck than was found in the *Devastation* and *Thunderer*, with the desire to make the vessel drier and more comfortable; and, owing to the height at which the turrets were carried, this was found possible without restricting the arcs of fire of the guns. The movement from the monitor type toward the modern battleship in respect of freeboard is clearly traced in these three ships of the *Devastation* class. Low freeboard, in spite of its effect in rendering inconspicuous the ship in which it was

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embodied, was gradually being abandoned. High freeboard was foreshadowed for future ships. The loss of the *Captain* had led to a serious study, by naval architects and mathematicians, of the stability of warships at large angles of rolling, and the advantages of high freeboard were by this time widely appreciated. High freeboard not only made a ship more habitable; by the form of stability curve it gave it allowed a vessel's beam to be reduced with safety, and thereby contributed to a steadier and more easily propelled ship than would have been obtained without it.

In other respects these three ships show the lines along which progress was being made. In the turrets of the *Devastation* the twin 35-ton guns had been loaded and worked by hand; but in the forward turret of the *Thunderer* the new hydraulic system of Messrs. Armstrong was applied with success to two 38-ton 12-inch guns; and this system was adopted for both turrets of the *Dreadnought.* The guns were loaded externally, the turrets being revolved by steam, after firing, till the guns were on the requisite bearing; they were then depressed by hydraulic power, and the 700-pound projectiles were rammed into their muzzles by a telescopic hydraulic rammer. In 1879 an accident occurred in the *Thunderer* which helped, it is said, to hasten the return to breech-loading guns. Simultaneous firing was being carried out; one of the guns missed fire without anyone either inside or outside the turret being aware of it. The guns were loaded again, and, on being discharged, one of them burst. Such double-loading, it was clearly seen, would not have obtained with breech-loading guns.

The *Devastation* had twin screws driven by independent engines, but these were non-compound engines of the trunk type working with a maximum steam pressure of 30 lbs. per square inch. In the *Dreadnought* an advance had been made to compound three-cylinder vertical engines, working with 60 lbs. per square inch in engine-rooms divided by a longitudinal watertight bulkhead.

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The evolution of the battleship was being forced along at a hot pace by the evolution of artillery. No sooner had the mastless turret ship received the sanction of the Committee on

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Designs as the standard type for warfare of the immediate future, than a sudden increase in the power of guns necessitated the consideration of new principles and brought into being a new type.

So far, defence had managed to compete fairly successfully with offence; the naval architect, by devoting as much as 25 per cent of the total of a ship's weight to protective armour, had been able to keep level with the artillerist. But it was clear that he could not follow much further, by the existing methods. Armour could not be thickened indefinitely. Penetrable armour was no better than none; worse, in fact, since it was a superfluity, and in a ship a superfluity was doubly wasteful, implying a loss of strength in some other direction. Armour might have to go altogether? It seemed that, after all, the predictions of Sir Howard Douglas might well come true; that, just as gunpowder had forced the foot soldier, after burdening him with an ever-increasing weight, to dispense altogether with body-armour, so rifled artillery would render ship armour increasingly ineffectual and, eventually, an altogether useless encumbrance.

The advance in artillery took place in connection with Italian construction. In 1872 Italy laid down the *Duilio*, and a year later the *Dandolo*, two mastless turret ships of a novel class, engined by Penn and Maudsley, and equipped with two diagonally placed turrets each designed to carry two 60-ton Armstrong guns; guns which were afterwards changed to 100-ton guns of 17¾ inches bore. In the same ships the Italians introduced a solution of the armour difficulty. They abandoned vertical armour altogether, except for a very thick belt over the central portion of each vessel which was to protect the vital machinery and the gun turrets.

The reply to these was the *Inflexible*, laid down in '74.

We have already seen how, in the last of the *Devastation* class, the central armoured breastwork was widened to the full beam of the ship. It had been proposed by Mr. Barnaby to take advantage of this arrangement to off-set the two turrets of the *Dreadnought* at a distance each side of the centre line of the ship, so as to allow a powerful ahead fire. Although not then approved, this suggestion was embodied in the *Inflexible* as her most distinctive feature. In this, however, she was forestalled by the Italians. Her two turrets, each weighing 750 tons, were carried diagonally on a central armoured citadel

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plated with compound armour of a maximum thickness of 24 inches. Forward and aft of this citadel the unarmoured ends were built flush with it, and along the centre line was built, the whole length of the ship, a narrow superstructure. This superstructure did not contribute anything to her stability; nor was such contribution needed in view of the comparatively high freeboard. But it rendered unnecessary a flying deck such as had been fitted in the *Devastation* class, and provided accommodation for the crew, without restricting to any appreciable degree the arcs of fire of the big guns.

