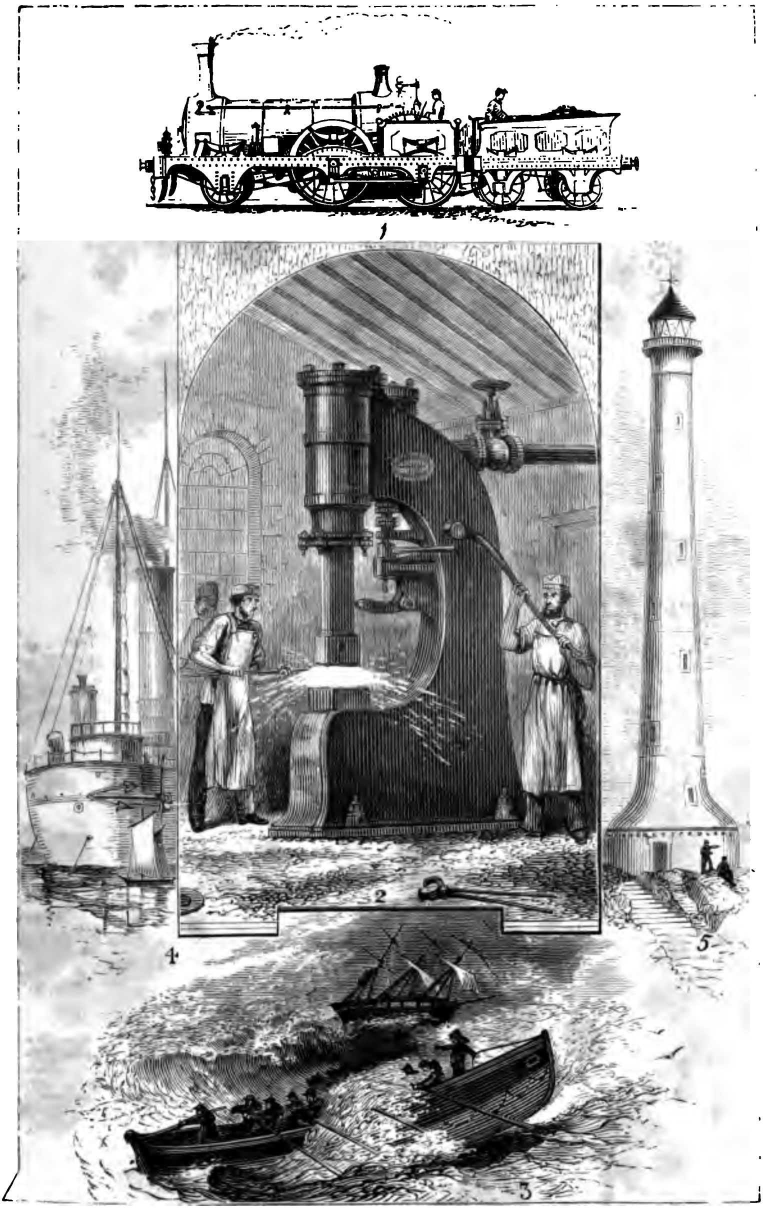
WONDERFUL INVENTIONS



1.—Locomotive Steam-Engine. 2.—Nasmyth's Steam-Hammer.
3.—Life Boat. 4.—Screw Steam-Ship.
5.—Cast-Iron Lighthouse.

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WONDERFUL

INVENTIONS

FROM THE MARINER'S COMPASS TO THE ELECTRIC TELEGRAPH CABLE

BY

JOHN TIMBS

EDITOR OF "THE YEAR BOOK OF FACTS," AND AUTHOR OF "THINGS NOT GENERALLY KNOWN," ETC.

NEW EDITION, REVISED AND CORRECTED, WITH ADDITIONS, BRINGING DOWN THE SUBJECTS TO THE PRESENT TIME

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ADVERTISEMENT TO THE PRESENT EDITION.

THIS new edition of the late Mr. Timbs' work has been carefully revised, and a considerable amount of fresh matter has been added. The alterations comprise the correction of some typographical errors; certain changes here and there in the explanations of scientific principles and in the descriptions of apparatus, with a view to greater clearness and precision of statement; and, in a few instances, the substitution of a sentence or a paragraph for one of the original author's, which, by the progress of time, may have appeared less accordant with the actual course of discovery or with the present state of opinion. The article on "The Microscope" has been almost entirely re-written. The additions consist of succinct notices of the most important and interesting developments which the various inventions have received since the appearance of the preceding edition of this work. The number of illustrations has also been increased by nearly half as many again as were contained in the former edition; and of these new cuts, several have been engraved expressly for the present volume.

NOVEMBER, 1881.

PREFACE.

HE more my Uncle Toby drank of this sweet fountain of science, the greater was the heat and impatience of his thirst." These words, uttered by the sentimental humorist more than a century ago, have, in the comparatively brief interval, received a legion of exemplifications. No province of human knowledge is more cumulative, or more closely follows the example of time, than do Science and its Applications; for, as remarked by one of its most celebrated Professors, "Science is nothing more than the refinement of common sense, making use of facts already known to acquire new facts." To present to the Reader some of the more important results of such acquisitions is the object of the present volume, ranging in its narratives from the Compass to the Cable, and keeping in view the old poet's mandate:

> "Up into the watch-tower get,
> And see all things despoiled of fallacies;"

—a labour of more gravity than implied by the stern personification of the past, upon the preceding page, who seems to say, "Look, my abridgement comes."

The Series commences with the Mariner's Compass, and ends with the Electric Telegraph, one of the most useful applications of magnetic power; for, although the ancients, in their attempt to leap from obvious facts to the highest point of generality, inferred from the magnet attracting iron that the magnetic pole of the earth would draw the nails out of a ship's bottom which came near it, they never anticipated "girdling the universe with a sentence in forty minutes."

The staple of these WONDERFUL INVENTIONS is the great discoveries in Electricity, Chemistry, and Mechanical Science. In the Telescope and Microscope, the application of the phenomena of Light allures us to brighter worlds, and transcends that genius which

> "Exhausted worlds, and then imagined new."

In the histories of Gunpowder and Gun-cotton, and Gas-lighting, we have triumphs of chemical science in mitigating the suffering of war, and exemplifying that concentration which produces high convenience.

The noble craft and mystery of Printing, likened to the lever of Archimedes, with which he could move the world, has culminated in the most intellectual application of Steam—a success of the last fifty years, and the consummation of an art which man may have borrowed from nature.

Among the *Curiosities* of the volume may be named the ingenious means by which men have taken note of time, and embellished the recording power with fancy and curious device; as in Clocks and Watches.

Nearly half the volume is devoted to the progress that has been made in the adaptation of Steam to Printing and Mining, Navigation, Textile Manufactures, Locomotion by land, and working Iron—from the time when the captive nobleman meditated on that mighty power which was so strangely to influence the material world with its illimitable applications.

It will thus be seen that the paramount Inventions given in this volume, as tales that are told, are taken, in great measure, from *our own time;* and the older Inventions—as in the case of Printing—have been perfected by the genius of our own age.

The materials of the present volume have been drawn from the most accredited sources; and especial care has been taken to award to each inventor his share in the invention. This has been no light labour, in which the Author has been aided by the experience of Forty Years, in publishing, year by year, a record of Facts in Science and Art.

With this introductory glance at the object of the Work, and the means by which it has been worked out, the Author commends the result to the kindly consideration of the Reader.

October, 1867.

["The Atlantic Telegraph Cables."—The Author has specially to acknowledge his indebtedness to the "Diary of the Cable," in the *Times*, and to the Engravings in the *Illustrated London News*, obtained at very considerable cost for that journal.]

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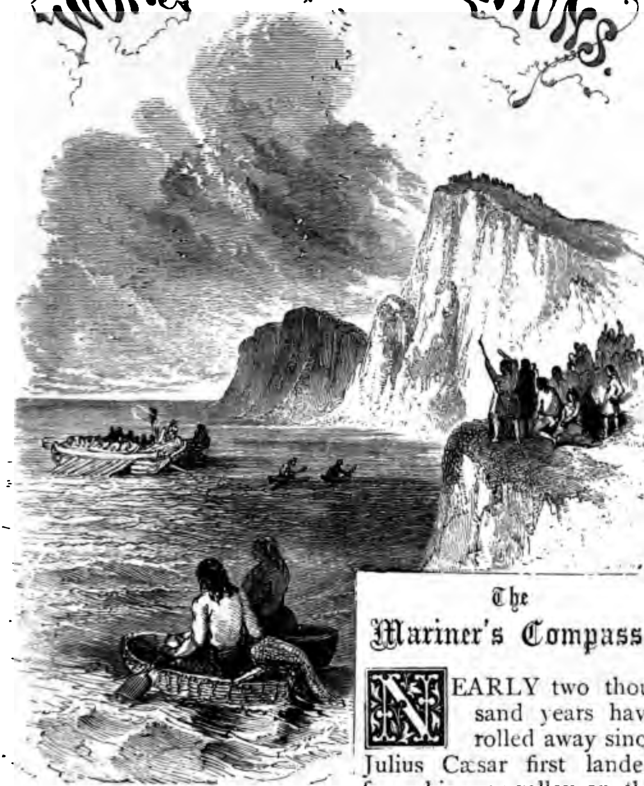


The Mariner's Compass.

NEARLY two thousand years have rolled away since Julius Cæsar first landed from his war-galley on the English coast. It was on a fine morning in August, just about the time that the Britons were harvesting their corn, when the Roman legions first saw the British war-chariots, with the blades of scythes projecting from the axle-trees of their wheels, as they went thundering along the beach below the cliff between Walmer Castle and Sandwich; and great must have been their astonishment, when the Romans saw from the decks of their galleys the half-naked, long-haired Britons, some of whom were paddling in their coracles, framed of slight ribs of wood, covered with the hides of oxen, in which they seldom ventured far from the shore. The Roman invader was beset by calamities, his galleys were scattered by a storm; he was ignorant of the height to which the tide rises in these narrow seas; his transports were dashed to pieces, and his galleys swamped with the rising waves.

Although it was not until centuries after this period that the knowledge of the directive power of the magnet became known to the Greeks and Romans, they were aware, long before the time of Cæsar, that an island, celebrated for its tin, lay somewhere on the north or north-west of Europe. The Greeks made many attempts to discover this tin island, which one of the latest investigators of the question, Sir Henry James, shows to have been St. Michael's Mount, off the coast of Cornwall. It appears, however, that the Greeks kept along the coast of Normandy and France, and were afraid to venture across our stormy channel, for they had no magnet to steer by. The Phœnicians, who were the earliest traders that visited England, baffled all inquiries that other voyagers made as to the situation of the tin island, and kept for centuries all the traffic in tin to themselves. It was in vain that the Greeks sent out ships to discover where these early Phœnician voyagers landed; the latter ran their vessels ashore on the coast of France, and would not steer across the English Channel until the Greeks had given up the search, and departed; nor does the secret of the Phœnicians appear to have been discovered until Cæsar had invaded Britain.

It will readily be perceived, by referring to a map of Europe, that a few hours would be sufficient to cross the narrow sea which divides France from England; and on a clear day our white island-cliffs may be seen from the opposite coast. Until the galleys ventured over, they would therefore keep in sight of the shore, and glide safely from headland to headland as they crept along the opposite coast. In those early times, chance or accident led to the discovery of distant countries. A vessel might be borne along by a heavy wind; and in dark, cloudy, or tempestuous weather, when the sun did not appear, these early mariners would neither be able to distinguish the east from the west, nor the north from the south: there they would be compelled to sail for days, ignorant of the latitude they were in, until they at last reached land; nor would they then be able to tell in what quarter lay the country they had left behind. Hundreds, no doubt, were lost who were thus driven out into those unknown and perilous seas without either map or chart, or any guide by which to steer. Tempest-tossed, they were carried they knew not where by the winds and currents:

> "Rude as their ships was navigation then,
> No useful compass or meridian known;
> Coasting they kept the land within their ken,
> And knew no north but when the pole-star shone."
> DRYDEN.

Even with the knowledge of the sea which the researches of centuries have contributed, still how great are its perils. It has been well observed: "How a small box of men manages to be buffeted for months up one side of a wave, and down another; how they ever get out of the abysses in which they sink; and how, after such pitching and tossing, they reach in safety the very harbour in their native country from which they originally departed, can, and ought only to be accounted for, by acknowledging how truly it has been written that 'the Spirit of God moves upon the face of the waters.'" There is nowhere to be found so inhospitable a desert as the wide blue seas, in whose beds the edifices and work of nations, whose history is altogether unknown to existing generations, are embedded and preserved:—

> "What wealth untold,
> Far down and shining through their stillness, lies;
> They have the starry gems, the burning gold,
> Won from a thousand royal argosies.
> Yet more—the depths have more—their waves have roll'd
> Above the cities of a world gone by;
> Sand hath fill'd up the palaces of old,
> Sea-weed o'ergrown the halls of revelry."

Curious it is to find that the discovery of the properties of a certain mineral substance proved a safeguard to the mariner in his ocean of peril, and thenceforth enabled him to steer with security as to his course. The Compass was the invention; the discovery which preceded it—for there must be a discovery preceding every invention—was the finding of the natural Magnet, or Loadstone; and the application of its properties—which was overlooked, although it attracted observation by a different peculiarity—"has influenced by its accidental discovery the fortunes of mankind more than all the deductions of philosophy." Locke says: "He that first discovered the use of the Compass, did more for the supplying and increase of useful commodities than those who built workhouses."

The power of the loadstone to attract iron was known to the ancient Egyptians, but was not by them applied to any practical purpose. It is a dark iron-grey mineral, approaching to black, found in great abundance in the iron mines of Sweden, in some parts of the East, in America, and sometimes, though rarely, among the iron-ores of England. It possesses the remarkable property of attracting iron, which it draws into contact with its own mass, and holds firmly attached by its own power of attraction. According to Pliny, it is named Magnet from its being abundantly found near Magnesia, a city of Lydia, in Asia Minor; and the ancient poet Hesiod also makes use of the term "Magnet Stone." The name loadstone is stated to be derived from an Icelandic term *leiderstein*, signifying *leading-stone*, so designated from the stony particles found connected with it. We find the word in Sir John Davys's "Dedication to Queen Elizabeth:"—

"To that clear majesty which in the north
Doth, like another sun, in Glory rise,
Which standeth fix'd, yet spreads her heavenly worth;
Loadstone to hearts, and loadstar to all eyes."

The attractive power of the Magnet, known thus early, is referred to by Aristotle, and by Pliny, who states that ignorant persons called it, *ferrum vivum*, or quick iron. The loadstone was also believed to be of two species, male and female. In the Middle Ages it was used medicinally—to cure sore eyes, and as an alterative. In modern times plasters were made from the ore; and much quackery was perpetrated by its means. Tradition refers the mysterious agency of the Magnet to accidental origin. The Greek story is that one Magnes, a shepherd, leading his flocks to Mount Ida, stretched himself upon the greensward to take repose, and left his crook, the upper part of which was made of iron, leaning against a large stone. When he awoke and rose to depart, he found, on attempting to take up his crook, that the iron adhered to the stone. He communicated this fact to some philosophers; and they called the stone after the name of the shepherd, Magnes, the Magnet. It is also denominated among many nations, the *love-stone*, from its apparent affection for iron.

Tiger Island, at the mouth of the Canton River, in China, in great measure consists of magnetic ore, as mariners infer from the circumstance of the needles of their compasses being much affected when in proximity to the island; and an ancient tradition exists among the Chinese of a mountain of magnetic ore, rising in the midst of the sea, whose intensity of attraction is so great as to draw the nails and iron bands, with which the planks of the ships are fastened together, from their places with great force, and cause the ship to fall to pieces. Ptolemy also places this mountain in the Chinese seas. In a work attributed to St. Ambrose, there is an account of one of the islands in the Persian Gulf in which the Magnet is found; and the precaution necessary to be taken (of building ships without iron), to navigate in that vicinity, is distinctly specified. We should add that the Chinese writers place this magnetic mountain in precisely the same geographical region that the story of the voyages of Sindbad the Sailor does; which is to be regarded as a confirmation of the Oriental origin of a great number of tales,—half fiction, half fact,—which are universally diffused amongst the legendary literature of every language.

At what period the most important property of the Magnet, "polarity," or its disposition to turn to the north and south poles of the earth, was first discovered, is not known. We have seen that the Greeks and Romans were alike ignorant of it. Among the Chinese, however, the Magnet appears to have been, from a very remote date, so far understood as to be used for the purposes of direction, in most of the leading countries of Asia, including Japan, as well as China, India, and even Arabia. The earliest notice of the Magnetic Compass being used on land prior to service at sea, is from the Chinese as follows. Honangti punishes Tchi-yeou at Tchou-lou. The Waiki said: Tchi-yeou bore the name of Khiang: he was related to the Emperor Yanti. He delighted in war and turmoil. He made swords, lancets, and large crossbows, to oppress and devastate the empire. He called and brought together the chiefs of provinces: his grasping disposition and avarice knew no bounds. Tan-ti-yu-wang, unable any longer to keep him in check, ordered him to withdraw himself to Chao-hao, in order that he might thus detain him in the west. Tchi-yeou, nevertheless, persisted more and more in his perverse conduct. He crossed the river Yang-chaoni, ascended the Kieou-nao, and gave battle to the Emperor Tanti, at Khounsang. Tanti was obliged to retire, and seek an asylum in the plains of Tchoulou. Hiuanyuan (the proper name of the Emperor Houang-ti) then collected the forces of the vassals of the empire, and attacked Tchi-yeou in the plains of Tchou-lou. The latter raised a thick fog in order that by means of the darkness he might spread confusion in the enemy's army ; but Hinan-yuan constructed a *chariot for indicating the south, in order to distinguish the four cardinal points*, by means of which he pursued Tohi-yeou, and took him prisoner, and caused him to be ignominiously put to death at Tchoung-ki, which received from this circumstance the name of the plain of the broken curb. This narrative professes to record a transaction that occurred in 2634 B.C., three centuries before the Deluge of our chronologers.

CHINESE MAGNETIC CHARIOT.—(*From Klaproth's Work.*)

Humboldt, in his *Cosmos*, allows that " a thousand years before our era, in the obscure age of Codrus, the Chinese had already magnetic carriages on which the moveable arm of the figure of a man continually pointed to the south, as a guide to find the way across the boundless grass-plains of Tartary ; nay, even in the third century of our era, therefore at least 700 years before the use of the Mariner's Compass in the European seas, Chinese vessels navigated the Indian Ocean under the direction of magnetic needles pointing to the south."

In the *Japanese Cyclopædia*, vol. 33, is a representation of one of these chariots. The figure in front was made of some light material; it was fixed upon a pivot, and its finger invariably pointed to the south, which was the *Kibleh*, or sacred point of the Chinese, to which they always turned when performing their devotions. It is intimated rather obscurely, that these magnetic chariots were first invented for a religious purpose; namely, to enable the devout to discover their *Kibleh* when the sun and stars were obscured by clouds—a purpose to which the Compass is frequently applied in the present day by Mohammedan nations; but there are also full descriptions of the use made of these chariots in directing the march of armies and guiding ambassadors. M. Klaproth has collected, from Chinese authorities, many curious anecdotes of the use made of these chariots: under the Tsin dynasty they formed a part of every royal procession. In the history of that dynasty, we find: "The wooden figure placed on the magnetic car resembled a genius wearing a dress made of feathers; whatever was the position of the car, the hand of the genius always pointed to the south. When the Emperor went in state, one of these cars headed the procession, and served to indicate the cardinal points."

In the history of the second Tchao dynasty, which lasted from A.D. 319 to A.D. 351, we read:—"The Chang-Fang (president of the Board of Works) ordered Kiai-Fei, who was distinguished by his great skill in constructing every kind of instrument, to build a number of magnetic chariots, which were sent as presents to the principal grandees of the empire." There are several accounts of the manner in which the magnetic figures were constructed: a magnetized bar passed through the arm of the figure, and the only variety of ingenuity displayed by the architect was in balancing the figure upon the pivot. We quote these details from a notice of M. Klaproth's work, in the *Athenæum*, No. 369.

Extracted from the annals of a Chinese historian, contemporary with the destruction of the Bactrian empire by Mithridates I., we find that the Emperor Tching-wang (1110 years before our era) presented to the Ambassadors of Tong-King and

Cochin China, who dreaded the loss of their way back to their own country, five magnetic cars, which pointed out the south by means of a moving arm of a little figure covered with a vest of feathers. To each of these cars, too, a hodometer, marking the distances traversed by strokes on a bell, was attached, so as to exhibit a complete dead reckoning. Maurice, in his *Indian Antiquities*, describes this instrument as a sort of magnetic index, which the Chinese called *Chimaus;* a name by which they at this day denominate the Mariner's Compass. Such inventions, says Sir John Herschel, are not the creation of a few years, or a few generations. They presuppose long centuries of previous civilization, and that, too, "at an epoch contemporary with Codrus and the return of the Heraclides to the Peloponnesus"—the obscure dawn of European history! Even the declination of the needle, or its deviation from the true meridian, was known to this extraordinary people at the epoch in question.

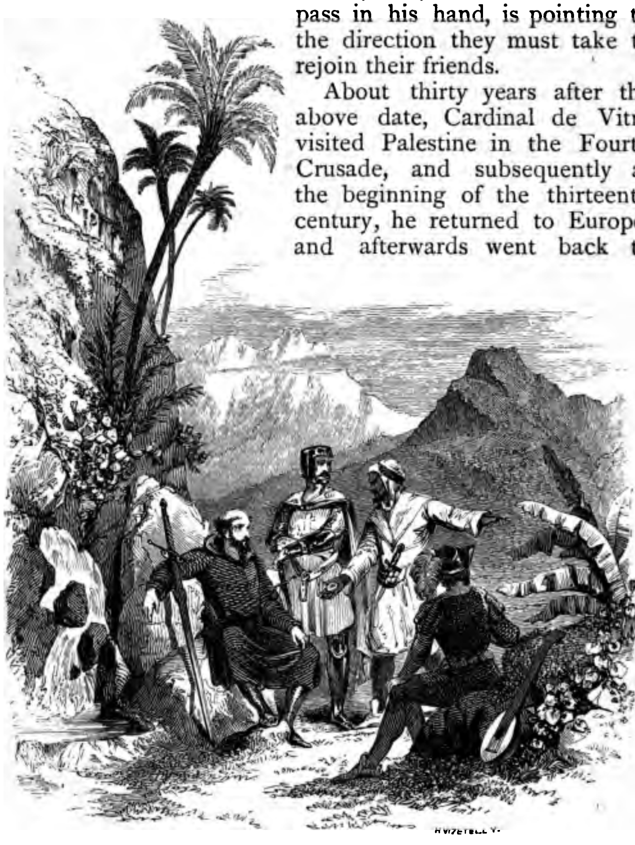
The Magnetic Car or Wagon was used as late as the fifteenth century. Several of these carriages were carefully preserved in the Chinese Imperial Palace, and were employed in the building of Buddhist monasteries, in fixing the points towards which the main sides of the edifice should be directed.

The Sea, or strictly speaking, Mariner's Compass, is first noticed as used by the Chinese in the dynasty of Tain, 265-419 A.D., in their great Dictionary *Poi-we-yeu-fou.* It was known on the Syrian coast before its general use in Europe, and is thus described by Bailak Kibdjaki, in 1242: "We have to notice amongst other properties of the Magnet, that the captains who navigate the Syrian Sea, when the night is so dark as to conceal from view the stars which might direct their course according to the position of the four cardinal points, take a basin full of water, which they shelter from wind by placing it in the interior of the vessel: they then drive a needle into a wooden peg or a cornstalk, so as to form the shape of a cross, and throw it into a basin of water prepared for the purpose, on the surface of which it floats. They afterwards take a loadstone of sufficient size to fill the palm of the hand, or even smaller, bring it to the surface of the water, give to their hands a rotatory motion towards the right, so that the needle turns on the water's surface; they then suddenly and quickly withdraw their hands, when the two points of the needle face north and south. They have given me ocular demonstration of this process during our sea-voyage from Syria to Alexandria, in the year 640 of the Hegira."

Earlier notices are given by the Arabic writers, but this is the most distinct. Instead of calling the magnet a needle, the Arabians name it *monasala*, a dart; hence the mistake of the feathers for *fleur-de-lis;* and the needle, therefore, still points to the south, as it does in China.

Humboldt considers it probable that Europe owes the use of the Mariner's Compass to the Arabs, and that these people were, in turn, indebted for it to the Chinese. In the fourth century of our era, Chinese ships employed the Magnet to guide their course safely across the open sea; and it was by means of these vessels that the knowledge of the Compass was carried to India, and from thence to the eastern coast of Africa. The Arabic designations *Toron* and *Aphron* (south and north), which are given to the two ends of the Magnetic Needle, indicate, like many Arabic names of stars, which we still employ, the channel and the people from whom Western countries received the elements of their knowledge.

In Christian Europe, the first mention of the use of the Magnetic needle occurs in the politico-satirical poem, *Le Bible*, by Guyot of Provence, in 1190; but it is evident from the terms used by him that it was an instrument but little known, and which had only lately been introduced into Europe. Cardinal de Vitry and Vincent de Beauvais, who were attached to the French army in the Crusades, both speak of the Compass as a great curiosity which they had seen in the East. Guyot, or De Provence, was a minstrel; and, as he wrote some five-and-twenty years before the Cardinal, probably obtained his knowledge of the polarity of the Magnet, and its application to the purposes of direction, from the same part of the world. As one reads the stories of these chroniclers, the imagination pictures the wild scenery of a Syrian landscape, where a party of bewildered travellers, composed of such as the persons we have mentioned, are resting beside some crystal spring. Around are picturesque hills, beneath one of which are grouped the persons who first brought authentic information to Europe of that invention which was so marvellously to influence the destinies of mankind. There sits the Cardinal, half soldier, half priest, frocked and tonsured, but armed with a two-handed sword; De Beauvais, with helmet on head, guarded at all points by his well-joined armour; and De Provence, who has just laid aside the lute with which he has beguiled his hearers and the time, listening to the strange accounts of the dark-bearded and turbaned traveller, who, with the small Compass in his hand, is pointing to the direction they must take to rejoin their friends.



About thirty years after the above date, Cardinal de Vitry visited Palestine in the Fourth Crusade, and subsequently at the beginning of the thirteenth century, he returned to Europe, and afterwards went back to the Holy Land, where he wrote his work entitled *Historia Orientalis*, as nearly as can be determined, between the years 1215 and 1220. In chapter xci. of that work, he has this singular passage:—"The iron needle, after contact with the loadstone, constantly turns to the north star, which, as the axis of the firmament, remains immoveable, whilst the others revolve; and hence it is essentially necessary to those navigating on the ocean." These words are as explicit as they are extraordinary; they state a fact and announce a use.

About 1260, Brunetto Latinè, author of *Le Trésor*, in French, and Dante's teacher, observes that the Needle was highly useful at sea; but at the same time notices the prejudices by which navigators were deterred from its adoption: "For," says he, "no master-mariner dares to use it, lest he should fall under the supposition of being a magician; nor would even the sailors venture themselves out to sea under his command, if he took with him an instrument which carries so great an appearance of being constructed under the influence of some infernal spirit." Dante refers, in a simile, to the needle "which points to the star." Navarrete quotes a remarkable passage in the Spanish *Leyes de las Partidas* of the middle of the thirteenth century: "The needle which guides the seaman in the dark nights, and shows him, both in good and in bad weather, how to direct his course, is the intermediate agent between the loadstone and the north star." Raymond Lully, of Majorca, the analytic chemist and skilful navigator, in 1286, remarked that the seamen of his time employed "instruments of measurement, sea-charts, and the magnetic needle."

To recapitulate. From its use on land the Compass became finally adapted to maritime purposes. When it had become general throughout the Indian Ocean, along the shores of Persia and Arabia, it was introduced into the West, in the twelfth century, either directly through the influence of the Arabs, or through the agency of the Crusaders, who, since 1096, had been brought in contact with Egypt and the true Oriental regions. The most effectual share in its use seems to have belonged to the Moorish pilots, the Genoese, Venetians, Majorcans, and Catalans. The old story that Marco Polo first brought the Compass into Europe, has long been disproved: as he travelled from 1271 to 1295, it is evident, from the testimony we have given us, that the Compass was, at all events, used in European seas from sixty to seventy years before Marco Polo set forth on his journeyings.

The earliest mention in English records of the primitive Mariner's Compass is that by Alexander Neckham, who describes the same in his *Treatise on Things pertaining to Ships.* Neckham was born at St. Alban's, in 1157. A translation of his works, from the Latin, was published in 1866.

In the reign of Edward III., the magnet was known by the name of the *sail-stone*, or *adamant*, and the Compass was called the sailing-needle or dial, though it is long after this period before we find the word Compass. A ship called the *Plenty* sailed from Hull in 1338, and we find that she was steered by the sailing-stone. In 1345, another entry occurs of one of the King's ships, called the *George*, bringing over sixteen horologies from Sluys, in Normandy, and that money had been paid at the same place for twelve stones, called adamants, or sail-stones, for "repairing divers instruments pertaining to a ship." Chaucer, who died in 1400, mentions the Compass; and states that the sailors reckon thirty-two points of the horizon, which is the present division of the card. We may here remark that Adamant is the name given to the magnet in old authors. Greene, in his play, *Tu quoque*, has—

"As true to thee as steel to adamant."

The mutual repulsion of two magnets, which takes place in some situations, is alluded to here:

"We'll be as differing as two adamants:
The one shall shew the other."

Adamant is thus used so lately as in the English translation of Gailland's *Arabian Nights*, and, what is more extraordinary, it stands unaltered in Dr. J. Scott's corrected edition (1810). In the story of the Third Calendar we have this passage:

"To-morrow about noon we shall be near the black mountains, or mine of adamant, which at this very minute draws all your fleet towards it, by virtue of the iron in your ships; and when we approach within a certain distance, the attraction of the adamant will have such force, that all the nails will be drawn out of the sides and bottoms of the ships, and fasten to the mountain, so that your vessels will fall to pieces and sink." As the word is now not current in this sense, it ought to have been changed to loadstone.*

At the close of the sixteenth century Dr. William Gilbert, of Colchester, published a book on magnetism entitled *De Arte Magnetica.* The novelty and importance of many of his discoveries, and the clear and ingenious reasoning used in his investigation, are so remarkable that the publication of Gilbert's book may be considered to mark the commencement of a new

* Nares's *Glossary*, new edit. 1858.

era in the history of physical science. The laws of the attractions and repulsions between the poles of magnets, and the very notion of a magnetic pole, are for the first time distinctly propounded in this work, which contains also a full account of all the facts concerning magnetism known in Gilbert's time, as well as his researches in other branches of science, and particularly in electricity.

The use of the word Compass had become familiar in the reign of Charles I. who employed it by way of comparison in one of his Golden Rules: "The breath of religion fills the sails: profit is the compass by which factious men steer their course." And Barton Booth, in one of his Songs, says:

> "True as the needle to the pole,
> Or the dial to the sun."

And Rowe, in his play of *Jane Shore*, has:

> "With equal force the tempest blows by turns
> From every corner of the seaman's compass."

The principle on which the Mariner's Compass is formed, may be easily understood from a knowledge of the leading laws of Magnetism. A piece of Loadstone drawn several times along a needle, or a small piece of steel, converts it into an Artificial Magnet. If this magnetized needle be then carefully balanced, so as to move easily on its centre, it will voluntarily turn round, until one of its ends points to the north; and if removed from this direction, will, when left at liberty, invariably return to the same point. The magnetized needle also possesses the power of attracting iron, and of communicating this power to another piece of iron or steel, similar to that of the Loadstone itself, in proportion to the intensity of the magnetic property which has been imparted to it.

The magnetic power can also be imparted to iron or steel, without the intervention of either a natural or an artificial magnet. If a bar of steel is held in a slanting direction, the upper end of the bar leaning to the south, and the other end to the north, and whilst in this position it is struck smartly at the lower end with a hammer, the bar itself resting against an anvil or other piece of iron, it will be found to possess the properties of a magnet; and if nicely balanced upon its centre, the poised bar will swing round until it points to the north.

Another very curious property is this. If the end of a needle pointing to the north be brought near to the end of a second needle, pointing in the same direction, they will move away from each other; but if the north end of one is brought near to the south end of the other, they will be mutually attracted, and approach each other. That end of the magnet which points to the north, is said to be its *north pole*, and the opposite is called its *south pole*. The powers of either a natural or an artificial magnet may be destroyed in several ways; by a red heat, by a stroke of lightning, or even by being laid in an injudicious position.

Sir John Ross, during his last voyage in the *Felix*, when frozen in about one hundred miles north of the magnetic pole, concentrated the rays of the full moon on the magnetic needle, when he found it was five degrees attracted by it. A curious notion has long been current, more especially on the shores of the Mediterranean, that if a magnetic rod be rubbed with an onion, or brought into contact with the emanations of that plant, the directive force will be diminished, while a Compass thus treated will mislead the steersman. "It is difficult," says Humboldt, "to conceive what could have given rise to so singular a popular error."

Canton, in 1750, divulged his method of making artificial magnets without the use of natural ones. This he did by using a poker and tongs to communicate magnetism to steel bars. He derived his first hint from observing them one evening, as he was sitting by the fire, to be nearly in the same direction with the earth as the dipping needle. He thence concluded that they must, from their position and the frequent blows they receive, have acquired some magnetic virtue, which, on trial, he found to be the case; therefore, he employed them to impregnate his bars, instead of having recourse to the natural loadstone. Dr. Knight also received considerable sums of money by *touching needles* for the Mariner's Compass.

It is curious to find that the Western nations, the Greeks and Romans, knew that magnetism could be communicated to steel, and that that metal would retain it for a length of time. "The great discovery of the terrestrial force," says Humboldt, "depended, therefore, alone on this—that no one in the West had happened to observe an elongated fragment of magnetic iron stone, or a magnetic steel rod, floating by the aid of a piece of wood in water, or suspended in the air by a thread, or in such a position as to admit of free motion."

In the reign of St. Louis (1461-1483), "the French mariners commonly used the magnetic needle, which they kept swimming in a little vessel of water, and prevented from sinking by two tubes." *

In the beginning of the previous century, Flavio Gioia, of Amalphi, made the great improvement of suspending the needle on a centre, and enclosing it in a box; hence Gioia, in after-times, came to be considered as the *inventor* of the Mariner's Compass, of which he was only the improver. He lived in the reign of Charles of Anjou, who died King of Naples in 1300. It was in compliment to this sovereign (for Amalphi is in the dominions of Naples) that Gioia distinguished the north point by a fleur-de-lis. This was one of the circumstances by which the French in later days endeavoured to prove that the Mariner's Compass was a French invention. Gioia's improvement consisted in attaching a card to the needle, which is the chief point of difference between our needle and that of the Chinese; externally, the two compass-boxes appear quite dissimilar. The European plan was to supersede the basin of water as used on the Syrian shore of the Mediterranean.

In the absence of all distinct evidence on this point Sir John Davis considers that the figure is an ornamental cross, and originated in the devotion of an ignorant and superstitious age to a mere symbol. Or, as the Compass undoubtedly came into Europe from the Arabs, the fleur-de-lis might be a modification of the *monasala*, or dart, the name by which the Arabs called the needle. This corresponds with the opinion at page 9.

All that has been stated as to the invention may be granted, without in the least impairing the just claims of Gioia to the gratitude of mankind. The truth appears to be this:—"The position of Gioia, in relation to the Compass, was precisely that of Watt in relation to the steam-engine,—the element existed, he augmented its utility. The Compass used by mariners in the twelfth and thirteenth centuries, was a very uncertain and unsatisfactory apparatus. It consisted only of a magnetic needle floating in a vase or basin by means of two straws or a bit of cork, supporting it on the surface of the water. The Compass used by the Arabians in the thirteenth century was an instrument of exactly the same description. Now the inconvenience and inefficiency of such an apparatus are obvious; the agitation of the ocean and the tossing of the vessel might

* Sir John Davis's *Chinese*, vol. ii. p. 222.

render it useless in a moment. But Gioia placed the magnetized needle on a pivot, which permits it to turn to all sides with facility. Afterwards it was attached to a card, divided into thirty-two points, called *Rose des Vents;* and then the box containing it was suspended in such a manner that, however the vessel might be tossed, it would always remain horizontal. The result of an investigation shared in by men of various nations, and possessing the highest degree of competency, may thus be stated. The discovery of the directive virtue of the magnet was made anterior to the time of Gioia. Before that period, navigators sailing the Mediterranean and Indian seas employed the magnetic needle; but Gioia, by his invaluable improvement in the principle of suspension, is fully entitled to the honour of being considered the real inventor, in Europe, of the Compass as it now exists." *

Dr. Johnson defines the Compass as "The instrument, composed of a needle and card, whereby mariners steer." It is constructed as follows:—A magnet made like the hand of a clock, with that end which points to the north shaped like the head of an arrow, is carefully balanced on a steel point and placed inside a circular box, and to this is attached a circular card, on which the divisions of NORTH, SOUTH, EAST, and WEST, are printed, and which is made to go round along with the needle. The cardinal points are named from the word *carda*, a hinge or pivot. By simply looking at the position of the needle, the mariner can see the direction in which the vessel is sailing, and regulate his steering accordingly. The box is also connected sideways by pivots to a frame composed of *concentric* circles, represented by two hoops, placed so as to cross each other; the card being suspended just in the centre of the two, whichever way the vessel may lurch, the card is always in an horizontal position, and certain to point the true direction of the head of the ship. The circles. or gimbals, are generally allowed to have been the invention of an Englishman. What is called the Dip of the Needle—that is, the angle which such needle, when supported on its centre of gravity, makes with the plane of the horizon—was discovered by Robert Norman, of Wapping, in 1594, and published in 1596, in a book now become scarce.

About the middle of the sixteenth century, it was discovered that the needle did not point directly to the north, but that its direction was somewhat to the east of that point; and this

* Campbell's *Maritime Discovery and Christian Missions.*

has since been called the *Variation of the Compass.* To account for this it was supposed that the magnetic pole of the earth did not coincide with that of the axis on which the globe itself turned. Subsequent observations and appearances have confirmed this theory; and the northern magnetic pole is supposed to be situated in the north-west extremity of Baffin's Bay.

The first chart, showing the variation of the Compass, is due to Halley, who is justly entitled the father and founder of Terrestrial Magnetism. The first Variation Compass was constructed before 1525, by an ingenious apothecary of Seville. So earnest were the endeavours to learn more exactly the declination of the needle, that in 1585, Juan Jayme sailed with Francisco Gali, from Marrinato Acapulco, for the sole purpose of trying in the Pacific a declination instrument which he had invented.

The Variation of the Needle must have been known to the Chinese as far back as the beginning of the twelfth century: it is mentioned in a work written by a Chinese philosopher, named Keontsoung-chy, who wrote about the year 1111, as stated by Sir Snow Harris, in his *Rudimentary Magnetism.* In the *Life of Columbus,* written by his son, the discovery is assigned to that celebrated man. He was sailing across the Atlantic Ocean, in his attempt to find a new world. On the 13th of September, 1392, in the evening, being about two hundred leagues from the island of Ferro, Columbus first noticed this phenomenon, which had never before been remarked. The variation was a little to the west: for Columbus perceived about nightfall, that the needle, instead of pointing to the north star, varied about half a point, or between five and six degrees to the north-west, and still more on the following morning. Struck with this circumstance, he observed it attentively for three days, and found that the variation increased as he advanced. He at first made no mention of this phenomenon, knowing how ready his people were to take alarm, but it soon attracted the attention of the pilots and filled them with consternation. It seemed as if the very laws of nature were changing as they advanced, and that they were entering another world subject to unknown influences. They apprehended that the Compass was about to lose its mysterious virtues, and, without this guide, what was to become of them in a vast and trackless ocean!

Columbus tasked his science and ingenuity for reasons with which to allay their terrors. He told them that the direction of the needle was not to the polar star, but to some fixed and invisible point. The variation, therefore, was not caused by any fallacy in the Compass, but by the movement of the north star itself, which, like the other heavenly bodies, had its changes and revolutions, and every day described a circle round the pole. The high opinion that the pilots entertained of Columbus, as a profound astronomer, gave weight to his theory, and their alarm subsided. As yet the solar system of Copernicus was unknown; the explanation of Columbus, therefore, was highly plausible and ingenious, and it shows the vivacity of his mind, ever ready to meet the emergency of the moment. The theory may at first have been advanced to satisfy the minds of others; but Columbus appears subsequently to have remained satisfied with it himself. The phenomenon has now become familiar to us, but we are not so cognisant of its cause. "It is," says Washington Irving, "one of those mysteries of nature open to daily observation and experiment, and apparently simple from their familiarity, but which on investigation, make the human mind conscious of its limits; baffling the experience of the practical, and humbling the pride of science." This was written nearly forty years since. We are, year by year, approaching the wished-for goal.

Columbus also discovered a magnetic line without variation. In 1498 he wrote :—"Each time that I sail from Spain to the Indies, I find, as soon as I arrive a hundred miles to the west of the Azores, an extraordinary attraction in the movements of the heavenly bodies, in the temperature of the air, and in the character of the ocean; I have observed these attractions with particular care, and have recognised that the needle of the Mariner's Compass, the deviation ot which had been *north*-east, now turned to the north-west.

The Chinese Compass, instead of consisting of a moveable card, attached to the needle, is simply a needle of less than an inch in length, slung in a glazed hole in the centre of a solid wooden dial, finely varnished. The broad circumference is marked off into concentric circles, on which are inscribed the eight mystical figures of Fohi; the twelve horary characters, the ten others which, combined with these, mark the year of the cycle, the twenty-four divisions of their solar year, the twenty-eight lunar immersions, &c. The old card Chinese Compass was a very common pocket companion on land or at sea, as a kind of almanack.

The errors of the Compass from the action of iron, now largely employed in the construction of ships, have demanded correction. In England, the magnetic action of the iron upon the Compass is neutralised by placing near it powerful magnets, the action of which is calculated to produce upon the needle equal effects, but opposite to those of the ship. The French mode is by employing a table of corrections, based upon minute observation, and applicable to every indication of the Compass affected. In spite of these precautions, fatal accidents are still attributed to errors of the Compass. Another plan consists of such modifications of the log of the vessel as would show not only the velocity, but also the direction of its motion, and the errors of the Compass; and which, in cases of shipwreck, would certainly determine whether the calamity was really due to those errors. A correcting Compass is used, which affords the means of taking the same position, whereby the deviation may be set right. When a vessel is nearing land, the needle is said to be affected; and certain rocks exercise a decided magnetic influence upon the Compass, volcanic rocks especially, but this influence is not felt on board ship. The action of the iron ships' sides is far different: nothing, not even the interposition of a non-magnetic body, will stop its influence. The ship herself, under her weight of canvass, may increase the deviation of the needle. To freight an iron ship before she has been at sea for a considerable time, to ascertain how her compass behaves, is imprudent; and a captain undertaking the command of an iron ship should have the experience of a long voyage, so that he may know how to deal with the deviations on board the vessel to be commanded.

There remains to be named one who directed his attention to practical Magnetism and its relation to Navigation, throughout a very long life. Such was William Scoresby, the Arctic explorer, who, in the year 1836, in a lecture, exhibited an important experiment, which does not appear to be generally known. He took a bar of iron, two or three feet long, about one inch in diameter, and placing it in the direction of the magnetic meridian,—that is, pointing to the north, at an angle of forty or fifty degrees with the horizon—he struck it a smart blow with a heavy hammer, by which, from a simple bar of iron, it became *a magnet.* Afterwards he placed the same iron bar in a direction at right angles with its former position, and, striking as before, its magnetism was thereby discharged, and it was proved to have none of the properties of a magnet. This is considered to be a very favourable illustration, though not so designed, by Scoresby, of the magnetic theory of Euler, disclosed in his *Letters to a German Princess.** Dr. Scoresby having published his various investigations of the influence of iron ships upon their Compasses, and the requisite correction, in 1855 communicated to the British Association a summary of his matured views, and the evidence in their favour, in which he recalled attention to his plan of *a compass aloft*, as affording a simple and effective mode of ascertaining the direction of a ship's course; and to exemplify this, and to determine other questions in magnetic science, Dr. Scoresby undertook, in 1856, a voyage to Australia in the Royal Charter, iron steamship. Everything corresponded with theory; but he never recovered from the exhausting efforts of this great scientific labour for a frame approaching seventy years of age. Upon one occasion, when a violent cyclone was raging, he ascended the mizen rigging to judge of the height of the waves, which he calculated to be then 30ft. He returned to England in shattered health, and gave an interesting account of his voyage to a large audience at Whitby; but while preparing the results of his labours for publication, he died in May, 1857, and was buried at Torquay, where a tablet has been erected by public subscription to his memory. Another memorial of his eminent services was presented to his widow, by subscription—namely, a chair, made of timber taken from the Royal Charter steamship, with a suitable inscription upon a plate made from a copper bolt from the above vessel.

Here is a simple experiment which perfectly illustrates the completeness of this invention. If a needle or other magnetised steel bar be fixed on the top of a piece of cork, which is then placed on the surface of the water and left to float unrestrained, the needle will turn till one end of it points nearly towards the north. Into this position it will soon settle, and the other end will, of course, point nearly towards the south; and if the cork be turned round, so as to direct the needle to the points opposite to those towards which it is naturally directed, it

* Communicated to *Notes and Queries*, December 1, 1866.

, as soon as it is released from compulsion, again assume the tion which it previously held. This at once explains the on why the mariner can direct his ship across the waves, ı in the darkest night and the remotest regions, as by his ıpass he can always ascertain the course his vessel is ng ; and by altering the bearing of the helm and shifting sails, he keeps his ship constantly under command, and es her to her destined haven. The benefits of this t invention were presently manifest : within twelve years, s doubled the Cape of Storms ; Di Gama found his course ıe East Indies ; Columbus trod the Bahamas. Such were early triumphs with the bar of steel, which the experimenter ng rubbed with a natural loadstone, it became a Compass le, and earned its name by threading the mariner's way ugh the labyrinths of the sea.

THE MARINER AND HIS COMPASS.

LIGHTHOUSES AND LIFEBOATS.

THERE is another provision for the safety of the mariner, which, if not so important as the Compass, tends to protect him from much of that danger to which he is continually exposed. This is the Lighthouse, erected on the sea-coast, or on some rock far away from shore, over which the waves of the stormy sea are unceasingly breaking, and which is placed there to warn vessels of shoals or other perils that might cause their destruction. A few centuries ago, our sea-girt island had few such lights to cast their blaze upon the boiling eddies, and warn ships from rocks, shallows, and sand-banks. The billows broke upon the beach over the wrecked vessel: for then, instead of Lifeboats manned with brave seamen, who from youth had been familiar with the dangers of the deep, there were often cruel wreckers prowling upon the shore ready to plunder the half-drowned mariners.

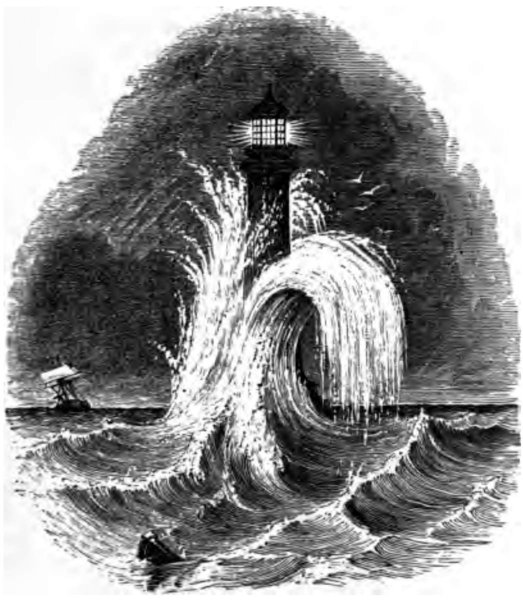
One of the earliest Lighthouses of which we have any account was built on a rock called Pharos, opposite the city of Alexandria, and surrounded by water. It consisted of several stories of galleries of a prodigious height; on the top fires were kept continually burning to direct sailors how to reach the harbour of Alexandria; it was then provided with a lantern, and Arab historians describe the huge mirror of metal which was placed here as a reflector, and which the inhabitants of Alexandria are said to have used to concentrate the rays of the sun, and thus burn the vessels of their enemies. This Lighthouse was built by one of the Ptolemies, A.M. 3670: it was 450 feet in height, or 50 feet higher than St. Paul's Cathedral; and its cost was 800 talents Attic (165,000*l.*), or in Alexandria double that sum. It was one of the Seven Wonders of the World; all lighthouses after it were called *Pharos*, and the description of Lighthouses might therefore be termed Pharology. Among the Roman remains of Dover Castle is a small *pharos.* Another ancient lighthouse was the huge lamp which blazed in the right hand of the Colossus of Rhodes. The oldest existing Lighthouse is that at Corunna, in Spain, said to have been erected in the reign of Trajan, and now fitted with a very fine modern light apparatus.

Among the most celebrated modern Lighthouses is the Tower of Cordovan, or Corduan, founded in 1584, finished in 1610, at the mouth of the Garonne river: thirty years since it was considered the best illuminated Lighthouse in France, and supposed "the finest light in the world." There is a fine print of it, engraved by order of Louis XIII. It is built of stone, circular in plan, architecturally ornamented, and more resembling a church tower than the plain tubular lighthouses of our days. In 1782 the simple plan of illuminating by a group of candles enclosed in a lantern fitted with glass sides, was superseded at this lighthouse by the method then newly introduced, in which a number of oil-lamps, each provided with a metallic reflector, took the place of the candles. On the Tower of Cordovan no fewer than eighty such lamps were mounted, but from the unscientific construction of the lamps and of their reflectors, the illumination was still very inadequate.

The difficulties so successfully surmounted in the construction of the Eddystone, the Bell Rock, and the Skerryvore Lighthouses and their brilliant lights, render them objects of great interest. Upon the Eddystone rock, about 14 miles S.S.W. from Plymouth, and fronting the entrance to Plymouth Sound, there had been built two Lighthouses, prior to that which now breasts the waves on the same reef. The first was designed by Mr. Henry Winstanley, a gentleman of Littlebury, in Essex, whose genius for mechanism had been displayed in various inventions. His was a polygonal building, about 100 feet high, which was commenced in 1696, and finished in 1700. That edifice was swept away in the great storm of 1703, together with its ill-fated architect, who was then within it, superintending some repairs. He had been heard to say a short time before—"he was so well assured of the strength of his building, that he should only wish to be there in the greatest storm that ever blew under the face of the heavens, that he might see what effect it would have upon his structure." Unhappily, his confidence proved most misplaced; for not a vestige of his labour was ever found, except some iron cramps, and part of an iron chain. Mr. Smeaton, the engineer, conceived, after examining the spot, that the Lighthouse had been "overset altogether," and had torn up a portion of the rock along with it.

The next Lighthouse on the Eddystone, was erected by Mr. John Rudyerd, a silk mercer, on Ludgate-hill, who was a Cornishman of very humble parentage. His building was altogether unlike the preceding ones, for its shape was the frustrum of a cone; it was constructed of strong oak-planks, and other timber, caulked with oakum, and bolted and clamped with iron. Its height was 92 feet, the work being terminated with an octagonal balcony, and light-room, surmounted by a cupola. But this Lighthouse, after enduring several tempests, was, on the morning of the 2nd of December, 1755, totally destroyed by fire: it broke out in the cupola, which was of light timber, and burnt downwards to the very foundations, nothing remaining but the iron cramps and branches, which had been fixed into the rocks, and the lower part, which had been filled with stone as ballast. The Lighthouse on the Bell Rock, off the coast of Fife, and the one placed at the entrance of the Mersey, on the Black Rock, are constructed similarly to the second Eddystone, so that there seems to be good reason for Rudyerd adopting the principle; he had been assisted by two shipwrights from the Royal Arsenal at Woolwich. Mr. Smeaton thought that the work was well done, though the worm had affected the timbers.

After a considerable lapse of time, the first stone of the present Eddystone Lighthouse, by Smeaton, was laid June 12, 1757, and completed in October, 1759. For the construction of this Lighthouse the stones were hewn, and dovetailed, and fitted to each other on shore, at Mill Bay, adjoining the Hoo, at Plymouth, and thence conveyed to the rock by yawls

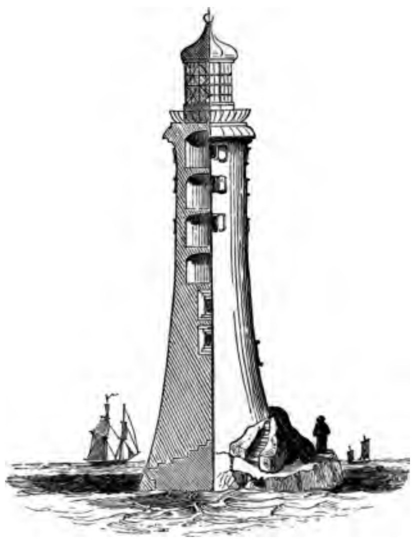


THE EDDYSTONE LIGHTHOUSE (SMEATON'S).

and other vessels. All the lower corners of stone are joggled and morticed into the rock itself, which was hewed for that purpose into six steps; and every surmounting course of masonry is likewise so ingeniously dovetailed together, as well as into each other, and strengthened with oak trenails, iron cramps, and chainwork, (the latter embedded in lead), that the whole may be regarded as constituting one solid mass, the base, 26 feet in diameter, being barely less than the surface of the rock on which it stands. The basement and exterior are entirely of Cornish Moorstone, or granite, but most of the interior is of Portland stone. The light-room is octagonal, of cast and wrought-iron framework, with copper window sashes, glazed with plate-glass; the whole surmounted by a cupola, (weighing about 11 cwt.), and a gilt ball. Below the light-room are two store-rooms, a kitchen, and a bed-room. On the course of granite under the ceiling in the upper store-room, is the following verse from the 127th Psalm, wrought in by a pick:

EXCEPT THE LORD BUILD THE HOUSE,
THEY LABOUR IN VAIN THAT BUILD IT.

There are in all, fifty-two courses of stonework to the top of the masonry; of these forty-six courses are contained in the



SECTIONAL VIEW OF THE EDDYSTONE LIGHTHOUSE (SMEATON'S).

main column, the height of which, to the floor of the balcony, is 70 feet. The height of the light-room to the top of the ball is twenty-four feet; the entire height is ninety-four feet; or within 7 feet of half the height of the London Monument. Notwithstanding this great elevation, such is the force of the sea, in great storms, that the waves sweep up the sides of the Lighthouse in one immense column, which rises to more than double its height, and then breaks over it in an archlike cataract of spray and foam; at which time the building is wholly enveloped in the water. Originally the light was shown by means of chandeliers, but these have been removed, and their place supplied by a framework, fitted with Argand burners, and parabolic reflectors of silvered copper.

The foregoing account of Smeaton's structure on the Eddystone we leave as it appeared in the first edition of this work, but probably before these lines come under the reader's eye, Smeaton's famous lighthouse will have become a thing of the past; for on the 19th of August, 1879, was laid the foundation of a new lighthouse on the Eddystone, designed by Mr. Douglass, the engineer-in-chief to the Trinity House. The top stone of the tower was put in its place by the Duke of Edinburgh on the 1st of June, 1881, but the completion of the lighthouse will require another year. It has been found that the shape of Smeaton's tower, tapering as it does in a curve upward from the very foundation, is by no means the best, for it allows the waves readily to run up towards the summit, where the pressure of the water acts with enormous leverage, thus tending to weaken the base of the structure. The shocks of the waves, thus delivered, caused much tremor throughout the edifice, and water was frequently driven through the joints of the masonry. It has more than once been found necessary to strengthen the structure; and massive wrought-iron stays have been passed from the lantern to the lower part of the tower. In 1865 the heavy seas which ran up the tower and struck the projecting cornice, were found to have actually lifted some of the stones, and it was judged advisable to reduce the projection of the cornice, and to fasten the stones together by bolts. But the shocks constantly delivered on the upper parts of the tower did not cease to weaken the foundation; and even the gneiss rock, on which the tower stands, appears to be so shaken as to allow the sea to partially undermine the base of the structure.

In the new design, Mr. Douglass carries his tower up vertically for a certain distance before it begins to taper in a curve; and he lays the foundation in a manner differing from

Smeaton's. The old lighthouse was built upon a portion of the reef which, in ordinary weather, is just at the level of high water, and which affords no more than room for the structure placed upon it; but the new one will stand upon a portion which is entirely submerged at high water, and which is the summit of a sort of platform of rock, slightly convex in its general form, and thus having a somewhat broad base at a level lower than its central part. In this central part an excavation has been made to receive the foundation; and the floor of this excavation is 2 feet 6 inches below the low-water mark at spring tides. The stones of the first course of the lighthouse are bolted to the rocky base by bolts of yellow metal, fixed in a manner presently to be described; and the stones of each subsequent course are made to dovetail with all the others with which they are in contact above, below, and on either side, the dovetails amounting to one-third the extent of the opposed surfaces, and having their interstices filled in with cement in such a manner as to render the joints stronger than the unbroken granite itself. The stones of the first course are two feet thick, and the metal rods with which they are bolted are two feet six inches long, and an inch and a half in diameter. For the reception of the bolt a hole is drilled through the stone, and a corresponding hole, undercut so as to be smaller above than below, is made in the rock beneath. The bolt is split at each end, and a wedge is inserted into the lower split, and is first put into the hole, in such a manner that, when the bolt is sent home, it is driven down upon this wedge and is made to expand, so that it fills the conical hole in the rock completely, and could not be pulled out again. A similar wedge is then introduced into the upper split, and is driven down so as to tighten this against the granite.

In this way, by successive courses of granite bolted or dovetailed as described, there will be constructed a solid cylindrical base, 44 feet in diameter and 22 feet high, having its upper surface 2 feet 6 inches above the high-water of spring tides. At the top of this base there will be a landing platform, 4 feet 3 inches wide, and from this will spring the base of the true tower, 35 feet 6 inches in diameter at its commencement, and 18 feet 6 inches in diameter under the cornice, the top of which will be 138 feet above the rock. With the exception of a water-tank, it will be solid to the height of 25½ feet above high-water spring tides. At this level the walls will be 8 feet

6 inches thick, diminishing to 2 feet 3 inches at the top. The tower will contain nine apartments, each 10 feet in height, in addition to the lantern, the seven uppermost being 14 feet in diameter. The elevation of the light will be 130 feet above high-water, instead of 72 feet as at present; by which its range will be increased from 14 to about 17½ nautical miles, so that it will just overlap the range of the new electrical lights at the Lizard. The precise kind of light and the precise kind of fog-signal which will be employed have not yet been determined upon.

There are used in the construction of this Lighthouse very large and flawless blocks of granite, supplied by the De Lank quarries, near Bodmin. Since these quarries lately passed into the possession of Messrs. Shearer and Smith, they have been in full operation, and promise a practically inexhaustible supply of blocks of a magnitude elsewhere unattainable. The granite is there found over an extent of twenty square miles, cropping out upon the surface, or even lying loosely upon it, and only waiting removal. Of these loose blocks, there are some from which might be cut twenty such monoliths as Cleopatra's needle.

The famous Bell-rock Lighthouse is situated upon the Inchcape Rock, in the German Ocean, about eleven miles southwest of the Forfarshire Coast, lying in the track of all vessels making for the estuaries of the Frith of Forth and Tay from a foreign voyage; and being a sunken rock, it is extremely dangerous; at spring tides it is about 12 feet under water. The top of the rock being only visible at low water, one of the Abbots of Aberbrothock attached to it a framework and a bell, which being rung by the waves, warned mariners to avoid the fatal reef. A tradition respecting this bell has been embodied by Southey, in his ballad of "Ralph the Rover." A noted pirate of this name is said to have cut the bell from the framework, "to plague the Abbot of Aberbrothock, and some time after to have received the just punishment of his malice by being shipwrecked on the spot."

In the year 1799, about seventy vessels were wrecked on the coast of Scotland, in a dreadful storm. This calamity led to the erection of a Lighthouse on the Inchcape Rock, by Robert Stevenson, from his own designs, but on the principle of the Eddystone Lighthouse. The work was commenced in August, 1807, and on February 1, 1811, the light was first shot from the summit of the majestic column. All the stones were shaped and prepared in the work-yard at Arbroath, and the Lighthouse is built as one solid mass from the centre to the circumference. It is circular, and externally of granite. The masonry is 100 feet high, and including the Light-room, is 115 feet; its diameter 48 feet at the base, and at the top 13 feet. The *solid* part of the building is 30 feet in height. There are five upper apartments above the water-room; all the windows have double sash-frames, glazed with plate-glass, and are protected by storm-shutters; for although the light-room is full 88 feet above the medium level of the tide, and is defended by a projecting cornice, or balcony (with a railing of cast-iron, like meshes of network), yet the sea-spray, in gales of wind, is driven against the glass so forcibly, that it becomes necessary to close the whole of the deadlights to windward. The light-room is of cast-iron framework, and plate-glass one-fourth of an inch in thickness. The light is from Argand burners, with parabolic reflectors, upon a frame, which revolves, and exhibits in succession a red and natural bright light; both so powerful as to be readily seen at 6 or 7 leagues distance. During storms or foggy weather, the reflector machinery rings two bells, each weighing about 12 cwt., to warn the seaman of his danger. The cost of this Lighthouse was 60,000*l.* It is one of the most prominent and serviceable beacons on the Scottish shore, and has been the means of preventing innumerable shipwrecks. The following beautiful lines were written by Sir Walter Scott in the Album kept in the Lighthouse, on his visit to it in the year 1815:

Pharos Loquitur.

Far on the bosom of the deep,
O'er these wild shelves my watch I keep;
A ruddy gem of changeful light,
Bound on the dusky brow of night;
The seaman bids my lustre hail,
And scorns to strike his tim'rous sail.

The Skerryvore Lighthouse, in Argyleshire, was built by Alex. Stevenson, son of the engineer of the Bell-rock Lighthouse. The mass of stone in this structure is more than double that used in the Bell-rock, and five times that contained in the Eddystone. The tower is 138 feet high, and the diameter at the base is 42 feet. In constructing this Lighthouse, the engineer appears to have chiefly relied on the weight rather than the extension of the materials for efficient resistance to the impact of the waves. The stones were not dove-tailed or joggled, but trenails were used merely to keep the work together during its erection.

The Commissioners of the Northern Lighthouses had for many years entertained the project of erecting a light-tower on the Skerryvore reef, and with that object had visited it in 1814, in company with Sir Walter Scott, who has graphically described it in his "Diary."

The building of this light affords a good specimen of the difficulties of Lighthouse construction. The Skerryvore reef, which stretches over a surface of nearly 80 miles, is composed of the very hard rock, gneiss, the surface of which is worn as smooth as glass by the perpetual action of the water. In numerous places it rises in small rocky islets, the principal one of which forms the base of the Lighthouse; and it is so small that at high-water little of the rock remains above the surface but a narrow band, a few feet in width, and some rugged lumps of rock, separated from it by gullies, through which the sea incessantly ploughs. The cutting of the foundation alone in this flinty mass occupied nearly two summers; and the blasting of the rock in so narrow a space. without any shelter from the flying splinters, was attended with much danger. Everything had to be provided beforehand, and transported from a distance, to barracks on the neighbouring island of Tyree; and also on the Isle of Mull, where the granite for the tower was quarried. Piers had to be built at both places to facilitate the shipment and landing of the materials; and a small harbour or basin had to be specially formed for the accommodation of the vessel required to permanently attend on the light-keepers. A steam-tug was also provided for conveying the building materials, which served in the early stages of the work as a floating barrack for the workmen. In 1838, Mr. Stevenson commenced by erecting a wooden barrack on the rock, as far as possible removed from the foundation; but in the great gale of the 3rd of November following it was entirely destroyed, and swept from the rock. Another wooden barrack was subsequently erected, and more strongly secured than the former one, and lasted many years after the completion of the building; notwithstanding, as Mr. Stevenson states, in his excellent account of the works, the men were often disturbed in their beds by the sea pouring over the roof, by the spurting of the water through the doors and windows, and by the rocking of the barrack on its supports. The difficult work was completed in 1844, and cost 86,978*l.*

Reflecting lighthouses in England originated about a century since. At a meeting of a Society of Mathematicians at Liverpool, one of the members wagered that he would read a paragraph in a newspaper at ten yards' distance by the light of a farthing candle. The wager was laid, and the proposer having covered the inside of a wooden dish with pieces of looking-glass, fastened in with glazier's putty, placed his reflector behind the candle, and read the paragraph. One of the company marked this experiment with a philosophic eye. This was Captain Hutchinson, the dockmaster; and with him originated the Reflecting Lighthouses, which were erected at Liverpool in 1763; a result calling to mind the lines in Shakspeare's *Merchant of Venice:*

> How far that little candle throws his beams,
> So shines a good deed in a naughty world.

The South Foreland Lighthouse was one of the earliest constructed in England, it is said, in the reign of Charles II. The original light was only burnt upon the flat roof of the tower, which was supplanted in 1793, when a light was constructed of fifteen oil-lamps. There was also a lower Lighthouse, to enable the mariner, in time of danger, to keep the two lights in a line, and thereby avoid the Goodwin Sands. These Lighthouses were taken down in 1841, and have been rebuilt.

Upon the Goodwin Sands, off the coast of Ramsgate, perhaps more noble ships have foundered than upon any other sandbank in the ocean. At one moment, a ship may be in ten fathoms soundings, and in the next strike upon this treacherous shoal, where her destruction is inevitable. To guard against this fearful danger, beacons have been reared here, but one after another washed away. In 1840, Captain Bullock, R.N. erected here a Safety Beacon, a column, about 40 feet above the sea-level, with a flag-staff 10 feet high, and a gallery made of sail-cloth to hold 20 persons on the top of the column, with access by ropes and cleets. It was secured to a stout oak platform screwed fast below the surface of the sand, with two tons of pig-iron ballast added to it, and oblique iron bars and chains communicating with the upper part of the column and the gallery. Next, Mr. Bush, C.E. attempted to erect here a Fixed Light, with a cast-iron base 64 feet high, and 30 feet in diameter, and 120 tons weight, to be sunk 30 feet below the sands; and upon this base he placed a column 86 feet high, with a lantern; but the whole of the works were washed away in one night. A floating light has, however, since been placed here, and saved many a goodly vessel from foundering.

In 1842, a noble Lighthouse was erected at the western extremity of Plymouth Breakwater, upon an inverted arch, founded 18 inches below low-water spring tides. The stones, of granite, are dovetailed and secured with dowels of slate; the centre light is 55 feet from the top of the Breakwater.

The Horsburgh Lighthouse, (named in memory of the late distinguished hydrographer to the India House,) the first light in the China Seas, Stevensons engineers, was built in 1851, on the Redro Branco Rock, at the entrance to the Straits of Singapore, ten miles from land. The tower is 95 feet high; the workmen employed in its construction were from various countries, no fewer than eleven different languages being spoken—viz. three varieties of Chinese, Malay, Javanese, Boyans, Kling, Bengalese, Papuas, Rawas, and English, so that many of the directions had to be given by signs. The Light is seen at fifteen miles' distance, the curvature of the earth preventing its being further visible.

Cast-iron has been extensively used in constructing Lighthouses. A small Light-tower was first erected on Gravesend pier. Next, a Lighthouse of cast-iron was built on Morant Point, Jamaica, designed by A. Gordon, in outline resembling that of the Celtic towers of Ireland. It was cast in England, and set up at Jamaica within six months, and at one-third of the cost of a stone lighthouse of equal dimensions: its height is 105 feet, and it was erected on the coral rock, by a derrick and crab from the inside, without any external scaffolding. The base is 27 feet of masonry and concrete. The tower shaft consists of tiers of iron plates, each 10 feet high, flanged together with nut and screw bolts, and caulked with iron cement. Ten radiating plates form the floor of the lightroom, secured to the tower upon brackets, and finished by an iron railing. Mr. Gordon has also built, on the same principle, at Gibbs Hill, Bermuda, a Lighthouse 130 feet high, and another at Point-de-Galle, Ceylon.

Lighthouses of iron, cast or wrought, or partly of gun-metal, are cheap, easily erected, strong to resist vibration in hurricanes, and safe from lightning, earthquakes, and fire; their lining and ventilation providing the desired and uniform temperature. Lighthouses have also been constructed upon iron piles, fixed in the sand by mooring screws, and made compact by cast-iron braces; the Maplin and Chaplin Lights, at the mouth of the Thames, and those at Fleetwood and Belfast, are on this principle. Others have been built upon hollow cast-iron columns, as that on the Bishop's Rock, thirty miles from the Land's End, and more exposed to the force of the Atlantic than the famed Eddystone Lighthouse. The six columns are sunk five feet into the rock, and tapering upwards, support, at a height of about 100 feet, the dwellings of the three light-keepers, with stores of provisions for four months; the whole is surmounted by the lantern, and the access to the dwellings is by a spiral staircase within a central column.

The sources of light in Lighthouses were, first, common wood fires, and then burning coals. A coal fire was employed in the Isle of Man for 180 years (as late as the year 1816). Tallow candles on wooden rods succeeded, and they were burnt in the Eddystone Lighthouse for forty years after it was completed by Smeaton. Then came lamps with twisted cotton wicks, and then common Argand lamps; all these were superseded by compound Argand lamps, with lenses and reflectors, and with lenses and reflecting prisms, instead of mirrors; the first light of this kind, on a large scale, was put up by Alan Stevenson, at the Skerryvore. Captain Drummond, whose famous light can be seen for sixty miles, suggested that incandescent lime should be employed for Lighthouses, heated by the burning of hydrogen in oxygen, passed through wire gauze and made to issue in two streams against the ball of lime: but about the year 1835 we were informed by the inventor that the apparatus for producing this light had not been sufficiently simplified to be used by persons who usually take charge of the lights in Lighthouses. Gas was first applied to the illumination of Lighthouses in 1847; in some cases it has been distinctly seen on board ships eighteen miles distant from the coast. In the above year the Hartlepool Lighthouse, then just built, was lit with gas, and by ingenious contrivances for the admission of air, the burner produced a rich opaque mass of flame, affording a powerful and steady light; and when this is placed in the centre of the optical arrangement of lenses, lenticular zones, and mirrors, an immense amount of intense light is spread over the horizon.