The *Inflexible* was of over 11,000 tons displacement, the heaviest and most powerful warship that had ever been built. She was 320 feet in length and 75 feet broad at the water-line; this unprecedented beam being required, in spite of the high freeboard, on account of the height at which the turrets were carried. Nevertheless, so improved was her propulsive efficiency as compared with that of former ships, so great the gain resulting from Mr. Froude's historic researches on ship form and the action of propellers, that a speed of 15 knots was obtained at a relatively small expense in horse-power.

The idea of sails was not yet altogether dead. In deference to a strong naval opinion she was originally designed to carry two pole masts, with sails for steadying her motion in a seaway and as a standby in the event of her propelling machinery being disabled. But this scheme was modified owing to the possibility of falling masts and rigging interfering with the working of guns and screw in action. It was decided that she should be brig-rigged for peace service; and that, on an anticipation of war, she should be docked to allow the cruising masts to be removed and replaced by two short iron masts without yards for signalling and for carrying crows' nests.

But it was in the bold abandonment of armour for the ends of the ship and its concentration on the sides of the citadel that the *Inflexible* design was most freely criticized. Armour, except in the form of an under-water protective deck, was not used at all forward and aft of the citadel. The ends of the ship were left unprotected, but subdivided; the compartments near the water-line formed watertight tanks filled with coals, stores, or—next to the side of the ship—cork. This criticism was directed from two directions.

To many naval men the attempt to beat the gun by adding

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to the thickness of the armour was a game no longer worth the candle. The point of view, moreover, that the defensive power of a ship was accurately represented by the defensive power of an armour patch upon its side was condemned as altogether too partial and theoretical. The same fallacy was abroad in respect of guns. "Men were apt to think and speak as if the mounting of a single excessively heavy gun in a ship would make her exceptionally powerful, no matter what number of powerful, but still less powerful, guns were displaced to make room for it. The targets and guns at Shoeburyness were held to be real measures of the defensive and offensive powers of ships."[1]

On the other hand, experience was at this time bringing to light the inefficiency of heavy naval artillery. In '71 a paper by Captain Colomb attracted attention, in which he analysed the effective gun power of the *Monarch*, and showed, by the light of experiments carried out by her against a rock off Vigo in company with *Captain* and *Hercules*, that "in six minutes from the opening of her fire on the sister ship at 1000 yards, she will have fired twelve shot, of which one will have hit and another may have glanced, and it remains an even chance whether the single hit will have penetrated the enemy's armour." In the following summer Mr. Barnaby was himself impressed with the difficulty which the *Hotspur* experienced in hitting the turret of the *Glatton* at a range of 200 yards in the smooth water of Portland Harbour: an experiment which, while confirming confidence in the reliability of a turret and its power to withstand shock, led him to question whether we were wise to put so much weight into the protection of turrets, and whether it might not be a better plan to stint armour on guns in order to add to their number and power.

From another direction the criticism was more directly effective. In '75 Sir Edward Reed, now a private member of parliament, made a pronouncement on his return from a visit to Italy in the following words: "The Italian ships *Duilio* and *Dandolo* are exposed, in my opinion, beyond all doubt or question, to speedy destruction. I fear I can only express my apprehension that the Italians are pursuing a totally wrong course, and one which is likely to result in disaster." The Italian Minister of Marine indignantly refuted the assertion, based as it must have been (he said) on incomplete informa-

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[1] Colomb: *Memoirs of Sir Cooper Key.*

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tion; and the construction of the *Duilio* and the *Dandolo* proceeded. But the remarks of the ex-Chief Constructor applied with equal force to the *Inflexible;* and in the following session he stated as much in the House of Commons. It was possible, he insisted, that in an action the cork and stores which filled the unarmoured ends of the *Inflexible* might be shot away, and the ends riddled and water-logged; and that in such an event the citadel, though intact, would not have sufficient stability to save the ship from capsizing.