The South Foreland High Lighthouse has been illuminated by electricity made to stream into the lantern by the revolution of two magneto-electric machines, each put in motion by a two-horse power steam-engine: the whole consumption to produce the light being the coke and water required to raise the steam for the engineer, and carbon points for the lamp and the lantern. Professor Faraday tells us of an experiment in 1860, "when the light shone up and down the Channel, and across into France, with a power far surpassing that of any other fixed light within sight, or anywhere existent." An electric machine has been constructed for the Lighthouse on Cape Grisnez, at Boulogne, of such power that the light is visible across the Channel; and to passengers crossing the Straits of Dover, on a clear night, its splendour is very striking.

One of the latest works of this class was the construction of the Lighthouse on the Wolff Rock, off the Land's End, where eighty-two hours are said to have been the whole time that was available to work on the rock during the year 1862. Some idea may be formed of the tremendous strain to which Lighthouses are subjected, from the fact that, at Skerryvore, where an instrument to test the force of the waves had been exposed, in the *maximum* case, it was found to have equalled no less than 6,083lbs. on the square foot; also from the fact that at the Bishop Rock light-tower, off Scilly, a massive bell, which was fixed with strong iron supports, built into the masonry at 120 feet above the sea-level, was struck with such force by a wave which ran up the tower, that it was wrenched from its position, and its iron supports were broken. To resist the impact of such enormous force, the greatest possible strength that can be devised is requisite; and this is obtained in stone towers by a solid mass of masonry, sometimes to the height of 30 feet above the sea-level; the stones being all dove-tailed together, both laterally and vertically, and united by hydraulic cement, so that the stones cannot be separated without being broken, and the whole base is literally as solid and indivisible as if it were a natural solid rock.

"In Lighthouse construction," says Professor Cowper, "one is struck with the intensity and exclusiveness of thought devoted to each part of the whole matter. The Admiralty intensely desire a Lighthouse upon a particular spot. The engineer is intensely occupied in surveying, levelling, and building; and with a perseverance almost superhuman, he continues his work during two or three years on the edge of a rock just showing itself above the waves. He makes a temporary barrack on wooden piles on some adjacent point. This is all swept away in one night. He builds it again, and is obliged to live in it for fourteen days together, the weather preventing all access to it. Presently, however, a tower, 138 feet high, stands securely fixed upon the exact spot assigned to it. But the philosopher has also been at work, quietly but intensely considering the laws of reflection and refraction, and has contrived a glass prism of a new form, —without a thought of standing knee-deep in water twelve miles from land. The glass prism and lamp are now mounted on the tower, and confided to the keepers. These men have no careless task. If they have many lamps in a revolving light, the going out of one is comparatively immaterial; but when one light only is used, *life and death* hang on its burning. Their intensity of thought is to keep it lighted. In the ship that is approaching are two small instruments—the quadrant and chronometer (the products of science); with these the captain will ascertain his position on the trackless ocean. He, probably, regards neither the construction of the Lighthouse nor its beautiful light. His intense interest is to see it. He says: 'If I have calculated rightly by my instruments, and made allowance for the convexity of the earth, at such an hour the light will come into view.' Judge of his delight when it meets his eye! It is as if his country watched for his return, and welcomed him home."*

In a letter of the Astronomer Royal, Dr. Romney Robinson relates some interesting details of his recent inspection of the Lighthouses of Ireland, thirty-six in number—the cleanliness, order, and discipline of which he much commends. Dr. Robinson states, in a note, that when leaving Gola Sound, though the gale was much abated, the waves were twenty feet high, and of such power that they made a clear sweep over the Stags of Aranmore, forty-five feet above the sea-level. With respect to the optical part of the Lighthouses, Dr. Robinson got additional evidence of the superiority of the dioptric to the

* Proceedings of the Royal Institution, 1851.

catoptric system. At Rathlin the keepers see the Maidens, distant twenty-seven nautical miles, in very clear weather; at the Maidens they saw Rathlin—"a good strong dioptric."*

Floating Lights, which have been incidentally mentioned, should never be placed where a suitable position can be had for a fixed building. The former lights must be comparatively small, they are liable to drag their anchors in violent storms, and thus, by their change of position, mislead instead of guide the mariner. They are, besides, much more expensive: the management of a floating light requiring 11 men, and costing about 1,300*l.* per annum; whereas a first-class Lighthouse requires but three men, and costs but 350*l.* Light vessels are ordinarily painted of a dark red colour, to make them readily distinguishable from other craft; and dark red, which is the opposite of green, being more conspicuous than any other on the surface of the water.

The optical apparatus of the first-class Lighthouse constitutes a striking result of applied science. The object of such appliances is the utilization of the light that would otherwise pass away from the lamp without benefit to the mariner. It is sufficiently obvious that only those rays can reach a ship which proceed in a horizontal, or nearly horizontal, direction; hence it is the purpose of the optical apparatus to gather up all the available beams and send them forth horizontally over the sea, either radiating equally to all points of the compass, or more commonly concentrated in a few powerful beams, which are made, by means of a rotation of the apparatus, to sweep round the whole horizon with a uniform or determinate period. There are two methods of projecting the light of the lamp in the required directions; the one is by metallic *reflectors*, and the other by *refracting* the beams through glass lenses and prisms. The former was the method first used, one of the earliest instances being the Tower of Cordovan, already mentioned. It was the illustrious French *savan*, Auguste Fresnel, who first succeeded in constructing lenses of sufficiently great diameter and sufficiently short focal length, and he ingeniously accomplished this by building up a lens in steps (*lentille à échelons*). The

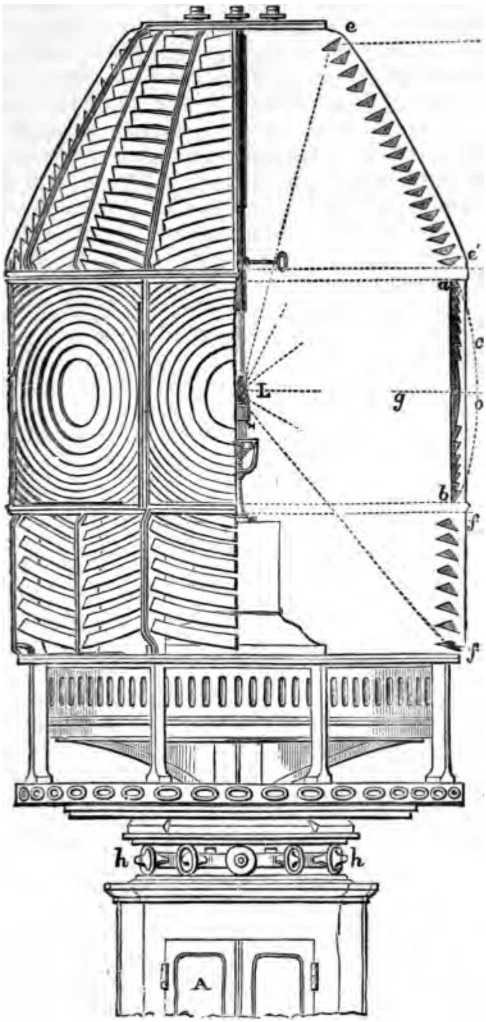
* Our Colonial Lights are numerous and costly. In the year 1867, there were six Lighthouses in process of construction by the British Government—one on the Little Basses Rock at Ceylon; one on the Roman Rocks at the Cape of Good Hope; two in the Bahamas, on Castle Island and Imagua Island; one on Sombrero Island; and one on the Dellamara Point at Malta.

structure of such a lens will be readily understood from an inspection of the next illustration, in which one lens is shown in section at *a b*; and it will be seen that similar portions of a series of lenses, having the same focal length, surround the centre, so that the whole has the same optical effect as a single lens of a very great thickness, as shown by the line *c o*. The figure represents the revolving optical apparatus of a light of the first class, constructed on Fresnel's plan. The whole of the light is here utilized, except that which falls upon the base and on the top of the apparatus; and while the rays falling upon the central zone, *a h*, are diverted by reflectors, those above and below are sent forth by total reflection from the surfaces of a properly disposed series of glass prisms, seen in section at *e e'* and *f f'*. The Tour de Cordouan was again the first Lighthouse upon which, in 1823, such a complete apparatus was erected; and the application of Fresnel's apparatus made the Lighthouses of France the most perfect in the world. A considerable number of years passed before the dioptric principle was used in British Lighthouses; and the Skerryvore Lighthouse, the building of which is described on page 30, was the first in this country to be supplied with so complete an apparatus as that represented in our figure.

Of kindred interest with that of Lighthouses is the Lifeboat, the invention of Mr. Henry Greathead, of South Shields, in 1789. It was first put to sea January 30, 1790; and Mr. Greathead received a reward of 1200*l*. from Parliament for this great means of saving life from shipwreck. Its principle is such an elevation of the two extremities as that, if overset, these elevated ends would be as light as the body of the boat; and to add to the effect, several pounds of cork are attached to the ends. The shape of the boat is curvilinear, approaching that of a crescent.

Among the earliest of Captain Manby's humane inventions was his simple method of converting any common boat into a Lifeboat, by merely lashing within the gunwale six or seven empty air-tight casks, a plan that has been found so efficacious in giving buoyancy, that sailors have put to sea in such a boat with a hole bored through its bottom. For this invention Captain Manby received a Parliamentary reward.

In the Great Exhibition of 1851, the general characteristics of the Lifeboats shown took for their common principle of buoyancy the construction of an air-tight lining in the interior of the boat—the space between the outward and inward sides,



REVOLVING LIGHT APPARATUS.

gradually widening until a very broad gunwale was formed. In other specimens the air-tight cell was placed lower, running in the form of a square or circular box round the boat, but beneath the thafts or seats. A few specimens were fitted with cork belts or furnishings, which keep the boat nearly as buoyant as air-tight tanks would do; and certainly have the additional advantage of not being rendered useless by an accidental blow from the sea against the wreck. The danger, however, is sought to be guarded against by the construction of several air-tight compartments—any of which, we are assured, would suffice to keep the boat, with her crew, above water. The long shallow shape of the boats was universal; and they were constructed alike at stem and stern, so as to avoid the dangerous necessity of going about. A Whitby boat was furnished with outriggers, supporting nets, into which people might leap from a ship, while the boat was kept at such a distance as to diminish the risk of her being swamped against the wreck. The Lowestoft and Yarmouth Lifeboats had their buoyant apparatus in the sides beneath the thafts; the oars double banked; and beside every man a pump for getting rid of the sea when it filled the boat. A label attached to these boats stated that they were in use over a range of coast of about 20 miles; not one of them had ever been upset, and they had saved from 500 to 600 lives. A Land's End Lifeboat was remarkable for the horizontal cuts or longitudinal openings like loop-holes, piercing her sides in continuous lines; beneath she was open to the water.

Holbrook's Iron Bottomless Boat, 26 feet long, was made of wrought and sheet iron, covered with strong netting; it had six floaters, made of sheet iron, filled with tubing formed into air and water-proof barrels, with tanks for 222 gallons of fresh water; provisions, warm clothing, compass, alarm apparatus, fuel, fireworks, rockets, and 1000 feet of line; and in the figure-head a kettle that would boil in ten minutes. The boat was secured with 400 screws and bolts, and 10,000 rivets. Having no bottom, this boat could scarcely capsize; should its floaters let in water, the barrels inside would remain buoyant; it would carry nearly 150 persons and food for many days.

Bonney's Lifeboat, which had been experimented with on the Serpentine and the Thames with unvaried success, was clinker built; the sides were doubled from the bilge to the spar-deck, and filled with gutta-percha water-tight cells; and the fore and aft parts divided into water-tight compartments.

The boat had sailed full of water, without impediment, and being hauled over, and then half filled with water, and released, righted itself immediately.

Here, too, was a Whitby Lifeboat, capable of emptying itself of water in four seconds, by two apertures in the bottom; and a Lifeboat of wood and cork, with gutta percha air-tight compartments, and scupper in the keel for letting out water.

Dyne's Lifeboat was built with diagonal battens laid lattice-wise, its outer sheathing formed of gutta percha; its buoyancy 350 cubic feet of air, capable of sustaining 9½ tons, and letting off shipped water by 3600 holes; in the convexed bottom were three perforated steadying fins, and between them two tons of water, not one ounce weight to the boat when upright; there were also galvanized springs placed at the stern, to act like railway buffers in collisions; besides a full supply of fusees, rockets, and other lights.

The Lifeboat which gained the prize of 100*l.* offered by the Duke of Northumberland, was modelled by James Beeching, of Great Yarmouth, and was of whale-boat body: "she would, from her form, both pull and sail well in all weathers; she would have great stability, and be a good sea-boat, ; she had moderately small internal capacity for holding water under the level of the thwarts, and ample means for freeing herself readily of any water that might be shipped; she was ballasted by means of water admitted into a well or tank at the bottom, after she was afloat; and by means of raised air-cases at the extremities, a light iron keel, and the absence of mid-ship side air-cases, she would right herself in the event of being upset; thus combining most of the qualities required of a lifeboat."

A Tubular or Double Lifeboat was invented by H. F. Richardson, in 1853: it is formed of two tubes of tinned iron, 40 feet long by two-and-a-half feet in diameter, and tapering at the ends. An iron framework unites the two tubes, which are divided into water-tight compartments, occupied by air-tight bags; the whole is surrounded by a cork fender. Seats for the rowers and passengers are placed above the framework. Colonel Chesney states this boat to have undergone several trials at Plymouth with great success, and he is of opinion that it cannot be upset.

Clarkson's Lifeboat was experimented with at Dover, in 1853: manned by thirteen persons, she was put to sea, was filled by a bucket with water, and set sail. The weight of water had no effect upon the boat: she maintained her position, the crew then endeavoured by every means to sink her, but in vain. The boat was then pitched off the pier into the sea, but instantaneously righted, and relieved herself of water; she was then turned over keel upwards, but turned into her proper position immediately.

The Expanding Tubular Life-raft, invented by G. F. Barratt, is formed of vulcanized India-rubber tubes, inclosed in canvas cases or nettings, lashed to cross spars, so as to form, when extended, a contrivance for floating on the water, or being rowed like a boat, in safety through a surf or heavy sea. The same inventor has produced a Collapsing Boat, consisting of tubes lashed round a boat-like framework, with three thwarts which shut up like a purse. The bottom is formed of nettings to enable the water to have a free course, and the thwarts are kept expanded by means of "moveable fishes."

A noted Lifeboat, called the *Mary Anne*, belonging to the ports of Hartlepool and Sunderland, is able to right itself immediately, when purposely capsized, particularly when the boat is under sail; the crew received, in four years, the sum of 250*l.* from the Board of Trade, for saving life, besides salvage money for assisting vessels in distress.

In London has been established the "Royal National Lifeboat Institution," for the purpose of placing their succours upon various stations of our coast, and rewarding services which have saved life from shipwreck. In November, 1866, this institution, since its formation, had contributed to the saving of 15,700 lives from shipwreck. The Society is supported by subscriptions, many in the form of bequests from benevolent persons. Thus, in 1866, Miss Ellen Goodman, of Eversholt, Bedfordshire, left the institution 600*l.* to pay for a Lifeboat, its equipment, and transporting carriage; Mr. R. Thornton West and Mrs. West gave the whole cost, amounting to 620*l.* of the Lifeboat station near West Wittering, on the Sussex coast; and in 1867, a lady of Upper Clapton, who had for many years been saving money for the purpose, at her death bequeathed to the institution 450*l.* with a request that a Lifeboat, named the *George and Anne*, should be stationed on the Isle of Wight, which request was readily complied with. Bequests of this nature are made under circumstances of touching interest, "which makes the whole world kin."

THE BAROMETER.

THIS instrument is named from two Greek words, signifying *the measure of weight*, since by it a column of air is weighed against a column of mercury.

The circumstances attending its invention were curiously accidental. The common pump had been well known for many centuries, and its phenomena explained by the well-known maxim that " Nature abhors a vacuum," why, had never been discovered. The Duke of Florence had employed some pump-makers upon his premises, who found that water would not rise higher than 30 feet, or thereabouts, when the air in the tube was exhausted. In their dilemma they applied to Galileo, who replied that nature had no power to destroy a vacuum beyond thirty-two feet; for, learned as Galileo was, he understood not the action of the weight of the atmosphere. At his desire, however, his pupil, Torricelli, investigated the subject.

EVANGELISTA TORRICELLI.

Evangelista Torricelli was a native of Piancondoli, in Romagna, where he was born in the year 1608. By the care of an uncle, he received an excellent education at the Jesuit School in Faenza, where he became remarkable for his mathematical and scientific attainments. At twenty years of age his uncle sent him to Rome, and he there became intimate with Castelli, then mathematical professor of the college of that city. About this time Galileo was endeavouring to overturn the received doctrine that substances descended in speed according to their natural gravity; and that consequently, if two weights were to descend from a high position, the one which was ten times the weight of the other would reach the ground ten times as soon. Galileo, however, was aware of the resistance offered by the air to the motion of bodies through it, and of the opposition which it occasioned to the effect of the earth's attraction. He went, attended by several officials, to test its validity; and two stones, of very unequal weight, were dropped from the Leaning Tower at Pisa. The truth was evident from the fact that the stones reached the ground nearly at the same moment; but it was in vain that Galileo pointed out that the difference in time of their descent was entirely owing to the unequal resistance of the air. Prejudice had darkened reason too much for conviction to enter into the minds of the persons by whom he was accompanied.

These several experiments, and similar facts which had been educed from them, were not overlooked by Torricelli; and he published two Tracts, one on the motion of fluids, and the other on machines, which soon obtained the notice of the venerable Galileo, by whom he was invited to Florence. After Galileo's death the Duke of Florence gave Torricelli the chair of Mathematics in the Academy; and he thus became his friend's successor, when he was about 39 years of age.

To return to the invention of the Barometer. Torricelli first imagined that the weight of the atmosphere might be the counterpoise to the 32 feet of water; or, at least, he was the first whom we know to have applied himself to try this supposition by experiment. He saw that if it be a weight of air which counterpoises the 32 feet of water, it must follow that by the substituting of mercury instead of water, the height of the column necessary to counterpoise the weight of air would be reduced in the proportion in which mercury was heavier than water. For instance, that if mercury be fourteen times heavier than water, bulk for bulk, the fourteenth part of thirty-two feet, or about two feet four inches, would supply the place and produce the effect of the water. He accordingly filled a tube more than three feet long, and open at one end only, with mercury, and then stopping the open end with a finger, he placed the tube in an open vessel of mercury, with the open end downwards. On removing the finger, the mercury in the tube sank until it stood in the tube at about

28 inches higher than the mercury in the vessel, leaving in the upper part of the tube an empty space, known as the Torricellian vacuum. The top of the column within the tube is therefore withdrawn from the atmospheric pressure, which, acting on the liquid in the open vessel balances the weight. Torricelli thus constructed what is at this time considered the best form of barometer. It should be stated that in 1601, that is, 12 years before Torricelli's observations, Descartes, the French philosopher, had made the same observation, although he does not appear to have turned it to any account.

Torricelli died in 1647, leaving his great discovery not quite complete; for, though he had made it apparent that the weight of the water and the mercury was a counterpoise of something, most probably of a weight of air, the latter was not quite certain. The suggestion, however, was taken up by Pascal, Mersenne, and others in France; and by Boyle, in England, the latter, by means of the air-pump, being enabled to subject air of different degrees of density, to the test of the barometer. Pascal, who had repeated Torricelli's experiments at Rouen, before more than 500 persons, and obtained the same results as Torricelli, did the same; and assuming that the mercury in the Torricellian tube was sustained by the weight or pressure of the air, he suggested that it would necessarily fall in ascending a high mountain, by diminution of the superincumbent column of air. At his request, his relative, M. Perrier, tried the barometer at the summit and base of the mountain of Puy de Dôme, in Auvergne; and the result was that the mercury, which at the base stood 26¼ inches (French), was only 23½ inches at the summit; the summit being between three and four thousand feet above the level of the sea. Similar results were afterwards obtained by Pascal himself; and he also discovered that the operation of the same law was very sensibly shown in the ascent of a church-tower, or even of a private house; thus establishing the fact of atmospheric pressure beyond dispute. The pressure of the atmosphere is equal to that of a column of mercury about twenty-eight inches high, that is, a pressure of about fifteen pounds on a square inch.

The discovery was, however, at first much misunderstood, and even disputed, until it was seen by a glaring instance, that the maintenance of the mercury in the tube was the effect of a perfectly definite external cause; whilst its fluctuations, from day to day, with the varying state of the atmosphere, strongly corroborated the notion of its being due to the pressure of the external air on the surface of the mercury in the reservoir. The truth is—it is the weight of the atmosphere—fifteen pounds on every square inch—that pushes water into the void left by the drawn-up piston of a pump; and there is, of course, a limit beyond which it cannot push the water, namely, the point of height at which the column of water in the pump tube is exactly balanced by the weight of the atmosphere. It is just a question of balance: fifteen pounds commonly support fifteen pounds,—a thing which everybody now understands, thanks to Galileo, Torricelli, and Pascal, the seer, the discoverer, and verifier of the fact. Pascal showed that many phenomena, which had formerly been ascribed to a vacuum, arose from the weight of the mass of air; and, after explaining the various pressure of the atmosphere in different localities, and in its different states, and the rise of water in pumps, he calculates that the whole mass of air round our globe weighs 8,983,889,440,000,000,000 French pounds.

Soon after the discovery, among many different methods for improving the construction of the Barometer, the continued variations of the altitude of the mercury suggested the idea of *the weather glass*. It was observed that the changes in the height of the mercury corresponded to changes of the weather, though experience was not yet sufficiently extensive to decide in what manner. The instruments are now manufactured in several different forms, but the principle is the same in all. The repeated observations during the ascent of the loftiest mountains in Europe and America, have confirmed the truth of the theory of the barometer. Indeed, the Barometer has been much employed as a convenient instrument for determining the elevations of mountains. To deduce the height from the barometric indication would be a very easy problem if the density of the atmosphere were uniform. This, however, is not the case.

Sir Henry Englefield constructed a Barometer expressly for these investigations. A rule or formula has been deduced from established theory and observed effects, by which the change of elevation may be drawn from the Barometer. To apply this rule it is necessary to know, 1st, the latitude of the place of observation; 2ndly, the height of the Barometer at the lower station; and 3rdly, the height of the Barometer at the higher station. By arithmetical calculation, the difference of the levels of the two stations may then be ascertained.

The atmosphere is densest near the surface of the earth, because it has to support the weight of the whole column of air above it; which, owing to its being very compressible, compels it to occupy less space. This law of decrease in pressure being known, its application is made use of in the measurement of Mountains; for the Barometer will indicate a less pressure at the summit than at the base, though the decrease will not be in the simple proportion.

The following interesting experiment was made with Wollaston's Thermometrical Barometer, 552 parts upon the scale of which are equal to 530 in altitude. With this instrument, boiled on the counter of a bookseller's shop in Paternoster-row, between 4 and 5 feet above the foot pavement on the north side of St. Paul's Churchyard, and boiled again in the golden gallery of the Cathedral, there was a difference of 254 parts; the corrected height indicated, therefore, 276 64 feet. General Roy makes the gallery above the north pavement to be 281 feet, which, allowing five feet for the difference of station, being the author's estimate to 267 feet; or, by another calculation, founded on General Roy's statement; the difference is less than two feet. In navigation, the Barometer has become an important element of guidance; and a most interesting incident is related by Captain Basil Hall, indicative of its value in the open sea. While cruising off the coast of South America, in the *Medusa* frigate, one day, within the tropics, the commander of a brig in company was dining with him. The conversation turned on the natural phenomena of the region, when Captain Hall's attention was directed to the Barometer in the state-room where they were seated, and to his surprise he observed it to evince violent and frequent alteration. His experience told him to expect bad weather, and he mentioned it to his friend. His companion, however, only laughed; for the day was splendid, and not a cloud specked the deep blue sky above. But Captain Hall was too uneasy to be satisfied with bare appearances. He hurried his friend to his ship, and gave immediate directions for shortening the top sails of the frigate as speedily as possible. His lieutenants and the men looked at him with surprise, and one of the former ventured to suggest the inutility of the proceeding. The Captain, however, persevered. The sails were furled, the top-masts were struck; in short, everything that could oppose the wind was made as snug as possible. His friend, on the contrary, stood in under every sail.

The wisdom of Captain Hall's proceedings was, however, speedily evident, just indeed as he was beginning to doubt the accuracy of the instrument. Hardly had the necessary preparations been made, and while his eye was ranging over the vessel to see if his instructions had been obeyed, a dark hazy hue rose in the horizon, a leaden tint rapidly overspread the sullen waves, and there burst upon the vessels one of the most tremendous hurricanes that ever seamen encountered. The sails of the brig were torn to ribbons, her masts went by the board, and she was left a complete wreck on the tempestuous surf which raged around her, while the frigate was driven along at a furious rate, and had to sail under bare poles, across the wide Pacific, full three thousand miles, before it could be said she was in safety from the blast.

The Aneroid Barometer, a recent French improvement, is named from a Greek compound, to express the principle of the instrument, viz., without liquid. The principle on which it is constructed may be explained in a few words. The weight of a column of air, which, in a common barometer, acts on the mercury, in the Aneroid presses on a small circular metal box, from which nearly all air is extracted; and to this box is connected, by nice mechanical arrangement, the hand visible over the face of the instrument. When the atmospheric pressure is lessened on the vacuum box, a spring, acting on levers, turns the hand to the left; and when the pressure increases, the spring is affected differently, the hand being turned to the right. It acts in any position; but, as it often varies several hundredths with such a change, it should therefore be held uniformly. The Aneroid is quick in showing the variation of atmospheric pressure; and to the navigators who know at times the difficulty of using barometers, this instrument is a great boon; for it can be placed anywhere, quite out of harm's way, and is not affected by the ship's motion, although faithfully giving indication of increased or diminished pressure of air. It may be suspended on or near the upper deck, for easy reference; and is not easily to be injured by mere concussion of air, or vibration when guns are fired. In ascending or descending elevations, the hand of the Aneroid may be seen to move, like the hand of a watch, showing the height above the level of the sea, or the difference of level between places of comparison.

The Barometer is absurdly called a *Weather Glass*, because it is observed that the changes of weather are indicated, not by the actual height of the mercury but by its *change* of height. One of the most general, though not absolutely invariable, rules is, that when the mercury is very low, and therefore the atmosphere very light, high winds and storms may be expected.

Mr. Daniell, the eminent meteorologist, wrote, some forty years ago, "The common barometers are mere playthings, scarcely two agreeing within a quarter of an inch; whereas the questions of meteorology, now of interest, require the measurement of 1-100th part of an inch of the mercurial column. The height of the mercury is never actually measured in these barometers, but they are graduated one from another, and their errors are thus unavoidably perpetuated; neither is the diameter of the tube ascertained with any degree of accuracy."

Admiral Fitzroy, in the *Barometer Manual*, published by the Meteorological Department of the Board of Trade, states that all Barometers should show the same pressure at the same place, if well made, whatever their construction, if duly corrected for their internal temperature—usually that of air close round them. A mercurial barometer, whether of one kind or another, may differ from and vary in its difference from a good and truly graduated Aneroid accurately compensated for temperature; but these differences are only fractions of the tenth of an inch generally. The Bourdon, or metallic barometer, may be occasionally exceptional, as it has undoubtedly shown special effects attributable to some cause besides pressure and temperature, probably electric.

Atmospheric currents and their pressure, or tension, occasion changes in Barometers much more considerable than those caused by rains or snow (which descend from one current of air while influenced or acted on by another). Two such currents of air, or winds, impelled against each other, and having more or less momentum, raise the Barometer, by an increase of tension, or pressure, laterally as well as vertically, and rain may fall, or snow, or hail, notwithstanding a high reading—perhaps considerably above 30 inches. In such cases the use of a thermometer, and a knowledge of seasonable temperatures (see any sixpenny manual), at once indicate the approach and temporary prevalence of either wind displacing another.

Clock-faced barometers, when they are in adjustment, are as much to be relied on for weather purposes as those with an exposed column of mercury, but are not used where great scientific accuracy is required; and further, the moisture of the air has no greater effect on this form of instrument than it has on any other. The only point in these instruments likely to mislead is the antiquated lettering, "Rain," "Change," and "Fair," which in modern barometers is well replaced by the words suggested by Admiral Fitzroy, and which serve as a perpetual memorandum to the observer.

Mr. H. A. Clum, of the United States, has invented "the Aelloscope," an apparatus intended to supersede the Barometer, and named because its special function is the viewing or indicating of storms. It combines the construction of the Barometer, having a cistern containing 70 lbs. of mercury, and a central mercurial column $2\frac{1}{4}$ inches in diameter. In this column rests a float, or buoy, supporting large cylinders, or air-chambers, made of German silver; and these, owing to their large displacement of air, are so sensitive of atmospheric changes, that exceedingly slight fluctuations are indicated which would not be observable in the ordinary Barometer. The indication is shown by a hand on a dial, read as easily as an ordinary clock; hence the trouble of reading by the delicate adjustment of a vernier, and nice observation of the top of the mercurial column, is altogether avoided.

THE THERMOMETER.

THE origin of the Thermometer, like that of the Mariner's Compass, remains in obscurity. We only know that the idea of measuring the degree of heat, which the atmosphere at different periods presents, s first conceived in Italy, that country which, during the ter portion of the Middle Ages, was distinguished by the tainments and discoveries of its scientific men.

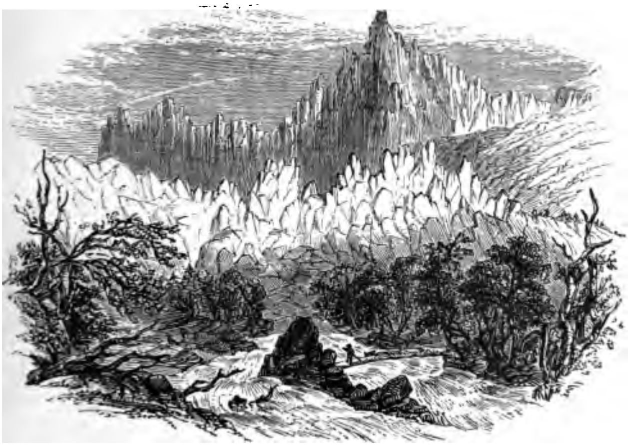
In the year 1626, there was a book published entitled, *Comentaries on the Works of Avicenna*, by a physician, named antorio, who resided at Padua; and in this work he claims the onour of having invented the Thermometer. Cornelius Drebel, of Alkmaar, in Holland, makes the same claim; and after carefully examining the evidence, it appears, that although Santorio was the first to point out the use of the instrument, Drebbel had also discovered and made its properties known before he heard anything of the invention of the Italian physician.

For some time after the invention of the Thermometer, it was chiefly used for ascertaining the changes of temperature alone, and the instrument was of the simplest description. A glass tube was formed with a ball at one end; the other end was open, and inserted in a vessel partly filled with mercury or coloured spirit—generally the latter. A portion of the air was previously expelled from the ball by warming it over a lamp, nd as the ball cooled the bulk of the included air diminished, nd the atmospheric pressure forced the liquid up the tube. Vhen the included air expanded by heat, it pressed down the pirit; on the contrary, when the temperature was reduced, its ressure upon the surface of the spirit decreased, and the tter was forced higher up the tube, as the air within beume contracted in bulk. A scale was then fixed beside the tube divided into degrees, so that the several changes could be measured as correctly as might be expected from the simplicity of the contrivance.

The invention soon attracted the attention of the celebrated Robert Boyle, who had already made great improvements in the Air-pump, and devised an alteration in the form of the heat-measurer. He left the tube open at both ends; the lower end was immersed in a small glass vessel containing both air and coloured spirit, and the vessel being formed with a neck, which closely encircled the tube, it was hermetically sealed to the latter. The variations in the temperature of the atmosphere caused the air in the vessel to expand or contract, and thus to press with more or less force on the surface of the spirit; the latter being consequently made to ascend or descend in the tube. Boyle, who was a son of the Earl of Cork, was a man distinguished for noble qualities of mind and heart. His chemical experiments date from the year 1646; shortly after which he turned his attention to the improvement of the Thermometer. He was one of the members of "The Invisible College," which was incorporated with the Royal Society.

In 1702, Amontons, a French philosopher, invented an Air Thermometer which was about four feet long. It consisted of a tube open at one end, the other turning up and terminating in a ball containing air, which was subjected to the pressure of two atmospheres, for it supported the weight of a column of mercury, occupying about 26½ inches of the vertical tube. Amontons recognised the importance of obtaining fixed points of temperature, and for one of these he proposed to adopt the boiling-point of water. Except, however, by the inventor himself, very few instruments were made on the principle he suggested.

All these early forms of the Air Thermometer were liable to serious objections. In the first place, their indications might, independently of any change of temperature, vary by reason of fluctuations in the atmospheric pressure. They were, to a certain extent, *barometers* as well as Thermometers; and, therefore, before the thermal effect could be ascertained from their indications, a correction would have to be applied for the barometric condition of the atmosphere at the time of observation. Again, as no precautions were taken to fill the air-chamber with perfectly dry and pure air, the expansibility would vary from one instrument to another. It would be affected also by the nature of the confining liquid, and the instrument would also be liable to derangement by the absorption or escape of a portion of the confined air. These objections were avoided in the more convenient instruments devised by the scientific members of the Florentine academy *del Cimento* towards the middle of the seventeenth century. In these instruments the expansion of spirits of wine was used instead of the expansion of air. The method of construction was identical with that still in use, the liquid filling a bulb and part of a narrow tube proceeding from it. This tube being hermetically sealed, while filled with the liquid fully expanded by heat, the space



GLACIERS OF CHAMOUNI.

ı the tube above the liquid is empty, or, at least, can contain nly the vapour of the spirit. As alcohol never freezes, the pirit thermometer is well adapted for very low temperatures; ıus, it was used by Saussure in his Alpine ascents.

Horace Benedict de Saussure was, at the age of twenty-one, ppointed to the Chair of Philosophy in the College of Geneva; ıd for five-and-twenty years he discharged the duties of a ublic teacher. In the intervals of his official labours, he ıved to make excursions in the sublime and romantic country ı which he was born; and before he was eighteen years of age he had explored the mountains in the neighbourhood. These excursions created in him new desires to explore more closely the lofty heights of the Alpine mountains; and in the year 1760, alone, and on foot, he made his way to the Glaciers of Chamouni, then little visited by those who lived in the locality. The ascent and descent were both difficult and dangerous, but they were accomplished by him in safety; and from this time Saussure, year by year, undertook many journeys to carry on his observations among the mountains in different parts of Europe. Between the years 1758 and 1779, he traversed the whole chain of the Alps no less than fourteen times by eight different routes, and made sixteen other excursions to the centre of the mountain mass. He went over the Vosges and the Jura, traversed the passes of Switzerland, trod the craggy heights of Germany; surveyed those of England, of Italy, and of Sicily and the adjacent islands; inspected the ancient volcanoes of Auvergne, and visited the mountains of Dauphiné and other parts of France. And all this he did with his mineralogist's hammer in his hand, clambering up to every peak that promised anything of interest, and making his notes on the very spot, where the different peculiarities existed which he had set out to describe; besides collecting specimens of the minerals and mountains.

In 1787, when forty-seven years of age, he ascended to the top of Mont Blanc, and in the intense cold of that lofty region he remained three hours and a half, noting the natural phenomena of that sublime district.

In the following year, accompanied by his eldest son, he encamped on the Col du Géant, at a height of 11,170 feet above the level of the sea, and remained there seventeen days without quitting his position. In the year after, he reached the summit of Monte Rosa in the Penine Alps, the last ascent of importance which he performed.

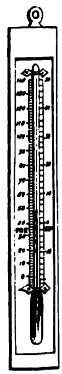
During his several journeys, while Saussure naturally turned his attention to the meteorological phenomena, he invented several philosophical instruments, the necessity for which he learned from his personal experience. Among others, a Thermometer for ascertaining the temperature of water at great depths; an hygrometer to show the quantity of watery vapour in the atmosphere; and an electrometer to develop its electrical condition.

The Thermometer which is now in general use is a slender tube of glass, terminating in a ball containing mercury, the air having been expelled, and the tube afterwards hermetically sealed. The idea of employing mercury for the purpose of measuring degrees of heat by its expansion, is supposed to have first occurred to Dr. Halley; but he did not employ it, owing to the rate of its expansion being much less than that of alcohol. Boerhaave ascribes the invention of the mercurial Thermometer to Römer in 1709; but it was not till the year 1724 that such a Thermometer was known in this country. In that year, a mercurial Thermometer which had been invented by Fahrenheit, of Amsterdam, in 1720, was described in a paper read to the Royal Society; in which it was shown that the

MONTE ROSA.

mercury employed as a thermometric liquid offers many advantages not to be found in either alcohol or air. Being easily deprived of the air it contains, and from its metallic quality able to conduct heat rapidly, the change in its volume both quickly and accurately represents the alterations in the temperature.

Fahrenheit's thermometer is the one now in general use in this country. Römer (*Réaumur*) is used by the German people; the French adopt that of Celsius, a Swedish philosopher, calling it *Centigrade*. It differs from that of Reaumur or Deluc, only in the distance between the points of freezing and boiling water being divided into 100 parts, and it is now much in use among the philosophers of the Continent. Now, Centigrade degrees being larger than Fahrenheits in the proportion of 9 to 5, to convert the one into the other we have only to multiply by 5 and divide by 9, or *vice versâ*. The main difference between the two former consists in the gradation of the scale—Reaumur fixing his zero at 32 degrees of Fahrenheit, and dividing the ranges between that point and the point of boiling water into 80 degrees; while Fahrenheit takes a scale of 212 degrees between his zero and the boiling point.



It is said that Fahrenheit obtained his zero by having mercury exposed in a tube to intense cold, in Iceland, during the year 1709. He then immersed the tube in freezing water, and found that the mercury stood at the 32nd degree above. On immersing it in boiling water, it stood at 212 degrees. This scale he obtained by ascertaining the capacity of the bulb; and dividing it into ten thousand parts, he found that the expansion of the mercury was just equal to two hundred and twelve of these parts when it was exposed to boiling water.

The Thermometer constructed by Reaumur was a spirit thermometer. He divided the capacity of the ball into one thousand parts, and then marked off the divisions, two of which were equal to one of those parts. He found his zero by exposing the instrument to freezing water; and then plunging it into boiling water, he observed whether the spirit rose to exactly eighty of those divisions, and if it did not he strengthened or diluted the spirit until it rose. But this instrument could never really be so made, as spirit boils long before it reaches the point of boiling water, and the one now called Reaumur's Thermometer is an improvement upon that instrument by M. Deluc, who determined the points of freezing and boiling water by experiments, and divided the distance between them into eighty parts, the zero of the scale being at the former point.

Other kinds of Thermometers have been invented for different purposes. One of the chief of these is the instrument for registering the *maximum* and *minimum* temperatures in the

Gutenberg, Schoeffer, and Fust, the Inventors of Printing, and Ancient Press.
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absence of the observer. One of the best known contrivances for this purpose is the invention of Mr. Six, of Colchester. It is, in fact, a spirit Thermometer with a long cylindrical bulb, and a stem twice bent, so that the two parts of it are parallel to the cylindrical bulb. The stem terminates with a slight enlargement, which is partly, and the rest of the instrument completely, filled with alcohol, except where a column of mercury occupies a portion of the stem. This column of mercury moves with the spirit, and at either end pushes forward a small index consisting of a piece of iron wire enclosed in a glass tube, which occupies nearly the width of the tube. When the mercury retires the index is left; and thus, both the maximum and the minimum temperatures to which it has been subjected during any desired period may be read off. The indexes are set for a fresh observation by bringing each into contact with the mercury by means of a magnet, which attracts the piece of iron through the glass, so that the index follows the magnet. Rutherford's "day and night Thermometers" consist of a spirit Thermometer, and a mercurial Thermometer of the ordinary construction, but provided each with a suitable index within the tube. The index in the spirit Thermometer follows the free surface of the liquid in its retreat towards the bulb, but is not shifted by the advancing liquid; while that in the mercurial Thermometer is pushed along only by the advance of the liquid. These two instruments are commonly mounted on one frame; and they are always placed with the tubes in a horizontal position. Rutherford's Thermometers, properly adjusted and corrected, have furnished innumerable observations of the utmost value in meteorological science.

PRINTING.

Printing described by the monks as the work of magic. Fust. Gutenberg. Schoeffer. Children returning from school with their horn-books.

(The Inventors of Printing.)

IF we could call up before us the *Scriptorium* of an English monastery in the olden time, we should see the monks seated at their desks, their ink, pens, brushes, gold, and colours before them; one busily employed in finishing some richly illuminated initial, another slowly adding letter to letter, and word to word, translating and copying the ancient manuscript before him as he progressed with his tedious task. From day to day, and month to month, would he slowly proceed, forming those thick, angular, black-letter characters, with no cessation, saving to attend to his meals, his prayers, and his sleep; unless he paused now and then with his quaint old-fashioned knife to erase some error he had made upon the parchment. Greece and Rome were then the great marts of these rare manuscripts; and many a journey did our Saxon ancestors make to purchase manuscripts at great cost, and, on their return to England, translate into the Saxon language, or multiply copies from the original. So precious were the manuscripts in those days, that an Anglo-Saxon bishop, named Wilfred, had the books of the four Evangelists copied out in letters of gold upon purple parchment; and such value did he set upon the work that it was kept in a case of gold, adorned with precious stones. The heathen sea-kings, the Danes, however, when they invaded England, burnt many valuable manuscripts, which had cost the Saxons years of labour to produce; and but for these ravages, England would have possessed the most valuable histories of any country in Europe since the dawn of Christianity. Many treasures that we lost for ever would then have been made familiar to us in the present day, through the invention of Printing.

It is hard to say when this "noble craft and mystery" did not exist: whether an impression be made by pressure of the hand upon snow, or by wood or metal upon paper or vellum, it is alike *printing;* and one of our recent discoveries, producing an impression of a fern, is called Nature-printing. Nearly four thousand years ago, seals were impressed upon soft material: next, characters were stamped upon clay in forming bricks, as in Babylon; of which art examples have been brought from Egypt, and from the buried cities of Asia. Besides these inscribed bricks have been found the wooden stamps to be seen in the British Museum. Brass or bronze stamps, with raised characters, with a handle at the back, for printing with colour upon papyrus, linen, or parchment, have also been found; the process resembling that of stamping linen with marking-ink in our day. The Romans used the above stamps, and it is strange that they did not engrave sentences upon blocks, and transfer them to surfaces, to save the slow operation of copying manuscripts. The Chinese claim to have printed from blocks several centuries before it was practised in Europe, or fifty years before the Christian era. Next, printing from pictures engraved upon wooden blocks was accomplished in the thirteenth century; then playing cards were taken from blocks by means of a burnisher, as engravers on wood take impressions on India paper in the present day; and next, the engravings of the *Biblia Pauperum* (Poor Men's Bible), with the text printed in from moveable types.

Whether moveable wooden types were ever employed to print an entire book is very questionable. The formation of *metal types* in a matrix or mould was the most important advance. This invention is now ascribed to John Gœnsfleisch, who was born at the village of Selgelock, in the year 1397, and went to reside at Mentz, or Mayence, with a family named Gutenberg, whose appellation he soon assumed, and ever afterwards bore. At Mentz he became implicated in a political insurrection, which being unsuccessful, he fled to Strasburg, where he had to look out for the means of a livelihood, and entered into partnership with other persons in "a wonderful and unknown art." An action at law arose, as proved by a legal document, dated 1439; and evidence produced on the trial showed that one of the witnesses had learned from Gutenberg to "take the pages from the presses, and by removing two screws, thoroughly separate them (the letters), from one another, so that no man may know what it is," thus proving that separated types were used, as well as some sort of press.

After some years' residence at Strasburg, Gutenberg returned to Mentz, about the year 1450, with all his materials. His partnership had expired; and at Mentz he became acquainted with Herr Faust, or Fust, a rich goldsmith and citizen, who was taught the secrets of the art, upon advancing the requisite funds. There is a strange story told of their work. The first of their productions was a Latin Bible, and the letters of this impression were such an exact imitation of the works of the penman, that they passed it off as an exquisite specimen of the copyist's art. Fust sold a copy to the King of France for seven hundred crowns, and another to the Archbishop of Paris for four hundred. The prelate, enchanted with his bargain (for the usual price was several hundred crowns above what he had given), showed it in triumph to the King. The King compared the two, and was filled with astonishment. They were identical in every stroke and dot. How was it possible for any two scribes, or even for the same scribe, to produce so undeniable a fac-simile of his work? The capital letters of the edition were of red ink. They inquired still further, and found that many other copies had been sold, all precisely alike in form and pressure. They came to the conclusion that Fust was a wizard, and that the initials were in blood; he was, accordingly, apprehended, and to save himself from the flames the unhappy Fust had to confess the deceit, and also to reveal the secret of the art. The whole mystery consisted in cutting letters upon moveable metal types, and after rubbing them with ink, and they were correctly set, imprinting them upon paper by means of a screw.

Another story attributes the invention of metal types to Peter Schoeffer, a native of Hesse-Darmstadt, who entered warmly into the designs of Gutenberg and Fust, and who suggested the idea of stamping the forms of the letters in lead or other soft substance; this they succeeded in accomplishing, and the initiatory process of printing was fully obtained. The principle of the screw-press had long been known, for it was just the time when the learning and scientific principles of the ancients were beginning to be revived. Schoeffer is stated to have discovered the method of forming the letters at the bottom of a sort of case or mould, called a matrix. He privately cut the whole alphabet, and when he showed his master the result of his labours and ingenuity, Fust was so delighted that he promised to give him his only daughter, Christiana, in marriage—a promise which he soon afterwards fulfilled. The types first cast are supposed to have been of lead, but afterwards, by the infusion of antimony, the metal was made sufficiently hard to bear the work to which it was subjected. Schoeffer's claim has been much controverted; and certain bibliographers maintain that Lawrence Coster, of Haarlem, who died in 1440, may be fairly credited with the earliest use of moveable types; it is also argued that experiments in the use of moveable types were, probably made about this period in every city where wood engraving and block printing were practised.

The harmony between the partners appears to have been interrupted soon after Schoeffer entered the business, and in 1458 Gutenberg was obliged to retire from the concern, having mortgaged his printing materials to Fust, which is proved by the initial letters used by Gutenberg and his partners in printing works between 1450 and 1455, being likewise used by Fust and Schoeffer in the Psalter of 1457 and 1459. Gutenberg having completed several works of importance, including the Mazarine Bible, started anew at Mayence, and there carried on business for ten years. He retired in 1465, and died on the 24th of February, 1468. His printing-office and materials were sold to Nicholas Bechtermunze, of Elfield, whose works are much prized, as they corroborate the genuineness of the works attributed to his great predecessor. There is no book known which bears the conjoint names of Gutenberg, Fust, and Schoeffer, nor any which has the imprint of Gutenberg alone; but there are several books attributed, from internal evidence, to Gutenberg's press. He had to endure much from misconception and ingratitude; he was persecuted by the guilds and the priests, and even his partners leagued against him. Posterity has, however, in some degree, made amends for the ingratitude of his contemporaries.

A statue of Gutenberg, by the celebrated sculptor Thorwaldsen, was erected at Mayence on the 14th of August, 1837,

STATUE OF GUTENBERG, AT MAYENCE.

when deputations from all the great cities of Europe attended the ceremony, to do honour and homage to the inventor of printing. At high mass in the cathedral was displayed the first Bible printed by Gutenberg. This statue of a man who had won for his city the gratitude of the world was exposed to view amid such joyful demonstrations of popular feeling as had been wont only to greet the return of some mighty conqueror. A Society, to which all the writers of the Rhenish provinces belong, hold annually at Mayence a meeting in honour of the memory of Gutenberg.

The capture of the city of Mentz by Count Adolphus, of Nassau, in 1462, interrupted the labours of Fust and Schoeffer: they and their work fled into the neighbouring States, and thus spread printing over the whole civilized world, and within fifteen years to every town of consideration in Christian Europe. It reached Bamberg in 1461; Subiaco and Rome, 1465; Elfield, 1467; Cologne, 1467; Augsburg, 1468; Venice, 1469; Milan, 1469; Paris, 1470; Florence, 1471; Basle, 1474; Westminster (Caxton), 1474; Antwerp, 1476; Geneva, 1478; Oxford, 1478; St. Alban's, 1480; Vienna, 1482; Haarlem, 1483; Cracow, Munich, and Amsterdam, 1500; Edinburgh, 1507; Dublin (last capital in Europe), 1551; Mexico, 1569; United States, 1639. Among the most skilful typographers are the Aldi, Frobenius, Plautinus, Operimus, the Stephani, the Elzeviri, the Gryphii, the Giunti, and the Moreti. The printing-office of Plautinus, at Antwerp, exists in its full integrity, and in the possession and use of his descendants, the Moreti; the same presses, the same types, with the addition of modern improvements, are still in use.

Thenceforth, down to the close of the last century, there appears to have been no alteration in the operation—the improvements consisting in the gradual increase of the size and power of the press, together with the great beauty and variety of the types.

For aught that appears to the contrary, the press used in Gutenberg's office differed in no essential point from those in use until the improvements of Blaew, in 1600-20. In the title pages of *Badius's Ascensius*, of Lyons (1495-1535), we have wood-cuts of his press: the table, with the form of type, remain, and the platten was brought down by a powerful screw, by means of a lever inserted into the spindle, such as might be seen in our time in a London printing-office.

It would appear from the device of *Badius's Ascensius*, just referred to, as well as that of Anthony Scholoker (an Englishman notwithstanding his name, at Ipswich), that the matrices and punches used early in the fifteenth century, were much in the same form as at the present time. For a long period the printers were their own typefounders; but as the art spread the casting of letters became a separate business. The earliest record of this change is found in a decree of the Star Chamber, dated the 11th of July, 1637, issued for the suppression of publications of the Puritans, and those who joined them in opposition to the Government, and who, it was believed, had established secret printing-offices for that purpose. By the above decree it was ordained that there should be only four letter-founders throughout the kingdom; and that when any vacancy occurred in that number, it should only be filled up under the orders and with the sanction of the Archbishop of Canterbury—the primacy at that time being held by Laud—and six Commissioners. The decree also regulated the taking of apprentices, and the employment of journeymen. The Star Chamber regulations remained in force, although the Court had been abolished; and the type-founder was still under restraint.

For the introduction of Printing into England we are indebted to William Caxton, and his successor, Wynkin de Worde, who established for themselves a high reputation both as printers and letter-founders. Caxton was born in the Weald of Kent, most probably in the year 1422-23. He was apprenticed to Robert Large, the mercer, in the Old Jewry. His master was Lord Mayor in 1439-40, and died in the following year. To Bruges, then a centre of commerce, Caxton was sent about 1441, and here he lived for about thirty-five years; first, we may suppose, as a clerk, then as a trader on his own account, and last, as head or governor of the English merchants settled in Bruges. In this capacity he was brought into close connexion with many English noblemen who resorted to Bruges on diplomatic or other errands, and also with the Court of Burgundy. With the Duchess Margaret, wife of Duke Charles, and sister of our Edward IV., he became a great favourite. In 1470, he held some office in her household; and it was "the dreadful command" of this "redoubted lady," as he expresses it, which led him subsequently to devote himself to literature and printing. In 1469, he translated from French into English the *Romance of Troy*, the demand for copies of which was so great that it was impossible to transcribe them sufficiently fast. This seems to have led Caxton to turn his attention to the new invention of printing as a means of multiplying his copies. Availing himself of the capture of Mentz, he secured one of the fugitive workmen of Fust and Schoeffer, and established a printing-office at Cologne, where he printed the French original and his own translation of the *Siege of Troy*. Whilst at Cologne he became acquainted with Wynkyn de Worde and Theodorick Rood, both foreigners, and Thomas Hunte, his countryman, who all subsequently became printers in England.

Such is the general version of Caxton's career; but Mr. Blades* has proved that Caxton derived from Colard Mansion, the first printer at Bruges, his types and his method of working. He shows that Caxton's first book was printed in 1472; was printed by Mansion himself, at Bruges, and not at Cologne, as hitherto believed; and that Caxton employed Mansion to cut and cast him a new fount of type, with the intention of practising the art in England.

Early in 1476 (not, as is generally said, in 1474), Caxton left Bruges, came over to England, and settled in Westminster (according to his own placard, preserved in Brasenose College, Oxford), in the Almonry, at "the Reed Pale," the name by which was known a house on the south side of Tothill-street; this house fell down in November, 1845, when wooden types are said to have been found here: its precise site is now

* In his masterly Life of Caxton, vol. i. 1861.

occupied by the principal entrance to the Westminster Palace Hotel. We have engraved this house. Its identity, however, has been questioned. It has been suggested that Caxton *first* set up his printing-press in the triforium of Westminster Abbey, near one of the little chapels, or in the ancient Scriptorium. (See *Curiosities of London*, p. 6.) Stow describes the press as in an old chapel, near the entrance to the Abbey. Caxton had subsequently an office in King-street, Westminster.

"CAXTON'S HOUSE," AT WESTMINSTER.

Caxton certainly practised his art under the protection of the Abbot of Westminster; and there produced the first book printed in England, the *Game of Chess*, which was completed on the last day of March, 1476. For fifteen years he continued, with astonishing industry, translating and printing; and he died, according to an entry in the registry of St. Margaret's, Westminster, towards the end of 1491, being about four score years of age. His epitaph has been thus written by some friend unknown: "Of your charitie pray for the soul of Maister

William Caxton, that in hys tyme was a man of moche ormate and moche renouned wysdom and connynge, and decesed full-crystenly the year of our Lord MCCCCLXXXXI.

> Moder of Merci shyld him frem thorribul fynd,
> And bryng hym to lyfe eternal that never hath ynd."

"Caxton," says Hansard, "must have been a man of wonderful perseverance and erudition, cultivated and enlarged by an extensivê knowledge of books and the world. Of his industry and devotedness some idea may be formed, when Wynkyn de Worde, his successor, states, in his colophon to the *Vitæ Patrium*, that Caxton finished his translation of that work from French into English *on the last day of his life.*

Wynkyn de Worde came, as we have already seen, with Caxton to England, and remained with him in the superintendence of his office until the day of his death, when he succeeded to the business: he carried it on in the same premises for about six years, when he removed to the "Sygn of the Sonne, in Flete-strete, against the condyth." He subsequently removed to the Swan, and the Falcon, the latter on the site of Falcon-court. De Worde cut new and improved founts, and provided his contemporaries with type; "and it is even said that some of the latter used by English printers less than a century ago, are from his matrices, nay, that his punches are still in existence." (Hansard, *Encyclop. Brit.*, 8th edit). His works amount to the extraordinary number of four hundred and eight: he made the first use in England of Greek, in moveable type; and of Arabic and Hebrew, cut in wood: he printed the first book on paper made in England. Richard Pynson, a Norman by birth, studied the art of printing under Caxton. Pynson was an earlier printer than De Worde, having established an office before the death of Caxton: his first work, date 1493, was printed at "the Temple Bar of London."

De Worde died about the year 1534. In his Will, still in the Prerogative Office, Doctors' Commons, dated 5th June, 1534, he bequeaths many legacies of books to his friends and servants, with minute directions for the payment of small creditors, and forgiveness of debtors, betokening a conscientious and kindly disposition. His device is generally that of Caxton, with his own name added to the bottom; but he also used a much more complicated one, consisting of fleur-de-lis, lions passant, portcullis, hearts, and roses, and other emblazonments of the Plantagenets and the Tudors.

Fleet-street has been the cradle of Printing almost from its first introduction: Wynkyn de Worde (assistant of Caxton), at the Golden Sun, Swan, and Falcon. The imprint to the *Demaundes Joyous* is as follows:—

"Emprynted at London in Fletestre
te at the signe of the Swane by
me Wynkyn de Worde
In the yere of our
lorde A M
C C C C C
and X I
.·.

There may be added Rastell, "at the signe of the Starre;" and Richard Tottel, the eminent law printer and publisher, "within Temple bar, at the signe of the Hande and Starre," now the house and property of Messrs. Butterworth, who possess all the original leases of the same, including Tottel's, in the reign of Henry VIII., to the present time.

The following were also contemporary printers in Fleet-street, viz.: Robert Copland, stationer, printer, bookseller, author, and translator: his sign, in 1515, was the Rose Garland. John Butler lived at the sign of St. John the Evangelist, in 1529. Thomas Bertholit, King's printer, dwelt at the Lucretia Romana: he retired from business about 1541. John Bedel, stationer and printer, lived, in 1531, at the sign of Our Lady of Pity. John Waylond, citizen and stationer, lived at the Blue Garland, 1541. Lawrence Andrew, a native of Calais, was a printer at the Golden Press, by Fleet-bridge. Thomas Godfrey, who will be remembered as the printer of Chaucer's works, lived near the Temple Bar.

Caxton used five distinct founts of type. At this time all books were printed in the old black letter, in imitation of the mode of writing used by the monks. Towards the middle of the sixteenth century, the style of type now used was introduced by Aldus, and was called, from the place of its origin, *Italic*. The great plainness of the Roman character, now gradually superseded other kinds of type, except in Germany.

Although the art of Printing was now firmly established in England, the printers were for a long time supplied with type from the Continent, that from the Dutch foundries being only used in superior works. Early in the last century, William Caslon, prompted and assisted by William Bowyer, a man of learning, and a printer, established the "Caslon Foundry," which not only obtained pre-eminence for British types, and put an end to the demand for those from abroad, but led to the supply of the best offices on the Continent. The Caslon Foundry still exists, and is represented by one of the same name and family. Another eminent founder was John Baskerville, of Birmingham. Caslon had considerably improved the Dutch types before Baskerville's attempt at type-founding; but the latter carried that improvement further, though not until he had expended upwards of 600*l.* before he could get a single letter to his satisfaction, and several thousands before he realized any profit. His types, however, ultimately were of great beauty; at his death, in 1775, they were sold by his widow to a literary society at Paris, and were used in printing some of the best editions of their first classics. He, doubtless, laid the foundation of that beautiful style of letter which has of late years so greatly improved our own castings. Another foundry was established by Dr. Fry, who assembled the most complete set known of founts for the Oriental languages. The Glasgow foundries, as well as those of Edinburgh, have always stood high in estimation.

Abroad, the art has equally advanced, and extensive foundries exist both in Germany and France, as well as in Italy—the Propaganda, in the last named country, possessing one of the most complete establishments in the world; though it does not exceed in extent the foundry of Brieskopf, which is said to contain punches for not less than four hundred alphabets. Nor is it equal to that of Didot, in Paris, where the most minute and beautiful specimens of ordinary typography have been produced, some to be read only by the aid of a magnifying glass.

We now come to the business of the compositor, which will be understood by the aid of the accompanying illustrations.

There are two *cases*, *upper* and *lower*—the *upper* for capital and small capital letters, the *lower* for small letters,—divided into compartments for each, those most frequently in use being largest, and nearest the compositor's hand. The compositor, having placed his *copy* on the upper case in front of him, takes in his left hand his *composing-stick*, a small iron frame with slider and screw, which is capable of being adjusted to any required length of line; with the forefinger and thumb of the right hand he picks up the types forming the words of his copy, and receives them with the thumb of the left hand in the stick, feeling that the *nick*, which is on the under side of each letter,

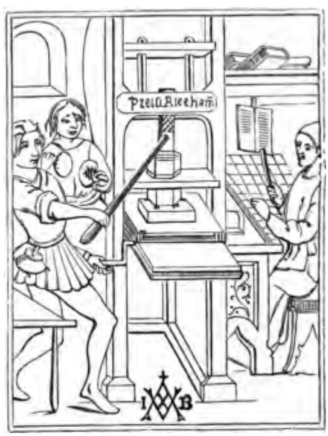
THE COMPOSITOR.

is uppermost as he drops it into its place. Between words are inserted *spaces*, which being lower than the letters do not produce an impression on the paper, and, varying in thickness, allow each line to be spaced out to a uniform width. All the letters are separate pieces of metal, fitting closely to each other; and, in a page such as this there are about 2,500 distinct pieces, each of which the compositor has to pick up separately, his wages being regulated by the number of thousands of letters he sets up. A *Fount* is any weight of type of the same body and face, consisting of every stop, figure, &c., in certain proportions, together with spaces and quadrats.

The matter being composed, made into pages, tied up, and correctly laid down on the imposing-table, the compositor places over them a chase, or iron frame, divided by cross-bars; he then adjusts pieces of wood, or metal, called *furniture*, and within the chase, next the pages, *side* and *footsticks*, wider at one end than the other, and between these and the chase fit wood quoins, which decrease in the same proportion as the side and foot sticks; he then unties the pages, pushes up the quoins, planes down the pages gently, and with a mallet and shooting stick, drives so as to act as wedges, forcing the separate types to become a compact body; and the united mass is called a *form*. Gutenberg, we read, used screws to lock up his pages, and of late years our printers have employed screws, instead of quoins, which may be a revival of the screw method of four hundred years since.* (See p. 60, *ante.*)

Attempts have been made to supersede to a great extent the manual labour of the compositor, by two machines, which are acted on in the same way as the keys of a pianoforte are when touched. The letters of each kind are arranged in different compartments, and one of each drops through, at each touch, as the key opens a valve at the bottom of the compartment. These machines are ingenious; but peculiar skill and long tuition are required before they can be efficiently used. Other machines have been constructed; but with little success in practice.

If, however, it has hitherto proved unprofitable to adopt machinery to arranging the types, such has not been the case with regard to the impressions to be taken from them. Until towards the close of the last century, but little improvement had been made in the form of the old wooden printing-press, except, as already stated, in enlarging the size and increasing the power of the screw. But at the period alluded to, Earl Stanhope, a nobleman of great ingenuity, who was himself an amateur printer, and exceedingly desirous of improving the art, invented, and with the assistance of Mr. Walker, a skilful machinist, brought to perfection, an iron press in which the power, instead of being derived from the screw, was derived from a bent lever that impressed the platten or iron plate upon the paper, which is brought down on the surface of the types. The peculiar property of this press is, that when the platten first moves downward, its motion is rapid, while,



ANCIENT WOODEN PRINTING PRESS, 1498.

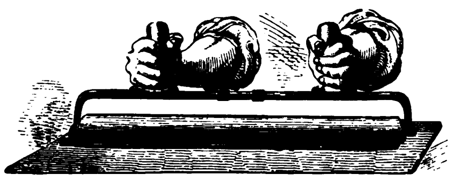
* *Stories of Inventors and Discoverers*, 1859, page 14.

when the power is about to be applied, it is slow, so that the greatest amount of force is concentrated just at the time when it can be of the greatest effect. This press of Lord Stanhope's was followed by several others of very ingenious construction. The most powerful was one called the Columbian press, invented by an American, named Clymer; and the quickest in its action was the Albion press, invented by Mr. Cope, and greatly improved by his successor, Mr. Hopkinson. The power in both these is obtained from the effect of levers alone ; and they are generally adopted for manual printing. During the troublesome times that preceded the Great Rebellion, the Puritans, jealously watched and persecuted, introduced ambulatory presses, which were constantly removed from town to town to escape the vigilance of the Star Chamber. At these presses, many of Milton's controversial pamphlets were printed ; and it is even said that the identical press at which the *Areopagitica* was printed is still in existence, and was lately in the possession of Mr. Valpy, the well-known printer of the Variorum Classics.

Let us now turn to the crowning advance, the application of the *Steam-engine*, which makes the printing-press, in one sense, a self-acting machine, and brings by its aid the productions of the noblest genius within the reach of myriads, whose means little more than suffice for the necessaries of life. This was accomplished by the invention of the *Printing Machine*, by which cylindrical pressure is applied in place of the flat, or platten, impression obtained by the common press.

Before, however, stating the circumstances of the application of steam-power to printing, we should notice an invention, without which steam machine-printing could never have been generally adopted. This is an improvement for inking the types by means of rollers. Printing ink consists of lamp-black and varnish, with some other constituents to increase the brilliancy of the colour, and keep the principal substances in coherence with each other. Formerly the ink was laid upon *balls* made of sheepskin stuffed with wool. The pressman, having a small portion of this ink on one of the balls, worked it against the other spirally, and occasionally dabbing the balls together

until the ink was very evenly spread or *distributed* over them both. With these he then dabbed the form (*i.e.* a quantity of types, which are arranged in their several pages, in certain positions on the bed of the press, where they are to give their impression to the paper), keeping them constantly twirling round in his hands, when not absolutely touching the face of the types, until at length the whole of the letters were equally and sufficiently covered. This process required great nicety, and was very laborious, while considerable trouble and attention were necessary to keep the balls in proper working order. All was at length obviated by the discovery of Mr. Foster, who by the intermixture of glue, treacle, tar, and isinglass, formed a composition which retained all the requisite qualities of softness, elasticity, and readiness to receive and impart the ink, and which could, moreover, be made to adhere round a wooden roller. It completely obviated a most unpleasant and unprofitable part of the art, and has proved of apparently indispensable value in machine printing. These rollers have been immensely improved.



But to return to the Printing Machine. The want of some means to meet the increasing demand for books and newspapers had long been felt; and as early as 1790, before even Lord Stanhope's press had been brought into use, Mr. W. Nicholson had taken out a patent for a Printing Machine, of which the chief points were the following. The type being rubbed or scraped narrower towards the bottom, was to be fixed upon a cylinder, which, with its type was to revolve in gear with another cylinder covered with soft leather (the impression cylinder); and the type received its ink from another cylinder, to which inking apparatus was applied. The paper was impressed by pressing it between the type and impression cylinders. This machine was, however, never brought into use.

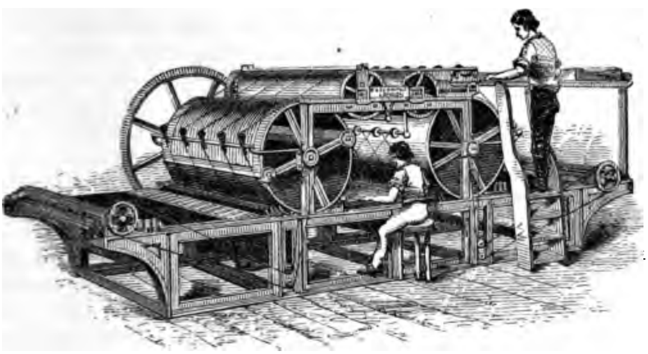
Some years afterwards, König, an ingenious German, who had been unable to obtain any support on the Continent, came to England with the idea of applying *steam* as the moving power to *common presses*, which by his plan should acquire accelerated speed, and at the same time dispense with the employment of the man who inked the type. Three enterprising printers, Messrs. Bensley, sen., R. Taylor, and G. Woodfall jointly supplied the capital for König's experiments, which, however, failéd. He then turned his attention to cylindrical machine printing, which Nicholson had demonstrated in 1790; and at length König produced a machine capable of working 1,000 impressions per hour, and requiring only the superintendence of two boys. This machine was set to work in April, 1811, and 3,000 copies of part of the *New Annual Register* were successfully printed by this means.

It was then considered practicable to extend the principles and capabilities of this machine to printing a newspaper: König obtained a contract with Mr. Walter, proprietor of the *Times* newspaper, for two large machines to print his journal; and on the 28th of November, 1814, the readers of the *Times* were informed that they were, for the first time perusing a newspaper printed by the application of steam-power, and working 1100 impressions per hour. In these machines, Nicholson's plan was so far altered, that the ordinary type was used and laid upon a flat surface, and the impression was given by the form passing under a cylinder of great size.

These machines were necessarily of a very complicated construction, and it may suffice to say that each consisted of a number of cylinders, which so revolved as to carry the sheets of paper, through the agency of a number of tapes and wheels, placed between them and the types on the surface of the table, which constantly moved backwards and forwards, receiving in turn the ink from the inking rollers, and impressing its form on the paper. Each machine was only capable of printing one side of the newspaper, and the sheets thus half printed by the one were *perfected* by the other. These machines were greatly simplified by Messrs. Applegath and Cowper, this being the first really useful machine: its principal improvement consisting in the application of two drums between the impression-cylinders, one of which reverses the sheet, and the other secures the *register* (that is, one page falling precisely on the back of another), by retaining it after the impression of the first form, just so long that it may pass on to the second cylinder in exact time to be impressed thereby upon the second form; and of the distribution of the ink upon a plane surface, instead of by a number of rollers, by which König's complicated machinery was got rid of. These machines, with numerous modifications, according to the plans of different makers, are now* in general use. The machines for the *Times* cost the proprietor of that journal 3000*l*.

The next improvement was the construction of a *perfecting machine* by König, for Messrs. Bensley, which delivered the sheet of paper printed on both sides. This double or perfecting machine, threw off from 800 to 900 sheets per hour, worked on both sides; while the single or non-perfecting machine, delivered in the same space of time from 1,300 to 1,400 sheets printed only on one side.

Messrs Donkin and Bacon, in 1818, obtained a patent for a most ingenious but complex machine, which claims the merit of being the first to print with the types arranged upon a



COWPER'S DOUBLE CYLINDER MACHINE.

horizontally revolving cylinder, instead of being placed on a fixed table as in other machines. Although the fundamental principle of this invention was found objectionable, one great point was gained, namely, the introduction of the composition inking rollers, which were first applied to this machine, and immediately superseded those covered with leather which were used by König.

Mr. Applegath next combined in one leviathan machine four of the single or now perfecting machines, all being simultaneously driven by steam. There are four places at which to feed it with paper, four printing cylinders, and four places at which the sheets are delivered when printed; the combined

* *Vide infra.*

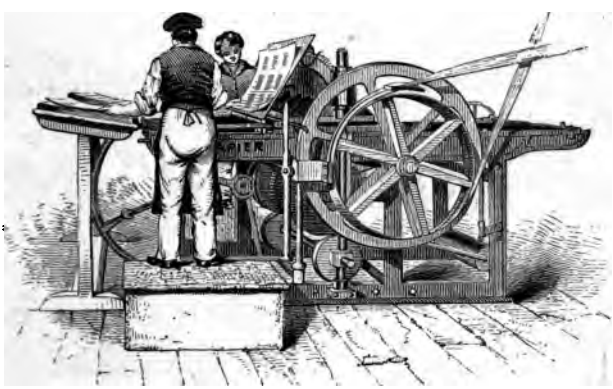
action of these four auxiliaries producing from 4,350 to 4,500 sheets per hour, printed on one side. Middleton's admirable perfecting machine is the same in principle as Applegath and Cowper's, but with some improvements.

Next, to avoid a great waste of motive power, Mr. Applegath abandoned the principle of placing the type on a plane table, and the reciprocating motion, and constructed a machine in which the type is placed on the surface of a cylinder of large dimensions, which revolves on a vertical axis, with a continuous rotary motion. The *Times* has the credit of being first in adopting this great improvement in newspaper printing. The cylinder is a drum of cast iron, about 5 feet 6 inches in diameter. The forms, or pages of type, are made segments of its surface, just as a tower of brick might be faced with stone. Eight printing cylinders, 40 inches in circumference, are arranged round the drum. Instead of the four impressions taken by the old machine in its double journey, eight sheets are printed in every revolution. In the vertical disposition there is the same centrifugal impulse as in the horizontal, but it is chiefly neutralized by means of the "column rules," which make the upright lines dividing the columns of the page. These column rules are usually long slips of brass, and in this instance they are so screwed to the sides of the iron frame, or chase, as to become powerful tension ties; and being made with a wedge-like section,—that is thicker towards the outer surface of the type—they keep it in its place, like the key-stone of an arch, or the stone ribs of a rubble vault. The type only covers a small portion of the circumference of the drum, and in the interval there is a large inking table, fixed like the type on its circular face. This table communicates the ink to eight upright inking rollers, placed between the several printing cylinders—the rollers, in their turn, communicating the ink to the type. So far the arrangement is perfectly simple, the machine being, in fact, composed of the parts in ordinary use, only made circular and placed in a vertical instead of a horizontal position.

The great problem of the inventor was the right mode of "feeding," or supplying the sheets of paper to their printing cylinders in their new position—or changing the sheet of paper, (the *Times* newspaper) in less than four seconds, from a horizontal to a vertical position and back again; and through still more changes of direction; all which is done by passing through endless tapes and vertical rollers in rapid motion, which convey it round the printing cylinders, each of which always touches the type at the same corresponding point, the surfaces moving with a great velocity.

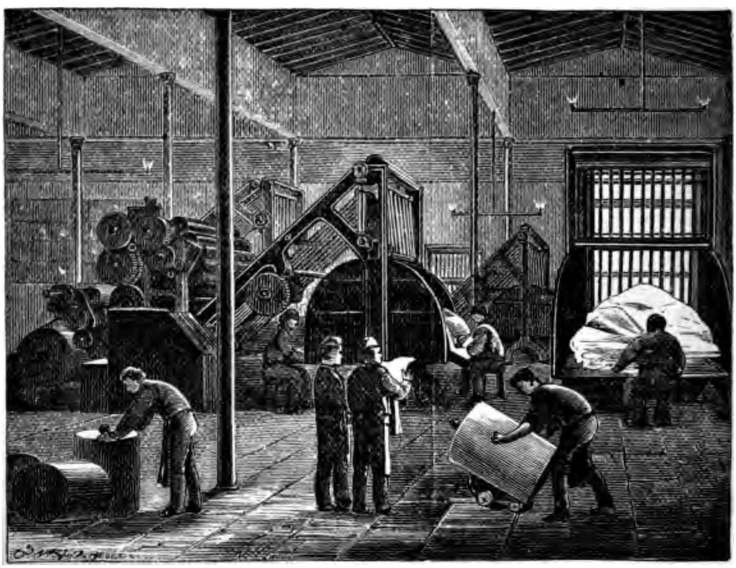
"No description," says Hansard, "can give any adequate idea of the scene presented by one of these machines in full work,—the maze of wheels and rollers, the intricate lines of swift-moving tapes, the flight of sheets, and the din of machinery. The central drum moves at the rate of 6 feet per second, or one revolution in three seconds; the impression cylinder makes 5 revolutions in the same time. The layer-on delivers 2 sheets every 5 seconds, consequently 15 sheets are printed in that brief space. The *Times* employs two of these eight-cylinder machines, each of which averages 12,000 impressions per hour; and one nine-cylinder, which prints 16,000."

Messrs. Hoe, of New York, have constructed machines differing from Applegath's Vertical, chiefly in the drum and impression cylinder, being not vertical, but horizontal; the type is fixed on the central cylinder, which has a continuous or rotatory motion, in contact with the impression cylinder, set around it. The *Times* has one of these machines with ten cylinders for working 20,000 impressions in an hour. Another American has improved upon Hoe's machine by converting it into a perfecting-machine. A horizontal cylinder machine, on the same system as Hoe's, made by Middleton, prints 20,000 impressions within an hour.



NAPIER'S PLATTEN MACHINE.

But for rapid newspaper printing these machines have more recently been superseded at the *Times* office, and elsewhere, by the machine known as the Walter press. The chief novelty in this machine is that the paper does not receive the impression from a form of type, but from a stereotype cast of the form, made of a cylindrical shape, so as exactly to fit the surface of a revolving cylinder, which is not necessarily of a great diameter. The stereotype curved plate is obtained by taking from the form of type an impression in *papier maché*, from which, after drying, it is easy to obtain one or more casts of the required shape in some metallic alloy fusing at a temperature too low to injure the paper mould. The Walter machine supplies itself with paper from a large roll, from which it cuts off the sheets when printed on both sides, and delivers them folded. The necessity of manual feeding being thus avoided, the machine may be driven at a very high rate of speed. The annexed sketch shows some Walter presses at work.



NEWSPAPER PRINTING-ROOM, WITH "WALTER" MACHINES.

Several flat-surface machines, which communicate the impression by a platten like the ordinary press, and are admirably adapted for fine book-work, are now in use. Their motion is similar to that of the hand press, and the work produced by them almost equals that from the hand press in excellence. In the platten machine of Messrs. Napier & Son, the inking apparatus is brought to very great perfection.

The Bank of England notes were formerly printed from steel plates; but in 1853, the Bank adopted the surface or letter-press mode of printing. The plates are produced by the electrotype process; the metal being so hard as frequently to yield nearly one million of impressions without being worn out. The notes are printed at a steam-press, constructed by Napier, and no less than 3,000 are printed per hour. The numbers and dates of the notes are added in an after-printing by a cylinder machine, to which is attached a very ingenious mechanism, which makes it impossible to commit any fraud by printing two notes of the same number.

The application of the Printing Machine to the working of wood engravings has been very successful. The printing of wood blocks had hitherto been a work of great expense and uncertainty, and its slow rate rendered it unequal to demand in any very extensive numbers. Engravings were then printed by a hand-press with great nicety of light and shade; but it remained for the Printing Machine to accomplish with rapidity more brilliancy than had been attained by the less rapid manipulation. The late Mr. Britton, who had long been accustomed to the fine work of the Chiswick Press for the illustrations of his costly antiquarian and topographical works, once declared to the writer, that many of the engravings in newspapers were then better printed by machine than press, that is, with sharper finish and more striking effect; the portraits are special examples of this progress, and the writer well remembers the time when a printer could scarcely be found to work portraits by the ordinary press. The large block of Haydon's *Dentatus*, drawn and engraved by William Harvey, is a remarkable labour; but few persons are aware of the requisite time and patience on the part of the printer to produce these impressions; and this was entrusted to Johnson, the practical printer, and author of the elaborate *Typographia*, or, the *Printer's Instructor*, printed in 1824.

The most notable instance of machines printing woodcuts dates from the establishment of the *Illustrated London News*, in 1842, by Herbert Ingram, bred a practical printer, in the town of Boston, which he subsequently represented in Parliament, and where a marble statue has been erected to his memory. His great newspaper at once proved a success, which he never for an hour neglected to improve; and his liberality to mechanism merited such a return. The large engravings in eight pages of the *Illustrated London News* have been "made ready" within two hours, and they are now worked at the rate of 1,400 impressions per hour; and some editions extend to 300,000.

We have spoken of the offices of our early printers, in Fleet-street. Here, too, was the cradle of steam printing: Bensley, of Bolt-court, being the first to aid the labours of König, who had applied to German and other Continental printers unsuccessfully. König and Bensley were joined by Woodfall and Taylor, printers; and out of their joint exertions grew cylindrical printing. Bensley's inking apparatus was, however, superseded by Cowper's—a very important advance. Soon after the above date, we remember to have seen the working model of a large cylinder-machine, which had been invented by Winch, a printers' joiner, while he was confined in the King's Bench Prison for debt.

Another important invention connected with typography, is the progress of *Stereotyping*, by which all the letters forming a page of type are cast in one piece or plate of type-metal, from a plaster mould taken of the page. When stereotype plates are printed, they are fixed upon blocks, which bring the plates exactly to the height of the regular printing types. Stereotyping was first practised by William Ged, of Edinburgh, in the year 1725; the plan was so opposed by the workmen that it was a long time discontinued, but was eventually adopted for saving the necessity of employing a large quantity of type.

There is still another process by which stereotyping becomes optional, even after the type is distributed; this is by taking moulds, to be hereafter used as matrices for the stereotyping, if required; if not, the expense of the moulds is comparatively trifling.

THE TELESCOPE.

HAT wonders yet remain to be discovered by the Telescope we know not, although every year brings to light some new world by its aid, that had stood unobserved, in the immensity of space, by the eye of man, since the 'as first rolled into the illimitable expanse, at the bidding)mnipotent. Through the power of this wonderful instruie human eye is enabled to sweep the whole solar system ktent of space so vast, that had the swiftest race-horse ever struck its hoof upon the earth, set out from the orbit ius, about three thousand years ago, and plunged on his ig course day and night without ceasing, he would not 'e traversed the half of this huge diameter that extends oo,ooo of miles. Where but few stars are visible, the : telescope of the Earl of Rosse has been turned, and rmaments have been discovered like our own, covered untless stars, seeming in that vast distance like a spot ig with the dust of thousands of diamonds, one almost ng to touch another, yet each lying from each millions of part, and every one a huge world, to which our own ears no more proportion than a single daisy does to the which it grows.

)avid Brewster observes that "while all other instrumachines of human invention, embody ideas with which familiar, and are limited in their application to terrestrial blunary purposes,—the Telescope, even in its most tary form, embodies a novel scientific idea. It enables ;ee what would for ever be invisible. It displays to us ng and nature of bodies which we can neither see, nor touch, nor smell. It exhibits forms and combinations of matter whose final cause reason fails to discover, and whose very existence even the wildest imagination never ventured to conceive, and like all other instruments, it is applicable to terrestrial purposes; but unlike them all, it has its noblest application in the grandest and remotest works of creation. The Telescope was never invented. It was a divine gift which God gave to man, in the last era of his cycle, to place before him and beside him *new* worlds and systems of worlds—to foreshadow the future sovereignties of His vast empire, the brightest abodes of disembodied spirits, and the final dwellings of saints that have suffered, and of sages that have been truly wise.

"When viewed from the highest peak of a mountainous region, our own globe is the largest magnitude we can perceive, and the circuit of its visible horizon the greatest distance we can scan; but vast as are their limits in relation to the eyeball by which they are seen, they are small when compared with the globe itself, or with its circular outline. The navigator who has measured the earth's circuit by its hourly progress, or the astronomer who has proved a degree of the meridian, can alone form a clear idea of velocity when he knows that light moves through a space equal to the circumference of the earth, in the eighth part of a second of time—in the twinkling of an eye. Bearing in mind this unit of velocity, we are enabled to soar to far higher conceptions. The light of the sun takes 160 minutes to move to the Georgium Sidus, the remotest planet of our solar system; and so vast is the unoccupied space between us and the nearest fixed star, that light would require five years to pass through it, and this, be it remembered, travelling a space vast as the circumference of the earth which we inhabit in the twinkling of an eye.* But

* Speaking of the comparative velocities of Light, Mr. Beckett Denison, in his able work, *Astronomy without Mathematics*, says: "The waves of sound go only 377 yards in a second, while the earth itself goes 18⅓ miles, and light ten thousand times faster than that; while electricity (which again is probably another kind of vibration, of the solid atoms of bodies, and certainly not a fluid) runs along a wire about half as fast again as light. So if the earth were a cannon ball, shot at the sun from its present distance, with the velocity it now travels with, and the moment of explosion telegraphed to the sun, they would get the telegram there in about five minutes, and see the earth coming in eight minutes, and would have nearly two months to prepare for the blow, which they would receive about

this space is nothing, compared to the distance of stars which have been discovered by the Telescope, which are, beyond doubt, many thousands of times more distant from us than the nearest fixed star, the light of which must have travelled thousands of years before it became visible to us, even by the aid of the Telescope. The swiftest messenger that could have been despatched, had it started from one of these distant stars on the morning of the Mosaic creation, would not yet have reached our own planetary system."

Before the invention of the Telescope, our earth was supposed to be the only planet that had a sun to light it by day, and a moon to shine upon it by night. By the telescope suns, moons, and worlds have been discovered, to many of which our earth may be likened as but a mole-hill to a mountain. By it the Pleiades, which, to the naked eye, show only a cluster of seven stars, were discovered by Galileo to contain forty; and in the moon he found, by the aid of his novel instrument, high mountains, whose summits are gilded by sunshine, and deep valleys, into which the gloomy shadows thrown from these high ranges settle down. The moon being so much nearer to us than any other heavenly body, the telescopic power is more conspicuous when directed to it. The surface of the moon can be as distinctly seen by a good telescope magnifying 1,000 times, as it would be if the moon were not more than *two hundred and fifty miles distant.*

The Telescope is an invention no germs of which can be traced in ancient times. Long tubes were certainly employed by Arabian astronomers, and very probably also by the Greeks and Romans; the exactness of their observations being, in some degree, attributable to their causing the object to be seen through slits. Some one has clearly explained the use of these tubes: "If stars be more easily discovered during twilight by means of tubes, and if a star be sooner revealed to the naked eye through a tube than without it, the reason lies in the circumstance that the tube conceals a great portion of the disturbing light diffused in the atmospheric strata between the stars and the eye applied to the tube. In like manner, the tube prevents the lateral impression of the faint light which the particles of air receive at night, from all the other stars in the

15 years before they heard the original explosion. This is merely taking the sun as a target to be shot at, without regard to his power of attracting the earth at the final rate of 390 miles a second."

firmament. The intensity of the image and the size of the star are apparently augmented."

Until the thirteenth century we have no positive records of the power of a lens, or convex glass, to present objects in a greater magnitude than when seen by the naked eye. Vitello, a native of Poland, makes this earliest statement; and soon after, Roger Bacon imagined a peculiar magnifying instrument, though there is no proof that he carried his conception into practice, or *invented* the instrument, or that he really describes a Telescope when he asserts that by his instrument a small army could be made to appear very large, and that the sun and moon could be made to descend to all appearance, down below, and stand over the head of the enemy. These ideas possibly might have produced either the Telescope or some modification of it, for magnified images produced by reflection, and that before the time of Jansen and Galileo. There is little doubt that the combination of two lenses, or of a concave and a convex mirror and a lens must have been often made during the three centuries which elapsed between the time of Bacon and that which is generally considered as the epoch of the invention of telescopes.

Dr. Dee, in his preface to Euclid's *Elements*, 1570, after speaking of the skill necessary to discover the numerical strength of an enemy's army at a distance, says that "a captain may wonderfully help himself thereto by the use of perspective glasses," by which nothing can be understood but a Telescope. And in a work called *Pantometria*, written by one Digges, which appeared in 1571, and which was brought out by his son twenty years afterwards, it is shown that by concave and convex mirrors of circular and parabolic forms, or by frames of them placed at certain angles, and using the aid of transparent glasses which may break or unite the images produced by the reflection of the mirrors, there may be represented a whole region; also, that any part of it may be augmented, so that a small object may be observed as plainly as if it were close to the observer, though it may be as far distant as the eye can descry. Still, this is a conception of the imagination as to the powers of a new instrument rather than a detail of fact.

That this combination, however, had not been applied to any great purpose of practical utility for many years afterwards, appears to be tolerably evident from the little intimation we have of it during the first half of the seventeenth century. In the year 1655 a work entitled *De Vero Telescopii Inventore* was published at the Hague by Peter Borellus, who ascribes the invention to two individuals, one named Zachariah Jans or Jansen, and the other Hans Lippersheim, both of whom were spectacle-makers at Middelburg.* In a letter written by a son of Jansen, it is asserted that the invention was completed in the year 1590; while in other accounts it is stated not to have been made until nineteen years afterwards—that is, in 1609. When these two makers, Jansen and Lippersheim presented a Telescope to Prince Maurice of Nassau, he desired the invention to be kept secret, as his country was at that time at war with France, and he expected to obtain some advantages over the enemy by ascertaining the number of their forces when at a distance. Descartes, however, gives a different account to this. He says, in his *Dioptrics*, that the principle of the Telescope had been discovered about thirty years before; that is about, or soon after, the year 1600, by a person named Metius, a native, or at any rate a resident at Alckmaer, and who was fond of amusing himself with making burning lenses of glass and ice, and who accidently placed a concave and a convex lens at the end of a tube. At any rate, whoever was the chief inventor of the instrument, the Jansens appear to have been the first to apply it to astronomical purposes; and the younger of the two is said to have been the first to discover the satellites of Jupiter, for he perceived four small stars near that planet, but did not continue his observations long enough to become acquainted with their true character, or at least not sufficiently so to authorize him in publishing his discovery to the world. It is, however, certain that the celebrated mathematician Harriot used a telescope magnifying from ten to thirty times, and that with it he discovered, in 1610, the spots upon the sun's disc; but whether he got his instrument from Holland or elsewhere, is not specified in his papers.

Meanwhile in April or May, 1609, the rumour reached Galileo, who was staying with a friend at Venice, that an optical instrument which would cause distant objects to appear

* The Rev. Charles Pritchard, F.R.S., President of the Royal Astronomical Society, in a discourse given by him at the Royal Institution, on the construction of the Telescope, began by stating that the earliest lens which he knew of had been seen by him in the remains of a shop at Herculaneum. Spectacles were in use in the fourteenth century; but it does not appear that an arrangement of lenses to view distant objects was made till 1608, when Hans Lippersheim, of Middelburg, made a telescope, in the form of a long thin tube, which magnified three times.

nearer to the observer, had been presented to Prince Maurice, by Lippersheim, who, it has been proved by Professor Moll, was in the possession of a Telescope made by himself so early as October, 1608. The truth of the report being confirmed to Galileo, he returned to Padua. There he sought out the principle of refraction; and with a leaden tube a few inches long, fitted with lenses, one convex and one concave, at each of its extremities, applying his eye to the concave glass, he saw objects pretty large, and pretty near to him. This little instrument magnified only three times. He carried it to Venice, where crowds of the citizens flocked to his house to see the magical toy. The interest excited by Galileo's invention amounted to frenzy. On ascending the tower of St. Mark's that he might use one of his Telescopes without molestation, Galileo was recognised by a crowd in the street, who took possession of the wondrous tube, and detained the impatient philosopher for several hours, till they had successively witnessed its effects. These instruments were soon manufactured in great numbers, but were purchased merely as philosophical toys, and were carried by travellers into every corner of Europe. Galileo was informed by the Doge of Venice that the Senate would be much gratified by possessing the instrument; this Galileo presented to the senators, who conferred upon him for life the Professorship at Padua, and raised his salary from 520 to 1000 florins. Galileo appears to be justly entitled to the honour of having invented that form of Telescope which still bears his name; whilst we must accord to John Lippersheim, the spectacle-maker of Middelburg, the honour of having previously invented the astronomical Telescope.*

* M. Boquillon was sent by the French Government on a scientific mission, the special object of which was to search for all documents bearing on the life and works of Galileo, in whatever public libraries, museums, or private collections they could be discovered. Thanks to the active intervention of M. Mateucci, Minister of Public Instruction in Italy, and to the assistance of the well-known astronomer M. Donati, as well as to that of several learned Italians, M. Boquillon obtained access to an immense number of manuscripts by Galileo, which he was allowed to read at his leisure and copy, so that he became possessed of sufficient material for the composition of a complete work on the life of the great *savant*. La Specola, one of the most useful establishments of the new kingdom of Italy, possesses most curious and interesting relics of Galileo. A portion of the building is denominated the "Tribune di Galileo," and contains a number of instruments used by him, and likewise those which belonged to the Academia del Cimento. M. Boquillon took photographs of the former. It is said that every instrument used by Galileo has been preserved.

Galileo's tube, or *cylinder*, as it was called, was now roughly manufactured in great numbers: they were made in London in February, 1610, a year after Galileo had completed his own. The first Telescope magnified three times; others he made possessed the gradually increasing power of magnifying four, seven, and thirty-two linear diameters; but they never had a higher power. What Galileo first saw with his Telescope is thus eloquently and picturesquely told by Sir David Brewster: "The moon displayed to him her mountain-ranges, and her glens, her continents, and her highlands, now lying in darkness, now brilliant with sunshine, and undergoing all those variations of light and shadow which the surface of our own globe presents to the Alpine traveller, or to the aeronaut. The four satellites of Jupiter illuminating their planet, and suffering eclipses in his shadow like our own moon; the spots on the sun's disc, proving his rotation round his axis in twenty-five days; the crescent phases of Venus, and the triple form or the imperfectly developed ring of Saturn,—were the other discoveries in the solar system which rewarded the diligence of Galileo. In the starry heavens, too, thousands of new wonders were discovered by his Telescope; and the Pleiades alone, which to the unassisted eye exhibit only *seven* stars, displayed to Galileo no less than *forty*."

But the discoveries of Galileo brought upon him persecution: hence the poet's line

"The starry Galileo with his woes."

Directing his second Telescope towards the moon, he stripped that luminary of the character of geometrical perfection absurdly attributed to all the celestial bodies by the schoolmen, according to whom they were all perfectly round, self-luminous, and uncorrupted by terrestrial tarnish. He found that the moon, instead of being a spherical orb, was no other than an earthy globe like our own; and that she always turned the same face to the earth, so that, except through the influence of what are called her "librations," the whole of one of her hemispheres is hidden from our sight. The idea which was suggested from the appearance of oceans and continents, mountains and valleys, on the moon, that she might be habitable, overwhelmed the schoolmen with horror, and struck the religious with alarm.

Shortly after, Galileo made his next discovery—that the *Via*

Lactea, or Milky Way, was an accumulation of myriads of stars, or, in the language of Milton, "powdered with stars." Not long afterwards, he discovered the satellites of Jupiter, and named them "Medicean Stars," in compliment to his patron, Duke Cosmo. His next observation was made on the planet Saturn, which appeared to him as constituted of three stars touching each other, for his instrument was inadequate for clearly showing the ring of this wonderful planet.

These discoveries, instead of procuring for Galileo the honour and respect he deserved, excited the anger and jealousy of many of his contemporaries, by the more bigoted of whom the

MILTON VISITING GALILEO IN PRISON.

cry of heresy was raised against him, because he published to the world his conviction of the soundness of the Copernican System. On two occasions his writings were condemned, and a sentence of imprisonment pronounced against him by the Council of the Inquisition : in fact at the time of his death in 1642, and for several years previous, he was confined a prisoner, in his own house, by the order of Pope Urban VIII., who granted this as a mitigation of the more severe sentence passed upon him. It was during one of these imprisonments that Galileo was visited by the poet Milton, then on his travels in Italy; and Milton, in one of his works, speaking of Italy, thus alludes to the circumstance :—"There it was that I found and visited the famous Galileo, grown old, a prisoner to the Inquisition, for thinking in Astronomy otherwise than the Franciscan and Dominican licensers thought." Nearly half a century after the invention, Milton thus described some of the wonders laid open by the Telescope :—

> "The moon, whose orb,
> Through optic glass the Tuscan artist views
> At evening from the top of Fesolé
> Or in Valdarno, to descry new lands,
> Rivers, or mountains, in her spotty globe."

Since the time of Galileo, Telescopes with a single concave lens as eye-piece have been called Galilean Telescopes, but they are not now used for surveying the heavenly bodies; for on account of the smallness of the field, or the space in which the object is seen, when these instruments are made of great magnifying power, they have been almost entirely discontinued for that purpose, and are now used principally for distinguishing objects at a short distance. A manifest improvement upon this eye-piece was devised by Kepler, who, in his *Dioptrics*, suggested that, instead of one, two convex glasses should be used; but he did not carry his design to any practical effect. The credit of having done so seems justly ascribed to Scheiner, a Jesuit, who, writing in 1650, gives a description of a Telescope with one convex glass, and states that he had used such an instrument before the Archduke Maximilian of Austria, thirteen years prior to that period, but acknowledged that it represented objects in an inverted position. Notwithstanding this defect, instruments with one convex glass were favourites with philosophers, on account of the larger field of view which they afforded; but Telescopes with two convex glasses were devised both by Kepler and Scheiner, and presented objects as they are perceived by the naked eye, viz., not inverted.

In Italy, Joseph Campani constructed two *refracting* Telescopes, the one thirty-four, and the other eighty-six feet long; and it was by these instruments that Dominique Cassini, in 1671-2, discovered the fifth and third satellites of Saturn. Louis XIV. greatly encouraged both the manufactory of Campani and the discovery of Cassini. The former he commissioned to make him a Telescope 140 feet long, and with it the latter discovered the first and second, or the two smallest, satellites of Saturn : he also first saw the ring of this planet, and discovered and measured the figure of Jupiter with the Telescope made by Campani.

The next improver of the Telescope was Huygens, son of the secretary of three Princes of Orange, and brother to the secretary who came with William III. to England in 1688. Huygens, was the author of several works on Mathematics and Astronomy, and was the first to ascertain that the two stars, seen by Galileo, in the neighbourhood of the planet Saturn, were in reality only parts of the apparent ellipse of the ring (or rather rings, as Sir William Herschel subsequently discovered them to be), by which that immense globe is surrounded. Huygens, being a good mechanic as well as a philosopher, turned his attention to the improvement of the Telescope. His aim was a long focal length to the object-glass, and he succeeded in constructing one of 122 feet focal length for an "aërial Telescope," which object-glass he afterwards presented to the Royal Society, and with which Dr. Bradley made many ot his observations. He fixed his object-glass of the requisite curve in a frame without a tube, but having joints, so that it could be turned in any direction at pleasure. This frame was attached to a long pole fixed vertically in the ground, and was directed by the observer to any particular part of the heavens, by means of a string which he held in his hands. Near to the ground there was an eye-glass which could be brought into precisely the same line as the object-glass; and thus the power of making observations was attained, although there was no tube to connect the two lenses with each other.

By whom the first *reflecting* Telescope was invented, is thus explained. The merit has been claimed for our countryman Digges, but without any sufficient foundation ; for the first clear notice we have of such an instrument is contained in a letter from the Père Mersenne to his friend and fellow-student Descartes, and was written about 1639 : but nothing particularly useful appears to have been effected. The size and unwieldiness of the instruments at that time in use, proved so great an inconvenience, that philosophers and mechanicians set themselves about obtaining an equal magnifying power in a smaller space. It was suggested that if the image were formed in the focus of a parabolic mirror, and were then observed through a convex lens, the entire object would thus be attained. Mr. James Gregory, of Edinburgh, was the first who made the position in this country; but, though he came to London for purpose, he could nowhere meet with an artist who would lertake the formation of such a mirror as he had designed; the attention of men of science was once more earnestly cted to the improvement of the *dioptric* Telescope.

[ere again great difficulties had to be encountered; for be-s the "spherical aberration" due to the forms of the cular surfaces, and by which the rays fail to concur rately at one focus, there was the far greater chromatic ration due to the varying refrangibility of the different . As the aberration in a mirror was smaller, and out the chromatic confusion, and consequently much e distinct, Newton set himself to construct such a mirror. had, when at Trinity College, Cambridge, entered in one is common-place books, dated January, 1664, "on the ding of spherical optic glasses; on the errors of lenses, and method of rectifying them, &c." To this Newton now ied himself, and purchased lenses, two furnaces, and ral chemicals. Towards the end of 1668, he first "made nall perspective to try whether his conjecture would hold l or not." The Telescope was six inches long: the aper-of the large speculum was something more than an inch, as the eye-glass was a plano-convex lens, with a focal th of one-sixth or one-seventh of an inch, "it magnified it forty times in diameter," which Newton believed was e than any six-feet refracting Telescope could do with nctness. It did not, however, through the bad materials the want of a good polish, represent objects so distinctly . good six-feet refractor; yet Newton saw with it Jupiter, the horns or "moon-like phase of Venus." He, therefore, idered this small Telescope as an "epitome" of what might lone by reflectors; and he did not doubt that in time a eet reflector might be made which would perform as much ny 60 or 100 feet refractor. He did not resume the truction of reflectors till the autumn of 1671: notwith-ding grinding and polishing, very little change took place, n he discovered the defect to arise from the different re-gibility of the rays of light. He then took a prism which iad purchased at Stourbridge fair, and having made a hole he window-shutter of his darkened room, he admitted ugh the prism a ray of the sun's light, which, after re-ion, exhibited on the opposite wall the solar or prismatic trum, and proved the different refrangibility of the rays of light to be the real cause of the imperfection of refra ting Telescopes. This he proposed to remedy by a metall speculum within the tube, by which the rays proceeding fro the object are reflected to the eye; or, in other words, l "found it necessary, before attempting anything in the practic to alter the design, and place the eye-glass at the side of tl tube rather than at the middle." On this improved princip Sir Isaac Newton constructed his Telescope, which was e amined by King Charles II.: it was presented to the Roy Society, near the end of 1671, and is preserved in the libra at Burlington House, Piccadilly, with this inscription: "T First Reflecting Telescope, invented by Sir Isaac Newton, a made with his own hands." It is described by Sir Dav Brewster as consisting of a concave metallic speculum, with or 14 inches radius of curvature, so that "it collected t sun's rays at the distance of 6½ inches." The rays reflected the speculum were received upon a plane metallic specul inclined 45 degrees to the axis of the tube, so as to reflect t rays to the side of the tube in which there was a small apert to receive a small tube with a plano-convex eye-glass wh radius was one-twelfth of an inch, by means of which t image formed by the speculum was magnified 38 times; wher an ordinary Telescope, of about 2 feet long, only magnifies or 14 times. Such was the first reflecting Telescope appli to the heavens; but this instrument was small and ill-ma and fifty years elapsed before Telescopes of the Newtoni form became useful in astronomy.

About the same time, Mr. Gregory succeeded in accompli ing the design which he had for so many years entertain and M. Cassegrain, in France, also described the principles which a reflecting Telescope might be made. Dr. Hooke w likewise engaged in the improvement of the Telescope; and 1674 he produced before the Royal Society the first reflect instrument in which the great speculum was perforated, so t objects might be viewed by looking directly at them.*

About 1720, Dr. Bradley, Professor of Astronomy at Oxfc who had hitherto used in most of his observations, the lo

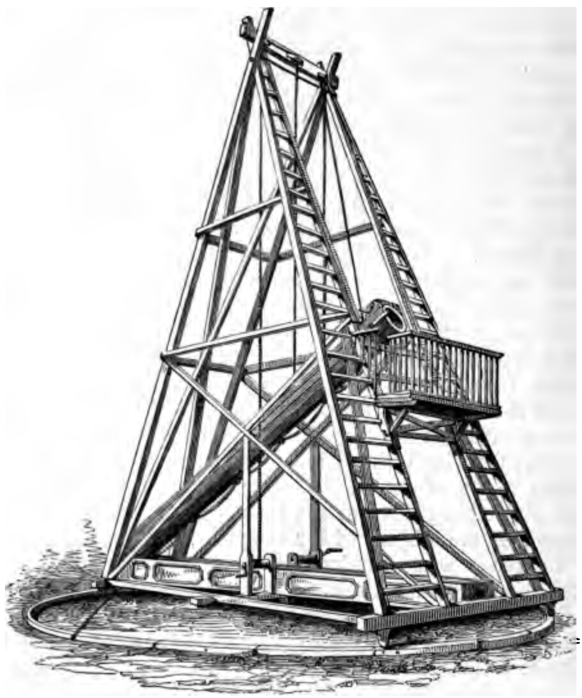
* Hooke is said to have proposed the use of Telescopes having a le of 10,000 feet (or nearly two miles), in order to see animals in the mo an extravagant expectation which Auzout, the French astronomer, w was a good optician and maker of Telescopes, considered it necessar refute.

focal instrument of Huygens, applied himself, in conjunction with M. Molyneux, of Kew, to the improvement of reflecting Telescopes, especially to reducing the inconvenient size of which they were then made. They succeeded admirably; and having, in 1738, directed the London opticians, Scarlet and Hearne, in their mode of construction, these artists were soon enabled to manufacture Telescopes for general use.

The improvement of specula during the whole of the eighteenth century was sought by all earnest opticians. At last, Dr. (afterwards Sir William) Herschel, while residing at Bath, employed his leisure hours in grinding and polishing specula, with which he formed Telescopes, both of the Newtonian and Gregorian kinds; and about the end of 1783, that is, subsequently to the discovery of the planet which is called by his name, being aided by the liberality of the King (George III.), Herschel set to work upon a speculum four feet in diameter, and forty feet in focal length. The plan of this Telescope was intimated by Herschel through Sir Joseph Banks, to George III., who offered to defray the whole expense of it (4,000*l.*). The thickness of the speculum, which was uniform in every part, was $3\frac{1}{2}$ inches, and its weight nearly 2,118 pounds; the metal being composed of 32 copper, and 1097 of tin; it was the third speculum cast, the two previous attempts having failed. The speculum, when not in use, was preserved from damp by a tin cover, fitted upon a rim of close-grained cloth. The tube of the Telescope was 39 ft. 4 in. long, and its width 4 ft. 10 in.; it was made of sheet-iron, 20th of an inch thick, and was 3,000th lighter than if it had been made of wood. The observer was seated in a suspended moveable gallery at the mouth of the tube, and viewed the image of the object with a magnifying lens, or eye-piece. This Telescope was completed in 1789; and on the 28th of August, about the first time it was directed to the heavens, a new body was added to the solar system, namely the sixth satellite of Saturn; and in less than a month after, the seventh satellite of Saturn, "an object," says Sir John Herschel, "of a far higher order of difficulty."

This magnificent instrument was placed upon the lawn of Sir William Herschel's house, near the corner of the road from Slough to Windsor. The Telescope was suspended and moved by an apparatus resting upon two concentric circular brick walls, and by twenty concentric rollers moveable upon a pivot, which gave a horizontal motion to the whole of the apparatus, as w as to the Telescope. The difficulty of managing so large an strument—requiring as it did two assistants in addition to observer himself, and the person employed to note the tim prevented its being much used. In 1839, the woodwork of instrument being decayed, Sir John Herschel had it clea away, and the tube removed to Hawkhurst, in Kent.

After Sir William Herschel, came John Ramage, an Aberd merchant, who, as early as the year 1806, had made reflec



RAMAGE'S REFLECTING TELESCOPE.

with specula six inches in diameter. These he improved u and, only four years after, produced an instrument with a : length of eight feet, and a mirror that measured nine in(He ventured still farther, and from a focal length of tw feet, with a speculum thirteen and a half inches in diameter, he at length completed Telescopes twenty-five feet long, with mirrors of fifteen inches. Although these reflecting telescopes showed the double stars very distinctly, yet in no instance did they aid in a new discovery: not even when Ramage had succeeded in making an instrument with a focal length of fifty-four feet, and a speculum twenty-one inches in diameter: in it objects were magnified about 6,500 times.

While the reflecting Telescope was thus progressing towards its present state of perfection, the endeavour to diminish the fringe of colours which surrounded the appearance of objects when viewed through dioptric instruments did not cease. An improvement made by Mr. Chester Hall, in 1729, greatly facilitated the attainment of a clear image through the eye-glass by using lenses of different kinds of glass. This idea was carried further by Mr. Dollond, about thirty years later. Euler had proposed to use hollow spherical segments of glass, with water between them, to diminish the aberration in Telescopes, which led Mr. Dollond to make experiments on wedges of different kinds of glass, to ascertain the various degrees of refrangibility which they possessed. He ultimately discovered that by using a convex lens of crown-glass, and a concave lens of flint-glass, the different coloured rays in each pencil of light. after refraction through both, fell upon the eye nearly colourless. For this improvement he was presented with the Copleian Medal by the Royal Society; and, a few years afterwards, in 1765, his son, Mr. Peter Dollond, made a still further improvement by diminishing the aberration occasioned by the spherical form of the glass. He planned a concave lens of flint-glass between two convex lenses of crown-glass, which almost did away with the fringed colouration of the image, and gave the still further advantage of a large aperture for the observation of the object when the focal length of the instrument was short. Various improvements were afterwards made by Mr. Ramsden and others (chiefly with a view to destroy the aberration) through the union of spheres of different kinds of glass.

Another great improvement in the construction of the Telescope was brought about by this singular means. The manufacture of flint-glass, indispensable for the achromatic Telescope, was so severely taxed by the British Government—that if a philosopher melted a pound of glass fifty times, he had to pay the duty upon fifty pounds. The Government then permitted a Committee of the Royal Society to erect an experimental glass-house, and compound, without the supervision of the exciseman, a pot of glass. Dr. Faraday superintended the chemical part of the experiment; and by the year 1830, the Committee succeeded in producing glass of superior quality for optical purposes; but the manufacture was not carried further.*

However, Guinand, a maker of clock-cases, in the village of Brenetz, in the canton of Neufchatel, was accustomed to grind spectacle-glasses for his own use. This led him to make small refracting Telescopes, with pasteboard tubes. It chanced that an achromatic Telescope of English manufacture came into the hands of Guinand's master. Guinand was allowed to take the instrument to pieces, to separate its lenses, and measure its curves; and fully understanding its properties, he resolved to make an achromatic Telescope for himself. Flint-glass was only to be had in England; and a friend, journeying thither, brought back as much flint-glass as enabled Guinand to supply several Telescopes. But the quality was bad, and Guinand next resolved to make flint-glass for his own use. He continued to experiment for this purpose from the year 1784 to 1790. At length he succeeded, and gave up his clock-case making business for the more profitable making of bells for repeaters. He prospered, and with increased means bought a piece of ground on the banks of the Doubs, and there built works, with a furnace that would fuse *two hundred-weight of glass*. Still he had many mishaps: his crucibles failed, and his furnaces burst, but these accidents only served to incite Guinand to further study how to prevent threads and specks which spoiled his glass. At last he succeeded in obtaining glass of uniform clearness and refractive powers, in pieces from 12 to 18 inches in diameter. He then acquired the art of soldering pieces of glass, and grinding out the joint-lines formed by globules of air and particles of sand; this he did by means of an emeried wheel, and then replacing the mass in a furnace, the vitreous matter expanded, every trace of junction disappeared, and he thus produced the finest discs of flint-glass.

Guinand's fame now spread, and having reached Frauenhofer, the Bavarian optician, he went to Brenetz, in 1804,

* See Pellatt's *Curiosities of Glass-making*, p. 44.

nd induced Guinand to remove to Munich; there he taught is art to Frauenhofer, who being an able chemist, soon learned ie processes, and the theory of manipulation; he studied ie refractive and dispersive powers of materials, and above ll, by his great discovery of the fixed lines in the spectrum, isured achromatic glass by means which no other artist ossessed. He was, however, cut off by disease in the prime life; or, as his biographer states, "he would have astonished urope with the production of an achromatic object-glass ghteen inches in diameter."

In 1814 Guinand left Munich, and returned to Brenetz, uther, in 1820, came M. Lerebours, the celebrated optician Paris, who purchased all Guinand's stock of glass. Another lful Parisian artist subsequently procured from Guinand ge discs of glass; and thus the refractive Telescopes of ince rivalled those of Munich; while England had lost pre-eminence in this branch of practical optics. The atious impost has, however, been repealed; and the con-iction of large object-glasses is now followed up with re-ibled energy.

Guinand's secret lay in agitating the liquid glass when at highest point of fusion; and when annealed and cool, arating the striated portions by cleavage. Guinand left two s, one of whom subsequently operated with M. Bontems, the nch scientific glass-maker. In 1851, he quitted France, l joined Messrs. Chance, Brothers and Co., of Birmingham, improving their glass manufactures. He produced a disc flint of 29 inches in diameter, weighing 2 cwt., which r being proved by grinding and annealing, received a incil Medal at the Great Exhibition of 1851. From this ression upon glass-making we return to the Telescope itself.

n his astronomical labours, Sir William Herschel's sole as-ant was his sister, Miss Caroline Lucretia Herschel, aunt to John Herschel, bart., the late representative of that truly ntific family. To Miss Herschel's indefatigable zeal, dili-ce, and singular accuracy of calculation, is due much of success of her brother's pursuits. Her attendance on both daily labours and nightly watches was put in requisition; only reading the clock, and noting down all the observa-s from direction, as an amanuensis, but subsequently cuting the extensive and laborious numerical calculations essary to render them available to science. For the performance of these duties, King George III. was pleased to place Miss Herschel in the receipt of a salary sufficient for her singularly moderate wants and retired habits. Her brother's observations were always carried on (circumstances permitting), till daybreak, and chiefly in winter. "She it was, who having passed the night near the Telescope, took the rough manuscripts to her cottage at the dawn of day, and produced a fair copy of the night's work on the ensuing morning; she it was who planned the labour of each succeeding night, and kept everything in systematic order." She it was—Miss Caroline Herschel—who helped our astronomer to gather an imperishable name. In the intervals, Miss Herschel likewise found time for astronomical observations of her own; these she made with a small Newtonian sweeper constructed for her by her brother, with which she found no less than eight comets; and, on five of these occasions, her claim to the *first* discovery is admitted. In these surveys were detected several remarkable nebulæ and clusters of stars, previously unobserved. On her brother's death, in 1822, Miss Herschel returned to Hanover, which she never again quitted; passing the last twenty-six years of her life in repose, she died on the 9th of January, 1848, in her 98th year. To within a very short period of her death, her faculties continued perfect, and her memory remarkably clear and distinct.

We now approach the most stupendous work of our time, namely, the Great Reflecting Telescope, constructed by the Earl of Rosse, at his seat, Birr Castle, at Parsonstown, about fifty miles west of Dublin. His Lordship has been characterised as "the great mechanic of the age, a man who, if he had not been born a peer, would probably have taken the highest rank as an inventor. So thorough is his knowledge of smith's work that he is said to have been pressed on one occasion to accept the foremanship of a large workshop by a manufacturer to whom his rank was unknown."

In the improvement of the Reflecting Telescope, the paramount object has always been to increase the magnifying power and the light by the construction of as large a mirror as possible; and to this point Lord Rosse's attention was directed as early as 1828. We have spoken of his mechanical skill, to which he adds profound mathematical knowledge; to these may be added command of money; for the gigantic telescope we are about to describe cost certainly not less than 12,000 pounds.

Lord Rosse having first ascertained the most useful combination of metals for specula, both in whiteness, porosity, and hardness, to be copper and tin, of this compound the Reflector was cast in pieces, which were fixed on a bed of zinc and copper ground as one body to a true surface, and then polished by machinery moved by a steam-engine, the peculiarities of the mechanism being entirely Lord Rosse's invention: they were chiefly, planing the speculum with the face upward, regulating the temperature by having it immersed in water, usually at 55° Fahrenheit, and proportioning the pressure and velocity. This was found to work a perfect spherical figure in large surfaces with a degree of precision unattainable by the hand; the polisher, by working above, and upon the face of the speculum, being enabled to examine the operation, as it proceeded, without removing the speculum, which, when a ton weight, is no easy matter. The machine gives the parabolic figure to the speculum so true, that it is thrown out of focus by a motion of less than the thirtieth of an inch. Thus was executed the three-feet speculum for the 26-feet Telescope placed upon the lawn at Parsonstown, which, in 1840, showed with powers up to 1000, and even 1600; and which resolved nebulæ into stars, and destroyed that symmetry of form in globular nebulæ upon which was founded the hypothesis of the gradual condensation of nebulous matter into suns and planets. The instrument also discovered new objects in the moon, as a mountainous tract, dotted with minute craters; and Dr. Robinson states that in this Telescope, a building the size of the Court-house at Cork would be easily visible on the lunar surface.

Lord Rosse next resolved to attempt by the above processes to construct another reflector, with a speculum *six feet* in diameter and *fifty feet focus*; and this magnificent instrument was completed early in 1845. The focal length of the speculum is fifty-four feet. It weighs four tons, and, with its supports, is seven times as heavy as the four-feet speculum of Sir William Herschel. The speculum is placed in one of the sides of a cubical wooden box, about eight feet wide, and to the opposite end of this box is fastened the tube, which is made of deal staves an inch thick, hooped with iron clamp-rings, like a huge cask. It carries at its upper end, and in the axis of the tube, a small oval speculum, six inches in its lesser diameter. The tube is about fifty feet long and eight feet in diameter in the middle, and furnished with diaphragms 6½ feet in aperture.

The Dean of Ely, Dr. Peacock, walked through the tube with an umbrella up.

The Telescope is established between two lofty castellated piers sixty feet high, and is raised to different altitudes by a strong chain-cable attached to the top of the tube, and is there balanced by counterweights suspended by chains. The immense mass of matter weighs about twelve tons, but it can be raised from its least altitude to the zenith by two men at the windlass in six minutes. On the eastern pier is a strong semicircle of cast-iron, with which the Telescope is connected by a racked bar, with friction-rollers attached to the tube by wheel-work, so that by means of a handle near the eye-piece, the observer can move the Telescope along the bar on either side of the meridian, to the distance of an hour for an equatorial star.

LORD ROSSE'S TELESCOPE, BIRR CASTLE, PARSONSTOWN.

On the western pier are stairs and galleries. The observing gallery is moved along a railway by means of wheels and a winch, and can be raised to various altitudes: a child can work the machinery.

Sir David Brewster eloquently describes the marvellous sight which this Telescope discloses,—the satellites and belts and rings of Saturn,—the old and new ring, which is advancing with its crest of waters to the body of the planet,—the rocks, and mountains, and valleys, and extinct volcanoes of the moon, crescent of Venus, with its mountainous outline,—the s of double and triple stars,—the nebulæ and starry s of every variety of shape,—and those spiral nebular ions which baffle human comprehension, and constitute :atest achievement in modern discovery. The account ›y an astronomer of the appearance of Jupiter was that it ›led a coach-lamp in the telescope, and this well ex- ; the blaze of light which is seen in the Rosse instru-

Rev. Dr. Scoresby records that from the guidance we ; of the comparative power of the six-feet speculum in ıetration of space, we might fairly assume the fact, that other Telescope now in use could follow the Sun if re- to the remotest visible position, or till its light would : 10,000 years to reach us, the grand instrument at .stown would follow it so far that from 20,000 to years would be spent in the transmission of its light earth. But in the cases of clusters of stars, and of : exhibiting a mere speck of misty luminosity, from the ıed light of perhaps hundreds of thousands of suns, the *tion* into space, compared with the results of ordinary must be enormous; so that it would not be difficult to he *probability* that a million of years, in flight of light, be requisite, in regard to the most distant, to trace the ous interval.

Great Northumberland Equatorial Telescope was the the Duke of Northumberland to the University of Cam- With this instrument, the planet Neptune was really ed by Professor Challis twice before its discovery by at Berlin. The object-glass, by Cauchois of Paris, is one in. aperture, and the focal length of the telescope is et. Special means are provided for easily placing the er in all positions in the surface of a sphere, whose is the centre of the Telescope. The observer, by means inch, can turn round the frame that carries himself and air; and by aid of a bar and ratchet-wheel, can raise er the chair on the frame. The Equatorial Telescope 'o axes of motion at right angles to each other, each a graduated circle attached to it. This kind of instru- ıas one advantage over all others—namely, the object is d in the centre of the field of view for hours, without ort on the part of the observer.

The Legislature of Victoria have voted the sum of 5,000*l.* for the construction of a large reflecting Telescope, to be erected at Melbourne, for the purpose of effecting a thorough survey of the nebulæ and multiple stars of the Southern hemisphere. The President and Council of the Royal Society (whose advice had been requested) have selected Mr. Grubb, of Dublin, the eminent optician, to construct this instrument. The great cost of equivalent discs of glass of the requisite purity has rendered it imperative to employ *catoptrics* instead of *dioptrics*—reflection rather than refraction—in a Telescope of large size. An image is formed in the focus of the mirror, and is examined by suitable eyepieces. The tube has a diameter of 4½ feet, and is of proportional length. The diameter of the speculum is but 6 inches less than that of the tube, or 4 feet, being 4½ inches in thickness, and weighing about 27 cwt. The grinding was performed by a polishing machine and steam-engine, constructed for and belonging to the Telescope, and which accompany it to Melbourne.

There are no results in the whole range of modern science more wonderful than those which have been obtained by the application of the spectroscope to the telescope. How impossible it appeared a few years ago that we should ever be able to know with certainty whether the chemical elements known to us on our planet exist in the far distant sun? But at the present day we recognise in our luminary the existence of most of our terrestrial elements, and are able even to trace to some extent their distribution at various depths in the sun's luminous envelope. Not only has our own sun been compelled to reveal the nature of the materials of which it is composed, but those immeasurably distant suns, the so-called fixed stars, have likewise been made to declare the secret of their composition.

Professor Nichol, speaking of telescopic discoveries, asks: "What mean those dim spots which, unknown before, loom in greater and greater numbers on the horizon of every new instrument, unless they are gleams it is obtaining, on its own frontier, of a mighty infinitude beyond, also studded with glories, and unfolding what is seen as a minute and subservient part? Yes; even the six-feet mirror, after its powers of distinct vision are exhausted, becomes, in its turn, simply as the child gazing on these mysterious lights with awful and hopeless wonder. I shrink below the conception which here—even at this threshold of the attainable—bursts forth on my mind.

Look at a cloudy speck in Orion, visible, without aid, to the well-trained eye; that is a stellar universe of majesty altogether transcendent, lying at the verge of what is known. And if any of these lights from afar, on which the six-feet mirror is now casting its longing eye, resemble in character that spot, the systems from which they come are situated so deep in space that no ray from them could reach our earth until after travelling through the intervening abysses, during centuries whose number stuns the imagination. There must be some regarding which that faint illumination informs us, not of their present existence, but only that assuredly they were, and sent forth into the infinite the rays at present reaching us, at an epoch further back into the past than this momentary lifetime of man, by at least thirty millions of years!"

Sir David Brewster remarks: "In looking back upon what the Telescope has accomplished; in reckoning the thousands of celestial bodies which have been detected and surveyed; in reflecting on the vast depths of ether which have been sounded, and on the extensive fields of sidereal matter out of which worlds and systems of worlds are forming, and to be formed—can we doubt it to be the Divine plan that man shall yet discover the whole scheme of the visible universe, and that it is his individual duty, as well as the high prerogative of his order, to expound its mysteries and develop its laws. Over the invisible world he has received no commission to reign, and into its secrets he has no authority to look. It is over the material and the visible that he has to sway the intellectual sceptre; it is among the structures of organic and inorganic life that his functions of combination and analysis are to be chiefly exercised. Nor is his task unworthy of his genius, or unconnected with his destiny. Placed upon a globe already formed, and constituting part of a system already complete, he can scarcely trace, either in the solid masses around him, or in the forms and movements of the planets, any of those secondary causes by which these bodies have been shaped and launched on their journey. But in the distant heavens, where creation seemed to be ever active, where vast distance gives us the vision of huge magnitude, and where extended operations are actually going on, we may study the cosmogony of our system, and mark, even during the brief space of human life, the formation of a planet in the consolidation of the nebulous system which surrounds it."

Since the preceding pages were written, several very notable improvements have been effected in the fabrication of object-glasses and of specula. Object-glasses, of diameters far exceeding any we have yet referred to, have been constructed. Thus, for example, Mr. Cooke, Mr. Grubb, and others, have produced glasses of two feet or more in diameter. The efforts of some eminent practical opticians are now directed towards the attainment of still larger dimensions; and it is not at all improbable that before long the astronomer will have at his command refracting Telescopes with an aperture of three feet, perhaps of four feet. The difficulties of constructing lenses of so large a diameter are very great. Repeated attempts have to be made before a flawless disc of glass can be obtained, and the cost of this preliminary step may amount to many hundreds of pounds; while the labour and skill required in the grinding and polishing processes are proportionately great.

In Reflecting Telescopes advantage has been taken of a very simple chemical process, by which an adherent film of pure highly-lustrous silver is deposited upon a glass surface. The speculum, instead of being cast in metal, is formed by grinding and polishing a thick glass disc. On the concave parabolic surface of this, the film of silver is spread, by simply immersing the speculum in the proper solution. The silver retains its brilliancy longer than speculum-metal, and whenever required can be renewed. A splendid reflector, with a silvered glass speculum four feet in diameter, was a few years ago erected at the Paris Observatory. The moderate cost of Telescopes of this kind, compared with Refracting Telescopes of equal aperture, has caused them to be much appreciated by private observers.

THE MICROSCOPE.

CERTAIN dispositions of pieces of glass ground to a lenticular form furnish man in the telescope with an instrument that opens to his gaze ever deeper and deeper regions of endless space, and it is remarkable that certain other slightly different arrangements of like pieces of glass supply him in the microscope with the means of looking into infinity in the opposite direction. These two noble instruments reveal to us the existence of two otherwise unknown worlds—the world of the infinitely vast, and the world of the infinitely minute.

A fine comparison between *the telescope and the microscope* has been drawn by Dr. Chalmers. He says, speaking of the two instruments:—"The one led me to see a system in every star. The other leads me to see a world in every atom. The one taught me that this mighty globe, with the whole burden of its people and of its countries, is but a grain of sand on the high field of immensity. The other teaches me that every grain of sand may harbour within it the tribes and families of a busy population. The one told me of the insignificance of the world I tread upon. The other redeems it from all its insignificance; for it tells me that in the leaves of every forest, in the flower of every garden, and in the waters of every rivulet, there are worlds teeming with life, and numberless as are the glories of the firmament. The one has suggested to me, that beyond and above all that is visible to man, there may be fields of creation which sweep immeasurably along, and carry the impress of the Almighty's hand to the remotest scenes of the universe. The other suggests to me that within and beneath all that minuteness which the aided eye of man has been able to explore, there may be a region of invisibles;

and that, could we draw aside the mysterious curtain which shrouds it from our senses, we might there see a theatre of as many wonders as Astronomy has unfolded, a universe within the compass of a point so small as to elude all the powers of the microscope, but where the wonder-working God finds room for the exercise of all His attributes, where He can raise another mechanism of worlds, and fill and animate them with all the evidences of His glory."

In point of time the discovery of the microscope must have preceded that of the telescope, for the simplest form of the microscope is merely a convex lens, and every convex lens is *pro tanto* a microscope; while the telescope is necessarily a combination of lenses, as is also the later and far more efficient kind of microscope. Microscopes then are of two kinds—*simple*, consisting of a single lens; and *compound*, consisting of a combination of lenses. No name or period can be associated with the invention of the simple microscope, for a knowledge of the magnifying power of convex transparent bodies must have existed even in the remotest antiquity. No one who has ever observed with any degree of attention a drop of dew or rain on the surface of a green leaf, could be ignorant of the magnifying effect of the transparent globule. There are other numberless instances in which transparent spherules of various materials are formed by nature or by art, and of which the optical property in question could not fail to have attracted attention. Of course such casual observations must be considered as very different from that systematic use of spherical or lenticular transparent bodies in the examination of minute objects, which would entitle the person who first made them to the honour of having invented the simple microscope.

That such microscopes must have been known to the ancients, the excessively minute work on some of the engraved gems which have been preserved to us, seems to conclusively prove, for some of the work is invisible to the unassisted eye. Indeed, Mr. Layard found among some glass vessels, in the ruins of Nineveh, a lenticular shaped piece of rock crystal, which was pronounced by the late Sir D. Brewster to have been formed expressly for optical purposes. Again, from passages in certain ancient authors, it would appear that glass globules or globular vessels filled with water were known as "burning-glasses," and also for their magnifying properties. There is a passage in *Seneca* which has attracted much notice this connection. He says—"However small and obscure ie writing may be, it appears larger and clearer when viewed rough a little glass globe filled with water." It is said also, at some small highly magnifying lenses have been found mong the ruins of Herculaneum. The learned Arabian hilosopher, Alhazar, who flourished about the middle of the leventh century, appears to have been acquainted with the agnifying properties of glass lenses, or spherical segments, ut he seems, like many others, to have placed his glasses close o the writing to be magnified, whereas better results would ave been obtained by holding the glass close to the eye, and hen placing the writing at a proper distance from the lens. But when in the thirteenth century spectacles came into use, the art of grinding lenses had of course become an established

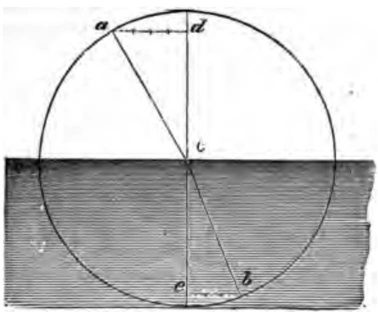


FIG. 1.

trade, and the difference between a common spectacle glass and a lens entitled to be regarded as a simple microscope is only in the degree of curvature given to the surfaces. The smaller the radius of the spherical surface into which the glass is shaped, the greater will be the magnifying power.

Here it may be not improper to briefly explain the optical principles upon which the powers of both microscopes and telescopes depend. The fundamental fact upon which the action of lenses depends, is that when a ray of light passes from one medium to another, its course is altered according to a law which we shall endeavour to explain.

Let the shaded part of Fig. 1 represent water, the level surface of which is supposed to be at right angles to the plane of the paper. Let *a c* be the direction of a ray of light falling upon the water at *c*. This ray will not preserve its course in the direction of *a c* produced, but will at *c* suddenly change its direction, following a straight line *c b*, which will be nearer to the perpendicular *d e* drawn through *c* than the direction of the ray before entering the water; that is, the angle *e c b* will be smaller than the angle *a c d*. But these angles are always related to each other in one and the same remarkable way, namely this,—if we set off from *c* equal distances *c a* and *c b*, along each of the directions and from *a* and *b*, the points so obtained, draw perpendiculars *a d* and *e b* on the line *d e*, the length of *b e* will always be three-fourths of that of *a d*. If the ray of light, instead of emanating from some point in the air as *a*, proceeds from a point *b* in the water, the rays will follow the same track, and the same relation of *b e* and *a d* will subsist. In the case of air and water the ratio of these lines is always 3 to 4, but it has a different value for each pair of

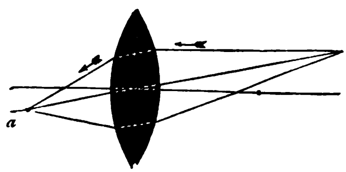


FIG. 2.

substances; thus for rays passing through flint glass the ratio is 5 to 8, and it varies for the different kinds of glass.

Let us now consider the case of a *double convex* glass lens, as shown in Fig. 2. Let *b* be a point from which rays of light emanate in all directions. Upon the *whole face* of the lens, rays from *b* will strike, and each of the rays on entering the glass, and again on emerging from it, will be refracted according to the law just explained. Now it is geometrically proved in elementary treatises on optics, that the spherical curvatures of the surface of the glass will by virtue of this law cause the several rays to take such a course that they will meet together at some particular point *a*. Conversely, if the rays proceed from *a* they will meet at *b*. In optical language *a* is called the *focus* of the rays from *b*, and *vice versâ*, and the pair of points *a* and *b* are sometimes named *conjugate foci*. The reader will remark that in Fig. 2 the courses of *only three* of the innumerable rays are traced, and that the remaining straight line in the diagram is that called the *principal axis* of the lens. If instead of *b* we take other points at about the same distance from the lens, no matter how far (within considerable limits) from the principal axis, the *foci* for these points will be at about the same distance as *a* from the lens on the other side. It will now be easy for the reader to understand how it is that a convex lens is capable of forming an inverted image of an object on a screen, as shown in Fig. 3, where, it should be carefully noted, the courses of only three rays from the highest, and three from the lowest point of the object, are traced. The tracks of the other numberless rays which emanate from these points, and *also from every point* of the object, must be supplied in imagination. The remaining line is as before the *principal axis*, and this coincides also with the direction of a single one of the rays emanating from the middle point of the object.

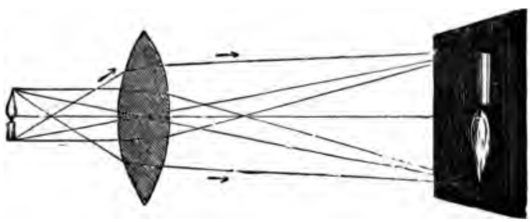


FIG. 3.

Returning now to Fig. 2, let us remark that with the same lens, the distance from the lens of the focus *a* depends upon the distance of the luminous point *b*, and of course the like applies to the *images*, which are simply assemblages of *foci* of points. If *b* were gradually removed from the lens in a direction parallel to the axis, *a* would approach nearer to the lens, but only up to a certain limit. The distance of *a* from the middle of the lens when *b* is at a very great distance is called the *focal length*, and it depends upon the nature of the glass or other material of which the lens is constructed, and upon the curvature of its surfaces. Rays of light cannot be brought to a focus by a lens at any point nearer to it than its focal length. But if the point *b*, instead of being at an extremely great distance from the lens is gradually brought nearer, the conjugate *focus a* will gradually recede from the lens, and when *b* has arrived at the focal distance *a* will be infinitely distant, or, in other words, the refractive effect of the lens will be to cause the rays issuing from it to be parallel to the line *b a*. It will be seen from the foregoing statements that we can easily ascertain the *focal length* of any convex lens by measuring the distance from it at which a well-defined image of the sun (or moon) is formed on a screen of ground glass. A few experiments made with a candle and a spectacle lens (or other lens such as an eye-glass), will soon render the reader familiar with the formation of images. He will find, for example, that with one and the same distance between the candle and the screen, there are, in general, *two* places for the lens, at each of which it will give an inverted image of the candle, but one of these images will be smaller than the object, and the other will be larger. Such images are called *real images* because they are made up of points to which rays of light actually do converge, and it will greatly assist the reader's understanding of optical instruments if he will realise the following statement to his own mind:—If such a screen as that shown in Fig. 3 be removed, the image still exists; that is, the rays from the several points of the object converge to corresponding points just as before. Now, it may be asked, why is the screen necessary for the observation of the image if the latter actually exists in the air? The reason why the image in the air is not visible from all sides will be obvious if one considers the well-known property of luminous rays to traverse a uniform medium in straight lines. The rays, therefore, when not dispersed by falling on a screen, continue their journey in straight lines, and their optical effect at any part of their subsequent course will be the same as if they emanated from a real object occupying the exact position of the image as seen upon the screen. With a suitable convex lens the inverted images, one smaller, the other larger than the object, may readily be seen when the observer's eye is placed in the track of the rays without the intervention of any screen. Now the purpose of the object-glass (or reflector, as the case may be) of the telescope and microscope is the formation of such an image, which it is the function of the *eye-piece* to magnify, and to cause to be viewed under the conditions requisite for distinct vision.

This brings us to remind the reader that the eye itself is optically a double convex lens, by means of which images are formed to a screen exactly as in Fig. 3. The screen in the case of the eye is the *retina*, on which is spread out a delicate network of nervous tissue. The conditions requisite for distinct vision are that rays of light emanating from the several points or parts of an object be brought to *foci* upon the retina —or, to speak more exactly, upon a particular part of it—and this is effected by a self-adjusting mechanism which operates to change the curvature of the surfaces of the crystalline lens. This adjustment extends to certain limits, and when an object is brought nearer to the eye than a certain distance (which varies from one person to another) the vision becomes indistinct, that is, the eye is unable to bring to a focus on the retina rays which have more than a certain degree of divergence. The condition which limits the power of the eye to distinguish any part of an object from the adjoining part, is that the foci on the retina of the rays from the several parts shall be separated by an interval not less than the dimensions of the physiological elements of the retina itself. It is these dimensions which determine the magnitude of the smallest point visible to the eye, and the function of the lenses in the microscope and the telescope is simply to distribute over the area of a number of the retinal elements, those foci which otherwise would fail to be discriminated by reason of their incidence on but one such element.

Presuming that the reader has realised to his own mind these conditions of distinct vision, he will have no difficulty in understanding the action of the single convex lens in the simple microscope. Referring again to Fig. 2, we have already stated the changes in the position of the focus *a*, as the point of emanation of the rays *b* is brought nearer and nearer to the lens from a great distance, up to the *focal distance*. It will be remembered that *a*, setting out from the focal length, recedes, continuing until it is at an infinite distance, or in other words, the emergent rays become parallel. Now the question arises, what happens if *b* be brought yet nearer to the lens than its focal length? It can easily be shown that the emergent rays then become divergent, and of course never meet in a point towards *a*. No *real image* of an object can therefore be formed under these circumstances; but, on the other hand, as the rays will diverge AS IF they emanated from a point on the axis *a b* at a *greater* distance from the lens than *b*, the result would be that an apparent, or what is optically termed a *virtual image* of the object, would be obtained. How this happens will be easily understood from Fig. 4, where the courses of three of the rays from *b* are traced, and the effect of the refraction they undergo is seen to be such that their divergence on leaving the glass is the same *as if* they actually emanated from the point B on the axis *c b* at a greater distance from the lens. As the same thing happens *for every point* of the object *b d*, an eye placed on the side of the lens would receive the rays precisely *as if* they had come from a real, larger, and more distant object occupying the position of B D. For this reason the lens is said to form a *virtual image.*

Microscopes are then of two kinds, namely, 1st, the *simple microscope*, in which a single lens is used, or a combination of

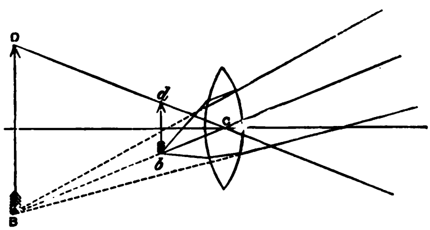


FIG. 4.

lenses having the same effect, namely, the formation of a *virtual image;* 2nd, the *compound microscope*, which must consist of at least two lenses, one of which, called the *object-glass*, has for its function the formation of a *real image*, and the other lens called the *eye-piece*, or *eye-glass*, magnifies the real image in the same way as the simple microscope magnifies the object. But the *object-glass* and the *eye-piece* of the compound microscope may, and in fact usually do, consist each of several distinct lenses, so disposed as to obviate certain defects in the result which are inseparable from the simple lens. It would be out of the province of this work to discuss in detail the various optical principles involved in the construction of the lenses of the admirable microscopes that are now constructed. The most important of these principles is that involved in the *achromatic lens;* for an account of which any elementary treatise on optics may be referred to. It must suffice here to remark that the simple lens produces, to a certain extent, the effect of a prism in decomposing rays of light, and therefore the images formed by such lenses are liable to exhibit coloured borders, by which clearness and definition are lost. The remedy is found in the employment of different kinds of glass to form two or three lenses, ground to such surfaces that a single lens is built up by their juxtaposition, which shall produce the required *refractions* without *dispersing* the rays into their chromatic elements.

It will be convenient first to sketch the history of the *simple microscope*, as regards the successive improvements or modifications introduced into its construction. Its use, as we have already seen, was known at a very remote period. In proportion as the magnifying power of the simple microscope is great, the lens has the greater curvature, and the radii of its spherical surfaces are shorter, and the nearer must the object be placed to the lens. The construction of very small lenses involves much difficulty, and their effective use is not to be acquired without much practice. About the middle of the seventeenth century there came into use small globules of glass made by fusing filaments of that substance in a flame. The spherical form assumed by the glass under these conditions obviated the necessity of grinding, and the globule was easily mounted by fixing it in a perforation in any thin plate of metal. Of course, a very high magnifying power is thus obtained, but the inconvenience attending the use of such instruments is the closeness of the eye, the lens, and the objects, and the very small portion of the object visible at once. The invention of the glass globules as simple microscopes has been claimed for various persons, amongst others for A. M. Hartsoeker, and the celebrated Dr. Robert Hooke, who, in the preface to a work entitled *Micrographia Illustrata*, published by him in 1656, clearly described the manner of making them. Having taken a clear piece of glass, he drew it out, by the heat of a lamp, into fine threads, and then holding the end of these threads in the flame, he melted them till they ran into a small round globule, which hung to the end of the thread. The globule was then stuck on the end of a piece of wood, with the thread, cut as short as possible, standing uppermost; and the ends were ground off, first on a whetstone, and then polished on a metal plate with Tripoli. The globule was then placed against a small hole in a thin piece of metal, and fixed with wax. "Thus fitted up," says Dr. Hooke, "it will both magnify and make some objects more distinct than any of the great microscopes do."

The "great microscopes" mentioned above, were the original kind of compound microscopes, to be presently described. These, as well as simple microscopes, were commonly made in Holland, at the end of the sixteenth century; and a Dutch naturalist named Leeuwenhoek (*born*, 1632—*died*, 1723) will ever be famous in the history of science as the first great systematic microscopic observer. Leeuwenhoek communicated the results of his observations from time to time to the Royal Society, in whose journals his name appears for the first time in 1673. All Leeuwenhoek's work was done with simple microscopes, consisting merely of small double-curved lenses mounted in plates of metal. "That with such imperfect instruments at his command," says Dr. W. B. Carpenter, "this accurate and painstaking observer should have seen *so much and so well*, as to make it dangerous for any one, even now, to announce a discovery without having first consulted his works in order to see whether some anticipation of it may not be found there, must ever remain a marvel to the microscopist."

Leeuwenhoek bequeathed to the Royal Society twenty-seven of the microscopic objects prepared by himself, each being mounted with its own double convex lens, which was let into a socket between two metallic plates riveted together, and pierced with a small hole; the object was placed on a silver point or needle which, by suitable means, could be turned round, and brought nearer to or farther from the lens as occasion required. The glasses were all very clear, and of different magnifying powers, adapted to the nature of the object to be examined. Each glass being mounted for the examination of only one or two objects, Leeuwenhoek always kept some hundreds of lenses by him.

In the *Philosophical Transactions* for 1696, Stephen Gray describes how, having observed that some particles in a globule of glass appeared distinct and enormously magnified when the glass was held close to his eye, he concluded that if he placed a globule of water, containing any small bodies, in a similar position, he should see these particles similarly magnified. His method was to take up, little by little, on a piece of thin brass wire, some water containing animalcules, until there was more than a hemisphere of water; on holding the drop near the eye, the animalcules were found to be enormously magnified. Dr. Hook has also described a method of using the "water-microscope." "If you are desirous," he says, "of obtaining a microscope with one single refraction, and, consequently, capable of procuring the greatest clearness and brightness any one kind of microscope is susceptible of, spread a little of the fluid you intend to examine on a glass plate; bring this under one of your globules, then move it gently upwards till the fluid touches the globules, to which it will soon adhere, and that so firmly as to bear being moved a little backwards or forwards. By looking through the globule, you will have then a perfect view of the animalcules in the drop."