The reply of the Admiralty was to the effect that Sir Edward Reed had assumed an extreme case, and that such a complete destruction as he had envisaged was, even if possible, never likely to occur in a naval action.

The effect of both statements was to cause widespread anxiety in the public mind, and a lamentable loss of confidence in the projected warship. A decision was therefore made to appoint another Committee, of unquestioned eminence and freedom from bias, to investigate and report on the *Inflexible* design. In due course the Committee reported. They confirmed in a long statement the Admiralty point of view that the complete penetration and water-logging of the unarmoured ends of the ship, and the blowing out of the whole of the stores and the cork by the action of shell fire, was a very highly improbable contingency; they found that the ship, if reduced to the extremest limit of instability likely to occur, viz. with her ends completely riddled and water-logged, but with the stores and cork remaining and adding buoyancy, would still possess a sufficient reserve both of buoyancy and of stability; and, balancing the vulnerability of the citadel with its 24-inch armour and the destructibility of the unarmoured ends, they came to the conclusion that the unarmoured ends were as well able as the armoured citadel to bear the part assigned to them in encountering the risks of naval warfare, and that therefore a just balance had been maintained in the design, so that out of a given set of conditions a good result had been obtained. Except that a recommendation was made that the system of cork chambers should be extended, no structural alteration from the existing design was proposed.

The *Inflexible* was followed by its smaller derivatives, the *Ajax* and *Agamemnon*, *Colossus* and *Edinburgh*, and by the *Conqueror*, an improved *Rupert*, with a single turret. Movement was in the direction of smaller displacements and less armour;

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construction was influenced at this time more by Italian than by French practice.

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All through this transitional decade, 1870–80, experience and various new developments were imperceptibly causing a gradual change of opinion as to what constituted the best type of battleship. At no period, perhaps, was the warship more obviously a compromise, at no time were the limitations of size and weight more keenly felt. So many considerations interacted with one another, so conflicting were the claims made of the naval architect, that it appeared indeed almost impossible to embody them in a satisfactory design. (And yet nothing is more remarkable than the unanimity with which designers, given certain conditions, arrived at the same final result: the *Duilio* and the *Inflexible* are a case in point.) Whatever the design might be, it was open to powerful criticism. And the chief part of this criticism was directed, as we have seen, against the use and disposition of the armour.

In '73 Mr. Barnaby had questioned the wisdom of expending a large weight in the protection of turrets. Three years later Commander Noel, in a Prize Essay, was advocating unarmoured batteries, with a view to multiplying the number of battery guns, utilizing for offence the weight thus saved. In '73 Mr. Barnaby had argued that the stinting of armour on the hull in order to thicken it on the battery would drive the enemy to multiply his light and medium machine-guns. Within a few years warships were bristling with Gatling and Gardner, Nordenfelt and Hotchkiss guns, which by their presence gave a new value to armour, however thin. Mr. Froude, too, in his experiments in connection with the *Inflexible*, brought into prominence the advantage which thin armour on a ship's ends conferred on her stability. The idea of substituting cellular construction for armour was proving attractive. While the French continued to favour the complete water-line belt, the Italians went to the limit in the *Italia* and *Lepanto*, in which the water-line was left entirely unprotected by side armour. Such armour as was carried was embodied in the form of a protective deck, a feature found above water and in conjunction with a side belt in our *Devastation* class, and under water and without side armour in the *Inflexible* and smaller con-

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temporary ships. The protective deck, which covered the vitals of a ship and deflected shot and shell from its surface, was a device which found increasing favour with naval architects. It was advocated by the Committee on Designs in '71 as possessing important advantages over a similar weight of side armour. If placed at some distance below water it formed the roof of a submerged hull structure which was immune from damage by gun-fire, the sides of this hull being protected sufficiently by sea-water. If, as was subsequently done, the protective deck were placed at a small distance above water, and if the sides of it were bent down so as to meet the ship's sides at a distance below water beyond which a shot was unlikely to penetrate, the deck offered other advantages: the vital machinery, though now partly above water, was still protected, the sloping parts of the deck being able to deflect shots which would have penetrated a much thicker vertical plate; moreover, if the ship's sides were riddled in action, the protective deck still preserved a large portion of the water-line area intact, and thereby secured her lateral stability.