One of the greatest improvements in the simple microscope was that devised by Lieberkuhn, about 1740; and consisted in mounting the lens in the centre of a small highly-polished concave silver speculum, of suitable curvature. The speculum concentrated a powerful light upon the part of the object under observation, and this obviated the great difficulty which had been previously found in illuminating opaque objects; for, by the proximity of the observer's head, the side of the object next the eye had necessarily been deprived of most of the incident light. Fig. 5 represents, in section, one of Lieberkuhn's microscopes. It consists of a piece of brass tube, about one inch in length and one inch in diameter, and provided with a cap, fitted with a screw at each end. At *a* is a small aperture, behind which is fitted the double-convex lens *a*, of half an inch focal length, and placed in front of the silver cap or speculum *l*, which also is pierced by an opening. In front of this is a small metallic disc *c*, three-eighths of an inch in diameter, and connected by a wire with the small knob *d*. When the knob is moved, the object attached to the side of the disc next the speculum is carried with it and adjusted to the position required. The tube is closed in front by the larger lens *b*, which serves to concentrate light upon the speculum.

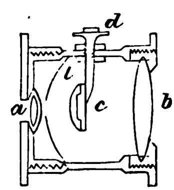


FIG. 5.—LIEBERKUHN'S MICROSCOPE.

Dr. Wollaston (*born*, 1787—*died*, 1826) contrived a combination of two lenses, by which the simple microscope gained much in definition and lightness. Wollaston's *doublet* consists of two *plano-convex* lenses, with focal lengths as one to three, and placed at a certain distance, best found by trial, with their plane surfaces towards the object, and with an interposed diaphragm. This arrangement transmits a pencil of rays of a greater angle than would any single lens, without any marked distortion. Wollaston invented also a lens consisting of a pair of hemispherical lenses with their plane faces turned towards each other, and a stop or diaphragm between. The lenses known as the *Coddington* and the *Stanhope* are very similar to this last. We must also mention a modification of Wollaston's doublet which was proposed by Mr. Holland, and consisted in substituting two lenses for the single lens next the eye. This arrangement is called the Holland triplet.

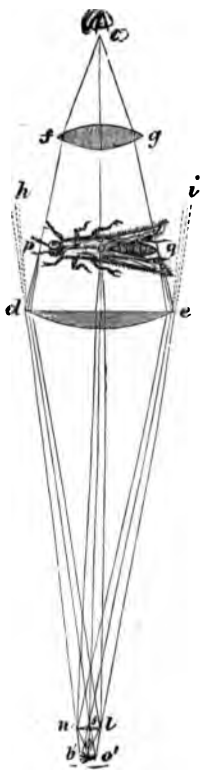


FIG. 6.

One of the earlier forms of the compound microscope may be illustrated by Fig. 6, which shows how the rays from a small object may form a magnified image of it. The first combinations, constituting compound microscopes, such as were made in Holland at the end of the sixteenth century, were simpler still. Huygens is of opinion that this instrument was invented not long after the telescope, and ten years earlier than the compound microscope; he tells us that in 1621 microscopes of this kind were seen in possession of Cornelius Debrell of Alkinaar, who resided in London, as mathematician to James VI.; and, adds Huygens, "those who were present have often told me this, and also that he was the first inventor of them." This statement is, however, contrary to that of Peter Borell, Dutch ambassador in 1691, who says that Debrell showed him a microscope which had been made by Jansen, the spectacle-maker at Middleburg, in 1590, and presented to the archduke of Austria; it was said to be six feet long. In the preface to the works of Galileo, published at Milan in 1808, it is stated that Galileo invented the microscope and telescope about the same time, and that he applied the former to examine objects otherwise invisible. Sir David Brewster, however, thinks it more probable that Galileo might have made a microscope in imitation of Jansen's, as he did the telescope. It is obvious that no single individual can be considered as the inventor of the microscope. In the preface to his *Micrographia*, published in 1667, Hooke describes his compound microscope. It was three inches in diameter, and provided with a number of tubes, by which it could be lengthened as occasion required. It had three glasses, but when it was necessary to examine the minute parts of an object, the middle glass was dispensed with. A microscope is described by Eustachio Divini, in the *Transactions* of the Royal Society for 1668, consisting of object-glass, a middle glass, and two eye-glasses. The eye-glasses were very large, three or four inches in diameter. In 1698 we find descriptions of two other forms of compound microscope; and from time to time, during the eighteenth century, various modifications of the compound microscope were devised, and some improvements effected in the mode of illuminating the objects. But the instrument remained so comparatively inefficient, that Wollaston declared it as his opinion that the compound microscope would never rival the single. Nor, indeed, did it until the principle of the achromatic lens had been applied to the object-glass of the microscope. This was accomplished in a successful manner only after the first quarter of the nineteenth century had passed; and the names that we find associated most prominently with these improvements, which, in another quarter of a century, have brought the compound microscope to be one of the most perfect instruments in the hands of the scientific inquirer, are those of Amici, in Modena; Selligues and Chevalier, in Paris; Frauenhofer, in Munich; Dr. Goring and Mr. Tulley, in London. Others, who largely aided and encouraged the improvements in the microscope, were Sir David Brewster, Sir John Herschel, Mr. Lister, Mr. Solly, and Mr. Bowerbank. At the present time we have in England several makers of microscopes, whose work is unsurpassed even by the most distinguished of their continental rivals.

Sir David Brewster likewise first pointed out the value of precious stones in the construction of microscopes. He formed lenses of ruby and garnet greatly superior to those of glass. Diamond lenses were next executed by Dr. Goring and Mr. Pritchard. Sapphire, zircon, topaz, and rock-crystal have also been used; but the diamond, when pure and homogeneous, and the garnet and spindle ruby, which have no double refraction, are the most suitable. It has been objected that diamonds are too expensive; and, says Sir David Brewster, "they certainly are, for instruments intended merely to instruct and amuse; but if we desire to make great discoveries, to unfold secrets yet hidden in the cells of plants and animals, we must not grudge even a diamond to reveal them."

It may now be not inappropriate that the reader should have placed before him some of the forms in which the instrument is now constructed by our best makers. But first we show in the diagram (Fig. 7) the object-glass of the modern compound microscope. It consists of three small plano-convex lenses, each of which is an achromatic combination of two lenses of different kinds of glass, cemented together. Fig. 8 will show the mechanical arrangements and aspect of a large and tolerably complete instrument. The large milled head, on the left, is for the rough adjustment; the small milled heads, near the tube, are for fine adjustment, and the two remaining ones are to give motion in two directions to the "traversing stage," for placing any required part of an object in the field. An instrument of simpler construction, well adapted for the use of students, or for the every-day work of a physiological laboratory, is represented in Fig. 9. A description of the various ingenious and elegant optical and mechanical adjuncts of the microscope would be far beyond the scope of this present article. Among the forms of the instrument which have aided in popularising the use of the microscope is the *binocular*, in which the rays that have passed through the object-glass are so divided by a prism, that half are sent to one eye-piece and half to another, in such a manner that the object may be viewed with both eyes at once, as in the ordinary opera glass. The resulting image presents the

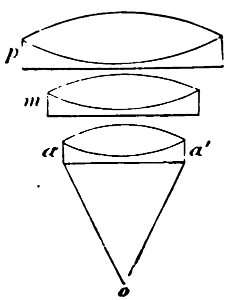


FIG. 7.

object in full relief, and the use of the instrument is commonly more agreeable to the eye than that of the monocular microscope. But the binocular form of instrument commonly

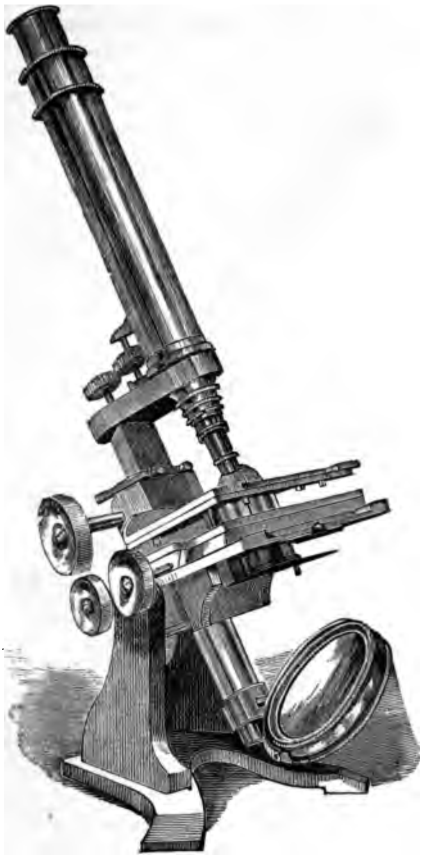


FIG. 8.—BAKER'S COMPOUND MICROSCOPE.

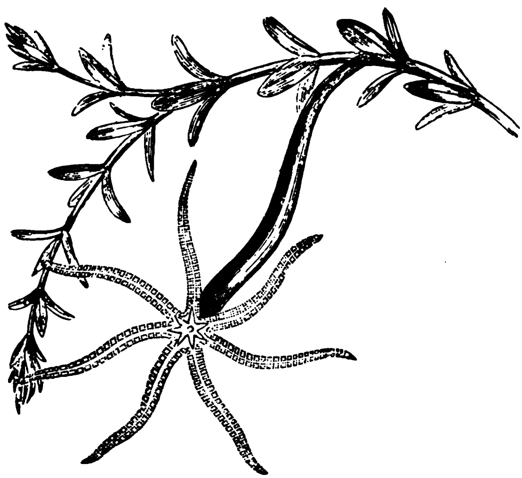
has a mechanical arrangement for withdrawing the prism when object-glasses of high power are used, so that one of the eye-pieces then receives the whole of the rays.

It would hardly be possible to over-estimate the services microscope has rendered to all branches of science. E those early researches of M. Trembley, of Geneva, wl enabled him, in 1739, to give an accurate description of "Fresh-water Polype," or *Hydra*, had the effect of chan

Fig. 9.—The Student's Microscope.

profoundly the conception of zoologists on the nature of mal life. *Hydræ* are found in ponds and streams, cli to the leaves of water-plants; and when stretched out appear like delicate hairs, of a quarter or half an in

:h. A common form is shown in Fig. 10. For the first an animal was found capable of propagating by bud-, like a plant; and of reproducing a perfect individual, ι even a small fragment of its body. Space would not nit even to name the structures and processes of organic which the microscope has been the means of revealing. ; this instrument that has created the science of *Histology*, ch describes the animal and vegetable tissues in reference their origin and development. Hence, physiologists have



10.—HYDRA, WITH ITS TENTACLES DISPLAYED AND MAGNIFIED, ADHERING TO A STALK OF ANACHARIS ALSINASTRUM.

n led to the remarkable conclusion, that each integral :ion of the animal or plant performs a series of actions ıliar to itself; and, as Dr. Carpenter expresses it, "the of a body, as a whole (like a symphony performed by a orchestra), consists in the harmonious combination of its rate instrumental acts,—the circulation of the blood, in-d of *making the tissues*, simply affording the supply of iment at the expense of which they *evolve tremulæ* from ıs previously existing. A single primordial cell, therefore, e first step in created life, and from the congeries of cells, to all appearance similar and equal, are developed those various parts of the noble casket which constitutes man, and incloses his immortal soul." *

"The comparative anatomist," observes the writer of a popular treatise on the microscope, "makes use of this instrument to determine from the structure of the teeth, the form, habit, and class of animals which lived, and have become extinct on our earth for many thousand years. Thus, Professor Owen, from the examination of the structure of the tooth of the megatherium, by demonstrating the identity of the dental structure with that of the sloth, has yielded us an unerring indication of the true nature of its food. By the aid of high-power magnifying glasses, we are informed that our island was once possessed of a climate nearly approaching to a tropical one; for if we examine a piece of drift-wood, found in the *eocene* clay (so called from its being the dawn of a new creation) of the estuary of the Thames, we shall find that these fragments belong to a class of plants nearly allied to the pepper tribe, and that they flourished in company with the turtles, vultures, crocodiles, and boa-constrictors of the Sheppey district."

There is a method of exhibiting to a number of persons simultaneously, greatly magnified images of small transparent bodies. It is the method of projecting images on a screen, with which everybody is familiar in the magic lantern, which is now so commonly used for displaying magnified images of photographic transparencies. When natural objects, illuminated not by a lamp but by sunlight, have their images similarly projected on a screen, the apparatus receives the name of the *solar* microscope. The only limit to the magnification of these images would be the imperfection of the optical apparatus; and the exhibition is, of course, more entertaining than solitary observation, and readily lends itself to popular scientific exposition. But as a supply of direct sunshine could not be commanded, an apparatus, which is identical with the solar microscope in all but its means of illumination, was quickly devised when a source of intense artificial light was available.

In 1832 was produced the oxyhydrogen microscope, which has since become so attractive in popular exhibitions. This novel application of Lieutenant Drummond's light was as

* *North British Review*, No. 50.

s :—A stream of oxygen gas, and another of hydrogen were brought into union and projected in an ignited upon a mass of lime, producing a light of intense acy, which, passing through a lens, threw the image of s magnified 10,000 to 100,000 times, in the manner of r microscope, upon a disc of 14 feet diameter. The iate objects consisted of fragments of insects, grass, ed, wood, &c. ; the minute external properties of which shown upon an exaggerated scale. A few hairs of an appeared like tubes, two inches in diameter. A small n of human skin exhibited the courses of the arteries ins. The sting of a bee was a monstrous barbed weapon, long. The lancet of the horse-fly was a sabre, about in length. But the most curious part of the exhibition ted of the animalculæ in a drop of water, some of which seen preying on each other; some skeleton larvæ ex- l even the vesicle of air which enables them to rise and id in the water; and some of the worms found in stag- vater appeared like large serpents.

roscopic research has been greatly advanced by the ishment of associations like the Microscopical Society of on, which was instituted, in 1839, expressly for encourag- iprovements in the optical and mechanical construction instrument, for the intercommunication and discussion, g its members, of observations and discoveries, and for xhibition of new appliances and objects. This society hes a journal at regular periods. Similar associations been established elsewhere; and in the United Kingdom large town has some association of amateur naturalists ed to microscopic research. Many of these have con- ed valuable additions to our knowledge; and there can doubt that the zeal of amateurs, if wisely directed, might ofitably expended in penetrating many of those mysteries iich the microscope gives the key. The interest mani- l in the results of the microscopic investigation of nature, licated by the fact that the *Journal of the Microscopical y* is by no means the only English periodical now ed to matters pertaining to the microscope.

CLOCKS AND WATCHES.

THE construction of the Barometer and Thermometer, the Sun-dial, the Compass, and the Clock, belongs to Directive and Registrative Science, the leading facts of which have been thus felicitously illustrated by Professor George Wilson. "There is," says this eloquent expositor "no more familiar natural phenomenon than that the sun leave in shadow that side of a body which is turned from him, an that this shadow changes its place in obedience to the apparet motion of the sun. And with no more than this fact of natui made over to him, even the barbaric mechanician construc his useful sun-dial, and the day measures itself into hours. 'Th wind,' said King Solomon, the greatest naturalist of his tim 'goeth toward the south, and turneth about unto the north it whirleth about continually: and the wind returneth accor ing to his circuits.' And the sailors of the ships of Tarshis had, like our sailors, their wind-vane and streamers, the anemoscopes and anemometers, though they did not so nan them, to tell from what quarter, and with what force the wir blew. The clock moved by the falling weight, the hour-glas with its noiseless shower of sand, the wheel turned by tl stream of water, the mill wrought by the ebb and flow of tl tide, the sea-salt crystallized by the heat of the sun, the borac acid of the volcanic lagoon evaporated by the heat of tl volcano, the direction and force of the wind noted down o paper by the anemometer, *i.e.* by a pen put between the finge of the wind itself, the photographic pictures which we comp the sun to draw with a chemical pencil of his own providin as often as we choose to spread a tablet before him: these a:

but a few familiar examples of the office of Directive Science. Between it and Registrative Science it is impossible to draw a sharp line of demarcation. A balance or steelyard, for example, falls as much within the one category as the other ; so do all kinds of chronometers. But where we avail ourselves of a natural agency, like the winds, as a mechanical motive power, or like solar heat, to induce chemical change, we may conveniently refer it to Directive Science ; whilst, where we employ such agency simply to signal to us a change in events, as when the sun-dial marks the passage of time, the compass-needle altered direction in space, or the thermometer altered temperature of the atmosphere, we may with equal propriety refer it to Registrative Science."

The earliest measurement of time, it is reasonable to suppose, must have been by those means which nature herself suggested. The rising and setting of the sun, and the changes of the moon, must in all ages and countries have first marked the periods fixed by men to unite for labour or recreation. The shepherd of the early ages reckoned by full moons, as does the hunter of the prairie at the present day. The shortening and lengthening of the shadows of rocks, trees, and mountains, gave the first notion of dividing the interval between sunrise and sunset, and afforded the first idea of the sun-dial. The sun-dial of King Ahaz, who lived about 742 years before Christ, is the first on record. Herodotus ascribes the invention to the Babylonians, although he states that the first used in Greece was made by Anaximander, B.C. 546 ; the first constructed on mathematical principles was planned near the temple of Quirinus at Rome, B.C. 293 ; until which period the heavenly bodies appear to have been the only measure of time known to the Romans.

The most perfect Sun-dial was, however, unavailable when the atmosphere was charged with clouds ; hence the dropping of water, or the running of sand through a tube, being nearly a regular motion, was at a remote period applied to the measurement of time. Hour-glasses were invented at Alexandria, B.C. 149 ; and Vitruvius relates that about the year B.C. 145, Ctesibius of Alexandria invented a *clepsydra*, or Water-Clock. This consisted of a small boat floating in a vessel which had a hole in it ; as the water escaped the boat gradually descended, while an oar placed in it pointed to the hours marked on the side of the vessel ; Ctesibius is even said to have applied toothed wheels to water-clocks. Clepsydræ were constructed in which the water dropped through a hole made in a pearl, as it was considered that neither could adhesion take place to fill up the hole, nor could the constant running of the water enlarge it. The clepsydra was used in Athens, as indicated by Demosthenes in his pleadings. In the third consulship of Pompey, it was first adopted at Rome. Pliny relates that Scipio Nasica discovered a method of dividing the hours of the night by means of water; and this is nearly all we know of the instruments for measuring time used by the ancients.

In modern times, Dom Charles Vailly, a Benedictine monk, is said to have improved the water-clock into a scientific instrument, about 1690; this instrument was a tin cylinder, divided into several small cells, and suspended by a thread fixed to its axis, in a frame, on which the hour distances, found by trial, were marked. As the water flowed from one cell into another, it very slowly put the cylinder in motion, so as to indicate the time on the frame. Later, an alarum, consisting of a bell and small wheels, was fixed to the top of the frame in which the cylinder was suspended, and a dial-plate with a handle was placed over the frame.

The French historians describe a clepsydra sent to Charlemagne by the Caliph Haroun al Raschid, in the year A.D. 800: it was of gilded bronze, round which the course of the hours was displayed; at the end of each hour, the number of brazen balls requisite to mark the hour was thrown out from above, and falling consecutively on a cymbal below, struck the hour required; and a corresponding number of horsemen issued from windows placed around the dial. These details are questionable: it is, however, more certain that the above is the first timekeeper recorded to have struck the hours.

Wheelwork was known and skilfully applied by Archimedes; but no description of any piece of mechanism resembling our clocks is found among the ancient Greeks. It would be almost impossible to point out when, where, and by whom the clock with wheels, having a balance, was first invented. It was, however, originally called an *horologe*—the word clock (probably from the French *cloche*) being applied even as late as the fourteenth century to the bell which was rung to announce certain hours indicated by the sun-dial or clepsydra.

The Romans learned to make sounding clepsydræ; and later still, Lucian describes, among the conveniences of certain newly-built baths, an *horologium* that proclaimed the hour by means of a roaring sound; this sound was, no doubt, produced by hydraulic pressure upon the air contained in a cupola with pipes attached to it.

Candle Clocks, by which Alfred the Great measured and rightly divided his time, consisted of six wax-candles, each twelve inches in length, with the divisions of inches distinctly marked upon it. These being lighted one after another regularly, burnt four hours each, at the rate of an inch for every twenty minutes. The six candles thus lasted 24 hours. The tending of these candle-clocks Alfred confided to one of his domestic chaplains, who constantly, from time to time, gave him notice of their working. When the winds blew, and caused the candles to burn faster, how the ingenious king surrounded the candles with horn in wooden frames, to make them burn steadily in all weathers, and thus made lanthorns, we need scarcely relate.

The first author who has introduced the term "clock" as applicable to a clock that struck the hours appears to be Dante, who was born in 1265, and died in 1321.* It, however, would appear that Striking Clocks moved by weights and wheels began to be made in the monasteries of Europe about the eleventh century.

The first clock of which we have authentic record was invented by Richard Wallingford, Abbot of St. Alban's, who in 1326 (reign of Edward I.) had it placed in his monastery. It showed the hours, the apparent motion of the sun, the changes of the moon, the ebb and flow of the tides, &c.; it continued to go until the time of Henry VIII., when Leland said, "all Europe could not produce such another." Wallingford was the son of a blacksmith, and at ten years of age the Prior of Wallingford took him under his care, and prepared him for Oxford. The account which Wallingford gives of his clock is preserved in the Bodleian Library.

The old clock in Wells cathedral (which was removed from Glastonbury at the Reformation) was commenced about the year

* The etymology of the word Clock is variously stated: thus, we have the following:—Saxon, *clugga*, *clucga*; German, *klocke*; Armoric, *cloch*, or *clech*; Irish, *clog*; Welsh, *cloc*; Belgic and Danish, *kloke*; Teutonic, *glocke*; French, *cloche*; Latin, *glocio*; Chinese, *glog*. It originally meant only a bell for striking a sound, and that signification it still retains in the French language.—*Curiosities of Clocks and Watches*, by E. J. Wood, 1866.

1325, by Peter Lightfoot, a monk of Glastonbury; the dial showed the motions of the sun, moon, &c.; on the top of the clock, eight armed knights pursued each other with a rotatory motion. The bell of the Wells clock is to this day called the *horologe;* and *clocks*, even at so late a period as the reign of James I., were often called *horologes*. The old interior works of this clock were of iron and brass, not differing materially in principle from the mechanism of later clocks, except that the appliances for the variety of the movements of the dial-plate were necessarily complicated. They exhibit a rare and interesting specimen of the art of clock-making at so early a period, in which the monks particularly excelled. After going five centuries, the works were found to be so completely worn out that about the year 1835 they were replaced by a new train, made by Thwaites and Reid, of Clerkenwell.

The middle of the fourteenth century seems to be the time which affords the most certain evidence of the existence of what would now be called *a clock*, or regulated horological machine. There is a clock at Dover castle bearing the date 1348. To this may be added the following records:—(1) It is said that the first clock at Bologna was fixed up in 1356. (2) Henry de Wyck, or Henri de Vic, a German artist, placed a clock in the tower of the palace of Charles X., about the year 1364, which has been generally described as the earliest clock of which the actual construction is known; and Mr. E. B. Denison, in his *Treatise on Clocks*, mentions a clock in Peterborough cathedral, still in use as to the striking parts, of which the combination is more like that of the Dover castle clock than that of De Vic, which was a large striking clock, going one day, and with one hand, (the hour-hand), and much the same except in the escapement, as many old church clocks still in existence. (3) Mention is made in Rymer's *Fœdera* of protection being given by Edward III. to three Dutch horologiers, who were invited from Delft into England, in the year 1368. (4) Conradus Dasypodius erected the great Strasburg clock about 1370. (5) According to Froissart, Courtray had a Clock about the same period, which was taken away by the Duke of Burgundy in 1382. (6) Lehmann informs us that there was a clock at Spire in 1395. (7, 8, 9) Nuremburg had a clock in the year 1462; Auxerre had one in 1483; and Venice in 1497. (10) The curious clock still to be seen in the north tower of Exeter cathedral is said to have been invented by Bishop

:enay in 1480; in this the earth is represented by a globe : centre, the sun by a fleur-de-lis, while a ball is painted and white, so as to represent the moon's phases by turning axis. (11) Clocks, according to a letter of the period, not very numerous in private families on the Continent the end of the fifteenth century; but there is good reason pposing that they became general in England about the period; for we find in Chaucer, who was born in 1328, ied about 1400, the following lines :—

> "Full sick erer was his crowing in his loge,
> As is a *clock*, or any abbey orloge."

·dinand Berthoud, who has written more on the subject of .work than any other person, concludes his researches with elief—for which there appear to be good grounds—that k, such as that of Henry de Wyck, is not the invention of ıan, but a compound of separate inventions, each worthy eparate contriver. Thus (1) Wheelwork was known and :d in the time of Archimedes. (2) A weight being applied naintaining power, would, in all probability, at first have similar to that of a kitchen-jack, to regulate the velocity. 'he ratchet-wheel and click for winding up the weight with-etaching the teeth of the great or main wheel from those e pinion in which they were engaged, would soon be found lispensable contrivance. (4) The regulation by a fly being ct to such great changes from the variations of density in tmosphere, and the tendency of a falling body to accelerate otion, would necessarily give rise to the automaton motion e balance, with which invention an escapement of some must have been coupled. (5) The last-mentioned two in-ons are most important ones, and would have induced such ;ree of equability in the motion of the wheelwork as would the way to a dial-plate, and its necessary adjuncts, a hand ınter; lastly, the striking part to proclaim at a distance, ıut the aid of the person to watch the hour that was indi-l, completed the list of inventions. And the supposition, De Wyck's clock was a combination of the successive in-ons of different individuals is confirmed by analogy; for :locks and watches of the present day have been brought eir degree of perfection by a series of successive inventions improvements upon what may now be called the rude clock of De Wyck, which is the most ancient clock of which we have a description.

One of the first additions to the mechanism already described was the alarum, or alarm, originally invented for arousing the priest to his morning devotions. Prior to 1344, when *small* clocks are first mentioned, the main-spring must have been substituted for the weight, as the moving power; and this may be considered a second era in horology, from which may be dated the application of the fusee; for these inventions completely altered the form and principles of horological machines. Of these small or portable clocks, one of the oldest in this country in a perfect state is the astronomical clock possessed by the Society of Antiquaries; this clock was made at Prague, in 1525, it is enclosed in a gilt brass case, and has a dial on the upper surface.

The clock placed in one of the towers of the palace at Hampton Court, in 1541, is described as the oldest English-made clock extant. When in action, it showed the motions of several of the planets. The dial and part of the wheels attached to the back of the dial still remain; and the small remnant of this venerable piece of mechanism may perhaps rise in our estimation when we remember that it was contemporary with Copernicus.

Henry VIII. appears to have patronised foreign artisans only. We find cited payments to the astronomer for mending a clock. At Strawberry Hill was a little clock of brass-gilt, which had been presented by Henry VIII. to Anne Boleyn, upon their marriage in 1532. At the Strawberry Hill sale, this famous clock was purchased by Queen Victoria for 110*l.* 5*s.*, it is now at Windsor Castle, and in going order; it is richly chased and engraved; the whole train is comparatively of recent date. Among valuable effects belonging to Henry VIII. in the palace at Westminster, in 1542, are several clocks, of iron, copper-gilt; and the same year Sir Anthony Denny presented to the king, as a new year's gift, a very singular clock, designed by Holbein. It had on its summit a clock driven by wheel-work, below which were fore and after-noon dials showing the time by shadows; and beneath them was a clepsydra, indicating the quarters of an hour by means of a fluid.

At Walton Hall is the clock which Sir Thomas More used in his study, and which is shown in the famous picture of the More family at Chelsea, designed by Holbein.

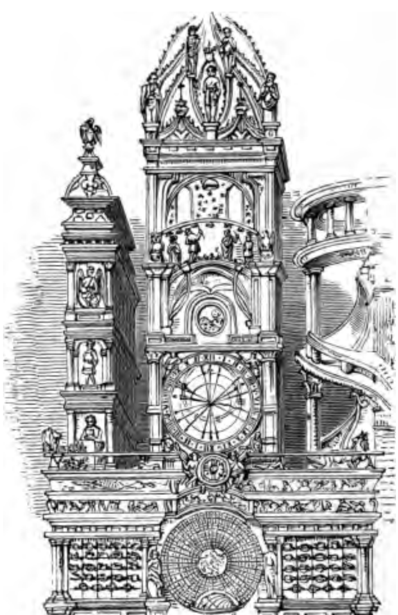
Martinelli, in 1663, describes an old clock going in his time on the Grand Piazza at Venice, in which, while two Moors struck the hour, three Kings entered from a door, and after making obeisance to figures of the Virgin and Child, placed in a niche, returned through a door on the opposite side. The striking figures in the above clock remind us of the two life-size figures of savages in an alcove outside the old church of St. Dunstan, in Fleet-street, and who, each with a club, struck the quarters upon two suspended bells, moving their heads at the same time. This clock and figures were made in 1671, by Thomas Harrys, then living in Water Lane. On the church being taken down, in 1829, the figures were sold, and are now set up in the grounds of St. Dunstan's Villa, Regent's Park. There is a like contrivance to the above in Norwich Cathedral; and the Paul's jacks at old St. Paul's were of this class of contrivances.*

The old church at Lubeck has a specimen of early clock-work, representing the changes of the heavenly bodies until 1875; and when it strikes twelve, a number of automatic figures are set in motion; the Electors of Germany enter from a small side door, and inaugurate the Emperor, who is seated upon a throne in front. Another door is then opened, and Christ appears, when, after receiving his benediction, the whole cavalcade retire amidst a flourish of trumpets by a choir of angels.

The famous Strasburg Clock, already mentioned, is in the south transept of the cathedral, and was made by a living artist of Strasburg, to replace the older one, which had fallen to decay. The full mechanism is set in motion at noon only.

* About this date, a new regulator for clocks was thus announced in the *Commonwealth Mercury*, Thursday, November 25th, 1668.—"There is lately a way found out for making clocks that go exact and keep equaller time than any now made without this regulator (examined and proved before his Highness the Lord Protector by such doctors, whose knowledge and learning is without exception), and are not subject to alter by change of weather, as others are, and may be made to go a week, or a month, or a year, with once winding up, as well as those that are wound up every day, and keep time as well; and is very excellent for all house clocks that go either with springs or weights; and also steeple clocks, that are most subject to differ by change of weather. Made by Ahasuerus Fromanteel, who made the first that were in England. You may have them at his house, on the Bankside, in Mopes-alley, Southwark; and at the sign of the Maremaid, in Lothbury, near Bartholmew-lane end, London."

The original clock was described in 1580, as having on its plate a celestial globe, with the motions of the sun, moon, earth, and planets; the phases of the moon; and a perpetual almanac on which the day of the month was pointed out by a statue; the first quarter of the hour was struck by a child with an apple, the second by a youth with an arrow, the third by a man with the tip of his staff, and the last quarter by an old man with his crutch. The hour itself was struck on a bell by the figure of an angel, who opened the door and saluted the Virgin Mary; near to the first angel stood a second, who held an hour-glass, which he turned as soon as the hour had finished striking. In addition to these was the figure of a golden cock, which, on the arrival of every successive hour, flapped its wings, stretched forth its neck, and crowed twice. Two hundred years after, this celebrated clock was almost entirely renewed, when great alterations in the original mechanism were made. A clock with similarly complicated machinery, though differing considerably in its external performances, was erected about the year 1385 in the cathedral of Lyons. *La Grosse Horloge* at Rouen has none of this machinery, but is remarkable for its large size and antiquity.



THE STRASBURG CLOCK.

Towards the end of the last century, a clock was constructed by a mechanic of Geneva, named Dros, with figures of a negro, a shepherd, and a dog. When the clock struck, the shepherd played six airs on his flute, and the dog approached, and fawned upon him. This clock was exhibited to the King of Spain, who, at the request of Dros, took an apple from the shepherd's basket, when the automaton started up and barked so loudly, that the King's dog which was in the same room, began to bark also.

At Versailles, in the *Cour de Marbre* of the palace, is "the clock of the King's death;" it has no mechanism, and only one hand, which is placed at the precise moment of the death of the last King of France, and which does not move during the whole of his successor's reign. This memorial dates from the time of Louis XIII.

One of the most celebrated ancient clock-towers was that of stone, which, in 1365-6, Edward III. caused to be erected at Westminster, in the courtyard, opposite the great Hall, and near the site of the present clock-tower of the Houses of Parliament. This *clochard*, or bell-tower, contained a clock which struck every hour on a great bell, to be heard in the Hall, in sitting-time of the Courts; and, in a calm, in the City of London. The tower also contained other large bells, which Stow tells us were "usually rung at coronations, triumphs, the funerals of princes, and their obits—of these bells men fabled that their ringing soured all the drink in the town." In the accounts we find nothing respecting the construction or even placing of the clock, or the casting of the bells; but bell-ropes and a vice or engine occur. In later accounts (Henry VI.) we however have the expense of maintaining the clock and bells. Thomas, Clockmaker, received 13*s*. 4*d*. a year as his salary for general superintendence; he also received 8*s*. for the making of the sail (*velum*) when it was broken; 6*s*. 8*d*. for amending the spring of the barrel; 12*d*. for the wire of the stobil, &c.; two great ropes (52 lb. and 49 lb.) at three halfpence the pound; for two ropes of thread for the little weight, 2*s*.; and for boards, laths, and matts, "bought for to stop the wind from the said clock," 22*d*. It is said that Henry VI. gave the keeping of this clock, with the tower and appurtenances, to William Warby, or Walsby, Dean of St. Stephen's, together with sixpence per day remuneration, to be received at the Exchequer. This clock-tower was demolished in 1715, and its site was denoted by a dial, which was engraved by Hollar; its bell, called "Great Tom of Westminster," was granted to St. Paul's.

Among the earliest of the Wheel Clocks seen in England was that of St. Paul's cathedral, London, in the year 1286, when the allowances to the clock-keeper were at the rate of a loaf daily, and a liquid measure, probably of beer. In 1344 an agreement relating to a clock then in the cathedral shows that iron and steel were then used for the frame and clock, as they were until towards the end of the sixteenth century; and the blacksmiths were in early times the makers of them, as the materials required heavy forging. In the *Affairs of the World*, 1700, it is stated that "Mr. Thompson, the famous watchmaker in Fleet-street, is making a clock for St. Paul's cathedral, which, it is said, will go one hundred years without winding up; will cost 3000*l.* or 4000*l.*, and be far finer than the famous clock at Strasburg:" this project was not, however, carried out. The present clock at St. Paul's is remarkable for the magnitude of its wheels, and the fineness of its works. It was made by Langley Bradley, in 1708, at a cost of 300*l.* It has two dial plates, one south and the other west, each between 50 and 60 feet in circumference, and long stated to be the largest in this country furnished with a minute-hand. The hour-numerals are a little over 2 feet in height; the minute-strokes of the dial are about 8 inches in length; the minute-hands are about 8 or 9 feet long, and weigh 75 pounds each; and the hour-hands are between 5 and 6 feet long, and weigh 44 pounds each. The pendulum is 16 feet long, and its bob weighs 180 pounds; but it is suspended by a spring no thicker than a shilling. Its beat is 2 seconds, that is, a dead-beat of 30 to a minute instead of 60. The clock goes eight days, and strikes the hour on the great bell, which is suspended about 40 feet from the floor. The hammer lies on the outside brim of the bell, has a large head and weighs 145 pounds, is drawn by a wire to the back part of the clockwork, and falls again by its own weight on the bell. The clapper weighs 180 pounds. The diameter of the bell is 10 feet; its weight is about 102 cwt., and it is inscribed "Richard Phelps made me, 1716." Below this bell are two smaller ones, on which the clock strikes the quarters.

Mr. T. Reid, in his *Treatise on Clock and Watch-making*, observes, that in St. Paul's clock, the fall for the clock-weight allows of such a force as, by the stroke of a hammer, it can make a bell of 11,474 lb. be heard at a distance of 22 miles. "We heard it in June, 1773. The day was still and calm; and attending to try if the clock could be heard when striking the twelve o'clock hour at noon (which we did hear), the sound which came through the air was not like that of a bell, but had a low, dull, and feeble tone, barely perceivable."

In 1288 or 1289, Westminster was provided with a public clock and clock-house built with a fine upon Chief Justice Hengham, which clock is stated to have been the work of an English artist. St. Mary's, at Oxford, was also furnished with a clock, in 1523, out of fines imposed on the students of the University.

Clocks remained with balances, it seems, for about 300 years after De Wyck's time, or till towards the middle of the seventeenth century, when pendulums were first applied to clocks. Before this time it was known that if a weight fastened to a string were suspended and put in motion, the several oscillations would mark small divisions of time with greater accuracy than any other known means. It is usually stated that the great Galileo, while a student at Pisa, observed that a lamp suspended from the roof of the cathedral performed its oscillations, whether great or small, in equal periods; and he afterwards discovered that the number of oscillations performed by a pendulum in any given time depended on its length. Galileo is then said to have suggested the application to a clock; but this cannot be reckoned among his discoveries, "for the ancient astronomers of the East employed pendulums in measuring the times of their observations, patiently counting their vibrations during the phases of an eclipse, or the transit of the stars, and renewing them by a little pressure of the finger when they languished; and Gassendi, Ricciali, and others in more recent times, followed their example."*

The invention is thought to have been made independently by several persons about the same time. Within the pediment of St. Paul's church, Covent Garden, built by Inigo Jones, was placed a pendulum clock, made by Richard Harris, in 1641, and stated by an inscription in the vestry to be the first made. If this inscription be correct, it negatives the claim of Huygens to having first applied the pendulum to the clock about 1657: although Justice Bergen, mechanician to the Emperor Rodolphus, who reigned from 1576 to 1612, is said to have attached one to a clock used by Tycho Brahe.† Inigo Jones, the architect of St. Paul's, having been in Italy during the time of

* *Encyclopædia Britannica.*

† In 1560, Tycho Brahe possessed four clocks, which indicated hours, minutes, and seconds: the largest had but three wheels, the diameter of

Galileo, it is probable that he communicated what he heard of the pendulum to Harris. Huygens, however, violently contested for the priority; while others claimed it for the younger Galileo, who, they asserted, had, at his father's suggestion, applied the pendulum to a clock in Venice which was finished in 1649.*

Dr. Hooke also claimed the invention. Mr. Denison considers Huygens to have been the discoverer of the true theory of the pendulum. George Graham was the first, in 1715, to apply a compensating power to counteract the effect of heat and cold upon the length of the pendulum; and John Harrison, in 1726, used different metals to compensate each other, the rods being placed in the form of a gridiron. Striking Clocks were made in great variety in the seventeenth century; several by Thomas Tompion, not only struck the quarters on eight bells, but also struck the hour after each quarter. Repeating Clocks were invented by Barlow, an English clergyman, who in 1676 employed Tompion to execute them.

Two large and important public clocks have been constructed in London since the year 1840. The first is the clock for the Royal Exchange, which was manufactured by Mr. Dent in 1843, and has been pronounced by the Astronomer Royal to be "the best public clock in the world;" the pendulum, which weighs nearly 4 cwt., is compensated, and the first stroke of the hour is true to a second; it has Mr. Airy's going-fusee, by which the winding is effected without stopping the motion; it has also an apparatus which enables it to be set to any fraction of a second. The clock has a remontoir escapement, and the pallets are jewelled with large sapphires. "Mr. Dent, finding himself unable to get this clock made for him, with the energy and genius by which he raised himself from a tallow-chandler's apprentice to the position of the first horologist in the world, he at once set up a factory for himself at Somerset Wharf, Strand; and there, with tools, worth about 2,000*l.*, expressly made for the purpose and under his personal

one of them being three feet, and containing twelve hundred teeth, a proof of the imperfect state of clockwork at that period. Brahe also observed irregularities in his clocks, dependent upon changes in the atmosphere. At the Stowe Sale in 1848, a magnificent Huygens clock, made by Stokenwerk, was sold to Mr. Paxton, for only fifty-one guineas, although it was said to have cost the Duke of Buckingham one thousand.—*Curiosities of Clocks and Watches*, p. 68.

* Adam Thomson's *Time and Timekeepers*, pp. 67, 68.

ons, he manufactured this clock, the first turret-clock
e had constructed." Here also is a set of chimes, 15
by Mears, the largest being also the bell for the clock;
ls, in substance, form, dimensions, &c., are from the Bow-
attern; they are thought to be too large for the tower.
his clock, the trains are contained within a strong cast-
aming; hollow iron drums are used instead of wooden
ers, for the driving barrels; and wire instead of hempen
are used for suspending the weights. The hands are
, and the hammers of the striking part are raised directly
he axis of the driving barrel, without the intervention of
and pinions. The pendulum is compensated, and the
roke of the hour is true to a second. For this purpose
ver and hammer are removed to their greatest distance
the time of striking; and the end of the lever remains
ely poised upon the rounded point of the projecting
of the pin-wheel, until the exact time of striking has
l, when it is released on the instant. The pendulum
nearly 4 cwt., but its vibrations are correct within the
n of a second. The clock has a remontoir escapement,
e pallets are jewelled with large sapphires. The chimes
: of a set of fifteen bells, made by Mears, which cost
the largest being also the hour-bell of the clock.

Westminster Palace Clock was made by Mr. Dent,
from the designs of Mr. Denison, about 1855. The
ials are 22 feet in diameter, and are the largest in the
with a minute-hand, which, on account of its great
, velocity, weight, friction, and the action of the wind
it, requires at least twenty times more force to drive it
he hour-hand. This clock goes for a week. The great
of the going part is 27 inches in diameter; the pendu-
15 feet long, and weighs 680 pounds; and the escape-
which is driven by the musical-box spring, weighs about
ounce. The barrel is 23 inches in diameter, but only
hes long, as it does not require a rope above a quarter
inch thick. The great wheels in the chiming part of
ock are 38½ inches in diameter. The clock is said to
east eight times as large as a full-sized cathedral clock.
rds its keepers 24 hours' work a week in winding up.
s with a rate of under one second a week, in spite of
pheric changes. The clock reports its own time to
wich by electrical connexion, and the clockmaker who

takes care of it receives Greenwich time by electricity, and sets the clock right whenever its error becomes sensible, which seldom has to be done more than once a month. On October 1st, 1859, the great bell sounded for the last time; its predecessor was similarly ill-fated.

The cost of this clock has exceeded 22,000*l.*; the outside gilding of the clock-tower cost 1,500*l.* In 1866 the President of the British Horological Institute stated, on the authority of Mr. Ellis, of the Royal Observatory, that there is no clock at Greenwich that keeps time so well as Mr. Denison's clock in the tower of the Houses of Parliament. It reports its own rate automatically twice a day to Greenwich by electric telegraph, a test to which no other public clock has ever been subjected. Persons taking the time from it should remember that exact Greenwich time is indicated by the first stroke of the great hour-bell, and also by the first stroke of any of the quarter-chimes, except those at the hour.

By electrical clocks, time may be transmitted as follows: The indicator is fixed, and furnished with a clock-face, the axis carrying an index or hand; the communicating disc is moved round by the oscillation of a pendulum, which is kept going by electricity. In this way one good clock can be made to communicate its own time to a series of skeleton clocks at any distance. A system of time-distributing clocks has been in use for about twelve years at Greenwich Observatory. Here are six such clocks, one outside at a distance of 400 yards, and one at London Bridge, all which are maintained in perfect unison by the action of only one pendulum. Every hour throughout the day and night, signals are sent by wires from Greenwich to various public and private establishments in London and elsewhere. Horological electricity also performs the office of dropping time-balls, similar to that at Greenwich, where the parent electro-magnet clock is, at various places in London, and also at Deal. It moreover fires time-guns at Shields and Newcastle; and exhibits an hourly signal in the clock-room at Westminster Palace, to enable the attendant to correct any errors which may happen in the great clock.*

By means of electricity in horology, time is now *laid on* to public and private establishments, and paid for as water or gas might be.

Mr. Vulliamy, who constructed the clock at the Queen's

* *Curiosities of Clocks and Watches*, p. 178.

Mews, Pimlico, has here employed stone dials (6 feet 10 inches in diameter), with the figures sunk (as in the Egyptian monuments), and a sunk centre for the hour-hand to traverse, so as to bring the minute-hand level with the figures, and thus avoid nearly all error from parallax.

The Horse Guards' Clock has about the same popular reputation for correct time at the West-end of the town, that St. Paul's Clock holds in the City. The Horse Guards' Clock was originally made by Thwaites, in 1756; it is a large 30-hour clock, striking the quarters upon two bells. The frame is of wrought-iron; the wheels are of yellow brass; and the pinions are iron, case-hardened. The going-part discharges the hours as well as the quarters, which is a considerable drag upon the clock, the present practice being to make the quarters discharge the hours. Originally, the pendulum was 8 feet 2 inches long, and to reduce the arc of vibration it was furnished with fans—it has been preserved as a *Curiosity;* the striking-parts were of the ordinary description. The work was throughout very coarsely executed. The clock was repaired, and improvements added by Vulliamy and Sons, 1815-16: it has since measured time with sufficient accuracy for any practical purpose not connected with astronomical observations; but much of its reputation may be conventional—from the rigid punctuality with which the slightest military movement is executed. The dials are each 7 feet 5 inches diameter, and painted white, with black numerals and hands; the Whitehall dial is very effectively illuminated at night by a strong light thrown from a lamp, with a reflector, placed on the projecting roof in front of the clock-tower.*

The General Post-Office Clock is described by Mr. Vulliamy as a very beautiful specimen of the art on a small scale, on account of the weight of the pendulum-bob, which is 448 lbs., requiring a maintaining power of only 33 lbs., to cause it to vibrate 2′ 20″ on each side of zero; this weight, considering that it is for an eight-day clock, which is much encumbered with rod-work and other disadvantages, is, in reference to the weight of the bob, an extremely small motive power.

In the International Exhibition of 1862 was a clock by Benson, which struck the hours and quarters on five bells, the largest weighing 22 cwt. The works were 300 feet from the

* A detailed account of the Horse Guards' Clock was communicated by Mr. B. L. Vulliamy to the *Curiosities of London,* 1855.

dial, the connexion being carried on underground. The weights exceeded a ton, and were 200 feet from the works. There was likewise a turret-clock, by Dent, which struck the hours on a bell weighing between three and four tons, and the quarters on four smaller bells. The wheels were of gun-metal; and each of the four dials was seven feet in diameter. Among the other horological machines in the Exhibition were, a steam or speed clock; a chime clock with 50 changes, silent clocks, cuckoo-clocks; a clock with a perpetual register of the week and month; an astronomical clock impelled by gravitation; a regulator to be wound up once in twelve months, and a geographical clock showing the time throughout the world. Several curious clocks are to be seen in the South Kensington Museum. Mr. Octavius Morgan, M.P., has one of the finest collections of clocks in England. The Dukes of Kent and Sussex possessed several valuable clocks at Kensington Palace.

Wooden clocks have been made for about two centuries; they were named Dutch, from being first produced in Holland, but they are now mostly made on the confines of the Black Forest, by peasant families; the labour being divided among the case-makers, the founders of the brass wheels and bells, the chain and chain-wheel makers, the painters and varnishers; and the clock-makers, who put the works together and finish them. The annual export of clocks from the Grand Duchy of Baden alone, not including watches, amounts to 1,000,000*l.* sterling.

American Clocks are made in vast numbers: at Connecticut one firm produces 600 clocks a-day; and in New Haven 50,000 brass eight-day clocks are made in a year at Jerome's factory: the wheels and plate-holes are all stamped, and there is but little manual labour in the whole of the movements. That which is accomplished in an American clock by a spring, the going, was in the tall, old-fashioned eight-day clocks performed by the gradual fall of a heavy weight.

The illumination of public clock-dials, so as to render them visible at night, dates from the year 1827, in London, but they had long before been introduced in the provinces.

The Time-ball signal is an invention of our own days, when everybody wants exact time, but cannot set up a transit instrument to obtain it. In England, especially about the metropolis, we naturally look to the fountain-head of astronomical science in this country, our National Observatory at Greenwich, for a regular supply of Greenwich time; and the question arises, ow is the astronomer in his sanctum to communicate his exact me to the outer world? Very easily. Anything in the shape f an instantaneous signal, given at any pre-arranged instant, nd regularly repeated every day, is all that is required for the urpose. Accordingly, we find that there has been for the past hirty years such a signal given daily from Greenwich Observa- ory. Upon one of the cupolas of that edifice there is to be een a large ball, which at five minutes to one o'clock daily is aised half-way up a mast, upon which it slides. At three minutes to one it is raised fully to the top, and remains there ill the instant of one, when, by the pulling of a trigger of the apparatus that supports it, it suddenly falls; the moment of one o'clock being that at which the ball first leaves the top of the mast, not that at which it reaches the bottom.

The accuracy of a clock depends chiefly on its escapement, or that part of the mechanism which connects the regulating power with the wheelwork. Mr. Babbage tells us that "clocks and watches may be considered as instruments for registering the number of vibrations formed by a pendulum or a balance. The mechanism by which these numbers are counted is technically called a scapement," which it is not easy to describe. Working models on an enlarged scale are almost necessary to make their action understood by the general reader; and unfortunately these are not often to be met with.

Repeating Clocks and Watches are instruments for registering time, which communicate their information audibly only upon the pulling of a string, or by some similar application. Several instruments have been contrived for awakening the attention of the observer at times previously fixed upon. Such are the alarums connected with clocks and watches. In some instances it is desirable to set them so as to give notice at many successive and distant periods of time, such as those of the arrival of certain stars on the meridian. Such was the Astronomical Clock of Ferdinand Berthoud, used at the Greenwich Observatory in the last century, and which, by means of a cord, was made to strike the seconds during the progress of an observation; the number of beats being counted gave the time of duration.

Alexander Cumming, F.R.S., the Edinburgh mathematician and mechanic, made a clock for George III. which registered the height of the barometer during every day throughout the year. This was effected by a circular card of about 2 feet in diameter, being made to turn once in a year. The card was divided by radii lines into 365 divisions, the months and days being marked round the edge, while the annual range of the barometer was indicated by inches and tenths by circular lines described from the centre. A pencil with a fine point pressed on the card by a spring, and, held by an upright rod floating on the mercury, accurately marked the state of the barometer; the card being carried forward by the clock, brought each day to the pencil. It was not even necessary to change the card at the year's end, as a pencil with a different coloured lead would make a distinction between two years. This Barometer Clock cost nearly 2000*l.*, and the maker was allowed a salary of 200*l.* a-year to keep it in repair.*

Curious clocks and clockwork have long formed great attractions in museums for public exhibition, such as that of Cox, the jeweller and mechanician, of the last century, whose collection contained 56 pieces, valued at 197,500*l.*; they were exhibited in Spring Gardens in 1773 and 1774. One of these wonders was a cage of singing birds, all of jewellers' work; their plumage was of stones variously coloured: they fluttered their wings, warbled, and moved their bills to every note of the different tunes they sung, "which were duets and solos, surprising melodies, to the universal astonishment of the auditors." The details of these clockwork automata occupy too much space to describe; Mason, the poet, has done this in a few lines:

"Great Cox, at his mechanic call,
Bids orient pearls from golden dragons fall;
Each little dragonet, with brazen grin,
Gapes for the precious prize, and gulps it in;
Yet, when we peep behind the scene,
One master wheel directs the whole machine:
The self-same pearls, in nice gradation, all
Around one common centre rise and fall."

Clerkenwell has long been the seat of the clock and watch manufacture in the metropolis. About the middle of the last century, Colonel Magniac, a famous clockmaker, had his workshops in an old mansion in St. John's Square; and his automaton clocks did much to render Clerkenwell noted as a clockmaking parish. Two of the most remarkable clocks manufactured by him for the Emperor of China were rare specimens of

* *Curiosities of Clocks and Watches*, p. 145.

chanical skill: in addition to regiments of soldiers, musical formers parading, beasts and birds, all in action, combined show what varied and graceful motions could be produced wheels, pinions, and levers; and while pleasing the eye, also armed the ear by the bell music, tunes, and chimes. Early the present century, the above mansion was taken down; d upon the site was built the clock manufactory of Messrs. Smith and Sons, now the largest clockmaking establishment in erkenwell.

In the yard round which the workshops are built is stored a ock of mahogany, walnut, and oak, the logs of which are to : cut up into boards for cases, after the wood has become ily seasoned. The principal divisions in the manufacture of clock are the brass-casting, the wheel and pinion cutting, the ise-making, and the movement-making. In the foundry the in-metal and brass-work are cast. In the brass-finishing shop, ie clock-rings, or barrels, are turned by the lathe, the hinges eing let into the rings, and soldered, and the whole subjected gain to turning, and finally finished. Here also the dials are ilvered. The cases for the clock-weights and pendulums, of sheet brass, are also made in this shop, at one end of which is a forge, used for forging the hammer stems, pulley-frames, pinions, repeating work, &c., of turret-clocks. Here also the brazing and soldering are effected. The wheels are cut out of solid brass for turret-clocks. The pinions of church-clocks are cut by another machine. The dials are made either of sheet copper, iron, or brass, the faces of which are coated with flake-white and varnish, and put into a stove, until hard enough to be polished to receive the figures; the divisions of the dials being set out by an index plate.

Next are the shops for grinding the edges of clock and watch glasses; and the glass-bending shop, fitted up with a furnace and annealing oven; grinding and polishing, &c. In the department set apart for "the system plan," each man attends to one particular branch of the business. Here is a fusee-engine by which the spiral groove is cut in the solid brass intended for the fusee.

There are two other clock-makers' shops: one for the fine work required for bracket-clocks, regulators, &c.; and the other for the works of turret and church clocks. In the former are constructed the frames of thick brass, hammered, and then pinned up and filed square. The pillars are turned.

and then the arbors of the pinions. The back-cock, the crutch, thumb-screws, and other brass works are then roughed out, and the several parts are finished, chiefly at a hand-lathe. The wheels being also finished, are fixed to their arbors of steel, and the exact positions of the centres of motion determined upon, by the deepening tool; the relative position of wheel and pinion being regulated by an adjusting screw. The maintaining power, consisting of the barrel, the main wheel, the going rachet, and the two clicks, the brass dial-plate, with the hands of steel, and the compensation mercurial pendulum of glass, with its steel rod and index, make up the several parts of the regulator.

Watches, under which name we include Chronometers, the highest forms of watches, are the concentrated results of the horological labours of many centuries; during which the Sun-dial, the Clepsydra or Water Clock, and the Watch were successively, and by advancing gradations of skill, constructed. The word Watch is derived from the Saxon *wæcca*, from *wæcam*, *wæccan*, to wake; the Swedish *vacht* or *veckt*, watch, guard; *vachta*, to watch; and the Danish *vagt*. The name watch was applied to pocket clocks, because they were instruments by which the progress of time could be watched or noticed.

Dr. Arnott has, in his peculiarly lucid manner, thus explained *the difference between a Clock and a Watch*: "A Watch differs from a clock in having a vibrating wheel instead of a vibrating pendulum; and, as in a clock, gravity is always pulling the pendulum down to the bottom of its arc, which is its natural place of rest, but does not fix it there, because the momentum acquired during its fall from one side carries it up to an equal height on the other; so, in a watch a spring, generally spiral, surrounding the axis of the balance-wheel, is always pulling this towards a middle position of rest, but does not fix it there, because the momentum acquired during its approach to the middle position from either side carries it just as far past on the other, and the spring has to begin its work again. The balance-wheel, at each vibration, allows one tooth of the adjoining wheel to pass, as the pendulum does in a clock; and as a spring acts equally well whatever be its position, a watch keeps time, although carried in the pocket, or in a moving ship. In winding up a watch, one turn of the axle on which the key is fixed is rendered equivalent, by the train of wheels, to about 400 turns or beats of the balance-wheel; and thus the exertion, during a few seconds, of the hand which winds up, gives motion for twenty-four or thirty hours."

The invention of the coiled spring, in a watch—the motive power in place of a weight, the source of motion in clocks—dates from the last quarter of the fifteenth century. It has been claimed for Nuremberg, famous for its watches as far back as the year 1477; for the town of Blois, in France; and China is said to have introduced the invention into Germany, whence it passed to France; and so into England. It is certain that Peter Hele, of Nuremberg, so early as 1490, made small watches of steel, which moved without weights, pointed out and struck the hours, and might be carried on the person. And Gaspar Visconti, a noble Milanese poet, alludes to a watch in a sonnet written by him in 1494, whence it would seem that watches had, by that time, found their way into Italy, which has, indeed, claimed for itself the invention of them. In the last century, a watch, said to have been found in Bruce Castle, Fifeshire, found its way into the museum of George III. This watch has a chased silver and blue enamel case, and the ciphers R. B., very indistinct, at each corner; upon the dial plate was engraved "Robertus B., Rex Scottorum;" and over it a thin covering of horn, instead of glass. This watch was assumed to have belonged to Robert Bruce, King of Scotland, who died in 1328; but the inscription was, doubtless, an historical forgery. Of similar character are the stories of the Emperor Charles V. forming a collection of time-pieces, and attempting to make them go together. But watch-making had made rapid progress soon after its invention; for the Emperor had a watch made in the jewel of a ring, and King James had the like. And in 1544, the guild of Master Clockmakers in Paris, obtained a statute from Francis I. securing to them the exclusive privilege of making clocks and Watches, within that city.

The date when watches, as a Continental invention, were first introduced into England, is much disputed. Towards the middle of the sixteenth century, springs were applied as the maintaining power to time-pieces, thus enabling them to be made small and portable; but these pieces, now called *watches*, were imperfect machines, going with even less precision than an old clock; they had only an hour hand, and most of them required winding twice a day. Abbot Whitings' watch, thick and octagon-shaped, and engraved on the cover of the face

"Richard Whytinge, 1536," is of accredited antiquity: it is traceable to the family, one of whom bought it at the sale of Abbot Whiting's personal property, after his execution and the dissolution of his monastery. It came into possession of the last Duke of Sussex, who, at Kensington palace, had the most curious collection of time-pieces in this country. At the sale of His Royal Highness' effects, in 1843, Charles Fitzpatrick Sharpe purchased this watch, which he bequeathed to the late Duke of Sutherland. Count D'Albanne has a silver watch of English workmanship, dated 1529; and in the Leverian Museum was a watch dated 1531. Henry VIII. had a watch that went for a week, and was in going order so late as 1696, when Derham published his *Artificial Clockmaker.* In the "Privy Purse Expenses" of Henry VIII. occur payments for "clokkes," which, it is certain from the descriptions given of them, in some instances, meant watches. Thus, we find 10*l.* 10*s.*, a large amount in those days, paid for a clock in a case of gold, doubtless, what we should now call a watch. In the Great Exhibition of 1851, was a watch said to have been the property of Henry VIII. By a "Royal Household Book" it appeared that Edward VI. had at his palace at Westminster, in 1542, "oone larum or watch of iron, the case being likewise iron gilt, with two plumettes of led:" this throws some light on the origin of the term watch, which is usually applied to small portable machines that do not sound the hours; while the name clock has been given to those instruments which strike upon a bell: the former word, here seeming to be for the first time used, appears to be synonymous with *alarum.*

In early times, watches were often made in the forms of skulls and coffins, suggested, doubtless, by the solemnity of the flight of time. Sir John Dick Lauder has a Death's-head Watch, which formerly belonged to Mary, Queen of Scots, and was bequeathed by her to her maid of honour, Mary Setoun, on Feb. 7, 1587, and afterwards came into the possession of the father of the present owner; this antique watch is of silver gilt, and is most elaborately ornamented. The forehead of the skull bears the symbols of death, the scythe and the hour-glass, placed between a palace and a cottage, to show the impartiality of the grim destroyer; at the back of the skull is Time destroying all things, and at the top of the head are scenes of the Garden of Eden and the Crucifixion. The watch is opened by reversing the skull, placing the upper part of it in the hollow of the hand, and lifting the jaw by a hinge : this part being enriched by engraved representations of the Holy Family, angels, and shepherds with their flocks. The works of the watch form the brains of the skull, and are within a silver envelope, which acts as a musically-toned bell; while the dial-plate is in the place of the palate. This curious work of art, which was made at Blois, is too large to be carried as a pocket watch. Another skull-watch, which once belonged to Mary, Queen of Scots, by its inscription and the date, 1560, shows that Francis II. of France presented it to his young wife many years before watches were supposed to have been brought to England from Germany. Several other of Queen Mary's watches are described : one in a case of crystal, shaped like a coffin; and another, made at Rouen, in which a thread of catgut supplied the place of the chain used in the work of modern watches ;—the catgut is not found in watches later than those of the sixteenth century. The earliest specimen of a chain instead of a catgut is in a golden egg or acorn-shaped watch made by Hans John, of Konigsberg; it has a small wheel-lock pistol, perhaps intended to serve as an alarum.

Watches did not come into general use until the reign of Queen Elizabeth, and then only amongst wealthy persons. The Fellows of colleges and other learned men in this age carried sand-glasses in their hands: for the newly-imported watches had not then commonly superseded the sand-glass. The early watches were worn as much for ornament as convenience; some elaborately pierced, others studded with precious stones, or enamelled both on the inner and outer cases. Some were oval, others octangular, round, cruciform, skull, acorn, pear, melon, walnut, tulip, and purse shaped. They had not glasses, the cases opening at the back and front, and covers pierced for the emission of sound. The wheels were small, usually about one-fourth that of the plate, when the watch was round. The size was greatly enlarged for the pendulum spring. The works were iron and steel, brass being used for the pillars of watches before the invention of the fusee. The wheels continued to be of steel; but, during the second quarter of the sixteenth century, brass was used, and is continued to the present time. These early watches were sometimes so small as to be set in the head of walking-sticks, the clasps of bracelets, in rings or in pendants; and we read of a striking watch mounted in a ring in the year 1542.

In the South Kensington Museum are three early watches, which display the progress of the art within a century of its invention. One is contained in an agate, gold-mounted case, the gold dial enriched with arabesques, and set with rubies. The height of this watch is one inch and three quarters, and its width an inch and a quarter; it is of Italian workmanship. The second watch is in the form of a cross, and in a rock-crystal, metal-mounted case; height 3½ inches, width one inch and a half. The third article at the Museum is a watch-case in bronze gilt, with perforated arabesque ornamentation: it is, probably, Venetian work, about the year 1550. Cruciform watches, of this period, were wrought with representations of the Crucifixion, the Virgin and Child, angels and cherubs.

Queen Elizabeth had a large collection of watches, mostly presents. The Earl of Leicester, Master of the Horse, gave to her in 1571-2, "one armlet or shakell of golde, all over fairely garnishedd with rubyes and dyemondes, having on the closing the air of a clocke." Then we read of other gifts, as "a clocke of golde, garnished with dyemondes, rubyes, emeraldes, and perles;" and in the inventory of the Queen's horological machines are four-and-twenty, mostly watches. Allusions to watches are not unfrequent by our early dramatists. Shakespeare and Ben Jonson have many. In Brome's comedy of the *Antipodes*, 1638, a character regrets that

> —every clerk can carry
> The time of day in his pocket;

and a projector, in the same play, proposes to remedy the grievance by a "project against the multiplicity of pocket-watches."

Watches were not generally worn in the reign of James I., when a watch was found upon Guido Fawkes, which he and Percy had bought the day before, "to try conclusions for the long and short burning of the touchwood which he had prepared to give fire to the train of powder." There is extant a curious watch of this period: it has a silver case, ornamented with mythological figures; it is of oval form; it strikes the hours, and has an alarum; shows the days of the week, the age and phases of the moon, with the days and months of the year, and the signs of the Zodiac. On the inside is a Roman Catholic calendar, with the date 1613. This watch ras a present from the Countess of Arundel to her son, Sir Villiam Howard, K.B., 1629.

The English Watchmakers of the City of London were ncorporated by Charles I. in 1631, and by their charter, all oreign clocks, watches, and alarums were forbidden to be rought into the country. Their journals show that in 1635 brass watch was 40*s*. value. In 1643, 4*l*. were paid to edeem a watch taken from a nobleman killed in battle. In Iollar's four engravings of the Four Seasons, a lady is repreented as Summer, with an egg-watch on her left side, susended from her girdle. Then we read of a seventeenth entury Dutch Watch, with a pedlar and his dog engraved nside the numerals, and outside the circle was rich foliage in Niello work. A gold enamelled hunting-watch of about 1630 or 1640 has four subjects on the front, back, and inner side of the lid and case, representing incidents from the *Gierusalemme Liberata* of Tasso. We have descriptions of several watches which belonged to Charles I., among which is the watch given by the King to Sir Thomas Herbert, and others to Mr. Worsley and Colonel Hammond; the latter, a large silver watch, is engraved with a figure of the King praying, and a praying figure of a man, with Christ above.

In 1658 was invented the spiral or pendulum spring, applied to the arbor of the balance, by which means effects were produced in its vibrations similar to the action of gravity on the pendulum of a clock. This spring was originated by Dr. Hooke, and improved by Tompion, the famous watchmaker, who was originally a farrier, and began his great knowledge in the equation of time by regulating the wheels of a jack to roast meat. Next, Quare, a London clockmaker, by applying the pendulum spring, and its means for regulating the oscillations to the greatest nicety, added to the hour-hand, minute and wheel-hands: many old watches were then altered to receive these improvements. Quare, in 1676, invented the repeating movement in watches, by which they were made to strike at pleasure, usually effected by compressing a spring, which caused a hammer or hammers to strike on a bell the hours and quarters. One of the first repeating watches was presented by Charles II. to Louis XIV. of France. Quare made for William III. a highly-finished repeating watch, which is still in good preservation; as is another made by Quare for James II. The English watchmakers of this century became so famous in their craft, that lest inferior articles should be sold abroad, as their work, a law was passed, in 1698, obliging all makers to put their names on their watches.

Watch jewelling, that is, the application of jewels to diminish the friction of pivots, was employed at the beginning of the last century, though tried much earlier. The horizontal escapement was invented in 1724, by Graham, an apprentice of Tompion, and to whom we are indebted for two of the most valuable improvements in clocks ever made, namely, the dead-beat, or Graham escapement, and the mercurial compensation pendulum. Graham's escapement is still employed in the Swiss watches; but in England it has been superseded by the duplex, and more recently by the lever, which is only the application of the dead-beat escapement to a watch. The inventions of Graham and Harrison, together with the art of jewelling the pivot-hole' of watches, only practised in England, gave to English watches, at the commencement of the last century, such pre-eminence, that the wealthy of every country sought to obtain them.*

In 1764, Arnold, of Devereux-court, in the Strand, presented to George III. a watch of his own manufacture, set in a ring. Its size did not exceed that of a silver twopenny piece. It contained one hundred and twenty different parts, but altogether weighed not more than five pennyweights, seven grains, and three-fourths.† So delicate were the works, that Arnold had to make tools himself before he could make the

* *Curiosities of Clocks and Watches*, p. 315.

† Thus minutely subdivided: The movement complete weighed two pennyweights, two grains, and one-eighth; the great wheel and fusee two grains and three-fourths; the second wheel and pinion three-fourths of a grain; the barrel and mainspring three grains and a half; the third wheel and pinion the ninth part of a grain; the balance, pendulum, cylinder, spring, and collet, two-thirds of a grain; the pendulum spring, the three-hundredth part of a grain; the chain one half of a grain; the barrel and mainspring, one grain and three-fourths; the great wheel and ratchet, one grain; the second wheel and pinion, the seventh part of a grain; the third wheel and pinion, the eighth part of a grain; the fourth wheel and pinion, the ninth part of a grain; the fly-wheel and pinion, the seventeenth part of a grain; the fly-pinion, the twentieth part of a grain; the hour-hammer, half a grain; the quarter-hammer, half a grain; the rack-chain and pulley, one grain and a third; the quarter and half-quarter rack, two-thirds of a grain; the quarter and half-quarter small and common pinion, two-thirds of a grain; the all-or-nothing piece, half-a-grain; the two motion-wheels, one grain; the steel dial-plates, with gold figures, three grains and a half; the hour snail and star, half-a-grain and one-sixteenth.

watch. The King was so delighted with the work that he sent Arnold five hundred guineas. When the Czar of Russia heard of this, he offered Arnold a thousand guineas to make a similar one for him; but this the artist refused, determined that his own sovereign's watch should be unique.

On Christmas day, 1770, Arnold, a watchmaker in St. James' Street, presented to George III. a small repeating watch in a ring, the cylinder of which was made of an Oriental ruby. Its diameter was the 54th part of an inch, its length the 47th, and its weight the 200th part of a grain.

Brequet, the celebrated French watchmaker, who flourished at the end of the last and early in the present century, was greatly encouraged by the Allies in 1815. The Emperor Alexander purchased several of his unequalled watches; and the Duke of Wellington had one of them, which, on touching a spring at any time, struck the hour and minute. It cost the Duke 300 guineas; he carried it fcr many years.

Brequet was not an advocate for flat watches, as he said they impeded the proper action of the wheels, and could not be depended on as time-keepers. He paid some of his workmen 30 francs a day, and none less than a Napoleon. He invented the touch watch (*une montre de touche*), in which the hours were indicated by eleven projecting studs round the rim of the case, while the pendant marked twelve o'clock. An index hand, at the back, when moved forward, stopped at the portion of the hour indicated by the dial; and the index and studs together enabled the time to be felt by the fingers. Touch watches were also made in the seventeenth and eighteenth centuries. A touch watch for the use of the blind was manufactured by Mr. Dent, and exhibited in 1851.

Napoleon I. had a pedometer watch that wound itself up by means of a weighted lever which rose and fell at every step; but those now made are for measuring speed in walking, which can only be useful to such as make regular steps of given length, a known number of which equal a mile.

Some of the old watchmakers made, what may be termed astronomical watches. Thus, we read of an oval silver watch by Dupont, with index hands to show the hours of the day, the day of the week, the day of the month, and the age of the moon, while there are other arrangements for denoting something about the constellations; and inside the cover are a sundial and a compass. Jean Baptiste Duboule, of Geneva, made a large watch which denoted the four parts of the day, th of the day, the day of the week, the day of the mont name of the month, the sign of the zodiac, the age moon, the phase of the moon, and the four seasons year. More practicable was a watch made by a peasant, Kuhaiesky, at Warsaw, which denoted the t different places under different longitudes—a conti which has been imitated in a modern English watch.

In 1839, there was made in Paris, by M. Rebellier, a parent crystal watch, in which the works were all visibl two-teethed wheels, which carried the hands, were of crystal, and the other wheels were of metal. All the were fixed in crystal, and each axis turned on rubie escapement was of sapphire, the balance-wheel of rock-c and the springs of gold. This watch kept excellent which the maker attributed to the feeble expansion crystal in the balance-wheel.

In 1844, Messrs. Hart, of Cornhill, made for the Abdul Medschid, a very costly watch: it was five inc diameter, in a double gold case, enamelled with flowe arabesque scroll-work, in brilliancy surpassing any foreig of the kind. The movement was duplex, with a chronc balance, and jewelled in ten ruby holes; the watch stru hours and quarters by itself. Wires, instead of a bel used, and the sound resembled that of a powerful an monious cathedral clock. The cost of this watch and a panion one, was one thousand two hundred guineas.

The Great Exhibition of 1851 contained several c watches. Messrs. Rotherham and Sons, of Coventry first in England employed machinery impelled by steam- for performing many of the processes in the completio watch, exhibited the various parts of a lever watch sh roughly cast, then as formed into proper shapes, and la finished. Several movements were also shown, and a be display of 137 watches of all kinds. The Internatior hibition of 1862 contained a reversible chronometer, a nometer showing the day of the month, a reversible self-winding watch.

The Chronometer, the most important and valuable that we possess, has long been manufactured in Engl a high state of perfection. The determination of the lor at sea requires simply accurate instruments for the m ıent of the positions of the heavenly bodies. This question ad been but inaccurately solved for want of good Watches, hen, about the year 1756, John Harrison, who had re- eived the Copley Medal for his improvements in watches, ontinued his labours, and in 1758 sent a timekeeper or trial on a voyage to Jamaica, and for its performance eceived 5,000*l.*; for Chronometers of a similar nature, ubjected to trial in a Barbadoes voyage, and explaining the rinciple of their construction, Harrison received 10,000*l.* nore. Ultimately, this maker's Watch succeeded so com- letely, that after it had been round the world with Captain Cook, in the years 1772-1775, the second 10,000*l.* was given o Harrison.

Chronometers are tried, or *rated*, at the Royal Observatory, Greenwich, where are frequently 100 chronometers at a time; wo observers, from comparisons, deducing the daily rates by hich the goodness of the watch is determined. The errors re,—general bad workmanship, and over or under correction or temperature. In the room is an apparatus in which the atch may be continually kept at temperatures exceeding 100° y the artificial heat of the chamber (as in a stove heated y gas); and outside the window of the room is an iron cage. ı which the watch is subjected to low temperatures.*

In 1834, Mr. Dent exhibited to the British Association Chronometer with a glass balance-spring, and presented an ccount of its rate kept at the Royal Observatory, Greenwich. n 1839, with twelve of Dent's Chronometers the differences of ongitude were taken at London, Edinburgh, and Markerstoun: nd by a mean of all the observations taken in going to the atter station, or returning, they were found to differ only by ive one-hundredths of a second.

The Astronomer Royal has arrived at these conclusions with egard to chronometers examined at the Greenwich Observa- ory. The material workmanship of all the chronometers is ery good, and there is very little difference between them. In niform circumstances of temperature every one of the chro- ıometers would go almost as well as an astronomical clock. The great cause of failure is the want of compensation, or he too great compensation, for the effects of temperature. Another very serious cause of error is brought out clearly in

* The interesting details of Rating Chronometers at the Royal Observa- ory are given, from authority, in *Curiosities of Science*, pp. 229-232.

the trial; namely, a fault in the oil, which is injured by heat. Nearly all the irregularities from week to week, which generally would be interpreted as proving bad workmanship, are in reality due to the two foregoing causes.

One of the New York Chronometers supplied to the Grinnell Arctic Expedition, after being subjected to the severest test, yet was so exquisitely provided with adjustments and compensations for the very great extremes of temperature to which it had been subjected, that in a polar winter, it was returned with a change in its daily rate, during a year and a half, of only the 18,000th part of a second in that time. The temperature registered during the winter in Wellington Straits was actually 46° below zero.

Clocks and Watches vary in their rate of going because of the expansion and contraction of the metals of which they are constructed. Thus, in regulating the length of the seconds pendulum, an exact acquaintance with the dilatation of metals is essential; for when the bob is let down the hundredth part of an inch, the clock loses two seconds in twenty-four hours; hence a thousandth part of an inch will cause it to lose one second per day, and a change of temperature equal to 30° of Fahrenheit will alter its length about one five-thousandth part, and occasion an error in the rate of going ot eight seconds per day. Variations of temperature also occasion variations in the balance-wheel of watches, which are obviated by various compensating apparatus.

Watchmaking in England is now allowed to suffer much from overstrained competition and other causes. Thus, our watchmakers complain of the Goldsmiths' Company, in the stamping of gold and silver watch-cases, injuring them materially, involving an additional expenditure of time and labour for their restoration, and thereby preventing the English watchmakers from competing on anything like equal terms with their continental rivals. It is asserted that the English manufacture is rapidly decreasing, owing to the fact that the light cases used by the Swiss makers would be ruined by the stamping process at Goldsmiths' Hall, so that English watches are of necessity heavier and costlier. In proof of this statement we are told that the annual importation of gold watches from Switzerland is about 35,000, while the total number of all kinds produced at home is but 26,000.

Again, in America, Watches are manufactured on a large scale by the aid of machinery. On the southern banks of the river Charles, Waltham, Mass., Mr. A. L. Dennison has erected a brick building, two storeys in height, and inclosing a large quadrangular court. Surrounding this large building there are 100 acres of land, on which, here and there, are placed the cottages which form the rural homes of the watch-makers. In a large building, so constructed that the greatest amount of light is admitted, there is accommodation for something like 250 hands, more than half of whom are females. Driven by a steam-shaft, the bands traverse the whole building, and move the various machines which are used in this manufacture. By means of machinery the first cutting of the stamps and dies is effected; also hardening and forming the barrels and chambers, coiling and fastening the mainsprings, gearing-wheels, and cutting their teeth, shaping of pinions and axles, cutting escape-wheels, trimming and marking the porcelain dials, drilling and shaping the jewels, and adjusting and fitting together the various parts.

In the Watchmaking country of Switzerland, watches are made in great numbers by women. In Great Britain 186,000 watches per annum are manufactured; and, as this goes a very little way towards supplying the demand, there is a large importation from Switzerland *—exceedingly profitable to somebody at our expense, as the price of the article is kept up by the artificial scarcity at home. In the valleys of Switzerland, in the cottages on the uplands, in the wildest recesses that men can inhabit, as well as in the streets of the towns, there are women helping to make watches. We are told that 20,000 women are actually so employed. Why not? The metal in the inside of a watch costs about sixpence in its unwrought condition. By the application of the fine touch so eminently possessed by women, guided by their fine sight and observation, that sixpenny-worth of metal is so wrought and adjusted as to become worth several pounds. If there are 20,000 Swiss women at work at their own windows, with their children about them and their husbands' dinner at the fire, making

* The following figures will serve to give some idea of the extent of the foreign trade:—In 1858 there were imported into Great Britain 346,894 watches. In the same year the number of watch-cases Hall-marked were,—In London, 83,614 silver, and 26,870 gold cases. In Chester, 13,648 silver, and 8,200 gold cases. In Coventry, 16,000 silver cases. In all, 148,323. In 1857, 14,141 watches of British manufacture were exported to America.

watches for Europe and America, why are there not 40,000 Englishwomen helping the family independence in the same way? Simply because the caste or guild of watchmakers will not permit it. By simply meeting the demand for watches at home, and yet more by preparing a due supply for America and our own colonies, our watchmakers would open a new vein of employment and profit for themselves and their households.

For three centuries and upwards, this country has been distinguished for the skill of its makers of Clocks and Watches. For a long time English watches were at a premium in every part of the civilized world. In the reigns of Henry VIII., Queen Elizabeth, Charles I., and Charles II., and up to a comparatively recent date, time-pieces made in this country were chased and otherwise ornamented with considerable artistic skill. The designs were, also, in many instances, good and tasteful. In the reign of George III. the style of the watches was no less in correspondence with the prevailing taste: they were plain, ugly, and unwieldy; but at the same time they were, in comparison with foreign watches, remarkable for the excellence of their workmanship. As regards the dials of House-Clocks, up to the beginning of the present century, they were decorated with engraved brass plates, many of which were of good design and beautiful execution. Thomas and Robert Bewick, John Scott, and other engravers of note, devoted time to this kind of work. At a period when, as regards Art Manufactures, we were standing still, throughout France and other countries on the Continent art was being highly cultivated, and made a part of general education.

In a French workshop we see evidence of this art-education; and to the science of manufacture more attention is paid by the body of the workmen than is the case in England. By the establishment of Schools of Art we are striving to improve our taste in ornamentation, so as to enable us to compete with our neighbours. The Clockmakers' Company possess a Lending Library of valuable English and foreign works on Horology, with a printed catalogue; and the British Horological Institute is active in its work of improvement. Our constructive excellence in Clock and Watch making is acknowledged; and we have only to attain the more extrinsic taste in ornament to complete the superiority:

"The greater part performed, achieve the less."

GUNPOWDER AND GUN-COTTON.

IN the countless records of

> "The big wars,
> That make ambition virtue,"

how striking is the contrast between the means and appliances of ancient and modern warfare. The battle-field of old, with its plumed troop and glittering helmet, its banner and armorial coat, was a scene of brilliant romance, which the mortal engines of the moderns with their volumes of smoke did much to obscure.* War was

* Smoke obscures the representation as well as the realities of war. There is but one battle scene in the Picture-gallery at Apsley House : this is Waterloo, taken from Napoleon's head-quarters, by Sir William Allan: of this picture the Duke of Wellington observed, "Good, very good—not too much smoke."

then shorn of its false charms ; and many there were who, looking back to the days when men fought shield to shield and hand to hand, might exclaim with our great bard :—

> "It was great pity, so it was,
> That villainous saltpetre should be digged
> Out of the bowels of the harmless earth,
> Which many a good tall fellow had destroyed
> So cowardly."

A modern battle-field is a most terrible spectacle. Tens and hundreds of thousands of men, determined on destruction, are rank opposed to rank, and horses and riders rush headlong upon each other. The air is filled with dark sulphureous smoke, through which the forked flames of the cannon are every moment flashing, as they send forth their messengers of death. The rush of mighty squadrons—the loud clang of arms, heard even amidst the roar of artillery—the rapid volleys of musketry, filling up with their sharper rattle the din which arises from the imprecations of enraged men, the screams of anguish and the groans of the dying—these are the fearful accessories of modern war. Yet, dreadful as is such a scene, the principal agent through which it is enacted has been instrumental in reducing the horrors of warfare. "Gunpowder," says a thoughtful writer, "though a warlike contrivance, has in its results been eminently serviceable to the interests of peace. Scarcely had it come into operation when it worked a great change in the whole scheme and practice of war. According to the old system, a man had only to possess what he generally inherited from his father, either a sword or a bow, and he was ready equipped for the field. According to the new system, first there was the supply of gunpowder, then there was the possession of muskets, which were expensive weapons, and considered difficult to manage. Then, too, there were other contrivances to which gunpowder naturally gave rise, such as pistols, bombs, mortars, shells, mines, and the like. All these things by increasing the complication of the military art, increased the necessity of discipline and practice ; while, at the same time, the change that was being effected in the ordinary weapons deprived the great majority of men of the possibility of procuring them. To suit these altered circumstances, a new system was organized ; and it was found advisable to train up bodies of men for the sole purpose of

.nd to separate them as much as possible from those mployments in which formerly all soldiers were occa- · engaged. Thus it was that there arose standing armies, : of which were formed in the middle of the fifteenth ; almost immediately after Gunpowder was generally "*

history of the invention of Gunpowder is involved in bscurity; the most ancient writers differing from each ı their accounts of this matter, and some of them con- g two distinct inquiries: the invention of the *composition* powder, and the discovery of the *means of applying it urposes of war.* It is claimed to have been invented ırs ago; but it is stated to have been used in China as A.D. 85; and the knowledge of it is said to have been ɜd to us from the Arabs, on the return of the Crusaders ɔpe: it is added that the Arabs made use of it at the f Mecca, in 690; and that they derived it from the was contended by M. Langles, to the French Na- [nstitute, about 60 years since.

. at the present day Gunpowder is probably far more ly used,—not in deadly waıfare, but in the shape of fire- –in China than in any other country in the world. The t allusions to it as a power in war among the Gentoos ious; as also is Philostratus's account of "those holy ɜloved of the gods," the Oxydracæ, who dwelt between ɜrs Hyphasis and Ganges (in Oude, the "holy land"— ea—of India,) and who arrested Alexander's victorious and "overthrew their enemies with tempests and ·bolts shot from their walls."

ɪeorge Staunton observes, that "the knowledge of Gun- in China and India seems coeval with the most distant events. Among the Chinese it has at all times been to useful purposes, as blasting rocks, &c.; although it t been directed through strong metal tubes, as the ans did soon after they had discovered it."

ɜr Bacon expressly mentions sulphur, charcoal, and e, as ingredients of Gunpowder; but, independently of ms of the Chinese and Indians, Marcus Græcus, who ioned by an Arabic physician of the ninth century, gives ɜipt for Gunpowder. Bacon is known to have travelled

* Buckle's *History of Civilization in England*, vol. i.

through Spain, and he may have seen the treatise on Gunpowder in the Escurial, and bearing the early date of 1219, in which it is traced to the Arabs and Saracens; though its early use in engines of war was, probably, more like that of fireworks than artillery. It was commonly used in the fourteenth century; its first application to the firing of artillery being ascribed to the English at the battle of Crecy, in August, 1346, as mentioned by Villani, the *Chronicles* of St. Denis, and Froissart; and moreover in some public accounts of the reign of Edward III., wherein are specified the names of the persons employed in the manufacture of Gunpowder (out of saltpetre, and "quick sulphur," without any mention of charcoal), with the quantities supplied to King Edward, just previously to his expedition to France, in June or July, 1346. The records show that a considerable weight had been supplied to the English army subsequently to its landing at La Hogue, and previously to the battle of Crecy; and that before Edward III. engaged in the siege of Calais, he issued an order to the proper officers in England, requiring them to purchase as much saltpetre and sulphur as they could procure. In the Harleian MSS. is an order from Richard III., which shows that Gunpowder was made in England in 1483.

Foreign writers mostly affirm the invention to be due to Barthold Schwartz, a monk of the order of St. Francis, and an accredited alchemist: he mixed, with a medical view, nitre, sulphur, and charcoal; a spark accidentally fell upon the mixture, and it exploded; he repeated his experiment, and appears in 1320 to have employed his powder to frighten some robbers from their haunts in the woods. Schwartz is believed to have died about 1354; and in 1853, there was erected at Freiburg, his birth-place, a stone statue of him. It should be added that the invention is claimed for him, because he did not learn it from any other person.

The oldest intelligible accounts of the different processes are not of an earlier date than 1540; those given by Tartaglia yield powder scarcely more powerful than the composition of a squib, which did not arise from ignorance of proper proportions, but from the guns being so weak that stronger powder would have destroyed them. Chemistry was not sufficiently advanced to enable the manufacturers to determine the best proportion of ingredients, but this they did by dint of mere experience. To secure perfect mixture of the three ingredients, the saltpetre was first dissolved, then the sulphur and charcoal being added, the mixture was stirred assiduously, by which means all three ingredients were brought into combination very effectually. The *graining* must have been less successful. The mixture was moistened with vinegar, wine, and brandy, more frequently than with water; this process being thought to add strength to the powder. The *Transactions of the Royal Society* record Prince Rupert's mode of making a Gunpowder tenfold the ordinary strength of that then used; likewise a method of blowing up rocks in mines, or under water. Much of our powder was imported from Flanders, until it was manufactured, by patent, by the Evelyn family in Surrey; and upon the stream of John Evelyn's own dear Wotton were formerly several powder-mills, worked by water or horses; a mill is but a slight wooden building with a boarded roof. Among the improvers of the process was the Bishop of Llandaff, Dr. Watson, the Cambridge Professor of Chemistry. A late great improvement in Gunpowder consists in employing "cylinder" charcoal—distillation being effected in cylindrical retorts, or ovens—by which the powder acquires so much additional strength that the proportion of charges used for ordnance is in consequence reduced nearly one third. Gunpowder, as now prepared, is for ordinary purposes rather *too* strong. Sir William Congreve actually made some Gunpowder, which exploded on percussion, and was in other respects highly dangerous.

The known composition of Gunpowder consists of seventy-five parts of nitre, fifteen of charcoal, and ten of sulphur. The powder may be described as a solid body, in which an enormous power is locked up, capable of being brought into immediate operation whenever wanted; the action being regulated by experience with wonderful precision. On the ignition of the Gunpowder, though the sulphur begins the combustion, it is not itself burned by the oxygen of the nitre, but unites chiefly with the potassium of that salt to form sulphide of potassium—and this union assists in giving to the flame of gunpowder its intense heat.

The enormous force of inflamed Gunpowder depends on the evolution of various gases. A cubic inch of Gunpowder is converted by ignition into 250 cubic inches of permanent gases, which, according to Dr. Hutton, are increased in volume eight times at the time of their formation by the expansive influence of heat; so that confined and ignited Gunpowder will exert, at least, a force of 2,000 pounds on every square inch opposed to its action.

Some of the effects of ignited Gunpowder are wonderful. When Gunpowder is heaped up in the open air and inflamed, there is no report, and but little effect is produced. A small quantity open and ignited in a room forces the air outwards, so as to blow out the windows; put the same quantity confined within a bomb, in the same room, and ignited it tears in pieces and sets on fire the whole house. Count Rumford loaded a mortar with 1-20th of an ounce of powder, and placed upon it a 24-pounder cannon; he then closed up every opening as completely as possible, and fired the charge, which burst the mortar with a tremendous explosion, and lifted up its enormous weight. In another experiment Count Rumford confined 28 grains of powder in a cylindrical space which it just fitted, and upon being fired it tore asunder a piece of iron which would have resisted a strain of 400,000 lbs.

The force of Gunpowder is ascertained by trying the power of a given quantity, in projecting a known weight. A charge of four drams of fine-grained or small-arm powder is expected to project a steel ball with the requisite force to perforate a certain number of half-inch wet elm-planks, placed three quarters of an inch asunder, the first being thirty feet from the muzzle of the barrel. A charge of four ounces of cannon powder must be capable of projecting, from an 8-inch Gomer mortar, a 68-lb. iron shot *not less* than 380 feet.

For the manipulation of Gunpowder, the ingredients are reduced to an impalpable dust, and are then mixed together in a small barrel before being placed in the incorporating cylinder mill, in charges of 42 lbs. each, moistened by two or three pints of water. The thorough incorporation and combination of the elementary parts of the ingredients are most essential in good gunpowder. The operation is one of tact, and requires experience to judge of its sufficiency, the practical indication of which is a uniform greyness of appearance and a "liveliness" of the composition during the latter part of the process.

The incorporated material termed mill-cake is then subjected to a pressure of about 75 tons per superficial foot, in a hydrostatic press, or by a considerable mechanical power, by which it is brought into a much smaller substance, called press-cake; after which it is crushed between toothed rollers, of different successive gauges, or broken by wooden mallets into

pieces, which are put into parchment sieves in a frame
ıded at the corners, to which a shaking motion is given.
sieve has in it two pieces of lignum-vitæ, which, by the
n given to the frame, continue to crush the powder until
pass through the holes pierced in the parchment of the
:quired. The Gunpowder is then glazed; *i. e.*, placed for
ır and a half in a canvas cylinder, or a large cask, which
le to perform about 40 revolutions per minute, by which
ıs of abrasion the grains lose their angular points, and
'e rotundity as well as smoothness.

: next operation in the manufacture is the drying thoroughly
legree of heat of not less than 140° or 150° of Fahrenheit,
in a stove, or by a temperature raised by means of steam,
effectually to drive off all remaining humidity, which the
›al, or any delinquescent impurity that might accidentally
l in combination with the saltpetre, may have induced.

ong numerous examples of the powerful effects of
owder is that in the celebrated siege of Gibraltar, when
assailed by the united forces of France and Spain, and
led by General Elliot.

: chief attack was made on the 13th September, 1782.
e part of the besiegers, besides stupendous batteries on
nd side, mounting two hundred pieces of ordnance, there
n army of 40,000 men. In the bay lay the combined
of France and Spain, comprising forty-seven sail of the
besides ten battering ships of powerful construction.
those the heaviest shells rebounded; but ultimately two
:m were set on fire by red-hot shot, and the others were
›yed to prevent them from falling into the hands of the
ı commander. The rest of the fleet also suffered con-
bly; but the defenders escaped with very little loss. In
ngagement 8,300 rounds were fired by the garrison, more
half of which consisted of red-hot balls. During this
›rable siege, which lasted upwards of three years, the
expenditure of the garrison exceeded 200,000 rounds—
barrels of powder being used.

ring the progress of the siege, the fortifications were con-
ıbly strengthened, and in the solid rock were excavated
rous galleries, having port-holes at which were mounted
' guns, which kept up an incessant fire upon the enemy's
npments on the land side. Communicating with the
: tiers of these galleries are two grand excavations, known

as Lord Cornwallis's and St. George's Halls. The latter, which is capable of holding several hundred men, has pieces of ordnance pointed in various directions.

ST. GEORGE'S HALL, GIBRALTAR.

Few persons are aware of the enormous quantity of Gunpowder used for military purposes. At the siege of Ciudad Rodrigo, in January 1812, 74,978 lbs. of Gunpowder were consumed in thirty hours and a half; at the storming of Badajos, 228,830 lbs. in 104 hours, and this from the great guns only. At the first and second sieges of San Sebastian 502,110 lbs. were used; and at the siege of Saragossa, the French exploded 45,000 lbs. in the mines and threw 16,000 shells during the bombardment. One day of the war in the Crimea, the Russians in Sebastopol discharged 13,000 rounds of shot and shell, the only result of which was *three men wounded.*

At the siege of Acre, in 1840, a vast quantity of Gunpowder was expended in three hours, with terrific effect. The naval force under the command of Sir R. Stopford sailed to bombard the town, then considered to be one of the strongest fortresses in the world, almost impregnable. But Sir Robert despatched a few of his line-of-battle ships to silence the cannon on the walls ; while, with the steam-frigates under his command, he kept further from shore, and threw, from the mortars on board of his vessels, large shells into the place. The fire was close and effective : and the guns of one of the seventy-four pounders was so placed, that the whole of her broadside was poured into one small space, described by an eye-witness as not more than ten feet square ; and all the balls striking nearly at the same instant, the force of the blow was so irresistible that the solid masonry cracked, yielded, and with a thundering crash finally fell into fragments, leaving a breach sufficiently wide enough for the assailants to enter the town. In the meantime, the Admiral contrived to ply the defenders with volleys of shells from the steam-frigates ; and one of these breaking through the roof of an encased building, there burst. This chanced to be the magazine, where all the ammunition of the place was deposited. The contents immediately exploded ; and the vast mass of the building, with the bodies of seventeen hundred men, was driven, like the outpouring of a volcano, high and reddening into the air. Thus, though at a great sacrifice, in three hours, was brought to a conclusion a war which might have covered whole provinces and countries with desolation. The British had but 18 killed, and 41 wounded.

This is one of the few instances recorded of a fort being taken by ships. The Duke of Wellington considered this achievement one of the greatest deeds of modern times. It was altogether a most skilful proceeding. On inquiring how it happened that so small a number of men were lost on board the fleet, he discovered that it was because the vessels were moored within one-third of the ordinary distance. The guns of the fortress were intended to strike objects at a greater distance ; and the consequence was, that the shots went over the ships that were anchored at one-third of the usual distance. By that means, they sustained not more than one-tenth of the loss which they would otherwise would have experienced. Not less than 500 pieces of ordnance were directed against the walls ; and the precision with which the fire was kept up, the position of the vessels, and, lastly, the blowing up of the large magazine, all aided in achieving this great victory in so short a time.

The Congreve Rocket, exclusively a British weapon, was first employed at the attack of Boulogne, in 1806, by Commodore Owen. This missile is contained in a metallic case, the carcase with a strong iron head, filled with composition as hard and solid as iron itself. The penetration of a 32-pounder rocket-case in common ground is nine feet; and it has been found in the different bombardments where this rocket has been used, to pierce the walls of solid masonry, and pass through the several floors. It is confidently asserted that the art of making the Congreve Rockets cannot be discovered, either by inspection or analysis.

There were formerly three public manufactories for Gunpowder—Waltham Abbey, Faversham, and Ballincolig. Of these, Waltham Abbey alone remains in the hands of the Government. The mills are situate on one of the branches of the Lea, and have been rebuilt since 1801. The produce is now 20,000 barrels per annum.

Foremost among the many improvements at Waltham Abbey, is the substitution of metal for wood in the construction of the machinery. Light iron wheels, with all the modern appliances for making the most of the water, replace the cumbrous wooden machinery, which dated back to Smeaton's time, and some of which was actually made by him. The chances of an accident have been considerably reduced by the introduction of special appliances. Thus, when an accident happens to one mill, all the others in the vicinity are instantly flooded with water, the very explosion being the agent by which this effect is produced. Hand-presses have been superseded by hydraulic presses, and the hand-corning system formerly adopted by a system of granulating by self-acting machinery. At Waltham Abbey for the preparation of the ingredients there are an extensive saltpetre refinery and a range of charcoal ovens. The machinery consists of twenty-one water-wheels, averaging about 4-horse power each, a 30-horse power steam-engine, and a 7-horse power portable engine, steam being supplied from three boilers equal to 90-horse power collectively. There are four pairs of mixing runners, two mixing machines, one charcoal mill, and twenty-two pairs of incorporating runners. Besides these there are four hydraulic presses, two breaking-down machines, three granulating machines, twenty dusting reels, four glazing barrels, and two drying stoves; the heat being regulated by a thermometer.

The explosion of a magazine stored with gunpowder has, in some instances, the effect of an earthquake. In the year

1864, on October 4, two powder magazines, in Plumstead Marshes, exploded shortly before seven in the morning: the buildings were isolated on the banks of the Thames, and were used for storing and embarking powder only. Two barges lay in the stream, unloading powder brought from Faversham Mills, the barrels being conveyed along a timber stage from the barges to the shore in barrows fitted with copper wheels. The instant the explosion occurred, the boats on the river entirely disappeared, and the second explosion following almost instantaneously on the first, destroyed the magazine and the neighbouring cottages. The effects of the explosions were distinctly felt through a radius of at least 50 miles, proceeding from the magazines as a centre, with one exception, the mansion of Sir Culling Eardley, which, although very near, suffered but little, a gentle hill being between it and the seat of the explosions. At Woolwich, many windows and doors of dwelling-houses were blown in. This catastrophe specially directed attention to the necessity of adopting measures for reducing, as much as possible, the risk of such disastrous accidents; and Mr. Gale proposes to render gunpowder less dangerous by a well-known method, which consists of diluting powder, or separating its grains from each other by means of a finely-powdered non-explosive substance; for which purpose Mr. Gale uses powdered glass.*

An official return has been made of the above explosion, with a Report from Colonel Boxer, in which it is stated that the quantity of powder exploded was 115,300 lbs.; that the Gunpowder was first ignited in one of the barges lying at the jetty leading to Messrs. Hall's magazine; that the cause is not accurately ascertainable, because of the fact of those who could have known it being killed; but that it very likely arose from a lighted lucifer-match, dropped (perhaps accidentally) from the pocket of one of the men unloading the powder. To account for the accident in this way, however, it would be necessary to suppose that there was either a leakage in the powder-barrels or a quantity of loose powder lying about, or both combined. Colonel Boxer strongly recommends the most stringent enforcement of the rules as to the manufacture, stow-

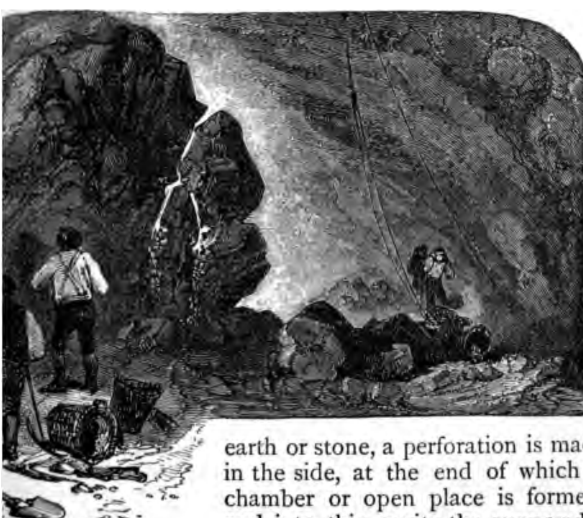
* Mr. Drayne, of the New Forest Powder Mills, Lyndhurst, in his process, does away with all machinery of a very complicated and dangerous character; and does not subject the powder to a very heavy pressure—which is a most perilous operation.

age, and removal of Gunpowder. The results of the explosion were the destruction of Messrs. Hall's magazine, of the Lowood Company's magazine, and of two barges; nine men and four children killed, and several other persons injured; some houses and cottages blown down; also, 150 yards of the river wall carried away, and 120 yards of it injured. Damage was done to buildings within a radius of 700 yards from the centre of the explosion; a church within a radius of 1300 yards was also injured, and at 1600 yards windows were broken, as also at one mile radius. At from one and a-quarter miles to a distance of five miles damage was done to windows, in some cases to a greater extent than in buildings closer to the explosion, owing to the higher position of the buildings. Even within a radius of ten miles some windows were broken.

The following is a summary of instances of Gunpowder explosions for a space of ten years:—Nov. 15, 1855, French Siege Train, 92 lives lost; July 11, 1856, Salonica, 1000; Nov. 18, 1857, Mayence, 25; March 30, 1859, Hounslow Powder Mills, 7; Aug. 6, 1859, Ballincolig Powder Mills, 5; Sept. 9, 1862, Powder Works, near Redruth, 5; Oct. 1, 1864, Erith Magazines, 10; Oct. 4, 1864, Powder Mills near St. Petersburg, 9; Nov. 7, 1864, Davington Powder Works, 2; Dec. 14, 1864, Her Majesty's ship "Bombay," 91; Jan. 18, 1865, Peninsular and Oriental steamer "Rangoon," 2; May 24, 1865, Magazine at Mobile, 300—total, 648.

The application of Gunpowder to the blasting of rocks by the Chinese, has been already mentioned; and of late years it has been similarly employed in great engineering works. In 1843, Mr. Lewis Cubitt, the engineer-in-chief of the South Eastern Railway, to avoid a tunnel of inconvenient length, resolved on reducing the South Down Cliff, a portion of the chalk rock on the Kentish coast between Folkestone and Dover. As this reduction would, by manual labour, not only have cost a vast sum of money, but occupy considerable time, the engineer determined to blow it up with Gunpowder. Accordingly a gallery of small dimensions was opened in the rock, from the western end; and at certain intervals chambers or open spaces were deposited. The chambers were then closed, only leaving small openings for the communication of fusees or ropes, having within them a copper wire which communicated with a small house on the surface, at a considerable distance from the spot where the firing was to take place. These were attached, at the other extremity, to a galvanic ·, which, by the passage of electricity through them, would : gunpowder. Mr. Cubitt was assisted by Lieutenant n, of the Royal Engineers. On the day appointed for eration a vast concourse of persons was gathered on the ı. Yet there was nothing to see but the undulating sur- ' the country, the sea in the distance, the small hut in :he operators were engaged; and a rope, which, at a short :e, seemed to be lost in the ground. The battery was d, and in a few seconds a low rumbling noise was heard, ntly under foot, an almost imperceptible uprising oc- , and within a few seconds the immense mass of rock, ıg upwards of 500,000 tons, was cast forward, and lay ed on the sea-shore. It is calculated that upwards of ıonths' labour, and 10,000*l.* expense, were saved by this κperiment.

sights are more astounding than that of blasting rocks ıne. Where it is requisite to remove a large quantity of



earth or stone, a perforation is made in the side, at the end of which a chamber or open place is formed, and into this cavity the gunpowder 'oduced; a fuse, so made as to allow the workmen : to a safe distance before it ignites the powder, is lighted, and in a few minutes the rock is torn from its bed, and the miners are enabled to proceed in the extraction of the mineral wealth which this explosion may bring to light.

Of late years many substitutes have been proposed for Gunpowder, which, however, still maintains its position as the best of explosive compounds for the various uses to which it is applied. At the head of these substitutes must be placed Gun-Cotton. In England it was first introduced by its inventor, Professor Schönbein, at the meeting of the British Association at Southampton, in 1846. The simplest process of making the Gun-Cotton consists in dipping the fibre into strong nitric acid, and allowing the acid to saturate it thoroughly; then, finally removing the cotton fibre, washing it until every trace of acid is separated, and drying it at a temperature under 100°. Gun-Cotton, though still resembling ordinary cotton to the naked eye, feels different, and presents a different aspect when examined microscopically.

In Schönbein's laboratory at Berlin, a certain weight of Gunpowder, when fired, filled the apartment with smoke, whilst an equal weight of Gun-Cotton exploded without producing any smoke, leaving only a few atoms of carbonaceous matter behind. Balls and shells were experimentally projected by this prepared Cotton, which was stated to have nearly double the projectile force of Gunpowder; in proof of which Schönbein experimented upon the wall of an old castle near Basle. It had been calculated that from three to four *pounds* of Gunpowder would be requisite to destroy this wall; but four *ounces* of Gun-Cotton, when fired, blew the massive wall to pieces. Again, the sixteenth of an ounce of the Cotton placed in a gun carried a ball through two planks at the distance of 28 paces; and, with the same charge and distance, drove a bullet into a wall, 3¾ inches. Such were the earliest experiments made by Schönbein, the inventor, in Switzerland.*

Gun-Cotton was used for the first time in actual warfare at the siege of Moultan, in the East Indies, in 1818-19; when

* Referring to Gun-Cotton in a recent lecture at Brooklyn, U.S., Professor Doremus stated that he treated a linen handkerchief with nitric acid, making it into gun-linen, and threw it into the wash with his other clothes. His servant girl washed and dried it, of course without perceiving any difference in its character. She then laid it upon the table to iron it, but, at the first touch of the hot iron, the handkerchief vanished with a light flash, leaving no trace behind! The handkerchief must have been very dry, which is contrary to ordinary laundry practice.

the brilliance and breadth of the flash of the guns fired by this new adaptation of science to the devastation of war are described to have been of terrific intensity. The new compound has its pacific uses. Gun-Cotton is soluble in ether, and forms *collodion*, of the greatest use in many of the arts, especially in photography. On being exposed to the air, the ether evaporates, leaving a thin transparent film behind, which is applied to wounded surfaces, instead of goldbeater's skin; it may be made into delicate bags, into which hydrogen may be introduced for balloons.

Another kind of Gun-Cotton has been prepared in the United States, by treating newly-prepared Gun-Cotton with a saturated solution of chlorate of potash. A pistol loaded with one grain of this cotton has sent a ball through a yellow pine door one inch thick, at the distance of 20 feet.

The British Board of Ordnance decided against the adoption of this new explosive compound in the military and naval services; but it was differently appreciated on the Continent, the Austrian Government presenting Professor Schönbein with the sum of 2,500*l.* as a reward for his invention. The study of Gun-Cotton was, however, resumed in England about the year 1862, with its practical application. Very considerable quantities of the material have been manufactured at the works of Messrs. Prentice, at Stowmarket, and at the Government Gunpowder Works, at Waltham Abbey: its application to mining and artillery purposes, and to small arms, is progressing; and Gun-Cotton cartridges are employed for sporting purposes.

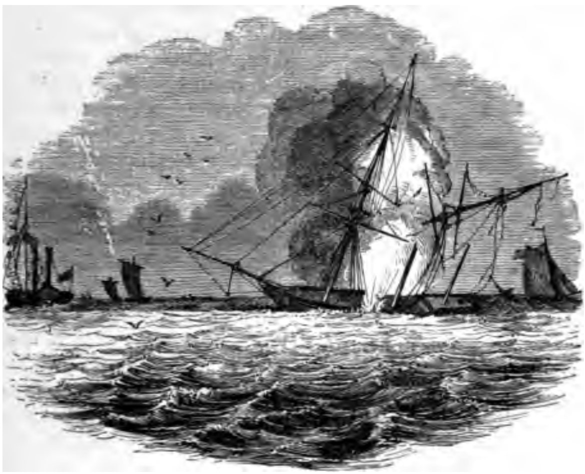
The material may be most perfectly preserved, apparently for any period, either by immersion in water; or, still more simply, by being impregnated with just sufficient moisture to render it perfectly uninflammable. In this condition, Gun-Cotton is much safer than Gunpowder can be rendered, even by mixture with very large proportions of incombustible materials. It may be transported with quite as much safety as the unconverted cotton. Its explosion is also much controlled by reducing the Gun-Cotton fibre to a pulp, as in the process of paper-making, and pressing this pulp into solid masses. General Hay, of the Hythe School of Musketry, reports that he has found the use of Gun-Cotton cleanly, and it has not the disadvantage of fouling the gun; that it has much less recoil, although the effect is the same; that one-third of the weight of charge is the equivalent proportion, and that it does not heat the gun.

In driving tunnels, shafts, and drifts, in connexion with engineering work, one-sixth weight of charge of cotton is equal in blasting effect to Gunpowder, and this has been proved in practice in a number of instances. At Wingerworth colliery, in driving a shaft through soft but solid rock, one-thirteenth of the weight of Gun-Cotton as compared to Gunpowder, and in the slate quarries at Llanberis, at Allan Heads, one-seventh, were required. At Allan Heads, in some lead mines, a tunnel was driven seven miles long; drift 7 feet by 5 in the hardest limestone; both ends worked with Gun-Cotton fired by an electric battery. The great advantage experienced was that the air was not contaminated by smoke, and that the work could be carried on more rapidly. And in several places, one pound of Gun-Cotton detached from thirty to sixty tons' weight of rock.

Professor Abel, who has thoroughly investigated the subject, states that the manufacture of Gun-Cotton is much safer and more uniform that that of Gunpowder, and when made it can be relied on. For shells and for military mines, both land and submarine, the compressed or solid form of Gun-Cotton presents special advantages, on account of its great compactness; a given weight arranged so as to ignite instantaneously under pressure (*i.e.*, in strong vessels) may be made to occupy the same space as an equal weight of Gunpowder, whereas formerly it occupied about three times the space of Gunpowder. Beautiful pyrotechnic effects may be readily produced by means of Gun-Cotton, and its fireworks may be displayed indoors without inconvenience. There appears at present no reason to doubt that the application of Gun-Cotton, with great advantage to at least some of the more important purposes for which Gunpowder is used, will, ere long, be fully established; and that this interesting explosive agent is destined to occupy a permanent and prominent position among the most important products of chemical industry.

One of the most remarkable materials recently employed to replace Gunpowder, as a destructive agent, is Nitro-Glycerine. This substance was discovered by Sobrero, in 1847, and is produced by mixing strong nitric acid and sulphuric acid with glycerine. It is poisonous, and the tenth of a grain will kill a dog. Its explosive force is ten times that of an equal weight of Gunpowder. With less than an ounce of it, a wrought-iron block, weighing about three cwt., has been rent into fragments; and terrific explosions with this formidable compound have taken place in various countries.

Among the most celebrated explosive schemes proposed in our time, was that of Mr. A. S. Warner, first described in 1831, and publicly experimented off Brighton, July 20, 1844, upon a barque of 300 tons' measurement. The vessel was towed out one



THE WARNER EXPERIMENT OFF BRIGHTON.

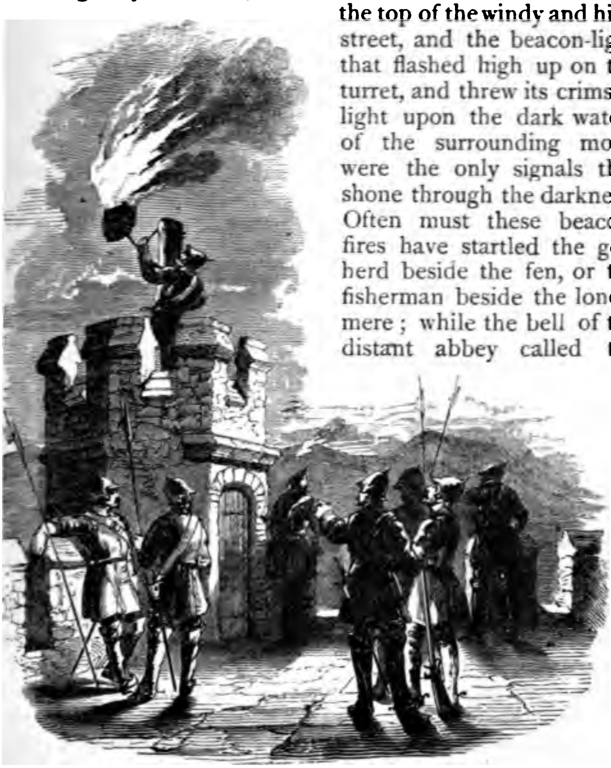
mile and a half from the shore, and 300 yards in the wake of another vessel, on board which was Mr. Warner. The signal was made from the shore; and within five minutes the instrument of destruction seemed to strike the vessel midships, from which point a huge column of water, intermingled with shingle ballast, shot up higher than the highest topmast; her mizen went by the board, her mainmast was shot clean out of her like a rocket; she heeled over to port to an angle of forty-five degrees; daylight was visible through her bottom timbers, and she seemed to part asunder as she went down, leaving only perceptible the top of her foremast. The time from her being struck and her sinking could not have exceeded two and a half minutes. This experiment showed the application at sea, in the blockade of towns, or defence of places from attack by sea; another application being for a long range in the destruction of forts and places of strength. The latter proved a failure. The former was accomplished by a shell dropped into the sea from the steamboat, on board which Mr. Warner was; the ship to be destroyed was then towed over the shell by the steamer, the explosion being caused, in some manner, by the ship itself; the smothered explosion proving that it took place under water.

Here may be described the Percussion Cap for firing off hand-guns, by the employment of fulminating mercury, which explodes by percussion or a blow, without the aid of heat, and causes the ignition of the Gunpowder. This was done so long ago as 1806, though the details were then imperfect. About the year 1840, Dr. Ure conducted a series of experiments with this and other detonating compounds, in detailing the results of which, he states that the French prepare 40,000 percussion charges from two pounds and a half of fulminating mercury. The explosion is effected by putting the detonating mixture in a little copper box or cell, called a *cap*, which is adjusted over the touch-hole, and so arranged as to the other part of the lock, that a smart blow bursts the cap, and explodes its contents. The little cell itself is destroyed, so that a new one is required for each firing. The caps are now made in large numbers at Birmingham, in much the same manner as metal buttons; blanks being cut out of a sheet of copper or mixed metal, and stamped or pressed into the proper shape. By a recent improvement, the cap is made double, or one cap within another, with the mixture between the two, and a small hole in the inner one to communicate with the gunpowder.

The Percussion Cap has, however, now been in a great measure superseded by the use of breech-loaders, which receive cartridges containing the whole charge—powder, shot, and cap—in one piece.

GAS-LIGHTING.

WHAT the dark winter nights in England were some centuries ago, may be imagined from the circumstance that there were, with but few exceptions, no common highways as now; and that the cresset which blazed at the top of the windy and hilly street, and the beacon-light that flashed high up on the turret, and threw its crimson light upon the dark waters of the surrounding moat, were the only signals that shone through the darkness. Often must these beacon-fires have startled the gosherd beside the fen, or the fisherman beside the lonely mere; while the bell of the distant abbey called the



monk to pray, and the layman to fight, until either the castle was stormed, or the assailants were driven off. In these, and in far later times, the solitary beacons that gleamed over the headlands of our sea-girt coast, served to alarm our island against the invasion of a foreign foe.

The word *Beacon* is of Saxon origin, and one of our epic poets has thus happily employed it in simile:

> His blazing eyes, like two bright shining shields,
> Did burn with wrath, and sparkled living fire;
> As two broad beacons, set in open field,
> Send forth their flames.
>
> SPENSER'S *Fairy Queen.*

And Gay has this couplet:

> No flaming beacons cast their flare afar,
> The dreadful signal of invasive war.

Johnson fully defines the Beacon as "Marks erected, or lights made in the night, to direct navigators in their courses, and warn them from rocks, shallows, and sandbanks."

Many an old man still remembers the time when, even in populous towns, a little oil-lamp only served to make darkness visible; and this, on stormy nights, was often extinguished, and the street was without a ray of light. When the streets were unlighted, the watchman went his nightly round, bearing his halbert in one hand, and his lantern in the other, calling out, "Lantern! and a candle! Hang out your lights!" for in this manner many a London street was lighted about four hundred years ago, there being a law which compelled a certain number of householders in each street to hang out lanterns with a "whole candle" during dark nights; and the watchman thundered at the door of those who neglected to do so. In Queen Mary's days, the watchman had a bell, which he rung at the end of the street every time he passed. A century ago, London was so badly lighted and watched, that the Lord Mayor and Aldermen went with a petition to the King, stating the city to be so infested by gangs of highwaymen that it was dangerous to go out after dusk. Before the doors of a few old houses in London are still to be seen on each side of the lamp-iron, a large extinguisher, in shape like the old post-boy's horn; into which the flambeaux or links were thrust after

ɜs of the house had been lighted home. Then came
f oil-lamps about 1762, and we had the lamplighter,
adder, oil-can, and cotton wicks, and flaring torch to
lamp at night. Dr. Johnson, when living in Bolt-
et-street, in 1776, is said to have had a prevision of
e from oil-lighting to gas-lighting, when, one evening,
window of his house, he observed the parish lamp-
:end a ladder to light one of the glimmering oil-lamps;
:arcely descended the ladder halfway when the flame
quickly returning, he lifted the cover partially, and
:he end of his torch beneath it, the flame was instantly
:ated to the wick by the thick vapour which issued
"Ah!" exclaimed the Doctor, "one of these days
; of London will be *lighted by smoke!*"

ıinese have for ages employed spontaneous jets of
ɜd from boring into coal-beds, for lighting and other
ıl purposes. The inflammable gas is forced up in
r 30 feet high, and conveyed in tubes for lighting the
d large apartments, and kitchens; and in a valley of
n the United States, the natural coal-gas has been
ɜmployed for lighting.

ing to the statement of a missionary, the fire-springs
ɜ" of the Chinese, which are sunk to obtain a
:d hydrogen gas for salt-boiling, far exceed our
wells in depth. Their springs are commonly more
o feet deep; and a spring of continued flow was
be 3,197 feet deep. This natural gas has been used
ıinese province Tse-schuan from time immemorial:
'table gas," in bamboo-canes, has for ages been used
r of Khiung-tscheu. In the village of Fredonia, in
ɜd States, such gas has long been used both for
ınd illumination.

sit by the fireside, we may see the alternate bursting
xtinction of pitchy vapour from coal: we witness gas-
n its rudest form. We can produce hydrogen gas
:co-pipe, by filling the bowl with powdered coal, then
over, placing the bowl in a fire, when the gas will
: the pipe-end. By a similar process, one species of
:her, a variable mixture of two or three, composed of
ıd hydrogen, is made in the outskirts of nearly every
-a-days, in enormous quantities; and then sent away
ge trough, or jar, as from a heart, to circulate through

pipes and tubes, for the purpose of lighting streets and houses.

The inflammability of coal-gas has been known in England for two centuries. In the year 1659, Thomas Shirley traced the *burning well* at Wigan, in Lancashire, to the underlying coal beds; and soon after, Dr. Clayton, Dean of Kildare, influenced by the reasoning of Shirley, actually made coal-gas, and detailed the process to the Hon. Robert Boyle, who died in 1691. He distilled coal in a retort, and thus obtained phlegm, black oil, and a spirit, which, being unable to condense, he confined in a bladder, and burnt the gas as it came from the bladder through holes made in it with a pin. Dr. Clayton also discovered that gas retains its inflammability after passing through water; by which means the phlegm becomes water, the black oil coal-tar, and the spirit gas. This fact might have brought gas-lighting into operation a century earlier, had there not been mechanical difficulties then too great to overcome.

In 1753, Sir James Lowther found a spontaneous combustion of gas at a colliery belonging to him, near Whitehaven; air rushed up, which caught fire at the approach of a candle, and burned with a flame two yards high, and one yard wide. It was found to annoy the workmen, and a tube was made to carry it off; and the gas being fired, burnt two years and nine months, without any sign of decrease. It was carried away in bladders by persons, who, fitting little pipes to the bladders, burnt the gas as they required it. Bishop Watson next, about the year 1750, distilled the coal, passed the gas through water, and conveyed it away through pipes; and we are only surprised that he did not bring gas into general use, with his influence as Professor of Chemistry.

Mr. Murdoch, the engineer, in Cornwall, in 1792, erected a small gas-holder and apparatus, which produced gas enough to light his own house and offices; but it was not until 1798, that having matured his plans, he constructed an apparatus for lighting the Soho Foundry, Birmingham, with arrangements for the purification of the gas: four years elapsed before the new light was exhibited complete at the Soho manufactory, at the Peace rejoicings in 1802; and upon a similar occasion, in 1814, gas was employed to light the pagoda and bridge across the canal in St. James's Park.

From the first lighting up of Boulton and Watt's Soho Foundry by gas, in 1802, to the close of 1822, a period of only twenty years, so rapidly had the discovery proceeded, and so high was the appreciation of it by the public, that, by the report of Sir William Congreve, it appears that the capital invested in the gas-works of the metropolis alone amounted to one million sterling; while the pipes connected with the various establishments embraced an extent of upwards of one hundred and fifty miles. In the course of a few years after gas was first introduced, it was, indeed, adopted by all the principal towns in the kingdom, for lighting streets, as well as shops and public buildings. Into private dwellings, through the careless and imperfect way in which the service-pipes were at first fitted up, and which occasioned annoyances, it was more slowly received. But a better knowledge of its management has been acquired.

At Birmingham, several manufacturers early adopted the use of gas: a button manufacturer used it largely for soldering. Mr. Samuel Clegg, about 1806, exhibited gas-lights in front of his manufactory. Halifax and other towns followed. A single mill at Manchester used above 900 burners, and several miles of pipe supply, for the erection of which, in 1808, was awarded the Gold Medal of the Royal Society. The success of gas-lighting in the cotton factory was not only the clearness and intensity of the light, but it was free from the danger and inconvenience of snuffing, which candles required; and it thus diminished the hazard of fire, and lessened the high insurance premium on cotton mills. Even the risk of gas explosions is greatly prevented by the unmistakeable smell which denotes the presence of gas.

In London, the use of gas made but slow progress; the light was poor, and the smell offensive. Lectures and experiments were made upon gas-lighting by F. Winsor, who, in 1803–4, lighted the old Lyceum Theatre; he also established a New Light and Heat Company, with 50,000*l.* for further experiments; in 1807 he lighted the wall between Pall Mall and St. James's Park, on June 4; and next exhibited gas-light at the Golden-lane Brewery, August 16, 1807. In the same year, part of Whitecross-street and Beech-street, Barbican, were experimentally lighted with gas.*

* One of the earliest Gas-works is that of the Chartered Gas-light Company's Works, in Brick-lane, St. Luke's, and a large coloured engraving of "Drawing the Retorts," in this factory, the frontispiece to *One Thousand Experiments in Chemistry*, published in 1820, came upon the public with the effect of a picture of Tartarus.

In 1809 Winsor applied to Parliament for a charter, when the testimony of Accum, the chemist, was bitterly ridiculed by the Committee. In 1810–12 was established the Gas-Light and Coke Company, in Cannon-row, Westminster: next removed to Peter-street, Westminster. In 1814, Westminster Bridge was lighted with gas; the old oil-lamps were removed from St. Margaret's parish, and gas lanterns substituted. On Christmas-day, 1814, commenced the general lighting of London with gas.

Mains were this year first laid in the City; and on Lord Mayor's day in the following year, Guildhall was, for the first time, lighted with gas.

In 1814, a Committee of Members of the Royal Society was appointed to inquire into the causes which led to an explosion of the gas-works in Westminster, which had only just been established. The Committee consisted of Sir Joseph Banks, Sir C. Blagden, Col. Congreve, Mr. Lawson, Mr. Rennie, Dr. Wollaston, and Dr. Young. They met several times at the Gas-works, for the purpose of examining the apparatus, and made a very elaborate Report. They were strongly of opinion that if gas-lighting were to become prevalent, the gas-works ought to be placed at a considerable distance from all buildings, and that the reservoirs or gasholders should be small and numerous, and always separated from each other by mounds of earth or strong party-walls. Yet the scheme had been so ridiculed that Sir Humphry Davy asked if it were "intended to take St. Paul's for a gasometer."

Dr. Arnott has truly said, with respect to the mistakes about gas-lighting, that "such scientific men as Davy, Wollaston, and Watt, at first gave an opinion that coal-gas could never be safely applied to the purposes of street-lighting." St. Paul's Cathedral was experimentally lighted with gas in 1822. In the same year, St. James's Park was first lighted with gas; and the last important locality to adopt gas-lighting was Grosvenor Square, in 1824.

The safety of gas-works was not, however, established; for in 1825, on the part of the Government, a Committee of scientific men inspected the gas-works, and reported that their occasional inspection of the works was necessary.

The apparatus for the production and purification of coal-gas consists, in the first place, of the *retorts*, or vessels for decomposing by heat the coal from which the gas is to be procured; secondly, of the *dip-pipes* and *condensing main*,

ed to conduct the gas into vessels, where it is removed
ie tar and other gross products; thirdly, of the puri-
ıpparatus, for abstracting the sulphuretted hydrogen,
ic acid, &c.; and lastly, of the gas-holder, with its tank,
ıich the gas is finally received in a purified state.

retorts are usually formed of cast-iron, and are com-
of a cylindrical shape. They are fixed in brick-work,
rnaces beneath them. For carbonizing a given quantity
l—that is, for separating the gaseous matter from it—the
red heat is the most favourable. The quality of the gas
l by coal varies greatly at different periods of the
; operation.

time which elapses from the period at which the retorts
rged, or fitted, to the moment when they are *drawn*, or
d of the residuary carbon, or cinder, varies with the
f coal used: cannel coal, which is easily decomposed,
s but three and a half or four hours, while Newcastle
kes six. The quantity of gas also varies with the quality
l: thus cannel coal yields 430 cubic feet of gas per
dweight; Newcastle coal about 370 feet.

dip-pipes are bent pipes from which the gas ascends out
retorts, as it is produced, into the *condensing main*, a large
on pipe placed in a horizontal position, and supported
umns in front of the brick-work which contains the
. The tar, aqueous vapour, and oleaginous matter
ascend with the gas from the retort, are left by it in
ndensing main. The gas has now to be further purified,
conveyed by pipes from the condensing main into other
tus, when, in small quantity, sulphide of carbon and
products are left; but in larger, carbonic acid and
retted hydrogen. These easily unite with quicklime,
is employed, in one form or other, in all gas establish-
for the last step of the purifying process to which
ıs is submitted to render it fit for combustion.

ery large establishments, the gas is forced in succession
h a series of vessels stored with lime to purify it
ghly, and it is then conveyed into the large vessel, the
der, in which it is stored up for use. This is an inverted
ical cup, of which the diameter is about double the depth.
constructed of sheet iron, well riveted at the joints,
ept in shape by stays and braces, perfectly tight. The
der is suspended in a tank containing water, by a chain

and counterpoise, over pulleys. As the gasholder, when immersed, suffers a loss of weight equal to that of the portion of fluid it displaces, arrangement has to be made to counteract the varying pressure resulting from the different depths to which it is immersed, or the gas in it will be expelled at different times with varying force.

Under the bottom of the tank in which the gasholder floats, the gas is introduced and conducted off by pipes, usually below the level of those in the street with which they communicate, so that they are apt to be filled up with condensed water, which passes off in a vaporous state with the gas. Vessels for receiving the condensed water are, therefore, connected with the entrance and exit pipes, and so contrived that the accumulated water can be easily removed.

The transmission of the gas for use is through the main and service pipes—the size of the former being relative to the united sizes of the latter; that is, the sum of the areas of the sections of main-pipes being equal to the sum of the areas of the sections of branch or service pipes supplied. The supply of gas to the main-pipe is regulated by the "governor," a piece of mechanism consisting of a rod and valve placed between them and the pipe by which the gas enters the gasholder.

The process termed *Carburetting* employs an apparatus, containing naphtha, complete in itself, which can be adapted to all existing gas lamps and burners, whether for public or private lighting. It tends to economy in consumption of gas, without diminishing the brilliancy of the light, and has been tried for a month in the public lighting of Moorgate-street, and in front of Cambridge House, Piccadilly, with satisfactory results.

The quality of gas has been much improved by passing it over naphthalin, when it takes up its vapour, thirty grains of which to one foot of gas increases the light seven or eight times; with oil, the result exceeds from four to five times; but even this is an important gain.

Here let us recapitulate the steps by which gas is produced. 1. The carburetted hydrogen, which constitutes the gas for illumination, is separated from the coal by distilling it in heated vessels or retorts. 2. The substance left behind in the heated retorts, after the volatile portions have been separated from it, forms the fuel known as *coke*. 3. The volatilized ıgredients are so far from being pure carburetted hydrogen, ıat they comprise tar, ammonia (sal-ammoniac), sulphuretted ydrogen, and other substances, all which must be removed y "purification" before the light-producing ingredient is btained. 4. The volatile product is condensed by passing ırough water. 5. The sulphuretted hydrogen is removed y lime or lime-water, leaving the carburetted hydrogen to be assed into the gasholder, and thence to streets and buildings y pipes laid underground; the supply being regulated by auges and valves.

Professor Frankland has lucidly explained at the Royal nstitution, the apparatus and processes used in the manufacıre, purification, and distribution of coal-gas, by a miniature aswork in actual operation. From retorts in a small furnace ıe products of destructive distillation are successively coneyed through stand-pipes, the hydraulic main, the water and ır well, the condensers, the exhauster, the purifiers, the stationıeter; and, finally, the gasholder, with its governor to regulate ıe pressure, received the purified gas, which was shown to be uperior to that supplied to the Institution.

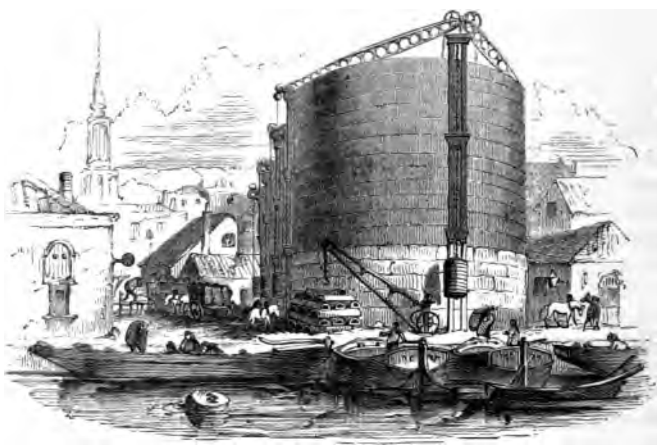
Gas has been adopted in railway carriages by being stored ı India-rubber bags made like the bellows of accordions and oncertinas, which close gradually by their own weight, and xpel the gas by closing; or the gas is contained in a highressure iron vessel, or gasholder, laid along the bottom of he carriage.

Steamboats are also lighted with gas: instead of the dull, moky flame produced by oil, the signal-lamps are brilliantly luminated by a jet of the clearest gas-light; at night in the ngine-room, every part of the machinery is more clearly isible to the engineer than during the day-time; while sunurners give light and ventilation to the passengers in the aloons.

The London Gas Company's works, Vauxhall, are the most owerful and complete: from this point, their mains pass across 'auxhall-bridge to western London; and by Westminster and Vaterloo Bridges to Hampstead and Highgate, seven miles istant, where they supply gas with the same precision and bundance as at Vauxhall.

Portable gas was employed in illuminating the London Ionument on Fish-street Hill, June 13, 1825, in commemoraon of laying the first stone of the New London Bridge. In the evening a lamp was placed at each of the loopholes of the column, to give the idea of its being wreathed with flame: whilst two other series were placed on the edges of the gallery.

Gas made from oil and resin is too costly for street-lighting, but has been used for large public establishments. Covent-garden Theatre was formerly lighted with oil-gas, made on the premises; and the London Institution with resin-gas, first made by Mr. Daniell, the eminent chemist. The lime-ball, Bude, Boccius, and electric lights, have been exhibited experimentally for street-lighting, but are too expensive. Upon the Patent Air-light (from the vapour of hydro-carbon, mixed with atmospheric air), proposed in 1838, upwards of 30,000*l.* were expended unsuccessfully.



THE CITY OF LONDON GAS-WORKS.

In the year 1865, the total revenue paid by the consumers and the public for gas in the metropolis, amounted to the large sum of 1,767,261*l.* 19*s.* 9*d.* per annum. This total increases every year with the growth of the metropolis and the increased consumption of gas. Yet London is ill supplied with gas, at a costly rate. Professor Frankland has had the illuminating power of the gas supplied to different large towns tested by

standard sperm-candles, and the results are as follows:—
in, 15·5 candles; Paris, 12·3; London, 12·1; Vienna, 9·0;
ıburgh, 28·0; Manchester, 22·0; Liverpool, 22·0; Glas-
, 28·0; Aberdeen, 35·0; Greenock, 58·5; Harwich, 30·0;
:rness, 25·0; Paisley, 30·3; Carlisle, 16·0; Birmingham,
. Thus the gas supplied to Edinburgh and Glasgow gives
e than twice the light of the gas provided for London.
Parliamentary Committee upon Gas Supply report that
find the illuminating power greater, and the quality of the
better, in Manchester, Edinburgh, Birmingham, Plymouth,
other towns, than in London; that the purification is
:rfect in London; that the effect of the Act was to raise
market value of the shares. It has been shown that for
ing with gas St. James's Hall, Piccadilly, 1,300*l.* per annum
aid, for what is called cannel-coal gas of 20 candles, at
ıd.; whereas, at Manchester, 3*s.* 2*d.* is paid for an infinitely
rior light.

:ofessor Frankland, in estimating the real source of light
ɔal gas, refers it to ignited hydrocarbon gases and vapours.
se gradually lose hydrogen when exposed to heat, and their
on particles shrink together and form compounds of greater
plexity, being some of the dense vapours which exist in a
lame; and even the soot produced by a gas-flame is not
, but requires intense and prolonged ignition to free it
ı hydrogen. A gas-flame is also perfectly transparent, and
s equal light in different positions.

he illuminating power of gas-burners is registered by an
ıratus for maintaining a constant pressure, and through
is supplied a small jet. The whole is inclosed in a case
rhich perfect ventilation is secured without fear of dis-
ance to the flame, by which erroneous results would
ue. This case has a glass front, on which is a graduated
:; there is also a similar arrangement at the back, so
the height of the flame can be accurately ascertained.
registering variations in the height of the flame, the light
ımitted through a slit on to a piece of sensitized paper, to
:h a tranverse motion is imparted in a photographic
era. A continuous image is thus secured, the varying
ht of the flame being indicated by the height of the image
lifferent points. Mr. Sugg, by his ingenious clockwork
ıratus for the measurement of the luminosity of the flame,
:h apparatus combines meter, governor, burner, &c., shows

that a certain gas-light is equal to that of twelve sperm candles.

It will be recollected that the danger of permitting gas-works to be constructed in the metropolis was urged by the Committee of the Royal Society, appointed in 1814, who reported that such works ought to be placed at a considerable distance from all buildings; and that the reservoirs should be small and numerous. Amidst the success of the invention, however, these precautions seem to have been strangely disregarded. Thus, within a third of a mile, as the crow flies, of one of the largest Gas-works in London, are Westminster Abbey and Westminster Hospital; hard by are the Houses of Parliament, and groups of public offices. Milbank Penitentiary has but the river between it and the London Works; close adjoining is a huge holder. The Phœnix Works at Vauxhall are close to those of the London Company; at Bank-side are extensive works; and opposite are the Whitefriars Works, which threaten the crowded city, and its stupendous cathedral, St. Paul's. Explosions of appalling extent and destruction of life and property have occurred, an evil only to be provided for by the removal of the great works out of the metropolis; to this the companies object, on account of the expense, although their profits enable them to divide 10 and even 20 per cent., besides a large reserve; and they tear up streets to the injury and annoyance of the public, even where subways have been made for gas and water pipes beneath the pavements.

The quantity of gas made by the several metropolitan gas companies is about 10,440,000,000 cubic feet per annum; the gas sold may be taken at 9,000,000,000 cubic feet per annum. The difference between these quantities is the amount of the loss incident to the distribution; in fact, so much worse than pure waste, as it is injurious to health on being absorbed into the earth and expended in the air. The manufacture consumes nearly a million and a quarter tons of coal a year; the loss represents 1,440,000,000 cubic feet, which, at the mean cost of 4*s.* 8*d.* per thousand, is worth 336,000*l.* per annum, or a dividend of nearly 6*l.* per cent. on the metropolitan gas companies, or 9*d.* per thousand feet on the cost of their gas. Yet, the West London Junction Gas Company has a meter at its works, and another three miles off, at the Great Western Station; and there is no difference between the quantities registered by these meters, conclusively establishing that gas mains can be laid so as not to leak.

An explosion of gas is a terrific scene of destruction. On October 31, 1865, at the London Gas-light Company's works, at Nine Elms, Battersea-road, a gas-holder exploded, killing ten persons, and injuring twenty-two. This was one of the largest holders in London, its capacity being 1,039,000 cubic feet, though the Company have one which will hold 2,000,000 cubic feet. The former was 150 ft. diameter, 60 ft. high, with a tank depth of 30 ft., and at the instant of the explosion was nearly full, being about 50 ft. to 55 ft. high. The meter-house was blown to atoms, and the force of the explosion struck the side of the gas-holder, bulging it in, and at the same time driving out a portion of the top. As the side plates were eight to twelve wire gauge, the force must have been very great. With the bursting of the top there was an immediate rush of gas, which instantly caught fire, and shot up in a vast column of flame, discernible at a great distance. The concussion ripped open another gas-holder, the escaping gas caught fire, and meeting the flames from the first gas-holder, rolled away in one vast expanse of flame: an awful crash followed, and many of the neighbouring houses were shattered to pieces.

Undoubtedly, the discovery of gas, and the application of it for the purpose of lighting our chief towns and cities by night, did as much good towards checking street robberies as the organization of the powerful Police-force. It is scarcely possible to overrate the importance of this invention, not only in an economical but in a moral point of view.

In quite recent times, the progress of discovery has brought about some considerable advances in the economics of gas-making, and in the applications of gas itself. These advances have not been alluded to in the foregoing account, which was written before these new applications had assumed their present importance. First, we shall mention how it has come to pass that one of the bye-products of gas-making, a substance which used to be regarded as absolutely valueless, now brings large profits. This substance is coal-tar, mentioned on page 181; which chemists have found to be composed of a mixture of a large number of different substances, many of which constitute the raw material of very valuable chemical products. Of these we need only mention the beautiful and varied series of *aniline colours*, such as mauve, magenta, &c., the manufacture of which has itself become a large industry. Among the latest products that chemistry has discovered is the means of preparing from coal-tar artificial *alizarine*, which is the same colouring principle as that of the madder-plant, so largely used for dyeing Turkey-reds, &c. Another substance derived from coal-tar is *carbolic acid*—now well known as a disinfectant.

It has been found that, for many purposes, the combustion of gas supplies a most convenient source of heat. In laboratories, and workshops of various kinds, gas is now largely consumed for heating purposes; and the use of gas-stoves, and gas cooking apparatus, is becoming common. Meanwhile, much attention is being paid to improvement in gas-burners, and other appliances by which the illuminating power may be brought to the highest possible degree; for gas, as the means of public and private illumination, is now threatened by a formidable rival, namely, the electric light. There is yet another application of gas which deserves mention here, and that is, the gas-engine, in which a series of small explosions of a mixture of gas and air is made the motive power for actuating an engine instead of steam.

ARTESIAN WELLS.

HIS method of raising water by perpendicular perforations or borings into the ground has been named Artesian from the belief that it was first used in the district of Artois, in France; but the name appears ıve been as well known in Italy as in Artois, from time ɛmorial. It is also probable that it was known to the ·nts; for Niebuhr cites from Olympiodorus: "Wells ıunk in the oases from 200 and 300 to 400 cubits in ı (the cubit is equal to half a yard), whence water and flows over." Through the Artesian borings the r rises from various depths, according to circumstances, e the surface of the soil, producing a constant flow or m. They are highly useful in districts where springs or s are scarce, or where the usual surface-water is of in-ent quality. Their action is due to the constant endeavour ater to seek its level, and the principle is the same as that ı artificial fountain. Thus, imagine a somewhat basin-ed bed of sand, or chalk, or any rock of a porous nature, : upon a stratum of clay impermeable to water, and to be red with another stratum equally impermeable. The former being saturated to a great extent by the water which flows it from its higher and exposed edges—a hilly region, per-, where rain falls in abundance—becomes a reservoir, h, if an opening is bored down into it through the over-clay, will discharge its waters upwards with a force mined by the level at which they are kept in the reservoir, ate at which they can percolate through its substance, and ize of the orifice; and, in proportion as this reservoir is ɛd by the borer, must the supply it affords on its upper in be diminished.

As the water becomes impregnated with the various substances through which it passes, a general geological knowledge of the country in which Artesian Wells should be bored is indispensable: indeed, the power of pointing out these situations is one of the practical applications of geology to the useful purposes of life.

The operation of boring these wells is performed with chisels or jumpers, augers, and similar instruments, attached to the lower end of an iron rod formed of many lengths, which screw into one another. To the upper end of this compound rod is attached a transverse handle, worked by two men, by which the boring instrument may either be turned round, where an auger is used, or raised—turned a little way between each stroke; whereas, in cutting through rock, the hole must be formed more by chipping than boring. In boring through soft strata, a kind of cylindrical auger is used, which, when full of earth, must be drawn up and cleared; and a similar instrument is used to remove the chippings produced by the chisels employed to perforate rock. As the weight of the rods required for boring to a great depth would render them unmanageable by hand, a triangle of poles, supported by tackle for raising the boring rod is erected over the hole; and to facilitate the cutting or chipping through rock, the rod is suspended over the hole by a chain, from an elastic wooden pole fixed at one end only in a pile of stones. The vibration of this pole, when set in motion, gives the required up-and-down motion to the rod, while the turning of the transversed handle causes the chisel or jumper continually to vary its strokes. But there has been devised a boring instrument to be readily slid up and down the rod, so that the charged auger alone has to be raised, without disturbing a single joint of the rod.