The ram was still in favour, but opinion was slowly changing as to the necessity for bow-fire. "It is my impression," wrote Commander Noel in '76, "that too great a value was attached by some of the authorities, two or three years ago, to bow-fire; and that the manœuvring of a fleet in action will be more for the purpose of using the ram effectually, and the guns in broadsides on passing the enemy." The firing of the heavy guns in the approach to ram was considered undesirable, owing to the obscuring of the scene by smoke. In short, bow-fire was not of primary importance, and the disposition of armament which sought to obtain a concentration of bow-fire at the expense of broadside fire was based on a false principle. Commander Noel advocated a broadside ship, of moderate tonnage, with an unarmoured battery of moderate-size guns, with an armour belt round her water-line of 10-inch armour tapering to 5 inches forward and aft, and backed by wood and coal. Watertight subdivisions he proposed as a defence against the ram and the torpedo.

As the decade progressed the navy and naval affairs were less and less a subject of public interest. The design of warships continued to be discussed by a small circle, but the Board, alive to the transitional nature of the citadel ships, and under the influence of a national movement for retrenchment

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and economy, had almost ceased to build. In the three years '76, '77, and '78 England laid down only two armoured battleships, while France laid down a dozen. In '78 four foreign ships building in this country were hastily purchased on a Vote of Credit. But by 1880 the French armoured navy was once more equal in strength to that of England.

The gun, by its rapid evolution, was blocking design. The long debates over sails and steam had been settled; it was now the achievement of powerful breech-loading guns of large and small calibre which threw all existing ideas of warship design into the melting-pot. It became known that the French at last possessed efficient breech-loading guns; and artillerists showed that, in spite of the inconvenience of long-barrelled guns in ships, long barrels and slow-burning powder were necessary if greater powers were to be developed, and that our short-barrelled muzzle-loaders were already becoming obsolete. In the summer of '79 public interest was aroused by the arrival at Spithead of some Chinese gunboats built by the firm of Armstrong. These gunboats each carried two 12-ton breech-loading guns mounted on centre pivots, one forward and one aft: guns so powerful and efficient compared with any mounted in the Royal Navy, that the possibilities of the diminutive craft were instantly appreciated. The contest between B.L. and M.L. was approaching a climax. The 100-ton M.L. gun was undergoing proof at Woolwich. In August a committee of naval officers visited Germany to witness and report upon the trials of Krupp's new breech-loaders, and these trials, and those of Armstrong in this country, confirmed the formidable character of the new ordnance. Armour was also improving its power; compound armour (of combined steel and iron) was found to possess unexpected powers of resistance to penetration.

The torpedo, moreover, in its growing efficiency was now beginning to have an effect, not only on the details of ship design, but on the whole nature of naval warfare. The influence of the torpedo in its various forms had been appreciated in the early days of the decade.[1] The catastrophic but,

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[1] Hitherto the torpedo had been used in warfare only in the form of a stationary mine, or motion had been given to it either by letting it drift on a tide or by attaching it rigidly to the bow of a vessel. After the American Civil War, in which conflict three-fourths of the ships disabled or destroyed were so disposed of by torpedoes, efforts were made to give motion to it, either by towing or by self-propulsion. In '69 Commander Harvey, R.N., brought to the notice of the Admiralty his invention of a torpedo or sea kite

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happily, fictitious Battle of Dorking, fought in the pages of *Blackwood's Magazine* in 1871, had been preceded by a naval action in which all but one of our fine ironclads had been sunk by torpedoes in attempting to ram the French fleet. The moral was obvious. From that time onwards the potential effect of the torpedo was seen to be very great. The ram seemed at last to have found a check. And it appeared that, in combating the ram, the torpedo had once more given the primacy to the fast-improving gun. Broadside actions of the old type, carried on at high range and speed, were predicted.[1]

In 1880 a new type of battleship was evolved of sufficient permanence to form the basis of whole classes of future ships.

An intimate account of the genesis of the *Collingwood* design is given us by the biographer of Sir Cooper Key, to illustrate the manner in which that prescient administrator succeeded in forecasting the trend of future construction. In '66, he says, Captain Key had put on paper a résumé of his ideas on warship design which was clearly several years in advance of current opinion. Briefly, he had maintained that the specifications for our first-class battleships of the future should be drawn to cover the following features so far as possible :—moderate speed, small length and great handiness ; perfect protection for vital parts and a complete water-line belt, rather than protection for personnel and above-water structure ; a main-deck armament of broadside guns of medium calibre amidships, and of lighter calibre towards the ends, in combination with an upper-deck armament of four large guns in two unarmoured barbettes, one mounted before the foremast and one abaft the mizzen-mast ; no sails. But for some years no approach was made to this ideal ship of Captain Key's ; the ideas it embodied were antagonistic to those held by the great majority of his brother officers.