One of the most celebrated Artesian Wells is that bored by the Messrs. Mulot at Grenelle, in Paris, which occupied 7 years, 1 month, 26 days, to the depth of 1794½ English feet; or 194½ feet below the depth at which M. Elie de Beaumont, the geologist, foretold that water would be found. The sound or borer weighed 20,000 lbs. and was treble the height of the dome of the Hospital of the Invalides, at Paris. In May 1837, when the bore had reached 1246 feet, 8 inches, the great chisel, and 262 feet of rods, fell to the bottom; and, although these weighed five tons, M. Mulot tapped screws on the heads of the rods, and thus, connecting another length to the end, after fifteen months' labour, drew up the whole. The engineers carefully noted the thickness of each stratum traversed, and the specimens they preserved formed a complete geological section.

It is generally supposed that a provincial well-digger introduced into England the process of *boring for water* by the Artesian method, and that Tottenham was the site of the first boring, about 1822. The priority of the invention is, however, due to Mr. Benjamin Vulliamy, who, upon his estate of Norlands, at the foot of Notting Hill, bored the first complete and overflowing well by means of a tube. Mr. Vulliamy, who was a man of scientific repute, and a skilful mechanician, finished his arduous work in November 1794. He began to sink his well in the usual manner; it had a diameter of 4 feet, the land-springs were stopped out, and the well was sunk and steined to the bottom. When the workmen had got to the depth of 236 feet, thinking the water to be not very far off, they did not consider it safe to sink any deeper. A double thickness of steining was then made about 6 feet from the bottom upwards, and a borer of 5¼ inches' diameter was used. A copper pipe of the same diameter as the borer was driven down the bore-hole 24 feet, at which depth the borer pierced through the rock into the water; and, by the manner of its going through, it probably broke into a stratum containing water and sand. At the time the borer thrust through, the top of the copper pipe was about three feet above the bottom of the well: a mixture of sand and water instantly rushed in through the aperture of the pipe; and in less than an hour and a half the water of the well stood within 17 feet of the surface; it rose the first 124 feet in 11 minutes, and the remaining 119 feet in 1 hour 9 minutes. The boring was then found filled with sand to the depth of 96 feet, the removal of which was a work of difficulty, as was also the rebuilding of a portion of the brick-work; but at length the water ran over the top of the well.

The depth of the Grenelle Well is nearly four times the height of Strasbourg Cathedral; more than six times the height of the Hospital of the Invalides at Paris; more than four times the height of St. Peter's at Rome; nearly four times and a half the height of St. Paul's, and nine times the height of the Monument, London. Lastly, suppose all the above edifices to be piled upon each other, from the base-line of the Well of Grenelle, and they would reach within 11½ feet of its surface.

Artesian Wells have, however, been bored of much greater depth than that of Grenelle. Thus, an Artesian Well, bored at Mondorff, in the Duchy of Luxembourg, is 2,400 ft. deep; and another at New Saltzwerk, in Westphalia, is 2,100 ft. deep.

Another Artesian Well has been commenced at Paris, at the Place Hébert, and has been continued in spite of the numerous difficulties met with at almost every step. The first 72 feet of the shaft are lined with masonry. Then succeeds wrought-iron tubing, forced in by screw-pressure. When this lining had been carried down through thirty-six beds, there was reached a row of sand mingled with such a quantity of water that the sand was almost in a fluid state. It was then found that the under-currents of water had driven the tubing out of the perpendicular. To obviate this was impossible, and the defect could only be remedied by taking up the tubes altogether, and continuing the masonry lining. The cylinders were removed with great difficulty, when it was found that the masonry could not be continued in the ordinary means, and a new method was devised. After several yards had been excavated below the existing masonry, and the sides shored up, a strong cradle of timber, exactly fitting the circumference of the well, was lowered and held suspended by stout chains to beams over the orifice of the well. This being done, the masonry was rapidly carried up from the cradle or platform as far as the existing lining, the chains being seated up in the work. One section being finished, another space was cleared, another platform was let down, by other chains, and the masonry laid upon it. Although the *calcaire grossier* was reached, the water sprung up in such abundance, that the sinking of the well by manual labour had to be abandoned, and recourse had to the *trepan*, an implement weighing no less than five tons, and composed of six branches, each armed with a steel chisel. It was expected that the work would be free from obstacles till the chalk was reached at an estimated depth of 472 feet.

Artesian Wells have been bored in and around London with opposite results, the alterations in the London strata being so great that no one experienced in wells will venture to infer from one place what will occur in another. The New River Company sunk a vast well at the foot of their reservoir in the Hampstead-road, at the cost of 12,412*l.*, and three years' operations, but the water obtained in the chalk was inconsiderable.

At Kentish Town, in 1856, an Artesian Well was abandoned when the borings had reached 1302 feet, no water having been met with, though a copious supply had been predicted from the lower greensands naturally expected to occur immediately below the gault; but the gault was found to be succeeded by 176 feet of a series of red clays, with intercalated sandstones and grits—a fact which set geologists pondering. The two Wells for the Government Water-works, Trafalgar-square, by C. E. Amos, C.E., were sunk in 1844, 300 feet and 400 feet deep; and cost nearly 8,000*l.* At South Kensington there has been sunk and bored, for the supply of the Horticultural Gardens, a well 401 feet deep, and 5 feet clear in diameter, the bore-hole being 201 feet deep from the bottom of the well; water rises 3 feet in the shaft, the pumps lifting 144,000 gallons daily, of excellent chalk spring-water.

Dr. Buckland, the eminent geologist, one of the first to show the fallacy, states that, although there are from 250 to 300 so-called Artesian Wells in the metropolis, there is not one *real Artesian Well* within three miles of St. Paul's: such being a well that is always overflowing, either from its natural source or from an artificial tube; and when the overflowing ceases, it is no longer an Artesian Well. The wells which are now made by boring through the London clay are merely common wells. It has been said that a supply of water, if bored for, will rise of its own accord; but the water obtained for the fountains in Trafalgar-square does not rise within forty feet of the surface, and is pumped up by means of a steam-engine—the same water over and over again.

Mr. Prestwich, jun., F.G.S., in his *Geological Inquiry*, considers "it difficult to account for the generally unfavourable opinion regarding Artesian Wells as a means of public supply, were it not that the annually decreasing yield of water from the tertiary sands and the chalk beneath London has produced an impression of uncertainty as to all such sources of supply; which, with the constantly increasing expense caused by the depth which the water has to be pumped, and the proportion of saline ingredients being so much greater in them than in the river waters, have been taken as sufficient grounds of objection. But it is to be observed, in explanation of the diminished supply from the present source, that the tertiary sands are of very limited dimensions; that the chalk is not a freely permeable deposit; and that the peculiarities of the saline ingredients depend upon the chemical composition of these formations.

All these causes, however, are local, and can by no means be considered as grounds of objection against the system of Artesian Wells generally." Mr. Prestwich suggests a fresh system of Artesian Wells, especially as none have as yet been carried *through the chalk;* though it is shown that the conditions in this country are more favourable than in France.

Arago was the first to observe that the temperature of the water in Artesian Wells increases with their depth, due regard being paid to the mean temperature of the climate in which they may be bored. This fact has been considered an argument in favour of the interior heat of the earth. At Grenelle, the water brought up from the greatest depth has a constant temperature of 81°7 of Fahrenheit, while the mean temperature of the air in the cellar of the Paris Observatory is only 53°. Mr. Walferdin has ascertained the temperature of two borings at Creuzot, within a mile of each other; commencing at a height of 1,030 feet above the sea, and going down to a depth, the one of 2,678 feet and the other about 900 feet. The results gave a rise of one degree of Fahrenheit for every 55 feet down to a depth of 1,800 feet; beyond this the rise of temperature was more rapid, being one degree of Fahrenheit for every forty-four feet of descent.

The water of the Artesian Well at Grenelle, instead of being allowed simply to rush up into the air, is made to ascend in a vertical tube, 110 feet high, at the top of which is a cistern or reservoir. Thence it is distributed by pipes to the places where it is required, the height of the reservoir giving sufficient pressure to carry the supply to even comparatively elevated places. An elegant structure of cast-iron, in the form of a light hexagonal tower or column, supports the reservoir. This tower is, of course, not placed immediately over the boring, but receives the water from it by a subterranean aqueduct. The tower, which is 139 feet in height, may be ascended by an open spiral staircase of 150 steps.

THE STEAM-ENGINE.

IF a person were required to name the invention or contrivance which more than any other has beneficially influenced the progress of mankind, he would surely name the Steam-engine. The advance of the mechanical arts, which marks the last hundred years, is observed to far exceed all that the long course of previous ages can show; and this rapid advance is, beyond doubt, largely due to the mighty instrument which the genius of Watt placed in the hands of industry, when he transformed a philosophical toy into the Steam-engine. Not less remarkable are the changes in social life, and in international commerce, which steam-power has brought about, by facilitating intercourse and cheapening the transport of commodities by sea and land. Half a century since, a distinguished American orator* spoke thus of the power of steam:—"In comparison with the past, what centuries of improvement has this single agent comprised in the short compass of fifty years? Everywhere practicable, everywhere efficient, it has an arm a thousand times stronger than that of Hercules, and to which human ingenuity is capable of fitting a thousand times as many hands as belonged to Briareus. Steam is found in triumphant operation on the seas; and, under the influence of its strong propulsion, the gallant ship still steadies with an upright keel against wind and tide. It is on the rivers, and the boatman may repose on his oars; it is on the highways, and exerts itself along the courses of land conveyance; it is at the bottom of mines, a thousand feet below the earth's surface; it is in the mill, and in the workshops of the trades. It rows, it pumps, it excavates, it carries, it draws, it lifts, it hammers, it spins, it weaves, it prints. It seems to say to men, at least to the class of artizans, 'Leave

* Daniel Webster, in 1828.

off your manual labour, give over your bodily toil; bestow but your skill and reason to the directing of my power, and I will bear the toil—with no muscle to grow weary, no nerve to relax, no breast to feel faintness.' What further improvements may still be made in the use of this astonishing power it is impossible to know, and it were vain to conjecture. What we do know is, that it has most essentially altered the face of affairs, and that no visible limit yet appears beyond which its progress is seen to be impossible. If its power were now to be annihilated, if we were to miss it on the water, and in the mills, it would seem as if we were going back to rude ages."

It has been asked, "What might the world have become, by this time, had the wonderful capabilities of steam been known to the nations of antiquity?" They were known in remote times, but it was long before they were understood, or beneficially applied. "A century ago," says Dr. Arnott, "no man had conceived it possible that human ingenuity would one day devise a machine like the modern Steam-engine, which, at small comparative cost, and with perfect obedience to man's will, should be able to perform the work of millions of human beings,* and of countless horses and oxen, and of water-mills and wind-mills; and which, in doing such complex and delicate labour as formerly was supposed to be obtainable only from human hands and skill, as of spinning, weaving, embroidering flower-patterns on cloth, &c., should work with speed and exactness far surpassing the exertions of ordinary hands."

It is curious to find the ancients employing this power in aid of superstition. Thus we read of the architect of Justinian, to annoy the orator Zeno, his neighbour and his enemy, conducting steam in leather tubes from concealed boilers, through the partition-wall beneath the beam which supported Zeno's house; and the steam being raised, the ceiling shook as if by an earthquake. Another ancient made an image of metal, with a hollow head, which he filled with water, having previously stopped the apertures at the eyes and mouth by wedges of wood; burning coals were then placed beneath the head, steam was shortly raised, which forcing out

* About ten years ago, the Steam-power of Great Britain was estimated in the *Quarterly Review* to be equivalent to the manual labour of 400,000,000 of men, or more than double the number of males supposed to inhabit the globe.

The Marquis of Worcester in the Tower.—Page 196.

he wedges, the steam escaped by eyes and mouth with a thick cloud and a loud report. Archimedes is stated to have constructed a "steam gun," which carried a ball, a talent in weight; and on the Æolopile, or Ball of Æolus, being full of water and placed on the fire, the steam rushed up a long pipe, and was applied to drive the vanes of a mill. The steam from a tea-kettle has been similarly employed. And about two centuries ago, the people of Staffordshire made a small steam-boiler in the form of a kneeling man, which being filled with water at the back of the head, and set on a strong fire, evaporated the steam by the mouth.

The importance of heat in the production of mechanical agents is evident from bodies, whether liquid, solid, or aëriform, exerting a certain degree of mechanical force in the process of enlarging their dimensions, or receiving an accession of heat; and any obstacle which opposes this enlargement sustains an equivalent pressure.

Thus, a pint of water, when converted into steam, occupies nearly 2,000 times the space of the water, because the heat merely produces a repulsion among the particles, and by no means fills up the insterstices. The powerful effects of high-pressure steam are illustrated upon a small scale by the little glass bubbles commonly called *candle* or *fire crackers;* they are hermetically, that is closely, sealed, and contain a drop of water, which occasions them to burst with violence when sufficiently heated to convert the water into steam.

The Steam-engine is much more intelligible than its name first suggests. It is, in fact, only a pump, in which the fluid is made to impel the piston, instead of being impelled by it; that is to say, in which the fluid acts as the *power*, instead of the *resistance*. It may be described simply as a strong barrel, or cylinder, with a closely-fitted piston in it, which is driven up and down by steam admitted alternately above and below from a suitable boiler; while the end of the piston-rod, at which the whole force may be considered as concentrated, is connected in any convenient way with the work that is to be performed. The power of the engine is of course proportioned to the size or area of the piston, on which the steam acts with a force of from 15 to 100 or more pounds to the square inch. The large vibrating beam is important, because one end being connected with the piston-rod is pulled down, while the power of the engine is applied at the other end to any mechanical purpose. Thus, when connected with immense water-pumps, it causes almost a river of water to gush out from the bowels of the earth.

The action of the Steam-engine, it may be added, depends principally upon the two leading properties of steam—namely, its expansive force and its easy condensation. To take the most simple view of these as moving powers, provide a glass tube with a bulb at its lower end. It is held in a brass ring, to which a wooden handle is attached, and contains a piston, which, as well as its rod, is perforated, and may be opened or closed by a screw at top: it is kept central by passing through a slice of cork. When used, a little water is poured into the bulb, and carefully heated over a spirit-lamp; the aperture in the piston-rod being open, the air is thus expelled, and, when steam freely follows it, the screw may be closed; then, on applying cold to the bulb—as, for instance, putting it on the surface of a little mercury in a glass,—the included steam is condensed, and a vacuum formed, which causes the descent of the piston, in consequence of the air pressing upon it from above. On again holding the bulb over the lamp, steam is reproduced, and the piston again forced up; and these alternate motions may be repeatedly performed by the alternate applications of heat and cold. This instrument gives a tolerably correct notion of the application of steam in the old engines, where it was employed conjointly with the pressure of the air as a moving power. In the most perfect construction of Watt's engine, to be hereafter described, steam is exclusively employed both for elevating and depressing the piston.*

* In Mr. Bourne's valuable work, *Recent Improvements in the Steam Engine*, 1865, is this admirable note,—" Steam in the production of power is itself condensed; and less heat will pass into the condenser than is generated in the boiler by the amount that is the equivalent of the power generated. If this were not so, a steam-engine would be a heat-producing engine; for the power of the engine is capable of producing heat by friction; and if we had in the condenser all the heat which the coal can generate, and if we also had the heat generated by the friction, we should have a total amount of heat greater than the coal could generate, which is an absurd supposition. There will, consequently, always be in the condenser less heat than the boiler produces; and the greater this disparity—supposing there is no loss by radiation—the more effective the engine will be. In a perfect engine the temperature of the condenser would not be raised at all; but the heat would totally disappear by its transformation into power. In such an engine, the steam would enter the cylinder at the temperature of the furnaces; and as it

But, in order to understand aright the simplicity of the means by which such great changes have been wrought, it is necessary to explain further what Steam is, and the manner in which it acts in propelling the machines to which it is applied.

From a common tea-kettle boiling upon the fire may be seen issuing by the spout a stream of vapour, which pours forth more energetically the more the water boils. This is the natural result of the application of heat to water; for as the bottom of the vessel is nearest the fire, it first feels the effect of the heat, which is next communicated to the water immediately above it. As this gets warm it expands, and thus becoming specifically lighter, it ascends through the mass, while its place is taken by the less heated water. This process continues, until at length the water acquires such a temperature that the particles next the bottom assume the form of vapour; and these, being lighter than the water, gradually rise in the form of bubbles of steam until they reach the surface, where they may be partially condensed into water again, or they may remain as vapour, having to overcome the resistance of the atmosphere, which presses with a weight of fifteen pounds on the square inch, above them. As the number of these vaporous globules increases, the sound of their propulsion against the particles of air accumulates until it becomes audible at a little distance, and then we hear what is called *singing*.

As the heat still continues to be applied to the water, this expansion of it gradually increases until it is diffused through the whole body in the vessel; the disturbance is shown in the upheaving and tumultuous agitation of the surface, and the water appears in a state of ebullition, or is what we call *boiling*. As the boiling goes on, the number of globules of water which are expanded into steam increases so much that the force overcomes the weight of the superincumbent atmosphere, and the steam pours forth.

We are in the habit of associating a smoky appearance with steam, because we generally observe it is beginning to be condensed; as when it escapes, for instance, from the spout of the tea-kettle; but when perfectly formed, it is quite invisible,

expanded more and more, its temperature would fall more and more, until finally it entered the condenser at the same temperature as the condenser itself. Such an engine indeed would not require a condenser, since the steam would itself condense as the heat left it by its transformation into power."

as shown in the experiment by Professor Faraday, just described. This invisibility may also be shown by boiling water in a flask, when perfect transparency will exist in the upper part of the vessel, which is filled with the hot vapour, and it only becomes visible when it escapes into the air, and begins to be condensed.

Dr. Lardner furnishes us with the following interesting examples of the motive power of a pint of water, when converted by the consumption of two ounces of coal into steam:—"A pint of water," he informs us, "may be evaporated by two ounces of coal. In its evaporation it swells into two hundred and sixteen gallons of steam, with a mechanical force sufficient to raise a weight of thirty-seven tons a foot high. The steam thus produced has a pressure equal to that of common atmospheric air; and by allowing it to expand, by virtue of its elasticity, a further mechanical force may be obtained, at least equal in amount to the former. A pint of water, therefore, and two ounces of common coal, are thus rendered capable of doing as much work as is equivalent to seventy-four tons raised a foot high."

In relation to the consumption of fuel, Dr. Lardner observes:—"The circumstances under which a Steam-engine is worked on a railway are not favourable to the economy of fuel. Nevertheless, a pound of coke burned in a locomotive engine will evaporate about five pints of water. In their evaporation, they will exert a mechanical force sufficient to draw two tons' weight on the railway a distance of one mile in two minutes. Four horses working in a stage coach on a common road, are necessary to draw the same weight the same distance in six minutes.

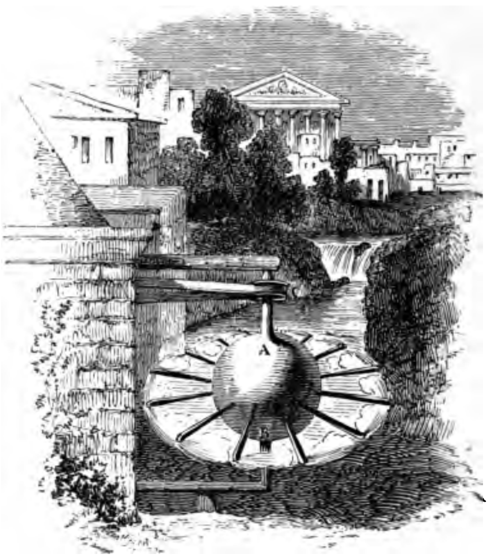
"The circumference of the earth measures twenty-five thousand miles; and if it were begirt with an iron railway, a train carrying two hundred and forty passengers would be drawn round it by the combustion of about thirty tons of coke, and the circuit would be accomplished in five weeks.

"In the drainage of the Cornish mines, the economy of fuel is much attended to, and coals are there made to do more work than elsewhere."

The Steam-engines employed in these mines are of a very superior description, and do a vast amount of work, in proportion to the quantity of fuel consumed. The number of engines employed is about eighty-two, with a total horse-power of between five and six thousand. The average quantity of water raised from the Cornish mines is about 9,000 gallons per minute, or nearly one million gallons per week. A striking illustration of the power of steam, as applied to these engines, is that the Menai bridge consists of a mass of iron not less than four millions of pounds' weight, suspended at a medium height of 120 feet above the level of the sea. The consumption of seven bushels of coals by the steam-engine would suffice to raise it to that height! The main pump-rod of one of the Cornish engines is about a mile in length. A quantity of about eighty gallons of water is brought up from this great depth by every stroke of the engine. To effect this, a weight of more than three hundred tons is put in motion at every stroke!

It may cause the reader some surprise to be informed that the discovery of the fact that a mechanical force is produced when water is evaporated by the application of heat (the first capital step in the invention of the Steam-engine) is very nearly two thousand years old, having been first pointed out by Hero of Alexandria one hundred and twenty years before the Christian era. This important discovery slumbered, as it were, for nearly seventeen hundred years before any application of it to practical uses was attempted; and for upwards of another hundred years before such application, even to the most limited extent, proved successful. About a century and a half ago a Steam-engine, constructed on an imperfect principle, was first used for the raising of water out of mines, which, though much improved upon during the next eighty years, was not sought to be applied to any other purpose.

The machine invented by Hero, which was moved by the mechanical force of the vapour of water, is supposed to have been constructed on the following principle. A hollow globe or ball was placed on pivots at A and B, on which it was capable of revolving; steam was supplied from a boiler through the horizontal tube at the bottom of the machine, which tube communicated with the pivot B. This steam filled the globe and also the numerous arms attached to it; while a lateral orifice at the end of each of these arms allowed the steam to escape in a jet. The reaction consequent on this produced a recoil and drove the arms round; if therefore there had been a pulley, as represented, at the upper part of the machine C, with a strap passing round it, the effect would have been to set any machinery in motion to which the other end of the strap might have been attached. This machine, after a lapse of nearly two thousand years, has been lately revived, and rotary engines, constructed on the same principle as Hero's, but simpler in



HERO'S MACHINE.

details, are now made as common toys. An excellent account of Hero's inventions has been published by Mr. Bennet Woodcroft.

Next in our chronicle of experiments is that made, in 1543, by Blasco de Garay, a sea-captain, to propel vessels by what has been somewhat loosely assimilated to a steam-engine. In going over the ground of history practised writers are continually stumbling. Thus a popular journalist, referring to the above experiment, said: "Three centuries ago Blasco de Garay attempted to propel a boat by steam in the harbour of Barcelona." To this positive assertion it was replied, "The evidence cited by the Spaniards, often repeated, is a letter from Blasco himself." By permission of the Queen of Spain, but after much hindrance, the person who questioned the statement was enabled to inspect this letter, which is preserved with the archives at Simancas, near Valladolid, and there is not one word about *steam* in the document. Blasco describes minutely a vessel propelled by paddles, worked by 200 men. It is true that the two letters at Simancas do not mention *steam*, as pointed out by Mr. Macgregor to the Society of Arts, in 1858; but the account of the experiment, as mentioned by Navarrete, leaves no doubt. We have not space for the entire details. Blasco de Garay is described to have presented to the Emperor Charles V. *an engine* which he had invented to propel large vessels without sails or oars. The account continues :— "The inventor did not publish a description of his engine; but the spectators saw that it consisted principally of an apparatus for boiling a great quantity of water; in certain wheels, which served as oars; and a machine that communicated to them the *steam* produced by the boiling water." Then we have the treasurer Ravago's objection, that "the boiler continually exposed the vessel to an explosion." The account concludes thus :—"These facts are extracted from the original register in the archives at Simancas, among the papers of Catalonia, the register of the War Office of the year 1543." The "cauldron of boiling water" is also mentioned in the account from Navarrete, under "Barcelona," *Penny Cyclopædia*, vol. iv. p. 438. Mr. Macgregor impugns Navarrete's report; and, as the result of his inquiries in Spain, he attests that not only are the letters at Simancas without evidence of the *steam*, but the statement is not known there, or at Barcelona, by the public officers. Supposing the evidence to be strictly correct, it bears only conjectural proof of the use of *steam*, though a boiler was used. Garay took away the machinery. It has been suggested that the moving power was obtained by an apparatus resembling the primitive steam-engine of Hero, just described.

Garay was rewarded, and the usefulness of the contrivance for towing ships out of port was admitted; yet it does not appear that a second experiment was made. The vessel was found to progress at the rate of a league an hour, or, according to Ravago, the treasurer, who was one of the commissioners, (but unfriendly to the design) at the rate of three leagues in two hours; but it *did* progress, and was found to be easily under command, and turned with facility to any point where it was directed. Favourable reports were made to the Emperor and to his son Philip II., but an expedition in which they were at that time engaged prevented the carrying out of the design to any practical extent. Thus the world was in all probability prevented for two centuries from reaping the immense advantages that would have resulted from the adoption of steam navigation.

At the conclusion of the experiment Garay, who was determined to keep his invention perfectly secret, immediately removed his machinery, leaving nothing but the bare wooden framework behind. This discovery, however, was thought so highly of that he was rewarded with promotion and two hundred thousand maravedis, besides having his expenses allowed him.

In the year 1615 a work appears to have been published at Frankfort, written by Solomon De Caus, an eminent French mathematician and engineer, from a passage in which M. Arago, the distinguished philosopher, claimed for its author a share of the honour of the invention of the steam-engine. De Caus was at one time in the service of Louis the Thirteenth, and afterwards in that of the Elector Palatine, who married the daughter of our James the First. During the latter period he visited this country, and was employed by Henry, Prince of Wales, in ornamenting the gardens of Richmond Palace. The passage referred to by M. Arago is much as follows:—Let there be attached to a ball of copper, *a*, a tube, *b*, and stop-cock, *c*, and also another tube, *d*; these tubes should reach almost to the bottom of the copper ball, and be well soldered in every part. The copper ball should then be filled with water through the tube, *b*, and the stop-cock be shut, when, if the ball is placed on a fire, the heat acting upon it will cause the water to rise in the tube, *d*, as indicated in the engraving. De Caus ascribed the force entirely to the air,

MACHINE BY DE CAUS.

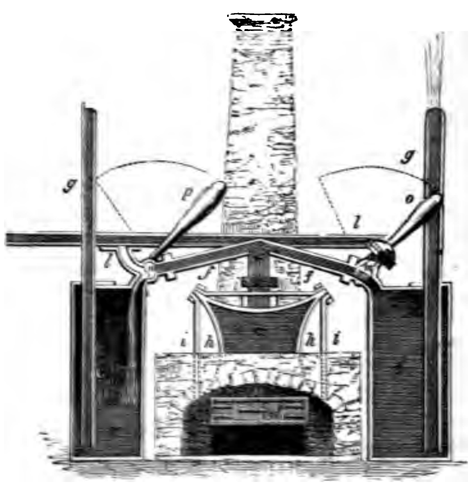
and not to the *steam*, which he does not mention, though the pressure may have caused the ball to burst with a noise like a petard. Notwithstanding the advocacy of M. Arago, De Caus is not entitled to any share in the invention of the Steam-engine.

A few years after the appearance of De Caus's work an Italian engineer, Giovanni Branca, proposed a machine consisting of a wheel with flat vanes upon its rim, similar to the boards of a paddle-wheel. The steam was to have been produced in a close vessel and made to issue with considerable force out of a tube directed against the vanes, which would cause the revolution of the wheel, the tube projecting from the mouth of a figure; but the steam had to pass through the atmosphere in its passage to the wheel. This method bears no resemblance to any application of steam-power in use in engines of the present day.

We now come to the more interesting claim of one of our own countrymen to the honour of being regarded as one of the chief inventors of the Steam-engine. Such was the Marquis of Worcester, who, living in the time of the Civil War between Charles I. and his Parliament, took part with the King, and after losing his fortune in the cause, was imprisoned in Ireland; he managed to escape, and fled to France, whence, after spending some time at the Court of the exiled Royal Family of England, he returned to this country as their secret agent; but, being detected, was committed prisoner to the Tower. It is said that during his captivity, while he was engaged one day in cooking his own dinner, he observed the lid of the saucepan was continually being forced upwards by the vapour of the boiling water. Having a turn for scientific investigation, he began to reflect on the circumstance, when it occurred to him that the same power which was capable of raising the iron cover of the pot might be applied to useful purposes; and on obtaining his liberty he set to work to produce a practical exposition of his ideas on the subject in the shape of a working machine, which he described in his work in the following terms:—

"I have invented an admirable and forcible way to drive up water by fire; not by drawing or sucking it upwards, for that must be, as the philosopher terms it, *intra sphæram 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 whole cannon, whereof the end was burst, and filled it three-quarters full of water, stopping and screwing up the broken end, and 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 feet high. One vessel of water rarified by fire driveth up forty of cold water, and a man that tends the work has but to turn two cocks; that one vessel of water being consumed, another begins to force and refill with cold water, and so successively; the fire being tended and kept constant, which the self-same person may likewise abundantly perform in the interim between the necessity of turning the said cocks."

In the accompanying figure of the Marquis of Worcester's engine the boiler is composed of arched iron plates, with their



THE MARQUIS OF WORCESTER'S ENGINE.

convex sides turned inward; they are fastened at the joinings by bolts passing through holes in their sides, which also pass through the ends of the rods *i*, *i*, *i*, a series of which rods extends from end to end of the boiler, being a few inches apart. The ends of the boiler are hemispherical, and are fastened to flanges on the plates *h*, *h*, *h*. It will be evident that, each plate being an arch, before the boiler can burst several, if not nearly all, the rods *i*, *i*, *i*, must either be pulled asunder or torn from the bolts at the point of junction; and as the strength of the rods and bolts may be increased to any extent without interrupting the action of the fire, there can be no doubt that a boiler might be so constructed as to be perfectly safe under any pressure which could be required for raising water to a given height, because the pressure in such a boiler will never exceed the weight of a column of water equal in height to the cistern. *b*, *c*, represent two vessels, which communicate with the boiler *a*, by means of the pipes *f*, *f*, and the way-cocks *m*, *n*, and with the reservoir from which the water is to be drawn by the pipes *l*, *l*: *g*, *g*, are two tubes, through which the water is elevated to the cistern; they reach nearly to the bottom of the vessels *b*, *c*, and are open at each end. The pipe *l*, as well as *f*, *f*, communicates with the vessels *b*, *c*, by means of the way-cocks *m*, *n*, which, by moving the handles *o*, *p*, can be so placed that either the steam from the boiler, or the water from the reservoir, shall instantly have access to the vessels *b*, *c*. Fire having been kindled under the boiler *a*, in the furnace *d*, the cock *n* is placed in the position represented in the engraving, when the water will have access from the reservoir to the vessel *c*, which being filled, the handle *p* is turned back, so that the cock shall be relatively in the position shown at *m*; the steam then fairly enters, through the pipe *f*, into the vessel *c*, and having no other mode of escape, presses on the surface of the water, which it forces up through the pipe *g*. During this operation, the pipe *m* having been placed, as shown, at *n*, the vessel *b* is filled from the reservoir through the pipe *l*, so that the water in the vessel *c* being consumed, the handle *o* of the cock *m* is turned, which admits the steam on the surface of the water in *b*, shutting off by the same operation the communication between *b* and the reservoir.

The Marquis of Worcester left a "Definition" of this engine, of which the only copy known is in the British Museum: it is printed on a single leaf, without date, and is judged to have been written for procuring subscriptions to a Water Company which the Marquis projected: he describes it as "a stupendous, or Water-commanding Engine, boundless for height or quantity, requiring no external or even additional help or force to be set or continued in motion, but what intrinsically is afforded from its own operation, nor yet the twentieth part thereof." The particulars are then given, and the account concludes with: "Whosoever is master of weight is master of force; whosoever is master of water is master of both; and consequently to him all forcible actions and achievements are easier." There is also preserved the manuscript of a very eloquent thanksgiving prayer addressed to God by the Marquis "when first with his corporall eyes he did see finished a perfect tryall of his Water-commanding Engine."

This machine is also described by the Marquis in his celebrated *Century of Inventions*, or one hundred contrivances which he projected: many of which have been brought into general use, including stenography, floating baths, telegraphs, and speaking tubes; carriages, from which horses can be discharged if unruly; locks and keys, &c. This work was first printed in 1663.* In the same year the profits that might arise from the Engine were secured to Lord Worcester by Act of Parliament. A tenth of the profits was to go to the King, Charles II., who, however, remitted this share upon surrender of a warrant dated at Oxford 5th January, 20 Car. I., by which His then Majesty did grant the Marquis lands to the value of 40,000*l.*, in consideration of a debt due to the Marquis from His Majesty. While the Marquis was a close prisoner in the Tower, the Engine was shown in operation, "beyond the Palace of the Archbishop of Canterbury," probably at Vauxhall, where the Lord Worcester states that he had "built premises as workshops for engineers and artists to work public works in," he having expended above 50,000*l.*—an enormous amount two hundred years ago—"trying experiments and conclusions of arts."

Lord Worcester died in retirement near London, April 3, 1667: his remains were interred in the cemetery of the Beaufort family, in Raglan church, the coffin being placed in an

* The *Century* has been seven times reprinted. The seventh edition, 1825, with explanatory notes by Mr. Partington, the able writer on the Steam-engine, is admirably edited: it is a small 8vo volume of 150 pages. There has since appeared "The Life, Times, and Scientific Labours of the second Marquis of Worcester. To which is added a reprint of his Century of Inventions, 1663, with a Commentary thereon." By Henry Dircks, Esq., C.E., 1865. This is a most exhaustive work.

arched stone vault.* Now, in the *Century*, the Marquis concludes his description of the Water-commanding Engine with these words : " I do intend that a model thereof be buried with me." Whether this intention was carried out is uncertain : the opening of the coffin would settle the question ; and we agree with a reviewer in the *Mechanics' Magazine*, 1865, that " It would, indeed, be a proud day for the British aristocracy, if it could be shown that one of the noblest of their class, descended

* Raglan Castle, Monmouthshire, now a picturesque ruin, stood at a short distance from the village of Raglan, on the right of the Abergavenny or great road into Wales. The fortifications were destroyed by the Parliamentary forces in 1646, when the timber in the parks was cut down and sold. The lead alone that covered the castle was sold for 6,000*l.*, and the loss to the family in the house and woods was estimated at not less than 100,000*l.* In 1640 some rustics, in the interest of the Parliament, came to search the castle for arms, from which, however they desisted; but the inventive Lord Herbert, afterwards Marquis, in the parley which ensued, " brought them over a high bridge that arched over the moat that was between the castle and the great tower, wherein the Lord Herbert had newly contrived certain water works, which, when the several engines and wheels were to be set a-going, much quantity of water through the hollow conveyances of the aqueducts was to be let down from the top of the high tower." These engines were set to work, and their noise and roar so frightened the parliamentary searchers that they ran as fast as they could out of the grounds upon being told that "the lions had got loose." The position of these water-works, as described by a contemporary chaplain, exactly coincides with some remaining vestiges in the stonework of the castle. Mr. Dircks, in his work already referred to, gives a view of this external wall of the keep of the castle, whereon are seen "certain strange mysterious grooves," on that side of the wall facing the moat, "which point like a hieroglyphic inscription to the precise place where once stood in active operation the first practical application in a primitive form of a means of employing steam as a mechanical agent." There are three large vertical grooves cut into the stone wall, proceeding from as many cells, which may each have held a steam boiler. From the summit of the three large vertical channels to the ground the distance measures 46 ft. The proximity to the moat is further evidence that the stone casings had something to do with the Marquis's "stupendous water-commanding engine," and that the pipes were probably used to convey water from the moat up to a cistern on the top of the citadel. At first sight, says the *Mechanics' Magazine*, the number of boilers for forcing up water to such a short height seems unaccountable; but the mode of using the steam, and the low pressure, must have led to much condensation, and consequent drain of steam. An interesting letter of the Marquis was preserved in the MS. collection of the late Dawson Turner, Esq., of Yarmouth, addressed to the Earl of Lotherdale, in order to induce him to take a share in the patent. The different eight points "defining" his "water-commanding engine" also exactly define the range of action of a modern steam pumping engine. It is "a perfect counterpoise for what quantity of water soever," and "for what height soever," and other "particulars."

from the royal Plantagenets, had given the first impulse to the introduction of the Steam-engine. Certainly, the general indifference in England with regard to the claims of the Marquis of Worcester seems marvellous, especially so when contrasted with the feverish and morbid anxiety of the French to annex the honour to their own country."

The French assert that Lord Worcester took the idea of the Steam-engine from De Caus; and in proof of this assertion bring forward a letter from Marian Delorme, a celebrated beauty of the reign of Louis XIII., to M. Cinq Mars, beheaded by Cardinal Richelieu, for the part taken by him in some conspiracy. The following is the substance of the letter:—

"PARIS, *3rd February*, 1641.

"Whilst you forget me at Narbonne, where you give yourself up to the pleasures of the court, and delight in vexing my Lord Cardinal, I, in accordance with the wish you expressed to me, do the honours at Paris, to your great English lord, the Marquis of Worcester, and I escort him, or rather he escorts me, from one curious sight to another; for example, we paid a visit to Bicêtre, where he pretends, in a madman, to have discovered a man of genius! Whilst crossing the court-yard of the hospital, more dead than alive from fear, and clinging to my companion, an ugly countenance presented itself behind the large iron bars, and cried loudly, 'I am not mad! I have made a discovery which must enrich any country that will put it in operation.' 'And, pray, what is his discovery?' said I to the keeper who showed us the establishment. 'Ah!' replied he, shrugging his shoulders, 'something very simple, but that you would never guess. It's the application of boiling water.' I burst out laughing. 'This man,' continued the keeper, 'calls himself Solomon De Caus; he came from Normandy four years ago to present to the king a treatise upon the wonderful effects of steam. Cardinal Richelieu dismissed this madman without hearing him. Solomon De Caus, instead of being discouraged, followed my lord the Cardinal everywhere, who, annoyed at finding him continually crossing his path and importuning him with his follies, ordered his imprisonment at Bicêtre, where he has been for three years and a half. He cries out to every stranger that he is not a madman, and that he has made an admirable discovery.' 'Conduct me near to him,' said Lord Worcester; I wish to speak with him.' They conducted his lordship: he returned sad and thoughtful. 'Now,' he exclaimed, 'he is indeed mad; misfortune and captivity have for ever injured his reason. You have made him mad; for when you cast him into this dungeon you cast there the greatest genius of his time, and in my country, instead of being imprisoned, he would have been loaded with riches.'"

There is another translation of this letter, which the Rev. Sydney Smith is stated to have copied from a periodical work, and which he believed to be authentic. A man of opposite tone of mind, Arago, who was rich in inventive faculty, and of ery ardent temperament,* was imposed upon by the above omantic fiction, now conclusively proved by M. Figuier to be . forgery. Nevertheless, a French artist has illustrated the tory with this circumstantial minuteness!

THE PRETENDED SCENE OF THE MARQUIS OF WORCESTER AND MARIAN DELORME MEETING WITH DE CAUS IN THE BICÊTRE.

In reference to the invention of Lord Worcester Dr. Lardner bserves that, "on comparing it with the contrivance previously uggested by De Caus, it will be observed that even if he (De Caus) knew the physical agent by which the water was driven pwards in the apparatus described by him, still it was only a ethod of causing a vessel of boiling water to empty itself; and, efore a repetition of the process could be made, the vessel ıust be refilled, and again boiled. In the contrivance of ord Worcester, on the other hand, the agency of the steam as employed in the same manner as it is in the Steam-engines f the present day, being generated in one vessel and sed for mechanical purposes in another. Nor must this disinction be regarded as trifling or insignificant, because on it

* The Emperor Napoleon III. said, when a captive at Ham, "Arago ossesses in a high degree these two faculties so difficult to meet with in the ame man—that of being the grand priest of science, and of being able to nitiate the vulgar into its mysteries."

P 2

depends the whole practicability of using steam as a mechanical agent. Had its action been confined to the vessel in which it was produced, it never could have been employed for any useful purpose." Here we may mention that Professor Millington has, in our day, designed an engine on similar principles to that of the Marquis, and which, with a few alterations, might be made available for the purposes recommended by Worcester.

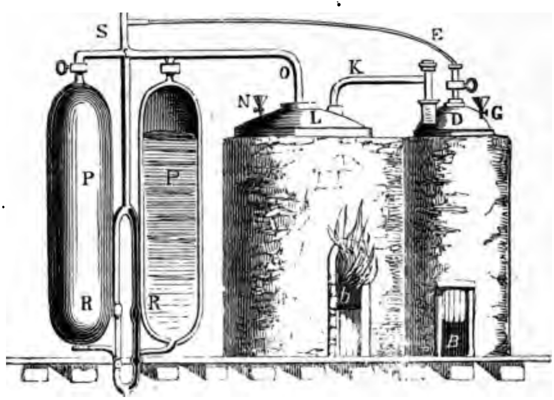
Sir Samuel Morland, Master of Mechanics to Charles II., next, in 1682, in a short tract on the Steam-engine, explained his "Principles of the New Force of Fire," converting water into vapour, in which he showed the number of pounds that may be raised 1800 times per hour to a height of six inches by cylinders half filled with water, as well as the different diameters and depths of the cylinders: his approximations are correct, and must have been the results of experiments; but Morland does not explain the form of the machine by which he proposed to render the force of steam a useful mover, and his researches were little heeded.

Denis Papin, the engineer of Blois, in 1688, produced a moving power by means of a piston working in a cylinder, to be effected by the condensation of steam into water; in other words, he imagined the formation of a vacuum by cooling the steam, and when he wanted it to cool, he *took away the fire*, or rather the heated plate; the piston was then pressed down again by the force of the atmosphere above. Papin did not make any machine at all, but only a small model; beyond this no further steps were taken, although Arago gives the invention of the Steam-engine to Papin. After the lapse of a few years, the necessities of the mining operations in Cornwall drew the attention of practical men to some means of drawing off the water which continually accumulated in the mines; and Captain Thomas Savery devised a machine for that purpose. This was a combination of the Marquis of Worcester's machine with an apparatus for raising water by suction in a vacuum produced by the condensation of steam. Savery stated that he derived the idea of his machine from having flung on the fire a flask containing a small quantity of wine, and called for a basin of water to wash his hands. The wine in the flask began to boil, and steam issued from its mouth; when it occurred to Savery to invert the flask, and plunge its mouth into cold water. Putting on a thick glove, to protect his hand from the heat, he seized the flask, and the moment he plunged its mouth into water, the liquid rushed into the flask and filled it. Savery then concluded that instead of exhausting the barrel of the pump by a piston and sucker, it might be accomplished by first filling it with steam, and then condensing the steam; when the atmospheric pressure would force the water from the mine into the pump-barrel, and thence into any vessel connected with it, provided the vessel was not more than thirty-four feet above the level of water in the mine. He thought, after having raised the water to this height, that he might use the elastic force of steam at a high temperature to lift the water to a much greater elevation, after the plan proposed by the Marquis of Worcester; and by condensing this same steam he considered he could reproduce the vacuum, and thereby draw up more water. Savery's machine may be described as follows :—

The engine was fixed in a good double furnace, so contrived that the flame of the fire might circulate round and encompass the boilers. Before the fire was lighted, the two small gauge-pipe cocks, G and N, belonging to the two boilers were unscrewed, the larger boiler L filled two-thirds full of water, and the small boiler D quite full. The said pipes were then screwed on again, as fast and as tight as possible. The fire *b* was then lighted, and when the water boiled in the large boiler the cock of the vessel P (shown in section) was opened. This made the steam rising from the water in L pass with irresistible force through O into P, pushing out all the air before it through the clack R. When the air had left the vessel, the bottom of it became very hot; the cock of the pipe of this vessel was then shut, and the cock of the other vessel P opened, until that vessel had discharged its air, through the clack R, up the force-pipe S. In the meantime a stream of cold water (supplied by a pipe connected with the discharging pipe S, but not shown in the cut) was passed over the outside of the vessel P, which, by condensing the steam within, created a vacuum, and the water from the well necessarily rose up through the sucking pump (cut off below M), lifting up the clack M, and filling the vessel P.

The first vessel, P, being emptied of its air, the cock was again opened, when the force of steam from the boiler pressed upon the surface of the water with an elastic quality like air, still increasing in elasticity, or spring, till it counterpoised or rather exceeded the weight of water ascending in the pipe S, out of which the water was immediately discharged when it had once reached the top.

The woodcut represents two reservoirs, P P, designed for alternate action; the tube E was for the purpose of conveying water from the discharging pipe, to replenish the boiler L when the water in it began to be consumed: this was done by keeping the boiler D supplied with water, and by lighting the fire at B, generating sufficient steam to press the water into L, through the pipe K.



SAVERY'S CONDENSING STEAM-ENGINE.

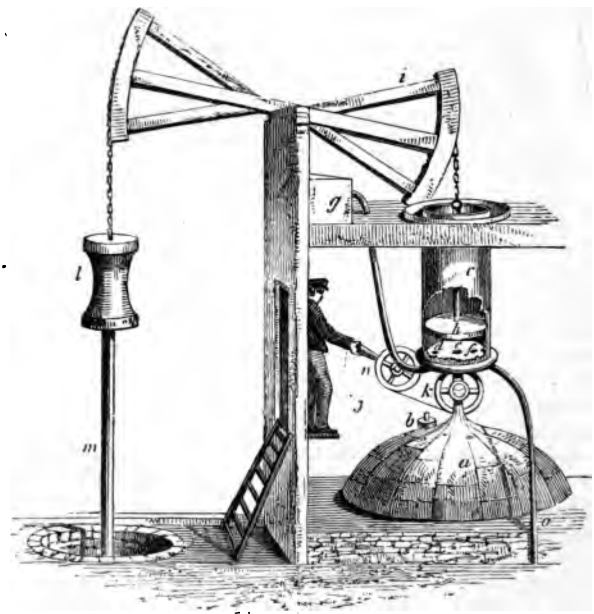
Thus was constructed the first engine in which steam was ever brought into practical operation. Savery exhibited a model of his engine to the Royal Society, June 14, 1699; and the Society gave him a certificate of its success. Savery presented a drawing of his engine, which is preserved among the Society's collection of prints and drawings at Burlington House: a description of the engine is printed in the 21st volume of the *Transactions*. Thus we are indebted to Savery for the introduction of a vacuum, which enabled his engine to perform double the work of that invented by the Marquis of Worcester. Savery's engine was first shown in a potter's house at Lambeth: though the engine was small, the water forced its way through the roof and struck up the tiles "in a manner that surprised all the spectators." By this success, especially the Royal Society's certificate, Savery procured a patent from the Crown for the manufacture of Steam-engines.

But Savery had his detractors : Desaguliers unjustly accused him of having derived his plans from the Marquis of Worcester. In the *Miner's Friend; or, an Engine to raise Water by Fire*, by Thomas Savery, Gent., published in 1702, or nearly forty years after the *Century*, Savery certainly carried out the plan. In his *Course of Experimental Philosophy*, published in 1763, Desaguliers distinctly stated that Savery, in order to claim the invention for himself, "bought up all the Marquis of Worcester's books that he could purchase in Paternoster-row and elsewhere, and burned them in the presence of the gentleman, his friend, who told me this." The contest as to the introduction of the fire-engine, which led to the atmospheric engine, which last, in its turn, generates the modern Steam-engine, must lie between the Marquis of Worcester and Captain Savery.

Then Savery is stated to have borrowed from Papin; but the former worked on essentially different principles. His moving power was the *elasticity of steam*, to which our engineers have again returned since Watt demonstrated the great advantage of it; whereas Papin used the pressure of the atmosphere, which can never exceed a few pounds on the square inch of the piston, and steam was only a subordinate agent by which he produced a vacuum. The arrangement also of the different parts of Savery's engine, and particularly the means he used for condensing the steam, are all his own, and mark him for a man of truly inventive genius. Such is the testimony of Professor Rigaud, F.R.S.

Desaguliers, who had been so active against Lord Worcester's claim, about 1717 applied to Savery's engine the safety-valve which Papin had invented for his Digester, eighteen years before, though it is strange that he did not apply it to his own steam-machine. Papin's Digester was invented upon the principle, that if vapour be prevented from rising the water becomes hotter than the usual boiling point; and the strength required for this machine, and the requisite means for confining the covers, must have shown Papin what a powerful agent he was using. The Digester is used for softening bones, and is employed in cookery and confectionery at the present day. Charles II. had a Digester made for his Laboratory at Whitehall; and with it was cooked a "philosophical supper," given to the Royal Society. Papin declared it would prepare jellies at one third of the usual cost; and make the hardest bones soft as cheese, with less than eight ounces of coal, producing "an incredible quantity of gravy." This machine was a souroe of great hilarity among the usually grave Fellows of the Royal Society.

An accidental visit to the tin mines of Cornwall next led to important results, about the year 1710, when Thomas Newcomen, an ironmonger, and John Cawley, a glazier, as they stood watching Savery's engine at work, detected the cause of its shortcomings in drainage. This Newcomen proposed to remedy by his atmospheric engine, in which there was a cylinder



NEWCOMEN'S STEAM-ENGINE.

c open at the upper end, through which a piston worked. This end of the piston was attached to a beam *i*, resting at the middle on a pier or shaft, and provided at each end with a curved piece of wood or iron, like a segment of the rim of a wheel, in order to maintain the position of the rods with which this beam was connected at either end. At the lower part of the cylinder there was a chamber, which, by means of a steam-pipe, communicated with the boiler *a*. In order to preserve it air-tight, the upper part of the cylinder was kept about six inches deep in water. On each side, at the bottom of the cylinder, there was a cock: one communicating with a reservoir of water *g*, and which when opened allowed a jet of water to enter the cylinder through the pipe *d*; another which allowed the condensed steam and air* to escape through *f* down the pipe *o*. In the foregoing engraving of Newcomen's engine the interior of the lower part of the engine is shown. The safety valve *b* was raised when the steam produced by the boiler exceeded the pressure of the atmosphere by more than one pound on the square inch, and the steam escaped through it. The water then boiling, the cock *k* in the steam-pipe *e* was opened by the attendant, who pushed down the handle to *j*; this gradually filled the lower part of the cylinder with steam: but the power of the steam being only sufficient to equal the pressure of the atmosphere, would not of itself raise the piston and beam; this was therefore effected by means of the weight or counterpoise *l*, which on the rise of the piston forced down the pump rod *m* into the pump below. The attendant then returned the handle to its original position, which prevented the admission of more steam from the boiler; and at the same time opened the cock *n*, which, communicating with the reservoir *g*, threw a jet of cold water into the cylinder. This instantly condensed the steam, and the piston, as it descended, in consequence of the pressure of the superincumbent atmosphere, drove out the water and air* from the bottom of the cylinder, and raised the pump-bucket in the mine. The steam-cock was again opened, and the piston again rose: again the steam was condensed, the piston descended, the water and air were driven out; and so the process went on so long as the services of the engine were required.

Humphrey Potter, a mere lad, who had to attend to the cock of the atmospheric engine, becoming tired of the monotony of his employment, ingeniously contrived the adjustment of a number of strings, which, being attached to the beam of the engine, opened and closed the cock, with regularity and certainty, as the beam moved upwards and downwards, thus

* *i.e.* air derived from the cold water.

rendering the machine totally independent of manual superintendence. The contrivance of Potter, which is the *Hand-gear*, was soon improved upon; and the whole apparatus was, about the year 1718, brought into complete working order by an engineer named Beighton.

The earlier Steam-engines may be regarded as Steam-pumps, and that of Newcomen the connecting link between the Steam-pump and the modern engine. Newcomen's engines, improved in various ways by Brindley, Smeaton, and other engineers, continued in use during the greater part of the last century; but it was in effect the same until the days of Watt, the result of whose labours has been a harvest of wealth, prosperity, and ingenuity, without a parallel in the history of the world.

James Watt, who was born at Greenock, in Scotland, January 19, 1736, had from his birth delicate health; and as he grew up, instead of being subjected to educational restraints, was, for the most part, left at liberty to choose his own occupations and amusements. His father was a mathematical instrument maker, and in his workshop little Watt soon found his toys. By amusing himself with a quadrant he was led to the study of optics and astronomy. He was found one day stretched upon the hearth, tracing with chalk various lines and angles. "Why do you permit this child," said a friend to Watt's father, "to waste his time so? why not send him to school?" Mr. Watt replied, "You judge him hastily; before you condemn us, ascertain how he is employed." On examining the boy, then six years of age, it was found that he was engaged in the solution of a problem of Euclid. Observing the tendency of his son's mind, Mr. Watt placed at his son's disposal a collection of tools, which he soon learned to use. He took to pieces and put together, again and again, all the children's toys which he could procure; and he employed himself in making new ones. Subsequently he constructed a little electrical machine, the sparks proceeding from which much amused the play-fellows of the young invalid.

The father, who was sufficiently clear-sighted, entertained high hopes of the growing faculties of his son. More distant or less sagacious relations were not so sanguine. One day Mrs. Muirhead, the aunt of the boy, reproaching him for what she conceived to be listless idleness, desired him to take a book, and occupy himself usefully. "More than an hour has now passed away," said she, "and you have not uttered a single word. Do you know what you have been doing all this time? You have taken off and put on, repeatedly, the lid of the teapot; you have been holding the saucer and the spoons over the steam, and you have been endeavouring to catch the drops of water formed on them by the vapour. Is it not a shame for you to waste your time so?"

Mrs. Muirhead was little aware that this was the first experiment in the career of discovery which was subsequently to immortalise her nephew. She did not see, as many can, in the little boy playing with the teapot, the great engineer preluding to more discoveries which were destined to confer on mankind inestimable benefits. Another relative, Watt's cousin, Mrs. Marian Campbell, describes him watching the steam from a tea-kettle, and by means of a cup and spoon showing the condensation of steam.

Young Watt was now sent to a commercial school, where he acquired a fair share of Latin, and a little Greek; but his chief success lay in mathematics. At the age of nineteen Watt went to London, and there sought a situation; but in vain: he began to despond, when he obtained employment with John Morgan, as mathematical instrument maker, in Finch-lane, Cornhill: he remained here but a twelvemonth, and then returned to Glasgow, taking with him twenty guineas' worth of additional tools. Here he opened a shop as "mathematical instrument maker to the University," and drew around him friends and patrons; among whom were Adam Smith, Dr. Black, and John Robison: the latter said of young Watt, "I saw a workman, and expected no more; but was surprised to find a philosopher as young as myself, and always ready to instruct me."

It was about the year 1762, or 1763, that Watt's attention appears to have been first turned to the principle of the Steam-engine, when he made several experiments with Papin's Digester; and by balancing a piston-rod with a weight at one end, and then admitting steam under it, he succeeded in obtaining a continuous motion. But it was not until the following year that his inventive and acute faculties were truly practically engaged upon the great object.

About this time, the expense of lifting the water from mines, sometimes from depths of seven or nine hundred feet, was great; drawing off the water alone, in some places, cost above 10,000*l.* a year; and the time seemed approaching when the mines would cease to be wrought at all, the outlay greatly exceeding the returns. Steam-engines had staved off this result for some years before Watt arose; but the quantity of fuel they consumed was immense when compared with the quantity of mineral and water they raised. With a model of one of Newcomen's engines, belonging to Glasgow College, Watt began his experiments. He soon found that it would not give the amount of work represented by the fuel consumed; and, having closely examined the structure of the machine, he was led to ask why the steam should do its work in the cylinder, and then be condensed there by a jet of cold water. Steam, like air, is an elastic fluid, and will rush into a vacuum communicating with a vessel in which it is contained. Let the cylinder of the engine be filled with steam; establish a communication between it and another vessel kept as free as possible of air, and in which a jet of cold water is playing; the steam will then be condensed, and the temperature of the cylinder will not be affected. This is the great discovery of Watt: his condensing engine keeps its place, after a century of progress in the arts; and it will most likely do so until steam itself retire, to make way for a cheaper, if not a more powerful, agent. Watt made his experiments with a little tin cistern, which is still preserved; while busy investigating the subject, he was once observed by a visitor kicking it beneath the table, to prevent questioning.*

* James Syme, M.A.: *Edinburgh Essays.*

In the progress of the invention one great anomaly struck Watt; the condensation of a little steam at 212° was sufficient to make water rise to the boiling heat of 212° of Fahrenheit's thermometer. On mentioning this strange circumstance to Dr. Black, that eminent chemist showed the cause of it, and then developed the properties of *latent heat*, which he had lately discovered. Although Watt hit upon the idea of the separate condenser in 1765, and had in two or three days worked out in his mind the leading points of the modern Steam-engine, yet it was not until the end of 1774 that his first model was brought to work satisfactorily. The machine-tools of the present day were not in existence; he could not even obtain a cylinder that was true in the bore, and bitter was his lament over the decease of his "white-iron man." Again, the financial difficulty was almost as great a difficulty to conquer as the mechanical one. Soon after his discovery of the separate condenser he entered into partnership with Dr. Roebuck, of the Carron Ironworks: a patent was taken out, Watt agreeing to cede to Roebuck two-thirds of all advantages to be derived from the invention. An experimental engine on a large scale was next constructed, the success of which, with the exception of some practical difficulties that presented themselves, was complete.

A few years afterwards Dr. Roebuck became embarrassed, when, in 1773, Matthew Boulton, of the Soho Works, near Birmingham, was induced to take Roebuck's two-thirds share of the patent of 1769 as a bad debt, until which time the practical application of the ingenious labours of Watt can scarcely be said to have commenced. It has been happily said that without Boulton there would have been no Watt.

In the following year an application was made to Parliament for an extension of the patent, and in 1775 an Act was passed extending the term, which, according to the original patent, would have expired in 1783, for a period of seventeen years longer. Watt now applied himself vigorously to the perfection of his invention in all its practical details; and the result was the construction, on a large scale, of what is now known as his single-action Steam-engine.

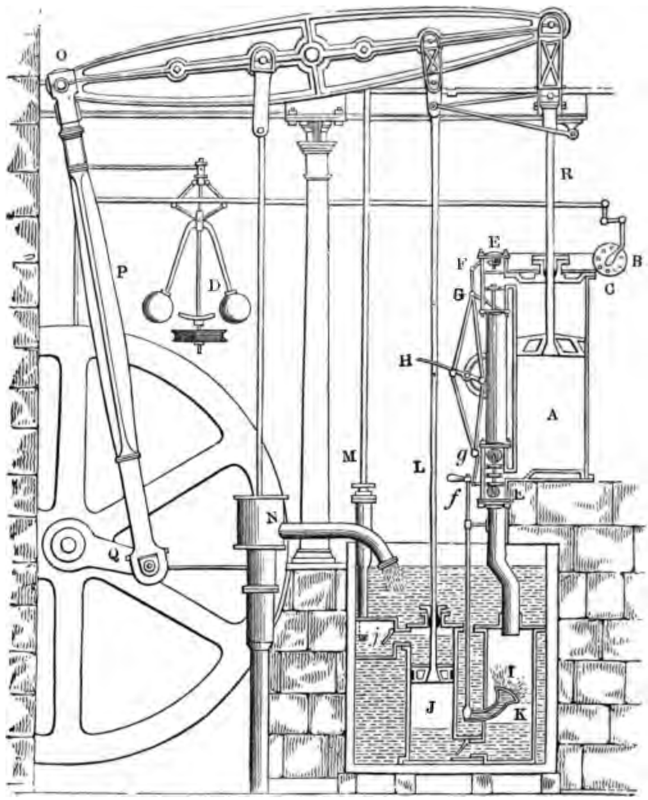
During the progress of the accessory improvements must be noticed Watt's ingenious parallel motion, of which he used to say, "Though I am not over anxious after fame, yet I am more proud of parallel motion than of any other mechanical invention I ever made." By this he attempted to remedy the irregularity of action caused by the suspension of the power of the engine during the ascent of the piston-rod; but his idea was divulged by a workman, who communicated it to one Wasborough, who at once adopted it, and took out a patent for the application of the crank to Steam-engines. To avoid litigation, Watt abandoned his idea of using a crank, and substituted "the sun and planet motion," an arrangement which may be seen in the "Old Bess Engine," now in the South Kensington Museum: this is a venerable relic of the Soho factory, where it commenced work in 1779, being the very first constructed by Watt on the expansion principle. It was the great show engine in the last century, and was at work in that establishment until a few years ago, when it was removed to its present resting-place. The completion of the rotative

SOHO IRONWORKS.

engine, which placed the whole industry of the country at the feet of the firm, should have given Watt unbounded satisfaction; but, on the contrary, he discountenanced it. Boulton, however, with great foresight, ignored Watt's advice in the matter. We are told that the first rotative engine was erected for Mr. Reynolds, at Ketley, in 1782, and was used to drive a corn-mill; and the third engine is still working, though in a modified form, at Whitbread's Brewery, in Chiswell-street. To remedy the irregularity of motion produced by the unequal supply of steam from the boiler, Watt invented the Throttle-valve, which being placed in the pipe through which the steam is conveyed from the boiler to the cylinder, the opening and partial closing of it, by means of a lever, increased or reduced the supply of steam, according as it was required. To secure the efficiency of the throttle-valve, and to make it self-acting, Watt connected the lever, by means of which its motions were regulated, with an apparatus, founded on the principle of the regulator employed in windmills, to which he gave the name of the Governor. This consists of two heavy balls, which are attached to a pair of levers that revolve with a spindle connected with the main shaft of the engine. The centrifugal action exerted by these masses is greater as the rotation is more rapid. The levers carrying the balls are so jointed with others, that the centrifugal force which causes the balls to diverge, acts upon a rod connected with the throttle-valve in such a manner that the greater the divergence the more obstructed becomes the passage of the steam; until at a certain limit the valve would be almost completely closed, and the speed of the engine would be effectually checked.

Before proceeding further, we think it desirable to bring before the reader at one view the high state of perfection to which the Steam-engine had been advanced by the superior intelligence and energy of Watt. This object will, we think, be effected by the study of the engraving and description of the double-action Steam-engine here given.

The steam from the boiler is conveyed to the cylinder A through the steam-pipe B, the supply being regulated by the throttle-valve C, which valve is under the direct influence of the governor D. On one side of the cylinder, at the upper and lower ends, are attached two square hollow boxes, marked E. which communicate with the cylinder by means of a passage in the middle of each. These boxes have each two valves, by means of which they are divided into three compartments. The top compartment in both boxes communicates with the steam-pipe, and the lower one with the eduction-pipe leading to the condenser. These valves move in pairs; that is, the upper induction-valve F and the lower exhaustion-valve *f* move together, and the same with the upper exhaustion-valve G and the lower induction-valve *g*. The piston R, being accurately fitted to the cylinder by packing, as it moves, divides the cylinder into two compartments, between which there is no communication. By opening the valve F, therefore, steam is admitted above the piston, while it is, at the same time, withdrawn from below the piston, and allowed to pass to the



WATT'S DOUBLE-ACTION STEAM-ENGINE.

condenser, by the opening of the valve *f*. In the same manner steam is withdrawn from above the piston by means of the valve G, and admitted beneath the piston through the valve *g*. These valves are all worked with one lever H (called the spanner), as will shortly be explained. Below the cylinder is the condensing apparatus, consisting of two cylinders, I and J, immersed in a cistern of cold water. A pipe K, having an end like the rose of a watering-pot, conveys water from the cistern to the cylinder I; the supply, which is, however, continual, being regulated by a cock. By this means the steam constantly passing into the cylinder I becomes condensed. The other cylinder J, called the air-pump, has a close-packed piston L, with a valve in it opening upwards, which operates like the bucket of a common pump, and draws off the surplus water that is continually collecting at the bottom of the condenser I, through the passage which communicates between the two vessels at the lower part, by means of a valve opening towards the air-pump into the reservoir *j*. The hot-water pump M then conveys this water into the tank which supplies the boiler. The cold-water pump N supplies the cistern in which the air-pump and condenser are submerged, so as to keep down its temperature to the proper limit. On the rod of the air-pump two pins are placed, so as to strike the spanner H upwards and downwards at the proper times, when the piston approaches the termination of the stroke at the top or bottom of the cylinder. To the working end of the beam O a rod of cast-iron P, called the connecting-rod, is attached, and is again fixed at its other end to the crank Q, by means of a pivot. Its weight is such that it serves to balance the weight of the piston-rod of the air-pump and cylinder, on the other side of the beam; while the weight of the rod of the cold-water pump is nearly equivalent to that of the rod of the hot-water pump. On the axle of the crank is placed the fly-wheel, and connected with it is the governor D, which regulates the throttle-valve, as before mentioned.

The working of the engine is as follows:—Supposing the piston to be at the top of the cylinder, and the whole of the space below to be filled with steam, the upper steam-valve and the lower exhaustion valve will be opened by the spanner being raised by the lower pin of the air-pump rod, while the upper exhaustion valve and the lower steam-valve are closed. By this means steam will be admitted above the piston, and the steam beneath it be drawn off into the condenser, where it will be converted into water. The effect of this will be the forcing of the piston, by the pressure of the steam above it, to the bottom of the cylinder. Just as this takes place, the spanner will be moved downwards by the upper pin on the rod of the air-pump; and the valves that were previously opened closed, while those that remained closed will be, at the same time, opened. The steam will, therefore, be admitted into the cylinder beneath the piston, and the steam above be drawn off into the condenser, and be converted into water, as before. While the above action is going on, the air-pump will draw off the hot water in the condenser into the upper reservoir, and at the same time the hot-water pump will convey this water back again to the tank which supplies the boiler.

In 1786 Watt and Boulton visited Paris, by invitation of the French Government, to superintend the erection of certain Steam-engines, and to suggest improvements in the great hydraulic machine of Marly. In Paris Watt met Lavoisier, Laplace, and Fourcroy; and discussed with Berthollet his new method of bleaching by chlorine.

After innumerable difficulties—among which may be mentioned the fight the Cornishmen made against paying the royalty of one-third of the fuel saved by the new engine—towards the end of 1787 Watt began to reap the fruits of his invention; he had 4,000*l.* at his bankers' and a promise of further instalments. To the frugal engineer this was, indeed, wealth.

As Soho prospered, Watt became a changed man, the racking headaches which disturbed his early life disappeared, and as the profits of his engine came in, he forgot to curse it. He became more cheerful and contented, and we feel assured that it is from this period of his life that his more favourable social qualities have been drawn by those who came in contact with him. We are told that he was passionately addicted to novel reading, and that he and his wife cried like children over a touching novel. To the world this gives a picture of the great mechanical genius it could little have expected.

The patent right which had been granted to Boulton and Watt for their improved engine having expired in the year 1800, Watt, although only 62 years old, retired from the active duties of Soho, leaving his two sons (one of whom died a few years afterwards) in conjunction with his former partner, the indomitable Boulton, who lived in the excitement of business; he not only remained, but in his old years set about no less a project than the reform of the coinage, then in a very low condition. The application of the Steam-engine to the presses, and his own love of art, enabled him to pursue this new branch of industry with a success in which not only this, but other nations participated. It might be said that he died in harness, for, although suffering from a cruel disease, he was as active as

HEATHFIELD HOUSE.

ever in his great establishment at Soho to within a year of his death, which occurred in 1809.* Watt, towards the latter years of his life, indulged in all the pleasures of being a landed pro-

* Mr. Smiles has written the joint biography of Matthew Boulton and James Watt with great success. The present representative of the Boulton family, M. P. W. Boulton, Esq., of Tew Park, gave Mr. Smiles full access to the Soho papers, and to the extensive original correspondence between Boulton and Watt, so that an authentic history is the result. Boulton's connexion with Watt arose in this way. Want of water-power was one of the great defects of Soho as a manufacturing establishment, and for a long time Boulton struggled with the difficulty. The severe summer droughts obliged him to connect a horse-mill with the water-wheel. "The enormous expense of the horse-power," he wrote to a friend, "put me upon thinking of turning the mill by fire, and I made many fruitless experiments on the subject." In 1766 we find him engaged in a correspondence with Benjamin Franklin as to steam-power. Eight years before Franklin had visited Boulton at Birmingham, and made his acquaintance. They were mutually pleased with each other, and continued to correspond during Franklin's stay in England, exchanging their views on magnetism, electricity, and other subjects. When Boulton began to study the "fire-engine," that is, in fact, the steam-engine, with a view to its improvement, Franklin was one of the first whom he consulted. From their correspondence it appears that Boulton, like Watt—who was at about the same time occupied with his invention at Glasgow—had a model constructed for experimental purposes, and that this model was then with Franklin in Landon.

prietor; but he still remained true to his old instincts. Upon his retirement to Heathfield, in the neighbourhood of Birmingham, he fitted up a room next his bedroom as a workshop, where he occupied himself with many curious inventions; among the best known of which was the famous Copying Machine, which he called his "likeness lathe." With this ingenious instrument, which reproduces with mathematical accuracy pieces of sculpture, &c., he amused himself almost up to the day of his death. Watt lived in this little garret, and it was fitted up with appliances for cooking his meals. The great inventor, who may be said to have moved the world, would seem to have lived in a wholesome fear of his wife, who detested dirt, and hated the sight of his leathern apron and soiled hands, and he was obliged to go through a cleansing process before he dared to enter her apartments. If we are to believe Mrs. Schimmelpenninck, she treated him as she did her pug-dog, whom she forced to wipe his feet upon the mat before venturing to cross the hall. No wonder that Watt stuck to his garret.

A visit to James Watt's workshop is thus described by a member of the British Association, who attended the Meeting of 1865, when he made a pilgrimage to this home of genius. "We were admitted into his workroom—a garret at the top of the house. It appears he had a scolding wife, who didn't like the messes and noises he made; so he was sent to the attic. This room is exactly as Watt left it. The very ashes are still in the grate; his little lathe has a bit of unfinished work in it; tools lie about; books and drawings are in old drawers, and strewed here and there. It is a miserable little place. Only four of us could get in at one time. In fact, the daughter of the house who went with us had to tuck herself up into all manner of shapes to prevent her crinoline sweeping all the letters into the corners. The house is a very good one, and Watt was rich when he died there; but it's clear his wife kept him and his little workroom in the background. This room has only been recently opened. By the will of Watt's son it was ordered to be left for ever as the old man left it when he last went out at its door. It was not looked into for more than thirty years."