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which was so shaped that, when launched from the deck of a steamer and towed by a wire, it diverged from the steamer's track and stood away at an angle of 45°. It could be exploded either electrically or by contact. The possibilities of this weapon were illustrated in a volume published in '71, one picture of which showed luridly " an ironclad fleet surprised at sea by a squadron of torpedo craft armed with Harvey's sea torpedoes."

The towed torpedo was overshadowed by the fish or self-propelled torpedo. In '70 Mr. Whitehead came to England and, prosecuting experiments under the eyes of naval officers, with a 16-inch torpedo successfully sank an old corvette anchored in the Medway at 136 yards' range. The result was the purchase by the Admiralty of his secret and sole rights. In '77 the first torpedo-boat was ordered.

[1] Colomb : *Attack and Defence of Fleets.*

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"In 1878 there had been laid down by the French, at Toulon, a ship called the *Caiman*. She was 278 feet long, and had a speed of 14½ knots. She carried a single 42-cm. breech-loading rifled gun at the bow, and another at the stern, each mounted *en barbette*, and she further carried on each broadside, between the barbettes, two 10-cm. guns, besides machine-guns. She was heavily armoured by a water-line belt 19½ inches thick amidships, and tapering in thickness towards bow and stern. The middle part of the ship, between the barbettes, was further protected by a steel deck 2·8 inches thick. Evidently, there was in this ship some approach to that general ideal which had been in Sir Cooper Key's mind in 1866—not, however, more than this. She gave a sort of hint to the constructors at the Admiralty, and, before Sir Cooper Key joined the Board, a new design, based indeed on the *Caiman's* hint, but yet differing widely from her, and, by as much as she differed, approaching more nearly to Sir Cooper Key's ideal, was in process of completion there. The ship was the *Collingwood*."

The *Collingwood* was of 9150 tons displacement, 325 feet in length, 68 feet in breadth, and 15·7 knots speed. There was in her, for the first time in the navy, that particular disposition of guns which Captain Key had recommended in '66: two guns at bow, two at stern, on turntables, and a strong broadside armament between them. In the end the adoption of a breech-loading system led to a larger barbette and a smaller battery armament: to 43-ton guns at bow and stern and only 6-inch guns on the broadsides; and in this way the final design differed more than did the original from the '66 ideal. "The bow and stern guns were protected by barbette and other armour, but Key had required that some protection should be given to the turntables and the machinery for working them. Hydraulics had greatly increased the quantity and importance of this machinery, and as by its means the crews of the guns were very much diminished, we can imagine the admiral concurring in the change as a natural development of his principle. So we can understand him as now definitely concurring in the abandonment of sail power for first-class battleships." In '78 he had flown his flag in the *Thunderer* at sea, and he had then experienced the reliability of the gun machinery and the difficulties attendant on the manœuvring of a modern fleet under sail.

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Both in armament and in disposition of armour the *Collingwood* was a great but a natural advance on the citadel ships of the *Inflexible* type. The symmetrical placing of the big gun turntables, one forward and one aft, proclaimed the advent of new tactical ideas—the recognition of the battleship as a unit which must take its place in the line with others, and the rejection of "end-on" methods of fighting which involved a concentration of bow-fire. The provision of the powerful secondary armament was a tribute to the growing efficiency of French torpedo craft, while at the same time serving, offensively, to force an enemy to protect himself against it: to spread his armour over as large a surface as possible in the attempt to preserve his stability in a protracted action. The concentration of armour on the fixed barbettes and on a partial belt over the central portion of the ship was in accordance with the *Inflexible* arrangement. But, in consequence of the strictures which had been passed on that vessel and on the exposure of her large unprotected ends, the *Collingwood* was given a longer belt, though not so thick. Fifty-four per cent of her length was covered with 18-inch compound armour, as compared with 42 per cent, and 24-inch armour, in the former ship. Although this longer belt appeared to confer greater longitudinal stability on the ship, its narrowness was such that it was of doubtful efficacy, as Sir Edward Reed was not slow to point out. So narrow was this belt, so big still remained the unarmoured ends, that the slight sinkage caused by their filling would bring the whole of the armour belt, he said, under water. Thus all the advantage arising from a longer citadel was more than destroyed by this lowering of the armour, and, so great was the consequent danger of the vessel capsizing, that he hesitated to regard the *Collingwood* as an armoured ship.

The *Collingwood* was laid down in July, 1880. But what was there to show that her design would be in any degree permanent? Was it safe to consider it sufficiently satisfactory to form the master-pattern for a number of new ships, urgently required?

For a short time there was uncertainty. "The French type, where there were isolated armoured barbette towers generally containing single heavy guns placed at the ends and sides of the ships upon the upper deck, with broadside batteries of lighter guns, entirely unprotected by armour, upon the deck

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below, did not commend itself to the English naval mind, yet, in the sort of despair which possessed us, the new Board turned somewhat towards the French system. The *Warspite* and *Impérieuse* were laid down in 1881, and were again a new departure in British design. . . . It was intended to adhere to sail power in these new types, and it was only after they were approaching completion that the utter incongruity of the proposal was realized, and sail power was given up in the last of the armoured ships to which it was attempted to apply it."

But the Admiralty still wished, without alarming the public, to regain as soon as possible a safe balance of armoured construction over that of France. "There was no design before the Board which was more likely to perpetuate itself than that of the unlaunched *Collingwood*. Suppose a bold policy were adopted? Suppose it were assumed that the time had come when diversities of type were to cease, would it be made less likely by the frank abandonment of sail power?"

The bold step was taken. Four more ships to the *Collingwood* design were laid down in '82, the five being thereafter spoken of as the "Admiral" class. "At the time, little note was taken of this very great step in advance. Even at this day it is scarcely remembered that this is the step which made possible, and led up to, our present great battle fleet, and that never before had so many as five first-class ironclads of a definite type been on the stocks together. . . . In the Admiral class there was the definite parting with sail power, the rejection of the tactical ideas brought to a climax in the *Inflexible*, and, above all, the definite adoption of the long-barrelled breech-loading rifled gun. Without question, we must say that we owe the Admiral class, and all that has followed, in great part to the enterprising and yet well-balanced mind that then governed the naval part of the Council at Whitehall."

§

At this point in the evolution of the ironclad it is convenient to bring our survey to an end. The *Collingwood* marks the final return (with one or two notorious exceptions) to the truly broadside ship, the ship with armament symmetrically disposed fore and aft, intended to fight with others in the line. From the Admiral class onwards the modern battleship evolved for years along a continuous and clearly

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defined curve of progression. It only remains to close this brief and necessarily superficial historical sketch with a few remarks upon the classification of warships.

In tracing the types of ironclads which superseded each other in direct succession, no mention has been made of other than those which formed in their time the chief units of naval force. Other war-vessels there were, of course, subsidiary to the main fighting force, whose value and functions we now briefly indicate.

So long as sails remained the sole motive power, warships retained the same classification as they had received in the seventeenth century. "Up to the time of the Dutch Wars," says Admiral Colomb, "ships were both 'royal' and of private contribution; of all sorts and sizes and 'rates.' Fighting was therefore promiscuous. Fleets sailed in the form of half-moons, or all heaped together and, except for the struggle to get the weather gage, there were no tactics. Actions were general." Then, in order to protect their fleets from the fire ship, the Dutch first introduced the Line of Battle: "in which formation it was easy for a fleet to leeward to open out so as to let a fire ship drift harmlessly through." And so the efficacy of the fire ship was destroyed. "But now, with a Line, each ship had a definite place which she could not quit. Hence the diversities in sizes began to be eliminated. The weakest ships, which might find themselves opposite the strongest, were dropped for ships 'fit to lie in the line,' i.e. for what were afterwards called 'line-of-battle ships.' These ships would be individually as powerful as possible, only subject to the objection of putting too many eggs in one basket. Uniformity would thus be attained. The fleet of line ships, however, required look-outs or scouts, which could keep the seas and attend, yet out-sail, the fleet. Hence the heavy frigate. Lastly, there was the much lighter attendant on commerce (either by way of attack or defence), the light cruiser."