Watt, in his retirement, was not unmindful of his early friends. In 1808 he founded a prize in Glasgow College, whence he had borrowed the model of Newcomen's engine; and in 1816 he made a donation to his native town, Greenock, towards forming a scientific library. In his latter days he still dwelt on steam navigation: he had long since inquired whether a "spiral oar," or "two wheels," were preferable for this purpose. But he lived to know that two steam-vessels had been impelled by steam-engines constructed at Soho on the principles invented by himself. In 1816, on a visit to Greenock, he made a trip in a steamboat to Rothsay and back again; and while on board pointed out to the engineer of the boat the method of *backing* the engine. It is remarkable that Watt made but feeble efforts to apply steam-power to locomotion on land: he constructed a steam-carriage; but we have no evidence of his anticipating the union of the rail and wheel.

In the Museum of the Patent Office the model engine constructed by Watt, and used for the purpose of turning his lathe, is now to be seen.

Watt died tranquilly at his house at Heathfield, on the 19th of August, 1819, in his eighty-third year. Age had not dimmed his intellectual vigour, his colloquial animation, or his benevolence; his instructive conversation, or his lively, and even playful, manner: he was even to the last "ready to distribute, willing to communicate." A marble sitting portrait statue—for which Chantrey received 6,000 guineas—was placed in Westminster Abbey, with an eloquent and truthful inscription from the pen of Lord Brougham; well befitting the memory of one whose cardinal merits were candour and truth. "Let James speak," said Watt's father; "from him I always hear the truth." The inscription tells us that James Watt,

Directing the force of an original genius,
Early exercised in philosophical research,
To the improvement of
The Steam-engine,
Enlarged the resources of his country,
Increased the power of man,
And rose to an eminent place
Among the most illustrious followers of Science
And the real benefactors of the world.

In the cemetery at Greenock it was proposed to raise to the memory of Watt, a monumental Tower, 514 feet above the level of the sea; with, in the upper turret an electric time-ball, and a gallery of memorials commemorative of men eminent in science and philosophy; but this project has not been executed. In the Watt Institution, at Greenock, however, his memory is honoured by a marble statue of the great inventor, by Chantrey, which was paid for by subscription; and the building which contains it was erected partly through the same medium, and partly by gift from the successors and representatives of Watt: here are deposited the books of the Greenock Library.

Arago has left this comprehensive tribute to the genius of Watt: "There are few inventions, great or small, among those which are so admirably combined in our present Steam-engines, which are not the development of some of the original ideas of Watt. Examine his labours, and, in addition to the principal points, you will find that he proposed machines without condensation, in which, after having acted, the steam is dispersed in the air; and which were intended for localities where large quantities of water could not easily be procured. The operation of the principle of expansion in machines with several cylinders was also one of the projects of the Soho engineer. He suggested the idea of pistons which should be perfectly steam-tight, although composed exclusively of metal. It was Watt who first had recourse to mercurial manometers for measuring the elasticity of steam in the boiler and the condenser; who conceived the idea of a single and permanent gauge, by whose assistance might always be ascertained, with a glance of the eye, the level of the water in the boiler; and who, to prevent this level ever varying injuriously, connected the movements of the feeding-pump with those of a float; and who, when required, placed in an opening in the cover of the principal cylinder of the machine the indicator, a small apparatus so constructed that it accurately exhibits the state of the steam, in relation to the position of the piston, &c. Nor was Watt less skilful in his attempts to improve the boilers, to diminish the loss of heat, and to consume those torrents of black smoke, which issue from common chimneys, however elevated they may be."

From time to time new power has been added to the Steam-engine, and, by numerous modifications by eminent workmen, it has been applied to all the purposes of manufacture; driving machinery, impelling ships, grinding corn, printing books, stamping money, hammering, planing, and turning iron: in short, of performing every description of mechanical labour where power is required. These successive advances, however, have not been the result of the genius of any one inventor, but of the continuous and successive industry and inventiveness of many generations; not of one man, but of the efforts of a nation of mechanical engineers.

The tomb of Watt, adorned by Chantrey's noble statue, is in a small chapel at the south side of Handsworth church; the window opposite is overshadowed by trees, which add to the solemn and imposing character of the figure. On the sides of the chancel are tablets to the memory of Boulton and Murdoch. This is a fitting place to meditate on the lives of these men: the lesson to be learned therefrom may be read in the motto on the massive base on which the statue of Watt is seated—" Ingenio et labore." From the church may be seen Heathfield House, the last residence of Watt: the grounds were laid out by Watt himself. Here he passed the closing years of his studious and useful life. The present owner of the estate, Mr. J. W. Gibson Watt, carefully preserves everything connected with the memory of the great engineer and practical philosopher who formerly resided here. Even the tools and the lathe in his private workshop are left just where the hand of James Watt last touched them, covered with the dust of seven and forty years: the trees overhanging the pool in the grounds were planted by the same hand.

STATUE OF WATT IN HANDSWORTH CHURCH.

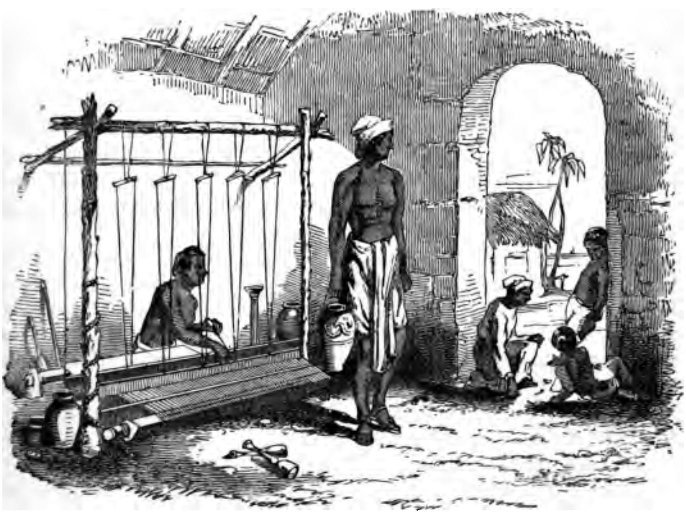
THE COTTON MANUFACTURE.

ALTHOUGH steamboats, perhaps, appear more prominently in our eyes than other benefits which Watt was the means of conferring upon mankind, it would be a mistake to regard these as the noblest monuments of his fame: progress in manufactures was contemporary with Watt's invention, and in course of time became dependent on it. Our textile and iron manufactures received an impulse at this period from the application of new or improved machinery, which, so far from having spent its force, has been increased from time to time by fresh triumphs of genius, and is still bestowing prosperity and wealth upon the nation. In one branch of industry has this forward impulse been especially apparent, namely, in the Cotton Manufacture; and it has been aptly remarked: "It is to the spinning jenny and the steam-engine that we must look, as having been the true moving powers of our fleets and armies, and the chief support also of a long continued agricultural prosperity."

Cotton, which is produced over many parts of the earth spontaneously, has been wrought into garments for the people of India for 3,000 years. We find it among the arts of Egypt and other eastern countries: the Egyptian looms were famed for their fine cotton fabrics, some worked with the needle in coloured patterns, and others woven in the piece; and the dresses painted on Egyptian monuments prove that such were used by the Egyptians more than 3,000 years ago, as they were at a later period by the Babylonians. Cotton was known in Spain in the twelfth century, and eventually it found its way to England; but, except for candle-wicks, it was not employed in England long before the year 1641, when it was used at Manchester in making fustians and dimities.

For ages had our grandmothers sat down to the spinning-wheel, and spun the yarn of wool or flax, which was afterwards sent to the weaver, and woven into strong homely dresses, by the old "weaver's beam and shuttle," with very little improvement, the same as that mentioned in the Book of Job. What the ancient cloths were may be seen by examining such as have been brought from the tombs of Thebes, or are swathed around the mummies of Egypt.

At all times clothing, to some extent at least, was necessary in the states where civilization existed; and we find in the antique monuments of Thebes plain representations of the implements by which the inhabitants wove the cloth that protected them from the changes or the inclemency of the weather.



HINDOO WEAVER.

Even at the present day the Hindoo, seated on the ground; with his legs in a hole, and the weft of his muslin tied to the branches of a couple of trees, throws his shuttle with a skill that, in the end, produces the most beautiful muslin or calico; yet such is the superiority obtained by the use of machinery, that the cotton grown on his native plains can be brought ten thousand miles, cleansed, spun, woven, dried, packed, and carried back again, and then sold in the province where its woolly fibre first silvered the bud, at a less price than that of the cloth produced by the Indian artisan.

There is a curious account of the early stages of a pound weight of unmanufactured cotton, which strikingly proves the importance of the trade and employment afforded by this plant: "The cotton wool came from the East Indies to London; from London it went to Manchester, where it was manufactured into yarn; from Manchester it was sent to Paisley, where it was woven; it was then sent to Ayrshire, where it was tamboured; it came back to Paisley, where it was veined; afterwards it was sent to Dumbarton, where it was hand-sewed, and again brought to Paisley; whence it was sent to Renfrew to be bleached, and was returned to Paisley; whence it was sent to Glasgow, and was finished; and from Glasgow was sent per coach to London. The time occupied in bringing this article to market was three years, from its being packed in India, till it arrived in cloth at the merchant's warehouse in London. It must have been conveyed 5,000 miles by sea, and about 920 by land; and contributed to support not less than 150 persons, by which the value had been increased 2,000 per cent."

It is unnecessary to remark that cloth made by weaving is formed by interlacing the threads with each other crosswise; but it is not so generally known that there are regular terms for all the different kinds of weaving. Thus, plain weaving is merely the process of making each single thread interlace with that next to it, by means of a shuttle sent horizontally between the threads, which are placed upright before the weaver. In weaving twilled stuffs the shuttle is made to pass over one and under two, or over two and under three or four, just as it is desired to produce that diagonal line which we perceive in galloons, bombazines, and fabrics of similar manufacture. When stripes are to be produced, the colours are arranged in the *warp*, which is the name given to the long threads, while the *weft*, the cross threads, is made to pass in the usual manner; but when checks are required, the colours have to be arranged both in the warp and weft; and, in the weaving of all kinds of patterns, they are produced by making the weft to pass under and over at particular spots, wherever it is wished the spots or flowers should be seen. In "shot silk" the warp is of one colour and the weft of another.

In all probability the weft was in the first place formed by throwing a ball of thread through the shed, as that open space is called which is formed by the weaver treading down first one treadle and then another, to raise or depress the alternate warp thread. And this ball, unwinding as it passed along, formed the weft; but afterwards a more convenient means was adopted in the common *shuttle*, which is a piece of wood, something in the shape of a boat, hollowed out in the middle, where the thread or cotton is placed, and so protected from the rubbing to which it would be otherwise subject. In the commonest mode of weaving the shuttle is passed from side to side with both hands; but about a hundred years ago what is termed the *fly-shuttle* was invented by an ingenious person, named Kay, who resided at Bury. By this invention the shuttle, with the aid of a string, can be cast both ways by the same hand, so that the workman saves a considerable portion of his time in the operation.

In India and China, to the present day, the warp is formed by laying the threads side by side in an open field: and in the infancy of cotton manufacture in England the same plan was commonly followed; but the uncertainty of the climate necessarily subjected the process to frequent hindrance, and a machine was invented called the *warping-mill*. This consists of a number of upright posts, which are fastened at top and bottom into the rim of a wheel, with a shaft, which turns like an axle, in the centre. This is made to revolve by means of what is called an endless rope—that is, a rope with the ends fastened together; which is passed round a short axle, and wound round and round by means of a handle. Close by this there is an upright framing, in which a number of bobbins are fixed, four or five end to end, and several tiers one above another. The ends of the threads of these several bobbins are then brought all together and passed through a sliding piece, which by means of a rope is made to travel up and down the outer framing of the mill. By turning the axle, therefore, the threads are made to wind spirally round the mill; and when a sufficient length has been obtained, by means of some pins the motion of the mill is reversed; and the process is thus continued until a sufficient number of threads has been obtained to form the whole breadth of the warp. This then is attached to the frame of the weaving machine, and the cross threads are interlaced, as has been already described.

At what period the Cotton Plant was introduced into the localities from which our supplies are now chiefly drawn is not precisely stated. The finest and best kind, which is known by the name of *Sea Island Cotton*, from its being grown on the low sandy islands off the coast of the United States, is the produce of a plant that appears to have been first carried to the Bahamas from the island of Anguilla (whither it is believed to have been transported from Persia), and was sent to Georgia in 1786. But there is evidence of the existence of the cotton plant in America long before there was any direct communication between the civilized world and the two great portions of that Continent; and we have it positively stated that the Spaniards found calico a common article in the dress of the inhabitants when they conquered Mexico.

Cotton is estimated by the length and shortness, the silkiness and coarseness, and the weakness and strength, of the several filaments, which are the downy hairs that grow on the surface of the white seed-pod of the plant. Some species of cotton thrive best in sea-air, and the produce is fine in proportion to their nearness or distance from the coast. Others again require the interior of the country. In dry climates the best plants, as on the mountain-bound shores of Brazil, are met with on the coast; while in damp climates, like that of Pernambuco, the most valuable produce is obtained from the interior. But whether seen bordering the lofty acclivities of the Andes, with the wide Pacific heaving its boundless waves to a limitless horizon, beneath a sky of more than Italian azure, or met with in the broad rich valleys, bright with the luxuriant bloom of tropical wild-flowers, a field of cotton shrubs, with their dark green leaves and silvery pods, and here and there a magnificent mangolia or a noble palm rearing its lofty head, is at all times a beautiful sight, and more especially in the picking-season, when hosts of busy labourers are gathering the valuable produce, and preparing it for shipment.

Nothing in the history of British commerce shows so marvellous a rate of progress as the importation of cotton from the United States within the present century. In the early stages of the trade the raw cotton manufactured in Great Britain was chiefly the produce of the West Indies; the finer sorts came from Surinam, the Brazils, and the Isle of Bourbon. But at the end of the last century the Sea Island cotton proved its superiority. This is only found in Georgia, Florida, and South Carolina, and is often termed by the inhabitants of the Southern States "*black* seed cotton," from the seed contained in the pods being black; while the seeds of the short staple cotton, or that which has the short filaments, is called the "*green* seed cotton" on account of its colour. This latter kind is also called *bowed* Georgia or *upland* cotton; having acquired the latter appellation from its being grown in the upper districts of the State, instead of on the low tracts along the sea-coast. It is called bowed cotton because the strings of a bow were made to twang sharply upon the mass of produce, and thus, by repeated strokes, to loosen the locks of cotton, and separate the seeds from the filaments; but this is now more speedily and effectually done by a *saw gin.*

In 1784 an American vessel arrived at Liverpool, having on board eight bales of cotton, when they were seized by the custom-house officers of that port, under the impression that they had been imported from some other country, as they had never before seen American cotton. In 1785 only five bags were imported, and next year six; such were the small beginnings of that immense trade which now gives employment to millions on both sides of the Atlantic. The total value of the American crop of cotton in 1855 was estimated at 140,000,000 dollars; and in 1856 the crop showed an increase of nearly 700,000 bales.

The capabilities of the British colonies for producing cotton are great. The West Indian Islands, Port Natal, and our other African possessions, will grow cotton quite as well as the United States; while Australia would produce an unlimited amount; and in the great colony of India the plant is indigenous. It has been computed that a piece of ground of the size of Yorkshire is sufficient to produce a quantity of cotton nearly double the annual consumption of England, stated, in 1860, to be 2,523,000 bags, of which 85 per cent. came from the United States. The rate is, however, rapidly changing. Whilst the supply from North America is passing away, that from the British possessions is greatly increasing, and especially in India, in consequence of the construction of railways and canals; whilst specimens of cotton cloth have been shown from the East and West Indies, and Australia, fully equal in quality to the best from New Orleans.*

The great starting-point of our Cotton Manufacture may be dated from the year 1760,—the beginning of a new era of commercial history and a century of commerce the most wonderful the world has ever known. In that year the Society of Arts offered a premium for the greatest improvement in the common spinning wheel, and afterwards offered 100*l.* for the construction of a machine that would spin six threads of wool, cotton, flax, or silk at the same time. This led to Wyatt's invention, which, as we shall presently see, proved impracticable.

In the year 1760, or soon after, Hargreaves, the Lancashire weaver, invented the Carding Machine, not very different from that now in use; and in 1767 he invented the *Spinning Jenny*, at first containing eight spindles, made to revolve by bands from a horizontal wheel. The power of the Jenny was then increased to 80 spindles, when the saving of labour so alarmed the workmen that a rising ensued, and they went through the county, destroying Carding and Spinning Machines, wherever they could find them, so as to drive away the manufacturer from Lancashire to the town of Nottingham. Hargreaves used to relate that he took the idea of the Jenny from the following incident: a hand-wheel with a single spindle being overturned, he remarked that the spindle, which before was horizontal, was then vertical; and as it continued to revolve, he drew the roving of wool towards him into a thread, when it seemed that if something could be contrived to hold the roving, as the finger and thumb did, and that contrivance could be made to travel backwards and forwards on wheels, six, or eight, or even

* A complete return of the value of the raw cotton imported in 1866 shows the total to have been 77,521,406*l*, as compared with 66,032,193*l.* in 1865, 78,203,729*l.* in 1864, 56,277,953*l.* in 1863, 31,093,045 in 1862, 38,653,398*l.* in 1861, 35,756,889*l.* in 1860, 34,559,636*l.* in 1859, 30,106,968*l.* in 1858, and 29,288,827*l.* in 1857. Of the vast amount paid in 1866 for raw cotton, the United States absorbed 34,977,986*l.*, while the corresponding total for 1865 was 12,035,484*l.*, and for 1864 1,711,890*l.* The value of the raw cotton received in 1866 from British India is set down at 25,270,547*l.*, as compared with 25,005,856*l.* in 1865, and 38,214,723*l.* in 1864. None of the new cotton fields appear to hold their own to any extent except India; the Bahamas, Mexico, China, &c., seem to be fast receding to their old insignificance as centres of production. A considerable quantity of cotton was still received, however, in 1866 from Brazil and Egypt.

twelve, threads, from as many spindles, might be spun at once. This was done, and succeeded; but Hargreaves, who, as we have said, having fled to Nottingham, could not bear up against the savage treatment he had received, and he died in great distress, having given the property of his Jenny to the Strutts, who thereupon laid the foundation of their great opulence and a peerage.

The demand for cotton goods which began to pour into the towns of Lancashire from abroad, about a hundred years ago, could no longer be met by hand-labour; spinners, chiefly women, were bribed to supply the weavers with yarn, but the weaver could not supply the manufacturer with cloth. Hand-labour had reached the limit of its capabilities in spinning, and genius, at length, furnished mechanism to take its place. Of the numerous processes to which cotton fibres are subjected, there are two in particular on which all the rest depend. Cotton, flax, and wool are received by the manufacturer in tangled heaps of fibres doubled and twisted among each other, and these must be laid lengthways and parallel. This was done by the *carding machine* (wire brush), which was greatly improved by Lewis Paul and Arkwright, who substituted machinery for the hand, and furnished the spinner with a riband of cotton some hundred yards long, instead of the short rolls formerly stripped off the cards. Wyatt, however, in 1739, introduced the method of spinning by means of two or more pairs of rollers with different velocities.

Next, M. de Gennes published in the *Philosophical Transactions*—the date is 1768—an account of a machine to make linen cloth without the aid of an artificer. It was to be worked by water-power, and the description contains all the germs of the power-loom, which was thereafter to produce such wonderful results. The chief difficulty which De Gennes conceived he had to overcome was breaking the threads of the warp; and this he said his machine would obviate, by preventing the shuttle from touching them; while he averred that it would set ten or twelve looms at work, and the cloth might be made to any width. Yet this machine, ingenious as it was, never appears to have been of any practical use; and, subsequently, Mr. Austin, Mr. Miller, and two Frenchmen, named respectively Dolignon and Vaucanson, attempted the same thing. Of these, only that designed by Mr. Austin was brought to any practical effect, and a power-loom was put up by him in the factory of

Mr. Monteith, near Glasgow; but after a short time even this was laid aside.

Arkwright, with more success, in 1769, the same year that Watt took out his first patent for improvement on the Steam-engine, introduced an invention which is described to have changed the character of the cloth trade. It is thus described by Mr. Syme: "If a riband of parallel fibres be caught between two rollers, of which the upper is pressed down on the lower by heavy weights, it will be drawn through and compressed as they revolve; but it will not be lengthened out. If, however, the end escaping from one set of rollers be caught between a second which turn twice or thrice as quickly, it will be drawn forward with greater speed than before. A known length of riband is passed through the first set by one turn: but if the second set be made to revolve twice as fast, the same quantity must pass between them in one half the time; or, as the tenacity of the fibres prevents the riband from tearing across, it will be drawn out to double its length and fineness. A slight twist is at the same time given to increase the strength of the '*roving*,' as the attenuated thread is now called. By repeating the process great fineness may be attained, and a still further twist given; and, by employing a sufficient number of rollers, a thousand threads may be spread in this way as easily as one. Arkwright at first employed water-power to move his machinery, and the yarn which he produced was therefore called *water*-twist. Such in principle were the two great inventions that effected an entire change in the manufacture of cotton, wool, and flax. The men by whom they were really invented, Paul and Wyatt, partners in the same establishment, did not succeed in procuring for them public favour; while Arkwright, possessing more perseverance, and perhaps equal inventive power, carried off the prize of fortune and fame to which the original inventors were entitled.

"Before Arkwright introduced spinning by rollers, Hargreaves, the ingenious mechanic of Blackburn, had contrived a frame in which a number of previously prepared rovings were drawn out to greater fineness and twisted into yarn, enabling one man to do the work of eight, or even eighty. Arkwright's invention prepared the rovings and spun the yarn; Hargreaves' could do the latter only. The former was best adapted for producing firm warp yarn; the latter for spinning the finer kinds used as weft. The union of the principles of both was requisite to perfect the art of spinning. Hargreaves (1767) attached the ends of several parallel rovings to spindles placed vertically in a frame, and seizing the whole by a clasp at some distance, drew it from the frame, when the reduced roving was twisted by the rapid revolution of the spindle, and then wound upon a bobbin. The rollers of Arkwright and the motion from the spindles are united in the *Mule* of Crompton, which was invented in 1779; and, after many unsuccessful attempts, made self-acting about forty years ago: so that one spinner can make 800, 1,000, or even 2,000 threads at once. The rovings part the rough rollers, which turn for some time, and then stop; the spindles are placed on a carriage, which

MULE-ROOM.

moves from the rollers, after they have ceased to turn and draw out the thread; the spindles revolve, the requisite twist is communicated to the fibres, and the thread thus spun is then wound on the bobbins as the carriage advances towards the rollers."*

As soon as the whole of these processes are performed, the mule disengages itself from those portions of the machine which have been used to propel it, and the attendant returns it again to the carriage, to perform its work afresh.

* *Edinburgh Essays.*

Some idea of the value of this last invention may be formed by the fact that, while the water-frame is capable of spinning a pound of cotton to the length of nineteen miles, or forty hanks, the mule has not yet met with any limit short of 950 miles to the pound of cotton, or 2,000 hanks. These inventions have, more or less, been extended to the spinning of other staples.

The story of Samuel Crompton and the Spinning Mule is a saddening one; though its results gave a wonderful impulse to the industry, wealth, and population of South Lancashire, and raised its villages to the importance of large and populous towns. Crompton was well educated, but "his little legs became accustomed to the loom almost as soon as they were long enough to touch the treadles." At his solitary loom, in an old mansion, he became, prematurely, a thinker; in this old place he toiled late and early for five years, during which time he worked entirely alone, and invented and completed his Spinning Machine, at the expense of every shilling he had in the world: we read of his playing the violin in the orchestra of the Bolton Theatre at 1*s.* 6*d.* per night, which assisted him in procuring tools for his mechanical operations. His machine was first called the Muslin Wheel, because it was available for yarn for making muslins; and finally it got the name of the Mule, from its partaking of the two leading features of Arkwright's machine and Hargreaves' Spinning Jenny. Crompton had just completed his first Mule, when the Blackburn spinners and weavers rose; and to save his new machine from destruction, he took it to pieces, which he hid in a loft of the old Hall, and there it remained for some weeks: but in the same year he completed the Mule, and spun upon it muslin yarn, and out of its first earnings he bought a silver watch. The demands for the new machine were now one hundred times greater than he could supply: the old Hall was besieged by cunning persons as well as purchasers, who came to get at the secret of the new wheel; and among them was Arkwright, who travelled 60 miles to get at the mystery. Crompton, as he could not retain the secret of his machine, nor patent it, gave it to the public, upon condition of being paid a sum of money, to be raised by subscription, which did not amount to 60*l.*; yet many wealthy Bolton firms built their fortunes upon this small investment. Then persons broke their promise of subscription, and denounced Crompton as an impostor: this made him moody and mistrustful. Before 1785 he removed to a farm-house near

Bolton, and there worked secretly at his machine: inquisitive visitors came, and among them Mr. (afterwards the first Sir Robert) Peel.*

In 1800, with 500*l.*, raised principally at Manchester, Crompton rented a factory-storey at Bolton, and toiled unceasingly: he sought reward from the Royal Society and the Society of Arts, but neither of these well-supported institutions would entertain the invention. The public had got it, and that was enough! Yet at this time there were 4,600,000 mule spindles, spinning 40,000,000 pounds of cotton wool in a year. He petitioned Parliament, and, after much delay, the sum of 5,000*l.* was granted him. About two years after this Crompton died, and was followed to the grave by a host of Bolton worthies; but to be treated with respect after death is but a poor recompense for being neglected while we are living! From that day little has been said or thought of Samuel Crompton.

But the last great triumph of mechanical ingenuity in this manufacture was that for which a patent was taken out by Mr. Roberts, a machine-maker of Manchester, in 1830. It obviated the necessity of an attendant to take the spindle back in the carriage; for the mule not only disengaged itself, but, by an intervening contrivance, returned without human aid to

* Mr. J. G. French, the eminent manufacturer of Bolton, who has, in his *Life and Times*, in a bold and manly spirit, raised Crompton from neglect, relates that when Crompton lived at Oldhams, he received two visits from Mr. (afterwards Sir Robert) Peel. On his first visit Crompton was absent; but Mr. Peel chatted with his wife, and gave young George half-a-guinea. Mrs. Crompton going into her dairy to bring her guest a bowl of milk, Mr. Peel took the opportunity to ask the boy where his father worked. George was pointing out the nail-head which, on being pressed, lifted the concealed latch of the door leading to the upper storey, when his mother returned with the milk, and by a look warned him that he had committed an error.

The objects of Mr. Peel's visits were to offer Mr. Crompton, first, a lucrative situation of trust in his establishment, and afterwards partnership in it. Both these offers were declined, partly from Crompton's love of independence, and partly from a jealous suspicion of persons in a superior social position, caused by a feeling of personal dislike to the future baronet, which he entertained all his life, arising, it is said, from some disagreement on Mr. Peel's first inspection of the mule. It is added, that when he called at the Hall in the Wood, to see the new wheel, in terms of his subscription of one guinea from Peel, Yates, and Co., of Bury, he brought with him several mechanics in his employment, who inspected the wheel along with him, and were able to carry away its details in their memory. To this there could be no reasonable objection, as such was the known purpose of the visit; but Samuel Crompton could not forget or forgive the indignity of being offered *a payment of sixpence each for these men.*

repeat its duty from the carriage, so that the only assistance required is that of a child to piece the threads when they happen to break. The yarn is now complete, and it has only to be prepared for sale, or the home trade, or for exportation.

We will now glance at the career of the honourable person at the head of these improvers of the Cotton Manufacture. Richard Arkwright was born of lowly parents in the town of Preston, in the year 1732; his boyhood was passed in indigent circumstances, and he was at length apprenticed to a barber. After he had served his time, he set up a business for himself in the neighbouring town of Bolton, where he continued to follow his humble occupation till he was twenty-eight years of age. In 1760 he quitted his employment as a barber, and took to travelling up and down the country collecting hair, which he sold to the makers of wigs, who had a business which, from the peculiar fashion of the time, was in great repute. Arkwright was a man of genius and knowledge beyond the requirements of his business.


RICHARD ARKWRIGHT.

He was fond of mechanics, and made experiments to discover "perpetual motion," which in Arkwright's time, and long after, was a temptation to young experimenters; there being a notion prevalent that Government would reward the discoverer of it with 10,000*l.* Not long after entering upon this hopeless enterprise, he turned his attention towards some means of supplying the rapidly increasing demand for spun cotton—cotton weft for the weaver's loom. He proceeded to put together the rudiments of his design, and, although struggling with poverty, he resolved in 1767 or 1768, being then settled at Preston, his native town, to bring his spinning machine into use.

About the same time Hargreaves had patented something for a similar purpose; and as Arkwright had already suffered much from the envy of others, he was suspicious of Hargreaves, and accordingly removed from his own neighbourhood to

Nottingham, where he was assisted by Messrs. Wright, the bankers, who advanced him the means for carrying out his projects. They at length grew tired, and introduced him to a stockinger, named Need, who brought him into communication with Mr. Jedediah Strutt, of Derby; he pointed out certain deficiencies in Arkwright's machine, and these being remedied, Arkwright in 1769 took out his first patent. Mr. Strutt and Mr. Need next became Arkwright's partners, and their first mill, worked by horse-power, was erected at Nottingham. They were successful, and in 1771 they established another mill at Cromford in Derbyshire, in which water was the motive agent. Arkwright tells us that he accidentally derived the first hint of his invention from seeing a red-hot bar of iron elongated by being made to pass between rollers; and though there is no mechanical analogy between that operation and the process of spinning, it is not difficult to imagine that by reflecting upon it, and placing the subject in different points of view, it might lead to his invention. Arkwright effected other improvements, for which a fresh patent was taken out in 1775. For five years these enterprising men worked on without profit. The time for their reward, however, came at last; and the tide of prosperity flowed abundantly. Mr. Arkwright engaged in various other cotton manufactories besides the one in which he was most largely interested; he served as high-sheriff of Derbyshire in 1786; and received knighthood on presenting an address of congratulation to King George III. But Arkwright's sedentary life induced ill-health, and on the 3rd of August, 1792, he died at the comparatively early age of sixty. He had presented, on two occasions, each of his ten children with the sum of ten thousand pounds; and he left at his death half a million of money; he had for a number of years fixed the price of cotton yarn for all the trade. A beautiful monument, sculptured by Chantrey, has been erected over Sir Richard Arkwright's remains in Cromford Chapel.

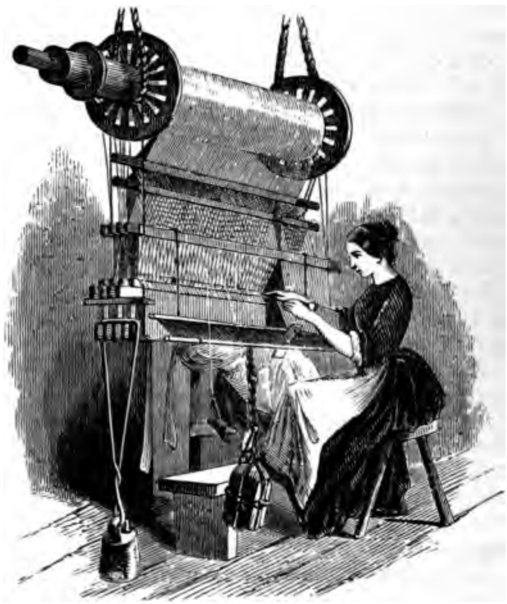
The power which gave motion to the rollers and spindles of Arkwright and his fellow inventors was supplied at first by falls of water. Manufacturers were accordingly under the necessity of planting their establishments in districts where water-power was readily obtained, however inconvenient those situations might be in other respects. Watt's improvements on the steam-engine, however, supplied them with what they wanted, at a higher price, certainly, but in any place and at any time they chose. As soon as Steam-engines were used to drive the machinery, factories might be set down in towns, made independent of drought or flood, and wrought by a motive power whose energies could be adapted with the utmost nicety to the work required. Steam-engines were accordingly employed in turning the rollers and other machines used in spinning the cotton as early as 1785; and the inventions of Watt and Arkwright, when thus combined, gave an impulse to the manufacture which neither of them by itself could have produced.* And, now, what were the advantages of this combination of intellect, industry, and capital? The quantity of cotton introduced into this country was under five million pounds when the inventions of Arkwright were projected: it was in 1865 8,731,949 cwts.

But the triumphs of the above combination were not confined to spinning. Several attempts had been made to weave cloth by machinery before 1769; but they had been unsuccessful or were soon forgotten. By a singular accident, however, this was effected. In the year 1784 some gentlemen were conversing upon the then recent invention of Arkwright for spinning yarn, when one of them observed that it would produce so much yarn, there would not be hands enough to weave it. To this, one of the party, Dr. Cartwright (brother of the political Major, whose statue is set up in Burton Crescent, London) observed in reply, that Arkwright must then invent machinery for weaving also. The Doctor's manufacturing friends pronounced this impossible. He was not, however, discouraged, and though entirely ignorant of mechanics, the idea had taken so strong a hold upon his mind that he shortly afterwards set about the construction of a machine which should perform the three motions of weaving: he succeeded so far that in the following year he patented his invention, and established a power-loom factory at Doncaster, but did not prosper. The Messrs. Grimshawe, at Manchester, were alike unsuccessful. The machine Dr. Cartwright contrived was rude and awkward, for his own loom was the first he had ever seen: he, however, persevered, and contributed much to render the power-loom what it is; but, after taking out several patents, and spending upwards of 40,000*l.* without any personal benefit, he relinquished all hope of fully accomplishing his object. One of the chief impedi-

* James Syme, M.A.; *Edinburgh Essays.*

ments with which the inventors had to contend was the frequent necessity for stopping the loom in order to dress the warp, which was continually liable to breakage. This was obviated by dressing the warp before being put into the loom, by the ingenious invention of the *dressing machine* of Mr. Radcliffe, of Stockport, who was assisted by one of his workmen, named Johnson. This piece of mechanism consists of eight rollers, four at one end of a frame and four at the other; these rollers are brought from the warping-frame, and the yarns from these are made to pass between two rollers, the lower one of which dips into a reservoir of thin paste, and thus transfers a coating of starch to the cotton; the yarns afterwards pass over and under brushes, (by which it is rubbed into the fibres,) and then over a heated copper box to dry them, and are ultimately coiled round the warp beam of the loom. Some time after the invention of the dressing-machine two manufacturers at Stockport, Messrs. Marsland and Horrocks, fairly brought the steam-engine into effective use, and Mr. Roberts, of the firm of Sharp and Roberts of Manchester, having introduced considerable improvements, the Power-Loom became fully and effectively established.

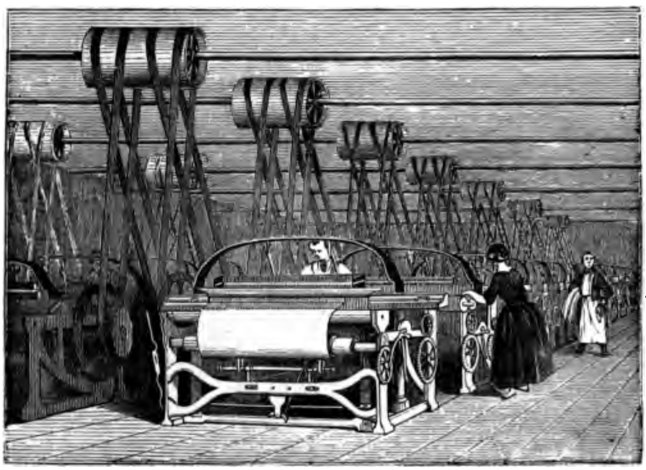
In order that the weaving should be perfect, great care is necessary in all the preliminary arrangements of the warp yarn, which must be extended on the loom in parallel lines, and with an equal degree of tension. The rods which separate the alternate threads, technically called the lease-rods, are to be set so as to keep the threads which are to go through one heddle quite distinct from those belonging to the other. Having received his yarn in a bundle, the weaver first rolls it regularly on the yarn cylinder, keeping the threads distinct by an instrument called a ravel, which is in fact a coarse kind of reed. After the warp is wound on the cylinder, the operation of "drawing-in" commences; that is, the alternate threads are to be drawn through their respective healds or heddles, and all the threads through the dents of the reed. The instrument used in this process is called a sley, or reed-hook, and is so constructed as to take two threads through every dent or interval of the reed. The lease, or separation of the alternate threads in the warp yarn, is made by the pins in the warping-mill, and is preserved by the lease-rods. These rods being tied together at the ends, secure the permanency of the lease and guide the operative in drawing the alternate yards through the heddles. To facilitate the process, the beam on which the warp yarn has been wound is suspended a little above the heddles, so as to allow the yarn to hang down perpendicularly. The operative then opens the loop in each of the twines of the heddles successively, and through each draws a warp thread. This is, therefore, an operation not very unlike threading a needle, having its eye in the middle instead of the end. After the threads have been



WEAVING.

passed singly through the loops or eyes of the heddles, they are drawn in pairs through the dents of the reed. The heddles are then mounted with the cords by which they are moved, and the reed being placed in the batten, everything is ready for the weaver to commence his operations.

The utility of the power-loom was too evident to be overlooked by the shrewd and enterprising members of the British manufacturing community, and it soon came into general use. The construction of the machine and the method of dressing have been improved since that time; and cloth is now woven, by the help of steam, with a rapidity and to an extent formerly unknown. A steam-engine of forty or sixty horse-power gives motion to thousands of rollers, spindles, and bobbins for spinning yarn, and works four or five hundred looms besides. This gigantic spinner and weaver needs very little assistance from man. It undertakes and faithfully discharges all the heavy work of putting shafts, wheels, and pulleys in motion; of throw-



POWER-LOOM ROOM.

ing the shuttle, working the treadles, driving home the weft, and turning round the warp and cloth beams. *One man may now do as much work as two or three hundred men* ninety years ago. Labour is greatly lightened, and the fruits of industry are vastly increased by the assistance of this untiring fellow-worker.

Mr. Syme, from whose able paper these illustrations are in the main quoted, remarks: "The substitution of machinery, in place of hand-labour, in spinning and weaving, has been productive of the most beneficial consequences to the whole kingdom during the century that has almost elapsed since the inventions of Arkwright and Watt were made. Results which the most sanguine never anticipated have been obtained, not in one branch of the trade or industry but in all. Really good Steam-engines and mill-gearing could not be manufactured when mechanical power was first introduced. Both were indispensable to success, and a revolution in working iron was the result. For many years after Arkwright's time, heavy shafts of wood and cast iron, huge wheels and pulleys, slow motion, and great friction, gave a ponderous and ungainly appearance to the factories, compared with the light wrought-iron rods, the smaller wheels, quintupled velocities and the diminished friction of the present day.

But the cloth was still white, and though adapted for many useful purposes, was but little fit for the purpose for which it has been to such an immense extent adapted—attire.

THE BIRTH-PLACE OF THE FIRST SIR ROBERT PEEL, AT BLACKBURN.

Calico-printing was first introduced in Lancashire, in the year 1764, by the Claytons, of Bamber Bridge, near Preston. About two miles east of Blackburn, there lived a tall robust man, who owned forty acres of poor grass-land, and three of his sons worked each at a loom in the dwelling-house. One of these sons chanced to spoil in the weaving a piece of cloth, which was therefore unsaleable. The father took it to the Clayton's, at Bamber Bridge, to have it printed of a pattern for neckerchiefs, which was done. The high price charged for printing induced the owner to attempt the art himself, which he did in a small apartment of his farmhouse. The experimenter was Robert Peel, father of the first Sir Robert Peel. The farmer had remarked the tediousness of the process by which the raw cotton wool was brought into a state fit for spinning by the common hand-card; and he it was, there is almost every proof, that invented the cylinder for doing the work much better and more expeditiously. Success attended him here sufficiently to induce him altogether to give up farming; and he turned calico-printer. He set to work, and with his own hands he cut away on blocks of wood with such tools as he could command till he had formed the figure of a parsley-leaf. At the back of each of these blocks he fixed a handle, and a little pin of strong wire at each of the four corners in front. Each of these blocks was ten inches long and five broad. He then got a tub, into which he put some coloured mixture, with a little alum in it. He next covered the tub with a woollen cloth which sunk till it touched the colouring matter, and became saturated with it. The calico was stretched tightly across the table-top, and the quondam farmer of Blackburn then touched the woollen cloth with the face of his parsley-leaf block, and as soon as the leaf was fairly covered with the colour, he placed it squarely on the cloth and struck it sharply with a mallet, so that the figure of the engraving was left upon the white calico. The little points at the corners enabled him to repeat the process with regularity, and so he continued till the whole was complete. As soon as it was dry his wife and daughters set to work and ironed it with the common smoothing-irons, and this they continued to do for some time.

But Peel was as little satisfied with this process as he had been with the hand-card; and having seen the good effect of a cylinder in that case, he resolved to try it in this. He had an oblong frame made, with a smooth wooden bottom, and upright posts, and a rail on each side. Running from side to side was a roller with a handle to turn it, and round the roller was a rope wound spirally. Each end of the rope was fastened to an oblong deal box, as wide and as long as the frame; it was filled with bricks and was very heavy. He wound his pieces of calico round smooth wooden rollers, which were placed in the bed of the frame under the box, and that being drawn backwards and forwards by means of the rope round the upper roller, the winch soon gave the requisite smoothness to the new work. This in truth was the *Mangle*, and the earliest printing-machine much resembled the same implement. Peel's machine, though it answered the purpose admirably, was superseded by superior machinery. This Robert Peel, "Parsley Peel," as he was called, also superseded the hand-carding of cotton-wool, by using cards, one fixed to a block of wood, and the other slung from hooks fixed in a beam, one of which remained in the kitchen of his farmhouse in 1850. Peel had his Carding-machine destroyed by mobs, and was driven out of the country by his neighbours. The son of this humble inventor, the first Sir Robert Peel, next established printworks at Bury; his residence being at Chamber Hall; and in a small cottage hard by (in consequence of the hall undergoing repair), was born his eldest son, Sir Robert Peel, the distinguished Minister, who once remarked of his father:—"He moved in a confined sphere, and employed his talents in improving the cotton-trade. He had neither wish nor opportunity of making himself acquainted with his native country, or society far removed from his native county Lancaster. I lived under his roof till I attained the age of manhood, and had many opportunities of discovering that he possessed in an eminent degree a mechanical genius and a good heart. He had many sons, and placed them all in situations that they might be useful to each other. The cotton-trade was preferred as best calculated to secure this object; and by habits of industry and imparting to his offspring an intimate knowledge of the various branches of the cotton manufacture, he lived to see his children connected together in business, and by their successful exertions to become, without one exception, opulent and happy. My father may be truly said to have been the founder of our family; and he so accurately appreciated the importance of commercial wealth in a national point of view, that he was often heard to say that the gains to individuals were small compared with the national gains arising from trade."

To return to Blackburn: Mr. Peel removed from thence to Brookside, two miles distant, for the sake of water, and there, by the assistance of his sons, extended his business very considerably. In 1773, his eldest son, Robert, left the concern, and entered into partnership with a Mr. Yates, and his uncle named Haworth, and with them carried on an extensive business at Bury. Two other sons entered into partnership at Bury, and were alike successful.

The principle of block-printing, however, was found too slow, especially when more than one colour was to be used, and cylinders were again employed. The patterns to be printed were engraved on the face of a cylinder, which revolves in connection with another of equal size. To the credit of this adoption Mr. Peel is specially entitled. The lower cylinder, on which the pattern is wrought, turns with half its circumference in a box which contains colouring matter, which in the course of its progress is shaven off by a blade of soft steel, except where the pattern is engraved. The cloth is passed between the two cylinders, and receives the impression of the pattern; it is afterwards passed over another cylinder filled with hot steam, and almost instantly dried. Where three or four colours are to be used, there must be as many cylinders; and thus a piece of calico, of twenty-eight yards in length, can be printed, in various colours, in about two minutes—a work which, by hand-labour, could not be performed in less than a week.

But another improvement was made. These cylinders had usually been made of copper, and they were not only expensive, but soon wore out. To reduce this expense was engraved a very small steel cylinder, of two or three inches in length, with the pattern desired, when the metal was in what is called the decarbonized or softened state, after which it was attempered till it became very hard. When it was hardened to the utmost, it was worked by powerful machinery against a large cylinder, which, being duly softened, received the design; that also was in its turn hardened, and then worked against the copper roller, which received the impression as originally engraved, and thus was fitted for the printing process.

At this time it was that chemistry came to the assistance of art, in *Chlorine*, which discharges all vegetable colours, and thus bleaches the cloth to a fairer and purer white in a few hours, than could by the old process of exposure to the air, on the grass, have been obtained in many months. This was of inestimable value, for in order to print the richest patterns the most perfect white that could be obtained was necessary. But the prints would not *wash*, and consequently, when once dirtied, a dress became useless, and the earth was ransacked to obtain what are called *mordants*, from the French word *mordre*, to bite, as they seem to make the colour bite into the cloth and become fixed: one of the plans adopted was to print the cloth with the mordant only, then to dip it in the dying-vat, and afterwards wash it out, when the mordant was found to have retained the pattern in beautiful integrity. Another plan is to print the pattern with lemon-juice; the piece is then steeped in the mordant, dried quickly, and dyed in the vat. When washed, the acid is found to have resisted the mordant, and the pattern stands out in pure white, all the rest of the cloth of course retaining the colour in which it was dyed. This is called *discharge-work*, and gave to the Peels an opportunity of imitating very beautifully the Indian patterns which were at that time very much admired.

Another discovery made by a person, not possessing scientific knowledge, was *resist-work*, which consists in printing the cloth with a kind of paste, and then dying it with indigo; when the paste will resist the colouring matter, and the pattern be pure white: without the paste the indigo would not wash out. The secret was sold to the first Sir Robert Peel, for five pounds.

In the history of inventions there are many episodes of enthusiasm, by which genius is misled as by the *ignis fatuus* that lures us from the safe path, and raises hopes never to be realised; while, on the other hand, alarmists spring up at almost every change. Spinners, weavers, and many kind-hearted men, at first believed that machinery would deprive operatives of their bread, reduce an industrious population to beggary, and turn thickly-peopled districts into wastes, occupied by steam-engines and spinning-jennies. The Cotton Manufacture has proved the reverse case. Liverpool is the port of Manchester, Leeds, and the populous country around; Glasgow of Lanarkshire. The merchants of Manchester and Glasgow required to be brought into easy and rapid connection with the cotton-growing districts of the world; and steam navigation and railways have followed. Lancashire, from being third in population among the English counties at the beginning of the century, is now more populous than Middlesex itself.

It was long thought that the British workman could never rival the delicate Cotton fabrics of the Hindoo; and it was even feared that the cheapness of labour in India would not only render it impossible to undersell the workers of that country, but would operate to the disadvantage of British industry. Machinery, however, spins finer yarns than the Hindoo fingers, and enables the British merchant to buy the Cotton of India, pay for its carriage to this country, turn it into cloth, and export it to Calcutta or Bombay, at a profit.* These useful fabrics have come into common use in India. Still more recently our Glasgow and Manchester manufacturers have obtained patterns from India, and have made imitations of them, perhaps not very successfully, since they continue to be in comparatively limited demand. They have not certainly affected the produce of the native Indian looms, which is preferred because it is more durable, more suitable for wear; it does not vary from the old traditional patterns of the country, besides being of fast colours, which use and constant washing rather improve than injure. Nor can we rival the muslins of Dacca. The fibres of the cotton are more consolidated, and the cotton itself, a short-stapled variety, is, perhaps, stronger than the American used in European muslins. This fact is well worth the consideration of our scientific manufacturers; and where the short-stapled Indian or American cottons are used for long cloths and gray shirtings (and the same may be said of all cottons), the want of "wear" which is complained of in English, in comparison with native fabrics, may be accounted for by the cotton not having been as sufficiently twisted by the jenny as it is by the spindle and hand process of the Indian spinner.†

The perfection of machinery has largely contributed to our success. Mr. H. Ashworth, late president of the Manchester Chamber of Commerce, has well illustrated this position of the Cotton Manufacture. "At first," he tells us, "the various operations of beating, carding, roving, and spinning were household operations; but progressively, with a view to economy of time and quickness, they led to the building of factories; and the concentration of them under one roof, with a propelling power of water or steam, gave a united and combined action to all the processes, which caused them to be carried on with the precision of clockwork. This led to the regulation of wages by the yard in length or the pound in weight of finished work, and in this way the discipline and productive power of a factory determined the income of the operative with uniformity and certainty. It led to the attraction of labour from all parts of

* James Syme, M.A.: *Edinburgh Essays.*

† See Dr. Forbes Watson's valuable work on the Textile Manufactures and the Costumes of the People of India. Printed for the India Office, 1866.

the country, and the population of Lancashire. which was 673,000 in 1801, had increased in 1861 to 2,428,744, or 360 per cent.; while the increase in the country as a whole was only 225 per cent. As a measure of progress, it is a striking fact that, while in the year 1760, according to Dr. Percival, the entire Cotton trade of Great Britain did not return for materials and labour more than 200,000*l.*, in 1860 the returns of our Cotton Manufacture were estimated by Mr. Bazley, M.P., at 65,000,000*l.* The value had increased 400 times, and we were consuming 270 times as much cotton. It has been stated that we now employ 36,000,000 spindles, that in one minute we can spin a length of Cotton which would wind four times round the earth, while every day 10,000,000 yards of Cotton fabrics come out of our looms. The price, at the same time, has been greatly reduced. In 1786, No. 42's cotton yarn was 10*s.* 11*d.*, while in 1860 it was only 11*d.* per lb. In the same period 100's yarn was reduced from 38*s.* per lb. to 2*s.* 6*d.* In 1790 a white cotton dress was 6*s.* a yard, while in 1860 the same quality of fabric was obtainable at 2½*d.* to 3*d.* per yard. As compared with fabrics of wool or flax, the economy of Cotton is striking. A garment of one pound in weight of flannel cost 3*s.* 1*d.* in 1860; of linen, 2*s.* 4*d.*; while of cotton it was only 1*s.*

It is calculated that about the middle of the last century, there were probably 20,000 persons engaged in the Cotton Manufacture of Great Britain; but by the population returns of 1851, it appeared that there were then upwards of half a million, exceeding by more than twenty thousand, the whole number employed in the silk, linen, woollen, and worsted manufactures of the island; these numbers referring to persons actually working in mills. The operatives are now a much better paid and more intelligent class of men than ever; though it must be confessed that commercial crises and unhappy strikes often chequer this prosperity. The great losses sustained through "the Cotton Famine" of late years have been met by benevolent relief,* as well as the best means to pre-

* The Liverpool Committee for obtaining subscriptions for the relief of the sufferers by the Cotton Famine had, up to the 31st of December, 1866. collected a gross sum of 103,068*l.* 6*s.* 3*d.*, of which 61,999*l.* 1*s.* 2*d.* had been spent in relief, and 390*l.* in expenses, leaving in hand a balance, less 400*l.* not collected, of 40,679*l.* 5*s.* 1*d.* This sum it is proposed to devote to the building of a Convalescent Hospital.

vent the recurrence of a like calamity, by the culture of Cotton in our colonies. It must, however, be carefully borne in mind that Great Britain no longer has the exclusive use of that superior machinery which at one time placed us so far ahead of other nations; and that there has been a gradual extension of those more refined mechanical contrivances which for a period appeared to give to the British cotton spinner and manufacturer a monopoly of the markets of the world. In the comparison of the spinning of French and English yarns it has been recently found that the application of a French invention has been of great importance; this being, the *combing machine*, which greatly facilitates the production of the fine numbers—in fact, renders that comparatively easy which formerly appeared almost impossible, and indeed, was so, except in the hands of the special few.

Professor George Wilson has eloquently said: "The most striking actions of machinery are those which involve not only swift irresistible motion, but also transformation of the materials on which the moving force is exerted. Take, for example, a Cotton Mill. On the basement story revolves an immense steam-engine, unresting and unhasting as a star in its stately, orderly movements. It stretches its strong iron arms in every direction throughout the building; and into whatever chamber you enter, as you climb stair after stair, you find its million hands in motion, and its fingers, which are skilful as they are nimble, busy at work. They pick cotton, and cleanse it, card it, rove it, twist it, spin it, dye it, and weave it. They will work any pattern you select, and in as many colours as you choose; and do all with celerity, dexterity, and unexhausted energy, and skill. For my part," continues the Professor, "I gaze with extreme wonder on the steam Agathodæmons of a Cotton Mill, the embodiments, all of them, of a very few simple statical and dynamical laws; and yet able, with the speed of race-horses, to transform a raw material, originally as cheap as thistle-down, into endless useful and beautiful fabrics." They who remember the display of Cotton machinery in the Great Exhibition of 1851,—whose perfections were alike watched and admired by sovereign and subject,—will bear testimony to the truthful eloquence of Professor Wilson's illustration.

STEAM NAVIGATION.

THAT the very obvious application of Steam Power as a moving agent on land and water should long have escaped the attention of James Watt must have struck every enquirer with astonishment. That he made some feeble efforts towards solving the problem of applying the new agent as a locomotive power is admitted; but that he never crowned his labours with a working model is equally indisputable. Indeed, he seems to have had some jealousy of William Murdoch's efforts in this direction, as we find him complaining to Boulton, that Murdoch was wasting his time on a fruitless attempt; yet that attempt was a more momentous one (the steam-engine itself excepted) than any other of the last or present century. William Murdoch's locomotive model, the first ever constructed, was exhibited, it will be remembered, at the Exhibition of 1851, on the gigantic screw-shaft of the James Watt, 91 gun ship, executed just three-quarters of a century afterwards by the firm of the Messrs. Watt.

But the sea as well as the land was destined soon to witness the triumphs of ingenuity and machinery: the present century has produced the process of diagonal bracing in the construction of ships, the application of Watt's engine to propel them, iron vessels instead of wood, water-tight compartments, and a multitude of other useful and important changes. Here, as in the textile manufactures, Steam lies in a great degree at the root of progress in Shipbuilding and sailing.

The antiquity of the paddle-wheel, as a means of propulsion, has been strangely overstated. It has been attributed to Egypt, Nineveh, and China, but the authorities given have in either cases failed to substantiate the fact. We find boats propelled by paddle-wheels mentioned by many early writers, such as

Julius Scaliger, in 1558; Bourne in 1568; Ranielli in 1588; and Roger Bacon, in 1597. Mr. Macgregor, in his exhaustive paper on the Paddle and the Screw, read by him to the Society of Arts in 1858, before considering the application of the Steam-engine to turn paddle wheels, notices briefly some of the other agencies employed: "The muscular power of men, of horses, and of other animals, was often used and frequently patented, even to the year 1848, by Miller; and 1856, by Moses. The Marquis of Worcester, in 1661, patented the application of a current, to turn paddle-wheels, or a vessel propelled by winding up a rope. Papin, in 1690, proposed to work the wheels by gunpowder, exploded under pistons. Conrad, in 1709, used the force of the wind; Maillard, in 1773, and Goutaret, 1853, applied clockwork; Harriott, in 1797, used falling water; weights were employed by Tremeere in 1801; Congreve, in 1827, used the capillary attraction of a wheel of sponge or glass plates; Dundonald, in 1833, applied the oscillations of mercury; and Jacobi, in 1838, employed an electro-magnet to work the paddle-wheels of a vessel on the Neva.

The absurd claims to priority urged by Spaniards on behalf of Blasco de Garay have been dissipated by the examination of a letter written by him in 1543, and now in the Archives at Simancas, where the paddle-wheels of his "steamboat" turn out to have been moved by men. There is not a word about steam in the letter (see *ante*, p. 203).

It appears that Denis Papin, in 1690, first proposed to use steam to work paddle-wheels: by means of rackwork moved by pistons descending in steam-cylinders by atmospheric pressure. He is said to have offered to the Royal Society to put his plan in practice for the small advance of fifteen pounds towards the expenses; the offer was rejected, chiefly, it is believed, from the Society being at that time in straitened circumstances. Savery, in 1702, scarcely ventured with timidity to suggest the use of his Steam-engine for the purpose: but it is asserted, in a French work, that Papin, in 1707, actually propelled a vessel on the Fulda by Savery's engine; and in the manuscript correspondence between Leibnitz and Papin, in the Royal Library, at Hanover, are to be read the experiments of the latter with a model steam boat, in the above year. When Papin resided in England, he witnessed an experiment on the Thames, in which a boat, constructed from a design of the Prince Palatine Robert, was fitted with revolving oars or paddles, attached to the two ends of a long axle, going across the boat; they received their motion from a trundle, working a wheel turned by horses; and this horse-boat beat the king's barge, manned with 16 rowers. In 1682, a similar horse-tow vessel was used at Chatham.

The first patent relating to a Steam-boat is that of Jonathan Hulls, in 1736. He placed a paddle-wheel on beams projecting over the stern, and it was turned by an atmospheric steam-engine, acting in conjunction with a counterpoise weight, upon a system of ropes and grooved wheels. His mode of obtaining a rotary motion was new, and would enable a steam-boat to be moved through water; but it was not practically useful. Had Hulls discovered the requisite application of the crank, the steam-engine, in all probability, would have been *then* applied not only to propel boats, but to various other useful purposes. Among other experimenters of about this period was M. Genevois, a pastor of Berne, who invented a steam-propeller, formed like the foot of a duck, to expand and present a large surface to the water when moved against it, and to close it into a small compass when moved in an opposite direction.

The Comte d'Auxiron and M. Perrier are stated to have used a paddle-wheel steamboat upon the Seine, near Paris, in 1774; but the account of their experiments is vague and unsatisfactory. Desblancs, in 1782, sent a model to the Conservatoire (still there), of a vessel in which an endless chain of floats is turned by a horizontal steam-engine. According to a statement of M. Arago, in an historic sketch of the progress of Steam, published in 1837, the Marquis de Jouffroy, in 1783, made attempts on a large scale at Beaume-les-Danes, and again tried a boat of considerable size on the Saone, at Lyons. This experiment excited much attention, and all the authorities agree in the assertion that the vessel used was upwards of 120 feet long and not less than fifteen feet beam. The dreadful disturbances which shortly afterwards broke out in France put a stop to his efforts; and for several years he was an exile from his native country. On his return, in 1796, he found the principal part of his invention had been adopted by the above-named Desblancs, a watchmaker at Trevoux, who had assiduously gathered information respecting the operations of the marquis. The latter appealed to the goverment; but Desblancs had obtained a patent during his absence, so that he was left without any redress. Robert Fulton, who afterwards took up an important position in reference to Steam-navigation, was at that time experimenting in France, and had adopted a series of flat boards, which were moved by an endless chain stretched over two wheels that projected on either side of the boat; but he ultimately abandoned this plan and used paddles. Desblancs complained of the infringement of his patent; and Fulton, after showing him the difference between the two machines, offered a portion of the advantages if he would bear a portion of the expenses of the trials; but no arrangement appears to have been entered into between them. Neither Desblancs nor his country obtained any advantage from his efforts; and this appears to have been nearly all that was done in France for Steam navigation before the close of the last century.

In 1778, the notorious Thomas Paine, the republican, proposed in America the propulsion of vessels by steam. Paine, at one period, employed himself much in mechanical speculations: in 1787, he submitted to the Academy of Sciences at Paris a plan for the construction of iron bridges, which he afterwards explained in a letter printed at Rotherham. He published four or five Treatises—on iron bridges, the yellow fever, on the building of ships of war, &c.

The enterprising spirit of the Americans was not likely to suffer them to be wanting in efforts to bring that to pass which had caused so much sensation on this side of the Atlantic, and which, even at that time, promised such immense results. Accordingly, we find that two individuals, named Rumsey and Fitch, were engaged in active rivalry in the United States in applying the Steam-engine to the propulsion of vessels. The latter of these two gentlemen, as early as 1783, was occupied in the construction of a boat, which he afterwards contrived to move with paddles, by the aid of a steam-engine, on the Delaware; and in 1785, he had so far completed his design that he presented a model of his apparatus to Congress. He was encouraged by the support of several wealthy men who provided the means for his experiments, and was so sanguine of success as to express his firm conviction that the ocean would ultimately be crossed by steam-vessels—a declaration which, when it was made, must have appeared to be little else than the notion of a visionary, but which many of Fitch's generation have lived to see so wonderfully realized. Rumsey, his rival, was also backed by a company; and in 1784 succeeded in the construction of a boat, a model of which in that year he exhibited to General Washington. This vessel was about fifty feet long, and was carried along the Potomac by means of a stream of water which, with a pump worked by a steam-engine, entered at the bow and was carried out at the stern, the reaction of the water being the impelling agent. The boiler only held about five gallons, and the fuel consumed was about six bushels of coal in twelve hours. Yet with this imperfect apparatus—when the boat was loaded with three tons weight, besides the engine, which was about a third of a ton more—Rumsey succeeded in attaining a rate of three or four miles an hour. He afterwards came to England, and by the assistance of some capitalists built another vessel, which was tried on the Thames, in the month of February, 1693; and in several trials made afterwards, one attained a speed, against wind and tide, of upwards of four miles an hour. About the same year, Mr. Lineaker, the master shipwright of Portsmouth dockyard, began a series of experiments on the same principle, which he patented.

Meanwhile, in England, one of Watt's patented improvements in the steam-engine, January 5, 1769, caused *the steam to act above the piston, as well as below it;* this was the first step by which the Steam-engine was successfully used to propel a vessel; "and this improvement," says Mr. Bennet Woodcroft, "was applied to the first practically-propelled steamboat, and is still used in the present system of Steam Navigation."

In the Commissioners of Patents' Museum, at South Kensington, is "the Parent Engine of Steam Navigation," the history of which is briefly as follows: For some years prior to 1787, Mr. Patrick Miller, of Dalswinton, Scotland, had experimented with double and triple vessels propelled by paddle-wheels, worked by manual labour. In the trips of 1786 and 1787, he was assisted by Mr. James Taylor, the tutor to his two younger sons; and at the suggestion of Taylor, it was determined to substitute steam-power for manual labour. For this purpose, early in 1788, Taylor introduced Symington, the eminent engineer, who had, the year before, patented "his new invented Steam-engine on principles entirely new," and Symington applied an engine, constructed according to his invention, to one of Mr. Miller's vessels,—which is the engine now at South Kensington. In October, 1788, the engine, mounted on a frame, was placed upon the deck of a double pleasure-boat, 25 feet long and 7 feet broad, and connected with two paddle-wheels, one forward and the other abaft the engine, in the space between the two hulls of the double boat. This engine propelled the vessel along Dalswinton lake five miles an hour.

There exists the following evidence, almost of the very day above named. In a letter from Dr. Franklin to Dr. Ingenhauz, dated Philadelphia, Oct. 25, 1788, the doctor remarks: "We have no philosophical news here at present, except that a boat moved by a steam-engine rows itself against tide in our river, and it is apprehended the construction may be so simplified and improved as to become generally useful."

After Mr. Miller and his friends had made experimental trips in the boat, the engine was taken into Mr. Miller's house, where it remained in the library until his decease in 1815. Some time after, the engine was sent by his son, packed in a deal case, to the banking-house of Messrs. Coutts & Co., in the Strand, and was there kept until 1837, when it was removed to Tilbury's storehouse, in Marylebone. Here it remained until the end of January, 1846, when it was forwarded to Mr. Kenneth Mackenzie, at Edinburgh. By him the engine was sold to his brother-in-law, a plumber, in Edinburgh, who removed the engine from the framing, and threw it into a corner for the purpose of melting; this intention, however, was not carried into effect, doubtless owing to the death of the plumber. It was subsequently found to be in the possession of Messrs. William Kirkwood, from whom it was purchased, and despatched to the Great Seal Patent Office, in 1853. Subsequently, it was transmitted to Messrs. Penn, the engineers, of Greenwich, who gratuitously rëinstated it in a frame, and put it again in working order, as an object of great public interest. The engine was returned as good as new, January 4th, 1855; and on the 29th of January, 1857, it was removed from the Great Seal Patent Office to the Patent Museum at South Kensington.*

The engine is of the class known in the early history of steam-machinery as the "atmospheric engine," in which the piston is raised by the action of steam, and then on a vacuum being produced beneath, by the condensation of the steam, it is forced down again by the pressure of the atmosphere. The cylinders (two in number) are open at the top, which is enlarged, to prevent the overflow of the water used for keeping the piston steam-tight upon the plan adopted by Newcomen. The lower part of each cylinder is furnished with James Watt's

* From Mr. Bennet Woodcroft's Descriptive Catalogue.

patented condenser and air-pump in a modified form,—the condenser and air-pump being attached to the cylinder, instead of being separate from it, as proposed by Watt. The valves are opened and closed by an improved arrangement of Henry Beighton's hand-gear. A T-head or cross-head is applied to the end of the piston-rod, apparently for the first time; and a communication is established between it and the paddle-wheel shaft by an arrangement of chains, ratchet-wheels, clicks, &c., for which Matthew Wasbrough obtained letters patent (in England only) March 10, 1779, whereby the rectilinear movement of the piston is converted into circular motion. To Symington, credit is justly due for combining these improvements in the same engine.

When it was applied to propel a boat, as already mentioned, numerous projects had been proposed and several abortive attempts had been made to propel vessels by steam-power, commencing with an experiment said to have been made in the year 1543; but the whole of the projects and experiments previous to the application of this engine proved valueless for any practical use.

The result of the experiments with this engine and with a larger one subsequently made on the same plan for Mr. Miller, demonstrated to Symington that a more simple arrangement of the parts forming a steam-engine was required before steam-power could be applied practically to navigation.

Accordingly, in 1801, Symington was employed by Lord Dundas to construct a steam-boat, and having by his former failures learned what was required, he availed himself of the great improvements recently made in the Steam-engine by Watt and others, and constructed an improved engine in combination with a boat and paddle-wheel, on the plan which is now generally adopted. This boat, called the *Charlotte Dundas*, was the first practical steam-boat; and for the novel combination of all the parts Symington obtained letters patent on the 14th October, 1801. In this vessel there was an engine worked by steam, acting on each side of the piston, and then discharged from the cylinder into a separate condenser (Watt's patented invention); the rectilinear motion of the piston was converted into rotary by a connecting rod and crank (Pickard's patented invention); and the crank was united to the axis of Miller's improved paddle-wheel (Symington's patented invention.) Thus had Symington the undoubted merit of having combined together for the first time those improvements which constitute the present system of steam navigation. The speed, when running alone and not towing other boats, was six miles an hour.

"The use of this vessel," says Dr. Macquorn Rankine, "was abandoned, not from any fault in her construction or working, but because the directors of the Forth and Clyde Canal feared that she would damage its banks. Yet the man in all Britain who possessed, at that time, the greatest practical experience of the working of canals--the Duke of Bridgwater—was not deterred by any such apprehension from ordering, in 1802, eight similar vessels, from Symington, to be used on this canal. The death of the Duke of Bridgwater, early in the following year, prevented the execution of that order. But Symington had evidently done all that lay in his power, and all that was necessary, to convert the steam-boat from an awkward piece of experimental apparatus to a practically useful machine; and the honour paid to his memory ought not to be lessened because the career of his invention was cut short by a misfortune."

The widow of Mr. Taylor received, in recognition of his efforts to introduce Steam Navigation, a pension from Government, of 50*l*. per annum; and in 1837, each of his four daughters, received a gift of 50*l*., through Lord Melbourne. About the year 1825, Symington memorialized the Lords of the Treasury, when 100*l*. was presented from His Majesty's privy purse; and a year or two afterwards a further sum of 50*l*. The poor inventor hoped that the allowance would be repeated annually, but his hopes were defeated. He received a small sum from the London steam-boat proprietors, and kind relatives contributed to his support in the decline of life. This was all that was awarded to the inventor of "the first practical steam-boat" in the great country of the steam-engine!!

Many attempts have been made, and much misrepresentation used, to obtain for Fulton, the American engineer, the credit of first using steam locomotion on the water. He certainly did not fail to profit by the labours of others. Dr. Cartwright contrived a steam-barge, which he explained to Fulton, some say in 1793, when he was studying painting under Benjamin West: others state 1796, when Fulton was introduced to Dr. Cartwright at Paris. Colden, the biographer of Fulton, states that he made drawings of an apparatus for Steam Navigation, in 1793, and submitted them to Lord Stanhope in 1795, who was then experimenting with duck-feet paddles, but never got beyond three miles an hour.

Although Fulton possessed much inventive genius, and had been engaged with Chancellor Livingston, who was at the time minister for the United States in Paris, in the construction of vessels to be propelled by steam, still he never accomplished anything until after he had seen the vessels of Symington.


ROBERT FULTON.

Before he returned to America, Fulton visited England, and there induced Symington to afford him much information, and even take a steam-trip on his account, during which Fulton noted in a memorandum-book the particulars of the construction and effect of the machine, which Symington unhesitatingly afforded him. Everything connected with his experiments for the accomplishment of Steam Navigation was shown to Fulton, and all he did not comprehend was explained to him. It is true that in the plea for a patent, jointly sued for by Fulton and Livingston, the former claimed the right as an inventor; but there is no apparent ground for such an assumption, and the honour is sufficient for him to have been the first to bring it into great practical application. Chancellor Livingston having supplied the means, a vessel was launched upon the Hudson, by Fulton, early in the spring of 1807. By the assistance of engineers from the works of Boulton and Watt, at Birmingham, the engines were completed in August, and everything was ready for the trip by the commencement of the new year; and the first attempt to navigate the waters of the New World by the aid of steam was made in January, 1808. Fulton thus described to a friend the disheartening circumstances under which the construction of the first steam-boat—nicknamed by the Americans "Fulton's Folly"—was patiently persevered in by himself. He records as follows: "When I was building my first steam-boat at New York, the project was viewed by the public either with indifference, or with contempt, as a visionary scheme. My friends, indeed, were civil, but they were shy. They listened with patience to my explanations, but with a settled cast of incredulity on their countenances. Never did a single encouraging remark, a bright hope, a warm wish, cross my path. Silence itself was but politeness veiling its doubts or hiding its reproaches."

Fulton's biographer describes the trial: "Before the boat had made the progress of a quarter of a mile, the greatest unbeliever was converted, and Fulton was received with shouts and acclamations of congratulation and applause. The vessel, *Clermont*, made her first voyage from New York to Albany, 140 miles, at the average rate of five miles an hour; stopping some time at Clermont to take in water and coals. The whole progress up the Hudson was a continued triumph. The vessel is described as having the most terrific appearance. The dry pine-wood fuel sent up many feet above the flue a column of ignited vapour, and, when the fire was stirred, tremendous showers of sparks. The wind and tide were adverse to them, but the crowds saw with astonishment the vessel rapidly coming towards them; and when it came so near that the noise of the machinery and paddles was heard, the crew, in some instances, shrunk beneath their decks from the terrific sight; while others prostrated themselves, and besought Providence to protect them from the approach of the horrible monster, which was marching on the tide, and lighting its path by the fire that it vomited."