Although this differentiation of types was based ostensibly upon displacement or tonnage, in reality it was formed on a more scientific basis. Admiral Sir George Elliot demonstrated, in 1867, that the real basis was not a rule of size, but a *law of safety*, similar to that which operates in the natural world; a law so important that it should under no circumstances be disregarded. He showed that sailing ships conformed to this

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law. He showed that the reduction of a vessel's size, for instance, endowed her with smaller draught and an increased speed; that the dispensing with one quality automatically gave another in compensation; and that thus the weakly armed vessel always possessed the means, if not to fight, to escape from capture.[1]

With the coming of steam and armour, all this was changed. Size had now no inherent disability; on the contrary, the larger the ship the greater the horse-power which could be carried in her, the greater her probable speed and sea endurance. The small ship had no advantages. The old classification had clearly broken down. The first ironclads, the *Warrior* and her successors, although of frigate form, belonged to no particular class; they were of a special type intended to cope with the most powerful ships afloat or projected; and subsequent ships were designed with the same end in view. These ships being faster as well as more powerful than those of a smaller size, there was no object in attempting to build others of a frigate class for the purpose of outsailing them.

As material developed, and as the warship became more and more obviously a compromise between conflicting qualities, differentiation of types was once more seen to be necessary. Attempts were made to classify on the bases of displacement, material, defensive and motive power, service, system of armament. In the end British construction divided itself into two categories: armoured and unarmoured vessels. And each of these categories was subdivided into classes of ships analogous to those of the old sailing ships.

But, during the transitional period 1860 to 1880, when armour and iron ships, steam engines, rifled guns, and fish torpedoes, were all in their infancy and subject to the most rapid development, no such classification was recognized. The circumstances of the Crimean War, with the adoption of armour and the sudden and enormous growth in the unit of artillery force which took place soon afterwards, led to the first differentiation of ironclads, into ocean-going and coast-defence vessels. We have already noted this fact. We have seen how, especially to the lesser Powers, the turreted monitor appeared to offer an economical and effective form of naval force; and we have noted how, in America, the evolution proceeded in the opposite direction, viz. from coast-defence

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[1] Vice-Admiral Sir G. Elliot: *On the Classification of Ships of War.*

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monitor to ocean-going turret ship. This differentiation prevailed for many years. It prevailed even in the British navy, in spite of its being in full opposition to the offensive principle on which that navy had always based its policy.

Later, although convinced that in any war involving this country and its colonies the chief combats must be fought in European waters, naval opinion saw the necessity for a type of ship designed primarily for the defence and attack of commerce: a speedy, lightly armed and protected type capable of overhauling and injuring a weaker, or of escaping from a more powerful enemy. The American War of '62, in which no general sea action was fought, gave the impulse to the construction of the type which eventually became known as the *cruiser*. Vessels were built in '63 expressly to overtake Confederate vessels and drive from the seas the Southern mercantile marine. These vessels were to annihilate the enemy's commerce without being drawn themselves to take part in an engagement, unless in very favourable circumstances. Several such ships were built. The first, the *Idaho*, was a complete failure; the next attempt was little more successful; and those subsequently constructed, the *Wampanoag* class, the finest ships of the type which existed at the close of the war, which were designed for 17 knots and to carry sixteen 10- or 11-inch smooth-bore cast-iron guns on the broadside and a revolving 60-pounder rifle in the bows, suffered from miscalculations in design and from the weakness peculiar to long and heavily weighted timber-built ships. "These pioneers of the type," says Brassey, "were followed, both in England and in France, by vessels believed by the builders of their respective countries to be better adapted for the work for which they were designed."

At first England and France had built and appropriated small ironclads to this secondary service; in France the *Belliqueuse*, in England the *Pallas*, were designed to this end. But in '66 the first ship of the cruiser type was built for the British navy: the *Inconstant*, of Sir Edward Reed's design, an iron-built, fine-lined vessel with a speed of 16 knots and a large coal capacity. She was followed by the corvettes *Active* and *Volage*, and then, in '73, by the *Shah* and *Raleigh*. Experience with the early cruisers showed the advantages of large displacement. "The greater number of the American corvettes had now been launched. A trial of one of them

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showed that the high hopes which had been entertained of their performance were fallacious. It now appeared no longer necessary that the English corvettes should possess such extraordinary power and speed, qualities which necessarily required very large displacements. The Admiralty, however, still believing in the wisdom of the policy which they had previously adopted, decided to follow a totally different course from that which all other navies had been compelled by financial considerations to follow. So far from diminishing the size of their ships, increased displacement was given to the new designs."[1] Full sail power was still required, for the high-power steam engine used by the cruiser for fighting purposes was most uneconomical. The *Raleigh*, for instance, burned her six hundred tons of coal in less than 36 hours, at full speed.

But after the *Raleigh* came a slight reaction. With a view to economy a smaller type of vessel was designed, the smallest possible vessel which could be contrived which would possess a covered-in gun deck in combination with other features considered essential in a frigate class ; the result was the *Boadicea* or the *Bacchante* class. In the late 'seventies size again increased, and the *Iris* and *Mercury*, unsheathed vessels of steel, with coal-protection for their water-line and extended watertight subdivision of the hull, were laid down.

From the unarmoured, unprotected cruiser was in time evolved, by the competition of units, the armoured cruiser. Russia led the way. Her *General-Admiral*, the first belted cruiser, was built to compete with the *Raleigh* and *Boadicea*. Then England designed the *Shannon*, partially belted and with protective deck and coal protection, to outmatch her. Eventually the cleavage came, and the cruisers were themselves divided into two or more classes, in accordance with their duties, size and fitness for the line of battle.

Of the development of torpedo craft this is not the place to write ; although the torpedo was fast growing in efficiency and importance, it had not, before 1880, become the centre and cause of a special craft and a special system for its employment in action. But after that date the creation of torpedo flotillas began to exercise a marked and continuous effect upon the evolution of the ironclad. The fish-torpedo, im-

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[1] Brassey : *The British Navy*.

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proving at a phenomenal rate in the first years of its development, and at first esteemed as of defensive value and as a counter to the ram, became, after 1880, an offensive weapon of the first importance. The ram, already suspected of being placed too high in popular estimation, suffered a decline ; the danger of its use in action was emphasized by naval officers, whose opinion alone was decisive : its use, as an eminent tactician explained, reduced the chances of battle to a mere toss-up, since there was " only half a ship's length between ramming and being rammed." The gun developed in power, in range, and accuracy ; but not (up to the end of the century) at so great a rate as its rival, the torpedo. The steam engine affected all weapons by its continuous development. It depressed the ram, enhanced the importance of the gun, and endowed the torpedo with a large accession of potential value in placing it, in its special fast sea-going craft, within reach of the battleship ; moreover, it enabled the cruiser to regain its old supremacy of speed over the line-of-battle unit. Armour, quick-firing guns, secondary armament, watertight construction, net defence, all influenced the development of the various types. But it was the torpedo, borne into action by the high-speed steam engine, which had the greatest effect on naval types in the last two decades of the century, and which at one time bid fair to cause a constructional revolution as great as that of 1860. The torpedo, according to a school of French enthusiasts, had destroyed the ironclad battleship and dealt a heavy blow at English sea power by paving the way for an inexpensive navy designed for a *guerre de course*. The ironclad was dead, they cried, and might as well be placed in the Louvre museum along with the old three-deckers ! In Italy and Germany, too, the logic of facts seemed to point to a vast depreciation in the power of existing navies : the fate of the expensive ironclad seemed assured, in the presence of small, fast, sea-going torpedo-boats. Still, it was noticed, England laid down battleships. True ; this was quite in keeping with her machiavellian policy. Had she not resisted—" not blindly, but with a profound clairvoyance "—all the inventions of the century ? Had she not successfully baulked the development of Fulton's mines, steam navigation, the shell gun, and the ironclad itself ? And, now that steam had made the blockade impossible and the torpedo had attacked the ironclad effectually, making sea-supremacy an empty term, could not the

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British Empire be destroyed by taking the choice of weapons out of England's hands ?

The prospect was alluring. Yet the ironclad survived the menace and remained the standard unit of naval power. Expensive, designed with several aims and essentially complex, —a compromise, like man himself,—it could not be replaced by a number of small, cheap, uni-functional vessels, each constructed for one sole and special purpose, without loss of efficiency and concentration of power. Nor could it be supplanted by a type which, like the sea-going torpedo-boat, could only count on an ascendancy over it in certain moments of its own choosing—for example, at night-time or in a fog. To every novel species of attack the ironclad proved superior, calling to its aid the appropriate defensive measures.

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