Mr. Dyer had sailed in the *Clermont*, and remembers the sensation created by her appearance, and the high admiration bestowed on the projector of so great an enterprise. That sensation in 1807 was precisely the same as the *Margery* created among the vessels on the Thames in 1815. In 1816, the Marquis de Jauffroy complained that the *Fulton* steam-boat on the Seine had taken the "paddle-wheels" invented by him and used at Lyons thirty-four years before, but also abandoned by him. To this charge Mons. Royou replied in the *Journal des Debats*, thus:—"It is not concerning an invention, but the means of applying a power already known. Fulton never pretended to be an inventor with regard to steam-boats in any other sense. The application of steam to navigation had been thought of by all artists, but the means of applying it were wanting, and Fulton furnished them." The *Fulton*, of 327 tons, was built in 1813, and the first steamer for harbour defence was built under Fulton's direction, 2,740 tons, launched in 1814.

This became the model ship for the iron-clad batteries and rams, since constructed with many changes. It will be seen by the drawings of Fulton's plans, that he had tried the several other kinds of propellers—the chain-float, duck's-foot, and the screw-fan—before adopting the paddle-wheel; for though the screw was good in principle, it was many years before it could be constructed to act efficiently.

But the *Clermont* soon had a competitor. Within a few weeks, Mr. Stevens, of Hoboken, launched a steam-vessel, which, as she could not ply on the waters of the Hudson, in consequence of the exclusive patent of Fulton and Livingston, he took round to the Delaware; and this was the first steamer that ever braved the tides of ocean.

It was not till nearly four years after this that Steam Navigation became practically useful, in the common sense of the term, in the British Isles; and there seems to be something like a coincident propriety in the fact that it was also a Scotchman by whom it was first made available on this side of the Atlantic.

Among the persons who had been acquainted with the experiments of Mr. Miller and his associates on the Forth, was Mr. Henry Bell, of Glasgow, who had been the medium of communication between Fulton and the Scotch coadjutors, and who had sent to the former drawings of the boat and engines which they had used. Some time after, Fulton wrote to Bell to say that he had constructed a boat from them, which prompted Bell to turn his attention to the introduction of Steam Navigation in his own country. He accordingly set to work, but had to make several models. At length he put one into the hands of Messrs. John Wood and Co., of Port Glasgow, who, from it, built for him a vessel of forty feet keel and ten feet six inches beam. This he fitted with an engine and paddles, and gave her the name of *Comet*, from the circumstance of a brilliant comet appearing towards the latter end of the year 1811, in which she was launched. This vessel Bell was enabled to turn to profitable account; for, being a builder, he had erected a bath-house and hotel at Helensburgh, a watering-place on the opposite bank of the Clyde, and he employed the *Comet* to convey passengers across the river, and thus derived a double advantage from it. The vessel was of twenty-five tons burthen, forty feet long, ten and a half feet beam, and four horse power; the engine being placed on one side and the boiler on the other, while the funnel was bent round, so as to rise in the middle of the deck, and serve the purpose of a mast. The *Comet* began to run in January, 1812; she was moved at first by mere paddles, and attained a speed of five miles an hour; but Bell substituted wheels, with four paddles of the malt-shovel form. The engine was made by Anderson, Campbell, and Co. (now Laird and Co.) and David Napier, then a workman, was employed in making the boiler.

There is another application of steam-power, the credit of which is due to Fulton. During the war between Great Britain and the United States, in 1814, the coast of the latter was much exposed to the insults and ravages of our cruisers. Fulton proposed to free his countrymen from this annoyance, and to defend the harbour of New York from attack, by means of steam-frigates. That which he actually did build much resembled the double boats, or *twins*, constructed by Miller of Dalswinton. But it was not to cannon and rapid movements that the merchants of New York trusted; for the frigate was fitted with machinery calculated to discharge an immense quantity of hot water through the port-holes of an enemy's ship, by which the ammunition would be rendered useless, and the crew scalded to death. The people of New York believed themselves safe against every hostile power, and the liveliest apprehensions were entertained in Britain: cutlasses without number were said to be moved by machinery; pikes, darted forth and withdrawn every quarter of a minute, would sweep the decks of our men-of-war; in short, the iron fingers of a modern Scylla would kill the sailors at their posts. Such is the account by Mr. Syme, who adds, little did either nation imagine that, before the lapse of forty years, Great Britain would depend on this very application of steam to maintain her supremacy at sea, of which many supposed it had deprived her.

Soon after the above success, Mr. Hutchinson, of Glasgow, had a vessel built by Thomson, an engineer who had been engaged in some of Bell's experiments. She was larger than the *Comet*, being fifty-eight feet long, twelve feet beam, and five feet deep; engines, ten horse power. She was named the *Elizabeth*, and performed the distance between Greenock and Glasgow, twenty-seven miles, twice a day.

Mr. Dyer tells us that in 1811, he endeavoured to introduce Steam Navigation into England, but found a strong conviction that it would not answer in this country, our most eminent engineers saying, "We don't doubt the success of steam-boats in the wide rivers and harbours of America, but in our comparatively small rivers and crowded harbours they will never answer." Even such scientific engineers as John Rennie and Peter Ewart, both advised Dyer to relinquish the attempt to introduce steam-boats, as sure to prove a waste of time and money to no purpose. However, when conviction came over the public mind that Steam Navigation would answer here—but not until after more than 5,000 tons of steam-boats had been launched on the Hudson in 1816, did it so come—then began the spread of Steam Navigation, since extended with such marvellous rapidity and perfection as to atone for the sluggish beginning.

The success of these enterprises was not likely to pass unnoticed by the shipowners and builders of the greatest port in the world; and we find that in 1814, a steam-boat was employed between London and Richmond. George Dodd, son of Ralph Dodd, the well-known engineer, from 1814 to 1828, had more to do with establishing steam-boats on the Thames than any other individual. He it was who started the Richmond packet, in 1814—the first steam-boat which succeeded in *plying for hire* on the Thames. He had to contend against the Watermen's Company, who for a long time succeeded in preventing any steam-boat plying for hire unless navigated by free watermen. The Richmond was not, however, the first steam-boat *seen* on the Thames. Sir I. M. Brunel, as may be read in his *Life* by Beamish, made a voyage to Margate in a boat of his own, propelled by a double-acting engine, and met with such opposition and abuse that the landlord of the hotel where he stopped refused him a bed! In 1813, according to Stuart, in his *History of the Steam-engine*, a Mr. Dawson, an Irishman, and Mr. Lawrence of Bristol, attempted to run steamers on the Thames, but succumbed to the opposition of the Thames watermen. Dawson's boat was sent soon after to ply between Seville and San Lucar, in Spain.

Another vessel, the *Margery*, about 70 tons, which was built on the Clyde, was taken south, along the east coast of Scotland. When she reached the Thames, the English fleet were at anchor: and she passed close. "The extraordinary apparition," says the *Greenock Advertiser*, "excited a great commotion among officers and men : none of them had ever seen a steamer before, and by some of them she was taken for a *fire-ship.*" She made her first trip from London to Gravesend on the 23d of January, 1815; she continued to run between the two places during the following summer, but was frequently laid up for repairs. At this early stage of the invention, accidents were frequent: an explosion paralysed public confidence in the safety of the early steamers; and immediately following such a disaster, we remember reading in the *Times* newspaper a long letter from Sir Richard Phillips, to prove by detail of the principle of the invention, that only by gross mismanagement could danger arise. Such was the origin of the River Steamer, which, in a beautiful country has been thus eloquently pictured:—

> I saw her when her smoky volumes curl'd
> O'er the wood. She paw'd the river tide,
> And dash'd the flaky waters far and wide;
> And, as she pass'd, her frightful hissings hurl'd
> Like some vast monster of a former world,
> Rent by convulsions from a mountain's side
> (Its stony sinews with new life supplied),
> Amid a new creation wondering whirl'd.
> The woods are mute, and the late leafy stems
> Are hid as with a murky vale of death.
> And now, the paintress Nature all regems,
> And paints with golden tints the monster's breath;
> The reign of beauty may not suffer wrong;
> So the sweet birds resume their cheerful song.

The *Margery* continued, for several years, to ply as a pioneer steamer on the Thames—in great repute as a pioneer steamer—till she was broken up. She was followed by another vessel, about 75 tons burthen, with engines of sixteen horse power, and wheels of nine feet diameter; built on the Clyde. When launched, she was called the *Glasgow*; but that name was afterwards altered for the *Thames*; she was brought round from Scotland, by her owner, Mr. Dodd, by means of both sail and steam, and had to contend with very rough weather in the Irish Sea. Of the voyage between Dublin and London, a passenger, Mr. Weld, gives some details: on Sunday, the 28th of May, 1815, they steamed out of the Liffey at noon, in the presence of many thousand spectators. Mr. Weld adds:—"We soon left far behind us all the vessels which sailed from Dublin with the same tide as we had done; and the following morning about nine o'clock we were off Wexford. The dense smoke which issued from our mast-chimney was observed from the heights above that town, and it was concluded that our vessel was on fire. All the pilots immediately put to sea to assist us; and on the arrival of the first boat alongside, surprise was mingled with disappointment, when they saw that we were in no danger whatever, and that their hopes were at an end." On reaching the Isle of Ramsay, off the Irish coast, several boats went off to the vessel's assistance, on the same supposition that deceived the Wexford pilots, namely, that the ship was on fire. When the *Thames* reached Portsmouth, great was the excitement among the spectators in the harbour. From Portsmouth, the steamer proceeded to Margate, and, after stopping a day, started for London, passing every fast sailing vessel on the passage; this being the most wondrous feat of the day.

Next, the *Regent*, built for a Mr. Hall, and put on the Margate line, proved a failure, and was, by the advice of Isambard Marc Brunel, fitted by Henry Maudslay, and became eventually one of the most successful of the early Thames steamers. The *Regent* engine was the first made by Maudslay, for a steam-boat; she was the first steamer to tow a ship to sea from the Thames; she was burnt off Whitstable in 1817, and was, it is believed, the first steamer burnt.

A year later, a vessel called the *Majestic*, which had been used as a towing-boat, and had once been as far as Calais, was employed to run between London and Margate. This year, 1818, Dodd's *Victory* was put on the Margate station; as was also the *Favourite*, with side lever engines, by Boulton and Watt. The *London Engineer*, with a chimney, by Maudslay, was likewise placed for a time on the Margate station, and is said to have been the first steamer which crossed the English Channel. Another vessel, called the *Sons of Commerce*, ran between London and Margate; and once performed the distance of eighty-eight miles in rather more than seven hours and a half. In 1817, the first beam-engine made by Boulton and Watt was placed by them in a Clyde-built boat, the *Caledonia*: she was purchased by the Danish Admiralty, and was employed as a government packet between Kiel and Copenhagen.

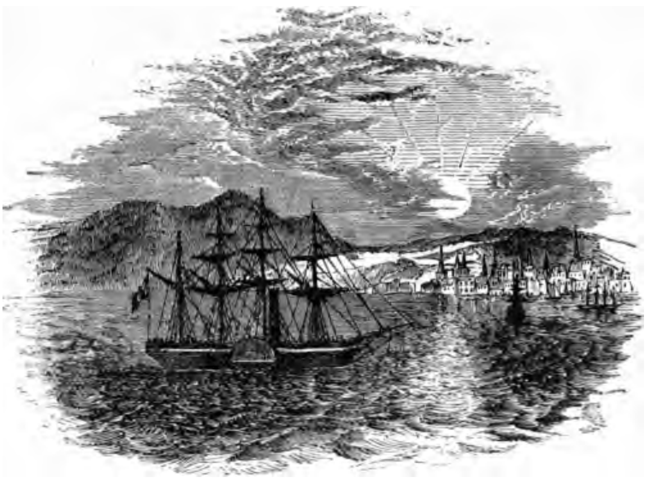
In 1818, so much had the principle of steam-navigation spread, that besides the vessels, then numerous on the Thames, there were two on the Trent, four on the Humber, two on the Tyne, one on the Orwell, eighteen on the Clyde, two on the Tay, two at Dundee, six on the Forth, two at Cork, two on the Mersey, three on the Yare, one on the Avon, one on the Severn, and two to run between Dublin and Holyhead. There were other steamers in active employment in Russia, France, Spain, and the Netherlands; and a large number on the rivers of the United States.

Up to this period, although there had been isolated voyages by sea, from one station to another, there had been no regular passages made. The delay which was often experienced by the sailing packets in traversing the stormy channel between Holyhead and Dublin, suggested the adoption of steam to obviate this loss of time. The first steam-vessel that ever sped regularly to the open sea was the *Rob Roy*, a ship of about ninety tons burthen, and thirty horse power, the property of Mr. David Napier, one of a family at Glasgow, almost every member of which became distinguished for eminence in mechanical science. This vessel Napier appointed to run between Glasgow and Belfast, a passage which she performed during the stormy months of winter, although steamers had only been out previously during the summer season; and after running for two years there, she was transferred to the station of Calais and Dover, as a Government packet. In the following year, Mr. Napier employed Messrs. Wood to build a vessel of 180 tons burthen, with two engines of 30 horse-power each, named the *Talbot*, followed by the *Ivanhoe*—the finest and most complete vessels of the time. These steamers were placed on the Holyhead station, to run between that port and Dublin, and assist the sailing packets which carried the mails; but such was their speed and regularity that they soon superseded them. Other vessels were added, strengthened by diagonal framing, under the direction of Sir Robert Seppings, the Surveyor of the Navy. And, according to evidence before Parliament, it appeared that, while one hundred mails by the sailing packets had, owing to the wind and other accidents of a sea voyage, been behind their proper time of arriving at the Post-office, only twenty-two, even in the most stormy state of the Irish Sea, had been too late when conveyed by steam-vessels.

In 1821, the *City of Edinburgh*, the first steamer built for a long voyage, was placed on the London and Leith station: builders, Wigram, of Blackwall; engines by Boulton and Watt; tonnage, 400; W. P. 80; length, 143 feet; diameter of wheels, 18 feet. In the same year the *Aaron Manby*, the first iron steamer, built by Manby, of the Horsley Ironworks, made her first voyage, commanded by Sir Charles Napier, when she conveyed a cargo from London to Paris direct, without transshipment.

For several years the extent and importance of our connexion with the United States had suggested that there might be a more frequent and certain transit across the Atlantic; and the project was now taken up with the ardour of scientific earnestness, and the energy of commercial enterprise. On July 19, 1819, the *Savannah* steamer of 350 tons, arrived at Liverpool, having made the voyage from New York in twenty-six days. The next ocean venture was the first steam voyage to India in the *Enterprize*, which left Falmouth, August 16. 1825: for this triumph the captain of the vessel obtained 10,000*l.*

Nevertheless, the project of Steam Navigation to America slept until 1836, when Dr. Lardner informed the British Association Meeting, at Bristol, that a company had been formed there for the express purpose of navigating steam-vessels directly, and by a single voyage, between that port and New York, and where was then building a vessel of 1,200 tons for the purpose. At length, in 1838, the *Sirius*, of London, and the *Great Western*, of Bristol, effected the voyage to New York almost simultaneously. The *Sirius*, an admirably built vessel of 700 tons, with 320 horse-power, started from Cork, April 4, 1838, and struck boldly and directly across the ocean for New York. A few days after, the *Great Western*, a vessel noble in every way in her proportions and appointments, which had been built under the direction of a company of British merchants, started from Bristol for the same destination. The voyage was triumphantly successful. The ships, it had been intended, should stop at the Azores, Halifax, or St. John's, to shorten the voyage; but, without calling at a single port for assistance or supply, they held on their course towards America, and at length, on the 23d of the same month, on the same day, the *Sirius* first, and the *Great Western* a few hours after, entered the harbour of New York. Long before their arrival notice of their coming had been given, and when the ships approached the shores of the greatest commercial city of the New World, they were greeted with flags and banners, and with music and ringing of bells, and the acclamations of an unnumbered multitude. In her second voyage out and home, the *Great Western* is stated to have netted about 3,000*l.* over and above her expenses; and in her third outward voyage, 3,500*l.* The *Sirius,* on the other hand, was found to be an uneconomical vessel, her accommodation not being equal to the expense of the voyage, and she was placed upon another line.



THE ARRIVAL OF THE GREAT WESTERN STEAM-SHIP AT NEW YORK.

The *British Queen* was the next Atlantic steamer built; she was the largest vessel then launched, and her length was 35 feet greater than that of any ship in the British Navy. This was followed by the *President.* Each of these magnificent vessels cost nearly 91,000*l.*, or nearly double the original estimate. The fate of the *President,* which sailed from New York, in March, 1841, remains to this day a melancholy mystery.

The large steamers hitherto named, were built of wood. The next stupendous novelty was, however, constructed of iron, and propelled by an enormous Archimedean screw, in place of paddles. This was the *Great Britain,* which, in trials, was commended as a weatherly ship, and the screw approved of as a means of propulsion at sea: she made her first voyage to New York in 1845, in 14 days, 21 hours: her vast length, 320 feet, a line of six masts, a wire rigging, rendering the "big ship" a marvel to the New Yorkers. On September 22, 1846, she left Liverpool for New York, with upwards of 180 passengers, then the largest number that had ever crossed the Atlantic in any steamer: in 9½ hours the vessel struck on the Irish coast: the attempts to raise her involved a series of mechanical operations attended with vast expense, and not until August, 1847, was the huge vessel rescued from her perilous position.

THE GREAT BRITAIN IN DUNDRUM BAY.

Next, the Oriental Steam-packet Company placed their splendid vessels on the waves of the Mediterranean, and brought the cities and the millions of India within the journey of a month. Again, and two years more saw a line of equally splendid ships bringing every fortnight the rich produce of our West India Colonies. A squadron of steamers then likewise commenced their missions of prosperity and peace beyond the isthmus of Panama.

We have now to chronicle the introduction of the Screw Propeller. Among the difficulties which prevented the steam-engine from being applied to navigation at an earlier period was the small space in the hold of a vessel at the disposal of the engineer, and the difficulty in adapting the engine to these limits. Then, how was the steam-engine, even when fitted to the confined hold of a river-boat, to urge the vessel through the water? Symington used the crank, Fulton, the sun-and-planet wheel, and both employed the improved water-wheels of Miller. A single engine with a fly-wheel worked the paddle-wheel shaft, but a heavy fly-wheel might be dangerous in river-boats, and was totally inapplicable to sea-going steamers. "The expediency of paddle-wheels at all," says Mr. Syme, "was soon questioned. They take up space, when it might be better employed, they may be too deeply immersed at the beginning of a voyage, and too little at the end, owing to the diminished draught caused by the consumption of one or two hundred tons of coals, and in a ship-of-war they are prominent marks to an enemy's shot. These objections to paddle-wheels have led to the introduction of the Screw Propeller into the merchant service and the Navy." Paddle-wheel steamers would in war be easily crippled by an enemy, and soon be rendered useless. The screw leaves a clear broadside for the guns, does not prevent the use of sails, and allows the machinery to be placed six or eight feet below the water-line, thus leaving the upper decks free for working the guns. The progress of the Screw in the Navy since 1839, when the *Rattler*, the first war ship fitted with it, has been most rapid. In 1852, there were 125 *armed* steamers, both paddle and screw, in the Navy, carrying 800 guns; at the great Naval Review at Portsmouth, in 1856, nearly twice as many steamers, principally screws, were assembled, carrying double the number of guns.

We must go back to early times for the first appearance of the Screw Propeller." "It is probable," says Mr. Macgregor, "that, as the action of a water-mill suggested the use of the paddle-wheel, so the motion of a wind-mill (a contrivance of unknown antiquity) may have prompted the use of the oblique vaned propeller." The use of the Screw Propeller in China may be of indefinite antiquity: a model of one was brought from that country about 1780. But the first distinct description of the Screw Propeller to be turned by machinery inside a vessel seems to have been by D. Bernouilli, of Groningen, in 1752, who proposed to use Screw Propellers at the bows, sides, and stern of a ship, and to drive them by a steam-engine. A sketch of this early suggestion is given in the *Annales des Arts et Manufactures*, tome 20. In 1775 Kraft noticed this invention in a memoir at St. Petersburg, and two years afterwards we find it mentioned in the *Monthly Review*, vol. 56. As usual, the idea was frequently reproduced or copied by other inventors; but even a century ago it included provisions for raising the screws out of water when out of use. In 1770, James Watt suggested a Steam Screw Propeller; Bramah, in 1785, patented a rotary-engine for this purpose; Ramsey, in 1792, put the screw between two hulls; and Lyttleton, in 1794, used a three-threaded screw; while Fulton, in 1798, tried one with four blades. The first screw steamer Mr. Macgregor could find was tried by Stevens in America, in 1804. In 1825, Brown used one on the Thames. And before 1830, Mr. Scott Russell saw a steamboat propelled by a screw.*

In the Patent Museum at South Kensington are several models of Screw Propellers, mostly contributed and described by Mr. Bennet Woodcroft. To Mr. Pettit Smith, more than any other engineer, is due the merit of having brought into general use the system of Screw Propulsion. Mr. Smith's is the double-threaded screw, the form of screw most commonly adopted; but instead of half a convolution, as proposed by Mr. Smith, about one-sixth of a convolution is found to give the best result. The length to give a maximum performance, however, will depend to some extent on the kind of vessel to which the screw is applied. Smith patented his Screw Propeller in 1836; and the Admiralty, to test it on a large scale, built the *Archimedes* of 237 tons burden, which made her first trip in 1839. In a debate in the House of Commons in May, 1855, on the grant of 20,000*l.* for rewarding the invention of the Steam Screw Propeller, it was stated that there were no fewer than 44 claimants for the reward: the list was then reduced by the Committee to five, an arrangement was effected for dividing the money, and Mr. Smith shared the Parliamentary reward. In 1858, Mr. Smith's services were commemorated by a splendid

* Mr. Macgregor, in his valuable paper, "The Paddle and the Screw, from the Earliest Times," with its curious engravings, 1858, says: "In the modes of propulsion adopted by aquatic animals may be found almost every plan which has been used by man with machinery. Thus, water is ejected by propulsion by the cuttle-fish and paper-nautilus; sails are used by the volella and water-birds; punting and towing by the whelks and the lepidosiren; a folding paddle by the lobster; feathering paddles by ducks; and oblique surfaces by fish of all kinds. A screw-like appendage is found in the wings of an Australian fly; but it is supposed to be shaped thus only when dried after death. There is, however, one remarkable animal which propels itself by a rotary movement, acting on the water by means very similar to those of the paddle-wheel and screw-propeller combined. This is the infusorial insect *Paramecium*, in which a furrowed grove runs obliquely round the oval-shaped body of the animal. A wave-like protuberance passing along the groove (with or without ciliæ), causes the body to rotate on its longer axis, and thus propels it as by the fore and aft stroke of a paddle, as well as by the screw-like progress induced by the spiral groove."

testimonial, presented to him at a public dinner in St. James's Hall, Piccadilly, towards the end of June; Mr. Robert Stephenson, M.P., presiding. The gift consisted of a silver salver and claret-jug, amounting, with the money subscribed, to 2,678*l.*, contributed chiefly by eminent naval officers, engineers, ship-builders, ship-owners, and men of science; and with the plate was presented an address engrossed on vellum. At this time, 174 of her Majesty's ships had been fitted with the Screw Propeller: 52 line-of-battle ships; 23 frigates; 17 corvettes; 55 sloops; 8 floating batteries; and 19 troop and store ships.

It is hard to say who was the inventor of the screw propeller, so old is the principle. We see it claimed, in 1857, for Frederick Sauvage, long resident at Perrey, near Havre, where he made his experiments with the screw in a small boat, which he had constructed and navigated in a large tub sunk in his garden. The Emperor of the French more than once assisted Sauvage with money, and when the poor inventor's state of mind required that he should be placed in a *maison de santé*, his Imperial Majesty took upon himself the payment of the expense. In 1866, Mr. James Lowe, engineer, who claimed to be the inventor of the screw propeller, was accidentally run over at Newington, on the 12th of October, and died in consequence.

There has likewise been invented a system of twin or double screw-propellers, driven by independent engines, for our men-of-war. So long ago as the year 1851, Captain Carpenter, R.N. experimented with a model of a vessel having two screws, one under each quarter, each worked by a separate and independent motive power. In consequence of the satisfactory results obtained by these experiments, Mr. George Rennie constructed in 1855 a small boat with separate and independent engines, each engine driving a screw propeller under the quarter; and thus the boat was enabled to manœuvre without the rudder, and make various evolutions by regulating the speeds of either or both propellers.

In 1857, Messrs. J. and G. Rennie made several gunboats of light draught of water for the Indian Government, to assist in the rivers in suppressing the Mutiny. These boats carried one gun forward, and being fitted with ordinary horizontal engines, but separate and independent of each other, to each screw propeller, the boat's head was enabled to be kept in the desired direction by going ahead with one engine and propeller and astern with the other when required.

The sea-going steamers of this country present specimens of constructive skill, mechanical completeness, and decorative taste, which are unsurpassed. Those built and engined in the Clyde, in speed, stability, or external appearance, are noble vessels. The vastness, however, culminates in the *Leviathan*, (now *Great Eastern*) constructed on the wave principle and lines of Mr. Scott Russell, at Millwall, in 1857, with these dimensions: length, 680 feet; breadth, 83 feet; depth, 58 feet; tonnage, 23,000 tons; carries of coals and cargo, 18,000 tons; nominal horse-power of paddle-wheel engines, (Scott Russell,) 1000 H. P.; nominal horse-power of screw engines, (Watt and Co.,) 1600 draft of water (light) 18 feet; ditto (loaded) 28 feet. The paddle-wheel engines are the largest specimens of Mr. Scott Russell's four cylinder engines that have yet been produced. The largest previously constructed were those of the *Victoria*, of 400 horse-power. The four cylinders of the *Great Eastern* engines are probably the largest steam cylinders ever made for marine service, at least in England. They are 74 inches in diameter, and have a stroke of 14 feet. Each cylinder is a casting in one piece, weighing 28 tons. The condenser is a casting in one piece of 36 tons. The upper frames are four castings, of 13 tons each, all cast in the works at Millwall without a flaw. The paddle-wheel shafts have Mr. Scott Russell's patent self-acting gearing, by which the engines engage or disengage themselves from either paddle-wheel. The paddle-wheels are 58 feet in diameter, and in turning once round will advance 60 yards. Ten revolutions of the wheel per minute would cover 600 yards, or 36,000 yards per hour, which is a speed of 20 miles an hour for the circumference of the wheel.

The story of the *Great Eastern* is a sad one. This ship originally belonged to the Eastern Steam Navigation Company, established to carry the India and China Mails by the long sea route, but in this they were overmatched by the Peninsular and Oriental Company. In 1854, the ship was commenced by Mr. Brunel, and nearly 100,000*l.* was expended before she was tried; pecuniary difficulties ensued, and in 1858 a new Company was formed with 330,000*l.* capital. In the autumn of 1859, she went to sea, when off Hastings a destructive accident occurred, and thence followed a series of casualties, without material injury to her hull or machinery; she rode out a gale in Holyhead harbour; encountered a hurricane in the Atlantic, which disabled her rudder and damaged her paddles, and left her for three or four days rolling about in the trough of a heavy sea. She ran upon a rock at New York, and broke her bottom plates for a length of 80 feet, which were repaired while afloat, and without going into dock; yet she came home safely. Then increased her financial difficulties, and eventually the ship was sold for 25,000*l.*, scarcely one third of its value as old materials.

The history of the Screw Propeller has been most ably written by Mr. John Bourne, C. E.,—with a comprehensiveness and interesting character, which has few parallels in this class of works. Mr. Bourne's Treatise is not a succession of dry mechanical details, or a sketchy history of the invention; but it is a masterly treatment of a truly great subject in a manner at once sound and attractive, practical and popular. The labour was beset with great difficulties, and there was much to clear away from the perplexing subject. Thus, in a recent number of this valuable work, we read of a specification which describes a great number of inventions, not one of which has come into use. The Treatise brings us down to the middle of 1862, the notices including references to various proposed methods of propelling vessels besides the screw system proper. We select one example of the Screw Propeller for quotation, namely, the invention of Mr. Charles Augustus Holm, who in 1853 took out a patent "for an improved form of Screw Propeller, the object of which was to obviate loss of effect either by impact or by dispersion. The leading edge of the screw is made so as merely to enter the water without propelling, and the pitch increases slowly at first and then very rapidly, until at the trailing edge it becomes infinite, the trailing edge standing in a line with the keel. The periphery or outer edge of the blade is turned over so as to form a curved flange, and is joined to the trailing edge by a spoon-like corner forming a portion of a sphere. For backing, a piece of flange like the circumferential flange is attached to the back of the screw. The propeller presents a peculiar appearance; its theoretical principle is sound, and Mr. Bourne has made a considerable number of these propellers, and fitted them to vessels. Although the screw acted in a perfectly satisfactory manner, Mr. Bourne came to the conclusion that it was no better than common screws in its actual efficiency. Any gain obtained from its superior action on the water was lost by the increased friction incident to the larger amount of rubbing surface."*

The progress of the construction of Marine Engines, a most important branch of our subject, has been ably illlustrated in an account of the great Marine Engine Factory of Messrs. Penn, at Greenwich, an establishment most intimately associated with the early history of Steam Navigation.

The construction of Marine Engines has gone on so rapidly that not many years ago a lady was receiving an annuity in consequence of her husband having first suggested the placing a steam-engine in a boat to move its paddle-wheels. This was in the year 1788, when the steam-engine was called a fire-engine, had no rotatory motion, and was only used for pumping water out of mines. Symington was employed to make the engine, as we have already narrated. The experiment was considered exceedingly successful; and the first little voyage under steam was made on the small Scotch lake of Dalswinton. It must be remembered that, as we have remarked, the steam-engine of that day having no rotatory motion, Symington had consequently to tax his ingenuity to convert the reciprocating action of the engine into another action which should turn the paddles; and this he contrived to do in a most ingenious manner, though by complicated means as compared with his second attempt. These little engines were the first examples of their kind, and are now in the Patent Museum at South Kensington, having been repaired and restored as already narrated at pp. 253, 254. They were constructed for the *Charlotte Dundas*, and were so perfect and complete that the boat might have been at work at this day had she been kept in repair. She had a cylinder, with the steam acting on both sides of the piston, working a connecting rod and crank, and the union of the crank to the axis of the paddle-wheels, which latter contrivance was Symington's patent. Perfect as this little vessel was, she failed to attract much attention from the public; but Fulton, the American engineer, saw at a glance what new life such a power would give his country, and he at once ordered an engine at Soho, and built a boat, so that the Americans had steam-vessels, a British invention, on the Hudson as soon as we had them on our rivers; for the first

* *Mechanics' Magazine.*

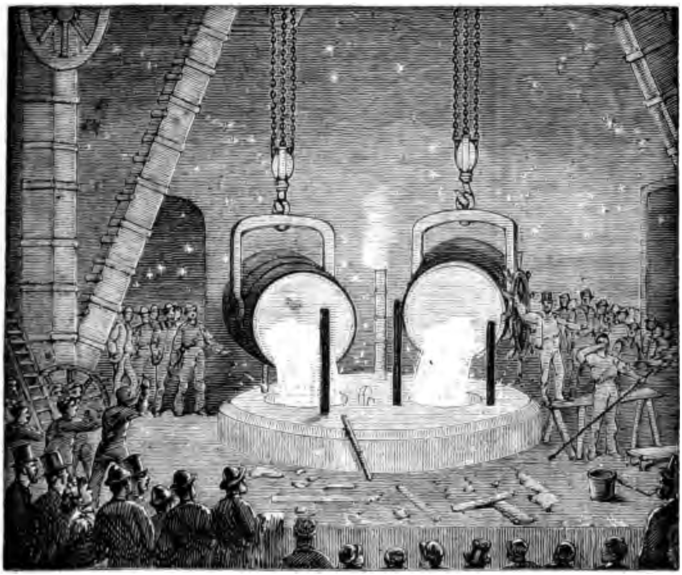
passenger steam-boat did not start here until 1812. This was Bell's *Comet*, and it is a remarkable fact, that the identical engine which propelled the first passenger steam-boat that ever ran was put in the Patent Museum at Kensington by the very man who made it and fitted it into Henry Bell's boat, *The Comet*. Since that date Steam Navigation has progressed with giant strides.

About the year 1836 steam-ship building was introduced on the Thames by Thomas Ditchburn, of Blackwall, in partnership with Mr. C. Mare. Among many other vessels constructed by them were some small boats to ply between the bridges in London, and from London to Greenwich and Woolwich. These vessels were fitted with engines by John Penn, the father of the present head of the establishment at Greenwich, who, thirty years before, had started as a millwright and machinist on the same spot where now stand the first marine engine-building works in the world. The engines placed in these little boats were on the oscillating principle, and so perfect in design, so excellent in workmanship, and so light and compact, that they excited the greatest interest; for the marine engines previously in use were chiefly of the class called side-lever engines, very excellent, but ponderous and large. Penn's oscillating engines were pronounced perfect, but the wise in such matters said the oscillating principle would only do for small engines; and they were not a little startled when they heard that John Penn was actually constructing a pair of oscillating engines of 260 horse-power for H.M.S. *Black Eagle*. These large engines turned out a great success, for in half the space, with half the weight, they were equal in power to the old side-lever engines. This success led to still greater efforts in the same direction, and engines of 500-horse power were built for H.M.S. *Sphynx*. Such great strides having been made by the engine-builders, the shipwrights were not behindhand, and sought to obtain speed. This was done by that remarkable vessel the *Banshee*, built by Mr. Lang. The highest rate of speed hitherto obtained is by the Royal yacht *Victoria* and *Albert*, with engines by Penn, of 600-horse power; the firm next constructed oscillating engines of 800-horse power for a yacht built for the Pacha of Egypt, to which we shall return.

The first screw introduced into the Royal Navy was applied to her Majesty's yacht the *Fairy*, built by Ditchburn about twenty-two years since, and fitted with engines by Penn. This wonderful little boat has been in constant use from that time until now, and still ranks as one of the best examples of that system of propulsion. For vessels of war greater compactness is necessary, to enable the engines to be placed below the water-line and out of the way of cannon-shot. These requirements led Messrs. Penn to design an entirely new class of engines, which they called trunk-engines, and which were specially adapted to drive the screw-propeller. The first of this class was fitted to the *Encounter* and *Arrogant* frigates, of 360-horse power; to which have been added the *Warrior*, *Black Prince*, and *Achilles*, with engines of 1250-horse power; the *Minotaur* and *Northumberland*, of 1350-horse power.

The business of the great firm of Messrs. Penn and Sons is carried on at two establishments—one at Greenwich, where the engines are built; and the other at Deptford, where the boilers are constructed and the engines fitted in all ships whose draught of water will allow of their getting alongside the wharf. The various fitting and tool shops at Greenwich cover seven acres of ground, and in them are employed about 1,300 men and boys. Here all the castings are made, some of immense size, from twenty to thirty tons of metal being run into some of the moulds for the cylinders. Screw-propellers and shafts are cast here in gun-metal, some of which, when finished, weigh twenty-four tons. The separate parts of each engine are made in different divisions of the factory, but all come together at last to be fitted in the great fitting-shop. In the works at Deptford, where the boilers are constructed, about 500 hands are employed, making nearly 2,000 hands in all. The quantity of wrought-iron boiler-plate used in this part of the works is 1,500 tons annually, which, when formed into tubes, the united length of which exceeds forty miles, would consume 1,200 tons of coal per day, and evaporating 11,000 tons of water, which yields a power equal to that of 40,000-horse power.

The accompanying engraving represents the operation of casting one of the cylinders for a pair of the enormous marine engines Messrs. Penn so frequently construct. Casting large masses of metal is always interesting, even when the casting is of the ordinary kind; but in the case of that shown here is peculiarly so, because the mass of metal, while of immense magnitude, has to be cast with all the exactness and perfection that can be given to the smallest castings. The operation is on the largest scale, yet its result is the highest degree of perfection both in material and workmanship. Here the molten metal is being poured into the mould. The iron, carefully selected, is melted in several cupolas, placed adjacent to the foundry. These are supplied with the metal and fuel by an hydraulic lift. When the metal is ready, the cupolas are tapped, and the molten iron runs through small canals into the foundry, where



CASTING A CYLINDER FOR A MARINE STEAM-ENGINE.

they empty themselves into two immense cauldrons. When full, these are lifted by ponderous cranes and tackles over the apertures left in the upper part of the mould; but of course they require to be raised on one side to cause the metal to run out. This is done by means of wheels with spokes on their outer edges, acting as levers. The pouring of so large a mass of metal equally into the mould is a most important matter, and is executed by the principal founder; for irregularity or too quickly running the metal would not only spoil the casting, but might endanger the lives of those present. The operation of casting one of these cylinders, which requires from twenty to thirty tons of iron to fill the mould, must necessarily employ machinery of the most ponderous character, and bring into play forces of immense power; yet the actual manipulation of these huge masses is done with the delicacy required in winding up a watch. The scene during the few minutes occupied in filling the mould is particularly fine in effect; the hitherto dark foundry being suddenly lit up with the glare of the rivers of liquid iron running over the lips of the cauldrons; the most beautiful coruscations of fire fly about in all directions; the air is positively full of coloured sparks; while the bright glow of the molten iron, almost white in its intense heat, lights up the features and forms of the workmen and numerous visitors in a wondrous manner; for at such times, not only are the visitors numerous, but all the younger hands of the establishment contrive to find their way into the foundry; and so do many of the old ones, for the hearts of the men, as well as those of the masters, must be in the work in such a factory as this.*

Of Steam-shipping we possess almost the exclusive monopoly. But the most astounding fact, as shown by Mr. Capper, in his account of the Port of London, is the enormous increase of this Steam-shipping during the last ten years. Between 1850 and 1860 the tonnage of our steam-vessels increased from 158,000 to no less than 454,000 tons. It must be recollected, too, that, inasmuch as one steamer in the coasting and short trades can do as much work as five sailing-vessels, this tonnage is really five times greater than it appears. Notwithstanding this, railways have proved formidable competitors, at least for passenger traffic. In the early days of steam-vessels, they were thought to be specially and peculiarly applicable to the navigation of inland waters. Mr. Porter, in his *Spirit of the Nation*, remarked, that "the countless thousands who annually pass in these packets up and down the River Thames seem almost wholly to have been led to travel by the cheap and commodious means that have been thus presented to them, since the amount of journeying by land has by no means lessened." The ten years that have elapsed since these words were written have effected a revolution. In 1835 the number of persons conveyed between London and Gravesend was ascertained by the

* Abridged from the *Illustrated London News*.

collector of the pier dues in that town to be nearly seven hundred thousand. It was stated in evidence before a Committee of the House of Commons, in 1836, that upwards of a million passengers, including those to and from Gravesend, at that time passed Blackwall in steamboats every year. But the steam-vessels have been obliged completely to abandon the struggle with the railways. Two lines, one on each side of the river, convey passengers to Gravesend; and, as a consequence, of the two or three fleets of admirable vessels which in 1851 performed the water-passage between London Bridge and that point with the greatest speed and regularity, scarcely one remains. Mr. Capper doubts whether, upon any river in England, there now exists a steamboat service of any moment where the river's bank possesses a railway.

Almost at the moment we write, the Victoria Docks, in the Plaistow Marshes, perhaps the finest in the world, present us with this impressive picture of our country's preeminence in Steam-shipping:—We come first upon a crowd of yachts, of all ages, rigs, and sizes; next, keeping to the west, is the *Donald Mackay*, one of our 2,000-ton merchant-fleet, with her skysail yards crossed and ready for sea. A little further is one of the finest models afloat of a fast screw trading steamer from Waterford. Still further westward we come upon four monstrous ships. First in rank comes the *Serapis*, the most magnificent transport ship in the world. Her spars look light for her size, yet they are those of a line-of-battle ship; but so great is her bulk that if her engines were disabled they would probably do little more than keep her head straight, unless in a gale of wind. Alongside of the *Serapis* lies a noble Spanish armour-clad ram frigate; she has immense strength, great beam, and her sides are curved to repel heavy shot. Another frigate for the same Government lies close to her. Then the *Crocodile*, a sister ship to the *Serapis*, but not in so forward a state. Here we have in one recess of this vast dock four of the finest ships afloat. Under the shears lies a large iron-clad frigate, for the Prussian Government, by Messrs. Samuda. The intention of placing two monstrous guns to fire end-on from her bow is evident from the work now going on, and she will have a formidable broadside also. Though of 3,470 tons she will only draw twenty-four feet of water. In the creek to the east of these docks another splendid armour-clad is almost ready for launching by the Thames Company. She will be 355 feet long, 60 feet beam, and 5,930 tons, and will be plated with 8-inch iron. Some of her guns will weigh fifty tons, and carry a shot of 500lbs. Of the speed of these splendid steam-ships we repeatedly read astounding records. One of the recent examples is the Egyptian paddle-wheel steam yacht *Mahroussa*, built by the Samudas, for the Viceroy of Egypt, which has performed the voyage from Southampton to Malta in the unprecedented short time of 157 hours. When under full steam, she consumes seven tons of coal an hour, and is without exception the fastest vessel afloat. At the measured mile in Stokes Bay her average speed was upwards of 18·4 knots an hour, which is equal to about 20½ statute miles. This splendid vessel is of 1,800 tons, and is fitted with machinery of 800-horse power. Her interior fittings are of extraordinary magnificence. Her cost is said to have been 166,000*l.**

The rapid progress of steam navigation in recent years, is well shown by the increase in the tonnage of British steam-shipping from the year 1870, when it amounted to 1,111,375

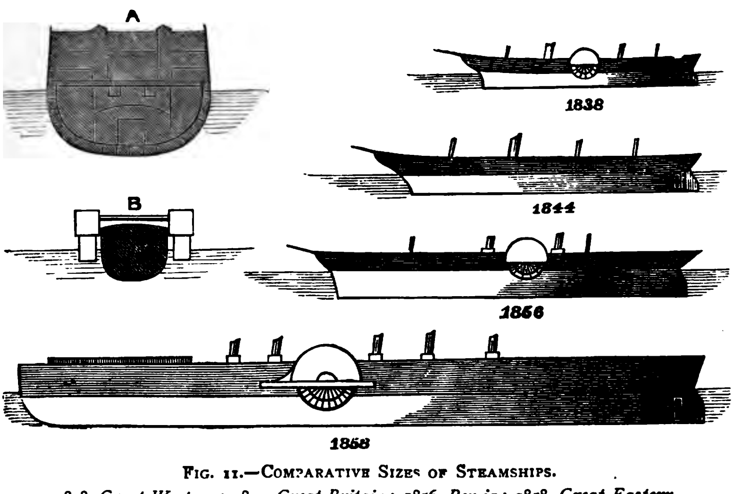


FIG. 11.—COMPARATIVE SIZES OF STEAMSHIPS.
1838, *Great Western*; 1844, *Great Britain*; 1856, *Persia*; 1858, *Great Eastern*.
A, Section amidships of *Great Eastern*; B, The same of *Great Western*. Both on the same scale, but on a larger one than their profiles.

* Abridged from the *Churchman*.

tons, to the year 1876, when the amount was no less than 2,150,302 tons: that is, during these six years, the tonnage of the steam-shipping of this country had nearly doubled. A remarkable increase of the size and power of steam ships of the best class has taken place since the *Great Western* was built for the Atlantic passage. The diagram (Fig. 11) shows the comparative sizes of the most remarkable steam vessels built between 1838 and 1858. The culminating magnitude was reached, of course, at one great bound in the case of the *Great Eastern*, which is still the largest vessel afloat. Although this ship did not prove a commercial success, it showed how

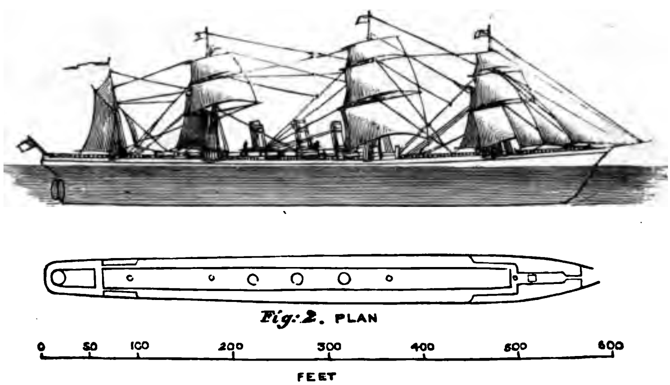


FIG. 12.—THE S.S. *City of Rome*.

enormous ships could be constructed; and it is noticeable that since Brunel's bold enterprise the size of steam-ships has been gradually increasing. The *City of Brussels*, and other noble vessels, have been built since the *Persia*; but these have now all been surpassed in size by a vessel built for the Inman Company, and launched on the 15th of June, 1881. This ship has received the name of the *City of Rome*, and, with the single exception of the *Great Eastern*, she is the largest ship in the world. Her speed is intended to be 18 knots an hour; and if this be attained she will convey passengers across the Atlantic in a period of time not much longer than would be occupied by an ordinary railway train traversing the same distance. Her engines will regularly work at an indicated horse-power of 8,000, but will be capable, when required, of working up to 10,000 H.P. The *City of Rome* is 600 feet in length, 52 feet in breadth, and 37 feet deep. Her length is therefore only 90 feet less than that of the *Great Eastern*. The tonnage of the *City of Rome* is estimated at 8,000 tons, and she will provide accommodation for 1,500 passengers, of

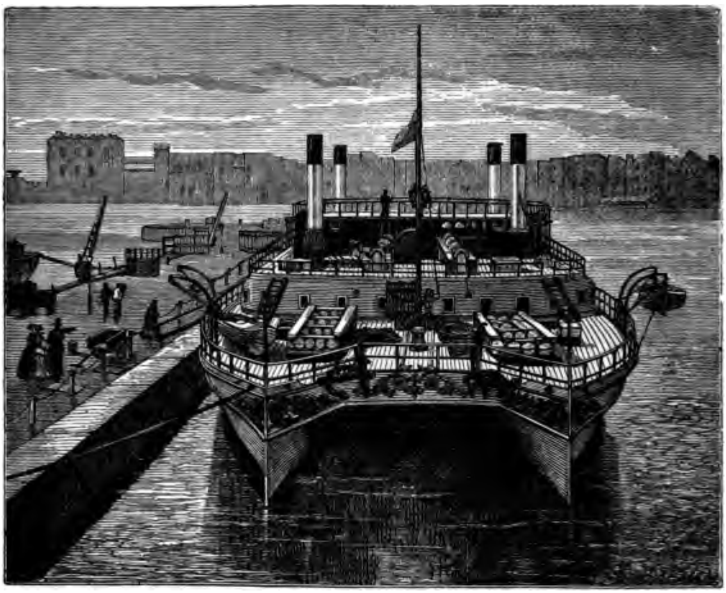


FIG. 13.—THE *Castalia* IN DOVER HARBOUR—END VIEW.

whom the first class will have at their command all the comforts and luxuries of a well-appointed hotel. The ship will be driven by a single screw-propellor, 24 feet in diameter, and the principal shafting will be 2 feet 1 inch in diameter, made hollow, and formed of Sir J. Whitworth's fluid-compressed steel. It will be seen from the sketch (Fig. 12), that the ship will carry three funnels and four masts. Other vessels of the same class are also in progress.

George Stephenson and his Son Robert.—Page 290.

One of the curiosities of steam-ship navigation is the *twin-ship*, which has been designed to meet the requirements of the steam service between Dover and Calais. The object is to obtain the greatest amount of steadiness; and Captain Dicey, a few years ago, built the *Castalia*, a vessel with two hulls, propelled by paddle-wheels placed between them. The *Castalia* has plied regularly across the Channel, but her speed having been found inadequate, the more powerful and efficient vessel, the *Calais et Douvres*, constructed upon the same general principle, has been placed upon the regular service.

An important point in the economy of the Steam-engine may be noted here, as specially interesting in connexion with the great question of Coal Supply. For some considerable time the consumption of the Steam-engine has progressively decreased. Some fifteen or twenty years ago marine engines, burning not more than 7 lb. of coal per horse-power per hour, were thought to do very fairly indeed. The Admiralty estimated consumption at that time was 8 lb., subsequently reduced to 6 lb. Now, a consumption of 3¼ lb. is not regarded as being eminently economical, and steamships might probably be counted by the score whose engines are developing a horse power per hour with from half to three-quarters of a pound less of coal; while under exceptional circumstances a very much higher duty than even this has been obtained during very long runs. The consumption of the *Octavia*, *Constance*, and *Arethusa*, between Plymouth and Madeira, represent a remarkable advance in economic efficiency over any engines previously supplied to the Navy, and demonstrates the practicability of introducing generally a greatly improved practice of steam-engine construction. The consumption of the above vessels compares most favourably with the consumption on board the competing *Liverpool*—over 4 lb. per horse per hour—a ship carrying very fair engines of the class commonly met with in our old wooden vessels.—Abridged from the *Engineer*.

* Abridged from the *Churchman*.

THE RAILWAY AND THE LOCOMOTIVE STEAM-ENGINE.

WHENEVER the history of our time is written, the invention of the Railway and the Locomotive Steam-Engine will furnish its most important and interesting chapter. Its benefits are more universally diffused than any other: nearly every man, woman, and child, participates in the profit and practical comfort, and even luxury, to be enjoyed by means of the Railway and its Engine. All ages share its physical completeness in conveying us without energy or effort from place to place, and contributing to convenience and enjoyment in a more direct manner than any other result of human ingenuity. It is the universal messenger of life, and is more tributary to the enjoyment of all classes than any other contrivance to be named: its iron roads are the very arteries of our existence as a commercial and manufacturing community, and they largely increase our pleasures, by the delightful change of scene which they bring within the reach of all grades of the community.

Such completeness as this invention presents has not, however, been the production of one mind. Railways of wood were used more than 250 years ago, to lessen horse-labour, between which and the introduction of iron rails was a long interval. Watt patented a locomotive engine, but it did not occur to him to place it on the rail: and the Directors of the Liverpool and Manchester Railway were for some time undetermined as to the kind of motive power which they should adopt, ere they decided upon the Steam Locomotive Engine.

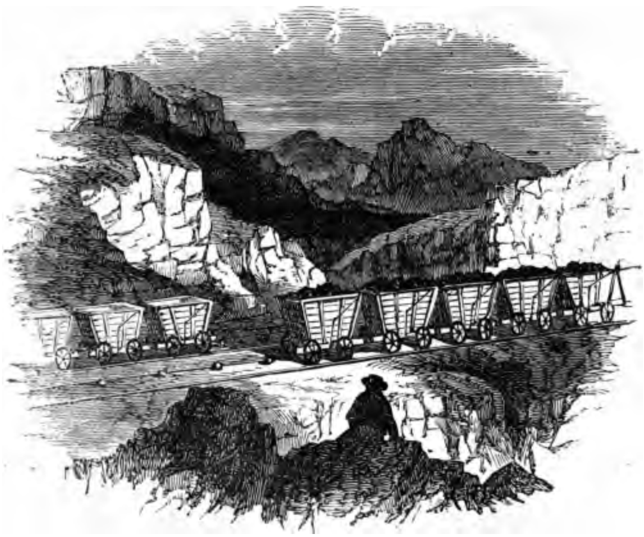
We have already narrated the triumphs of Steam and ingenuity applied to the mines, the navigation, and the cotton manufacture, in the main due to important improvements effected in smelting and working iron. Before Mr. Cort's time, the wrought-iron formed in the furnace was prepared for use in the arts by the shingling hammer, which beat out the hot piles of metal into bars two or three yards long, and then welded several of them into one. Mr. Cort employed heavy rollers in reducing the balls of wrought-iron taken from the furnace into forms required in the arts, which could not always be done without the assistance of the steam-engine. The rollers make from 60 to 400 revolutions per minute, and travel as fast as ordinary railway trains, and it requires a powerful engine with a heavy fly-wheel to carry the plates through. "Sometimes, however," says Mr. Syme, "the forge-hammer must be employed for work which the rollers cannot perform. The shafts to which the paddle-wheels of steamers, or the driving-wheels of locomotives are keyed, could not be manufactured between cylinders, or under the old forge hammer. The former in some cases weigh twenty tons, and are many feet in length, and uniform strength throughout the mass, as well as thorough welding of the several pieces, are indispensable." Nasmyth's steam-hammer was invented for such work. "A heavy block of cast-iron, sometimes five tons in weight, and attached to the lower end of a piston rod, working in an inverted cylinder, is lifted by admitting steam beneath the piston, and then allowed to fall upon the work by its own weight; or, by a little management, it may be made to slide up and down without striking at all. The heaviest work is forged under the blows of this ponderous hammer, which acts with an energy that the strength of iron cannot withstand, and yet it is kept in such control that a nutshell may be cracked or an egg chipped as easily as iron beams are welded or shaped."

Mr. Syme proceeds to describe among the revolutions in working iron, "iron blocks squeezed between rollers, or compressed in the jaws of an iron alligator—two or three welded into one, or formed into a sheet, squeezed out to greater thinness; huge shears working with marvellous rapidity, clipping three-quarter-inch plates at the rate of ten feet each stroke; circular saws, moving with greater speed than the fastest railway trains, cutting railway bars in two with a precision otherwise unattainable; heavy hammers uniting ponderous bars of iron; slight ones, striking a thousand times in a minute; holes punched through masses of iron almost a foot thick, as easily as if they were pieces of wood or cheese; and sheets nailed together with a firmness that gives to hundreds of united plates the stiffness of one. Another invention of the greatest importance is the manufacture of steam cylinders, of uniform diameter from top to bottom, valve faces accurately planed, and piston-rods of the same thickness throughout. This was formerly left to the eye of the workman; but Maudslay's *slide-rest* has changed the state of things entirely. Instead of allowing the cutting tool to lean against the chest of the workman, the machine takes off shavings to the same depth throughout, and uniform thickness is secured in all parts by the machine sliding its own cutting tool along; and the services of the workman, except at the beginning and end of the operation, are dispensed with altogether. This principle, so simple in its nature, has been applied to the turning of rods, the planing of surfaces, the boring of cylinders, the formation of cones, the cutting of screws, and other purposes; and nine-tenths of all the fine mechanism is through the agency of the slide-rest and planing machine."

This progress in machinery and manufactures led to great changes in travelling and the carriage of goods and mineral produce. Formerly, when coal was found, easy means of conveying it from the high regions in which it lies, were soon thought of. In the neighbourhood of Newcastle-upon-Tyne, the produce of the mines began to be borne to vessels waiting in the river by the laying down of pieces of wood upon the ground, end to end, for the wheels of coal-wagons to run upon. An oak railway was laid down between the pit and the wharf, and the wagon-wheels had broad flanges to keep them from slipping off the rails. Trains of wagons were allowed to run down an incline by their own weight, or were dragged along the level ground by horse-power. They were easily stopped by locking the wheels. Then we had the contrivance illustrated in the next page.

Lord Keeper North, in 1676, describes "rails of timber from the colliery down to the river, exactly straight and parallel; and bulky carts made with four rowlets fitting these rails, whereby the carriage is so easy that one horse will draw four or five chaldron of coals, and is of immense benefit to the coal merchant."

These ways were much improved; but a century and a half elapsed before the rails were laid upon cross pieces, or sleepers, to which they were fastened by pegs, and the spaces between filled up with sand, stones, or any other substance. After a time, much inconvenience was felt from the upper pieces becoming worn out or displaced, whether by the swelling of the soil from rain, or from any sudden shock, when the whole of the way was necessarily interrupted until another piece was put into its place. This suggested other pieces placed longitudinally throughout the whole track, and fastened by pegs or screws, so that where one was injured it could within an hour be taken out and replaced without injury to the rest.

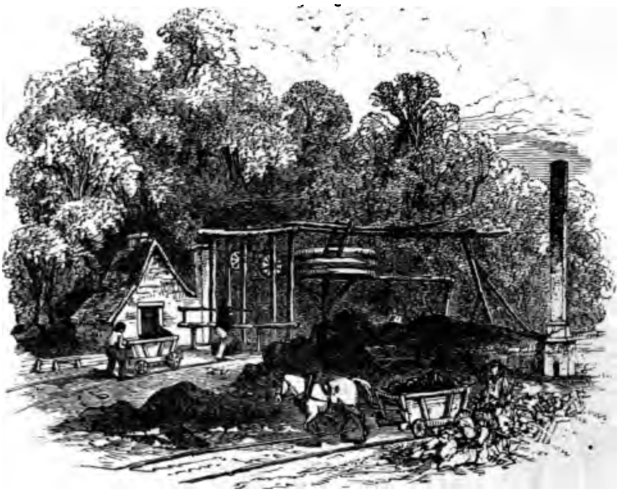


THE SOUTH HETTON COLLIERIES RAILWAY—SHOWING HOW A TRAIN OF LOADED WAGONS DRAWS A TRAIN OF EMPTY ONES UP THE INCLINED PLANE.

The wagons used to carry the coals on these railways usually held from three to four tons, and were drawn by one horse each, going upon small wheels, to which was added the flange. About the year 1716, thin iron plates were laid upon the surface of the rails, which by their greater smoothness, offered less obstruction to the tyre * of the wheels, so that the labour of the

* "The meaning of the word *tyre* is something fastened round,—as, attire round the body, tiara round the head, a tier of guns round a ship or fort.

horse was lightened. The roads were then called *tram-roads*, having been first laid down, it was said, by Outram, from whose name, omitting the first syllable, the word is said to have been first derived. "The derivation would apply equally well to the word trammel—the rail flanges being in reality trammels to gauge the road, and confine the wheels."

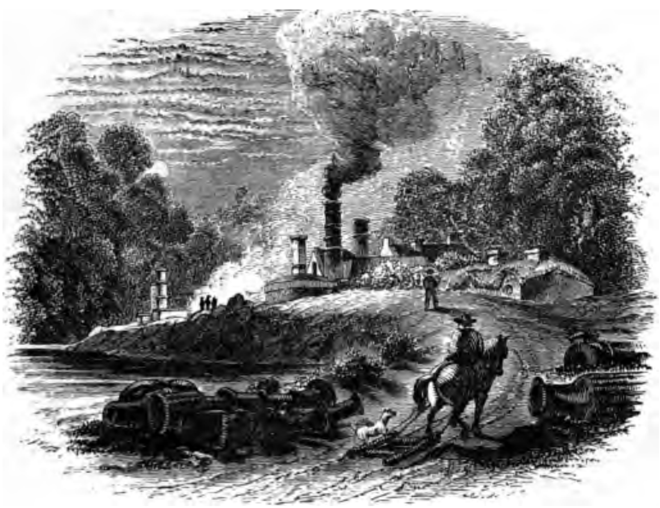


MOUTH OF COAL-PIT, BROSELY, SALOP.

From 1716 till fifty years afterwards, these were all the improvements effected in the tram-ways: stone ways were tried instead of wooden ones, but the surface was rougher, and they soon fell into disuse. A suggestion was made about the year 1767. At the Colebrook Dale Iron Works, in Shropshire, a wooden railway required frequent repairs, which were often expensive and inconvenient. Iron happened to be then very

With respect to the word *rail*, the planks forming a path for the wheels, connected by cross timbers, inclosed a space, from which apparently comes *rail*,—a cognate, probably, of apparel, which applies to dress, and also to the tackle of a ship; also, raiment and night rail, expressing clothing which encloses the person. Probably, the resemblance of the timbers in form to the rails of a post-and-rail inclosure may have supplied the nomenclature." We quote these etymons, which are somewhat fanciful, from the *Encyclopædia Britannica*, eighth edit. art. Railways.

low in price, and a Mr. Reynolds, one of the proprietors of the Colebrook Dale Works, suggested casting their pigs of iron in longer lengths than usual, and laying them down on the surface of the tramway; observing that when the price of iron rose, they could easily take them up and dispose of them. This, however, was never done; nor were the scantlings, as they were called, ever removed until they were replaced by the improved iron rail which afterwards came into use. George Stephenson tells us, from the books of the Colebrook Dale Company, that in 1767, between five and six tons of cast-iron rails were made at these works; but only as an experiment, at the suggestion of one of the partners.



IRON-WORKS, COLEBROOK DALE.

In the tramroad, however, the rail was liable to be covered with dust or gravel. To obviate this, Jessop, in 1789, laid down at Loughborough cast-iron edge-rails, from which the guiding edges were removed, and applied round the edges of the wheels, forming flanges, the rails being elevated sufficiently to allow the descending flange to clear the ground. This appears to have been the first system of rails laid down on cast-iron chairs and on sleepers: the rails were pinned or bolted into the chairs. This improvement was brought into use at one of the Duke of Norfolk's collieries, near Sheffield, in 1776; but the first edge railway of which we have any account was laid down in 1801, at the Penrhyn slate quarries, in Wales. It was composed of pieces four feet six inches in length, each of which was, with the end of the piece that joined it, fitted into an iron block firmly embedded in the road. To keep the wheels in their places, they were made with a grooved tyre, but this wore away and made the carriage *drag*, when Mr. Watt put a regular flange on each side of the wheel, thus giving both to the rail and the wheel a flat surface. Such was the advantage of this plan, that two horses could draw a train of twenty-four wagons, each containing a ton weight of material; and no more than ten horses were required to do the work which it had formerly required four hundred to perform.

Edge-rails now came into general use; but the outer flanges of these were soon removed as unnecessary. In the rails there have been various changes: some have been cast with the thickness greater in the middle than at the ends, so that whilst the latter rested on the *chairs*, the middle might rest on the solid ground. These were called *fish-bellied* rails, and instead of cast were of rolled wrought-iron, patented by Birkenshaw, in 1820; similar in form to Jessop's, but rolled in continuous lengths, embracing a number of spans, with stiffening ledges or flanges on the under side. This form of rails grew into favour, and was adopted in the construction of the Liverpool and Manchester Railway, which was opened in 1829. The rail weighed 33 lbs. per yard, and was laid in cast-iron chairs, spiked down to square stone blocks, at three feet bearings. This line served as a model railway for those which more immediately succeeded it. The edge-rail and flanged wheel are happily matched: they constitute essentially the mechanical idea of a *Railway*—the basis of the whole system. The gauge or measure of a railway is taken at the distance apart of the upper surfaces or treads of the two rails forming a line of rails, or a way. There are two gauges, known as the *narrow gauge*, 4 feet 8½ inches, and the *broad gauge*, 7 feet between the rails. The narrow is the national or Stephenson guage, adopted with few exceptions, the most important of which is the broad gauge, 7 feet, introduced by the younger Brunel on the Great Western Railway, but now being changed.

One of the mistakes of this day, notwithstanding the experience in the traction of carriages on railways by animal power, was that if engines did move forward on a perfect level, the slightest ascent would stop their tractive action. No more erroneous idea could have been entertained, for comparatively steep inclined planes were soon surmounted by railway engines. To obviate the supposed defect of an insufficient adhesion of the wheels to the rails, Mr. Blenkinsop patented a machine to move a large cog-wheel, the projections of which fitted into a rack, which was laid down alongside the railway. This plan was adopted, and worked many years, on the Hunslet Moor Collieries tramway, near Leeds; and its relic, the notched rack, long remained on the Moor after it was disused. We may here mention, so useful had these railways been found, that the proposal to levy a tax on iron in 1806, was opposed, because it would increase the expense of constructing them about 700*l.* a mile.

About this time an iron tramroad, or railway, was projected, to open a direct communication between the chalk and lime works at Merstham, in Surrey, and the Thames, at Wandsworth. The train of carriages carrying the lime and chalk, was drawn by one horse: this railway was completed in 1805; as a speculation it failed, and only small detached portions remain. To preserve the necessary level, the railway took its course through a natural break in the range of the chalk hills; but in the highest part it was sunk not less than 26 feet; yet no chalk was discovered, the soil being, in the deepest part, a stiff gravelly clay, though lying between the chalk hills of Coulsdon and those of Merstham. The late Sir Edward Banks, when a labourer, worked on this railway, then under construction: he rose to be builder of three of the noblest bridges in the world—those of Waterloo, Southwark, and London; besides many other public works. When working at Chipstead, he was so impressed with its retired and picturesque churchyard, that he chose it as the depository of his remains. His tomb bears his bust, and representations of an arch of each of the three great bridges, with a long inscription, referring to his forty years' work; his benevolence and simplicity of manners, his integrity, justice in purpose, and firmness in execution: such was one of our earliest railway "navvies"—and an honour to any rank.

The above tramway—the Surrey Iron Railway—as it was called, crossed the turnpike-road near Wandsworth, and here, some sixty years ago, a home tourist, on seeing one of the railway trains drawn by one horse, musingly speculated upon the benefit which would accrue from four or five millions of the public money being spent in extending double lines of iron railway from London to our cities and great towns. He adds, "We might, ere this hour, have witnessed our mail-coaches running at the rate of ten miles an hour, drawn by a single horse, or impelled fifteen miles an hour by Blenkinsop's steam-engine." Here we have the suggestion of uniting railway communication into *a system*, as connecting lines are now called.

It may readily be conceived that Locomotive Engines did not at once start into approximate perfection, but have been gradually matured by successive modifications and improvements. The Railway was perfected in this progressive manner, and it was followed by the Locomotive. The first suggestion of the application of Steam-power to the propelling of carriages is due to the illustrious Watt, who proposed it in 1759, to his friend Dr. Robison, at Glasgow College. Watt projected Steam carriages on roads; but as we have already said, he did not contemplate placing the Locomotive upon the Railway. And Oliver Evans, of Philadelphia, *thought of* the same thing in 1782, when he patented "a Steam wagon;" but it does not appear that anything more than a good high-pressure stationary engine was the result of his labours.

A letter of Dr. Darwin to Boulton is preserved, without date, in which the doctor lays before the mechanical philosopher the scheme of "a fiery chariot," which he had conceived,—in other words, of a locomotive steam-carriage. He proposed to apply an engine with a pair of cylinders working alternately, to drive the proposed vehicle; and he sent Boulton some rough diagrams illustrative of his views, which he begged might be kept a profound secret, as it was his intention, if Boulton approved of his plan and would join him as a partner, to endeavour to build a model engine, and, if it answered, to take out a joint patent for it. But Dr. Darwin's scheme was too crude to be capable of being embodied in a working model; and nothing more was heard of his fiery chariot,—except it be in the oft quoted passage in Darwin's *Botanic Garden*, first published in 1789, but written it is known at least twenty years before it was published:

Soon shall thy arm, unconquered Steam, afar
Drag the slow barge, or drive the rapid car;

Or, on wide-waving wings expanded bear
The flying chariot through the fields of air.
Fair crews triumphant leaning from above,
Shall wave their fluttering 'kerchiefs as they move;
Or warrior bands alarm the gaping crowd,
And armies shrink beneath the shadowy cloud:
So mighty Hercules, o'er many a clime
Waved his huge mace in virtue's cause sublime;
Unmeasured strength with early art combined,
Awed, served, protected, and amazed mankind.

In the Midland counties Darwin was a celebrity who, in his time, possessed sufficient influence to get most of what he said believed; but his prediction is scarcely entitled to more credence than the fancied prevision of the Atmospheric Railway, by Coleridge, in his *Ancient Mariner:*

For why drives on that ship so fast,
  Without or wave or wind?
The air is cut away before,
  And closes from behind.

But in another and less widely known poem by Darwin, *The Temple of Nature*, published in 1820, there occurs this anticipation, more remarkable than the above. In a note to line 373, canto ii. of the poem, the author sets out with, "the progressive motion of fish beneath the water is produced principally by the undulation of their tails;" and after giving the rationale of the process, he goes on to say that "this power seems to be better adapted to push forward a body in the water than the oars of boats;" concluding with the query: "Might not some machinery resembling the tails of fish be placed behind a boat so as to be moved with greater effect than common oars, by the force of wind or steam?" Darwin also projected an "aërial steam-carriage," (the "flying chariot," in the above passage,) in which he proposed to use wings similar to those of a bird, to which motion was to be given by a gigantic power worked by high-pressure steam, though the details of his plan were not bodied forth.

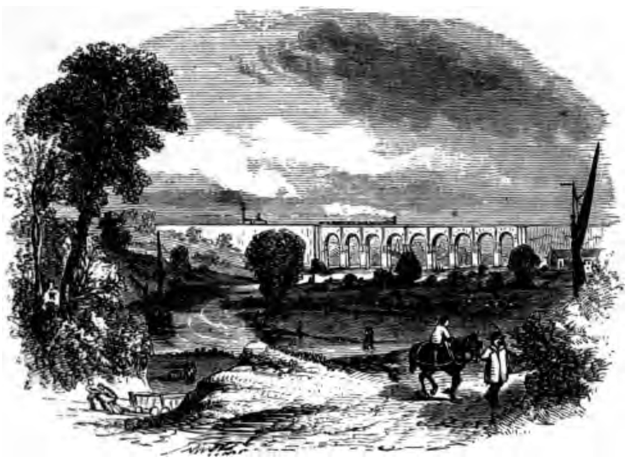
Leaving these poetic flights, we return to our chronicle. In 1784, Watt patented a locomotive carriage; and in the same year his friend and assistant, Murdoch, constructed a non-condensing steam locomotive of lilliputian dimensions. This Locomotive was placed on three wheels; the boiler was of copper; the flue passed obliquely through it, and was heated by a spirit-lamp; the steam cylinder was only three-fourths of an inch in diameter, with a stroke of 2 inches, turning a crank on the axle of the larger wheels, which were 9½ inches high. This little locomotive, standing not higher than 15 inches above the ground, could run at a speed of six or eight miles per hour. This model is interesting, inasmuch as it was the first ever made by an Englishman, preceding that by Trevithick by many years. It is to be seen at South Kensington, in the Patent Museum. Here also is a small model of a locomotive intended for the common road, patented in 1802 by Richard Trevithick and Andrew Vivian. This was supposed to be the first model in existence of a locomotive. But in the Museum of the Patent-office at Paris, there is a model of a locomotive of long prior date; and in an adjoining church, now appropriated as a kind of hospital for old decayed engines, is the original locomotive that actually ran upon the road, but in doing so killed a man, and subjected the inventor to imprisonment.

In 1804, Richard Trevithick constructed a high-pressure Locomotive for the Merthyr Tydvil Railway, in South Wales; it had a great defect in the slipping of the wheels, which Mr. Blenkinsop endeavoured to obviate in 1811, by employing a rack-rail, in which a large toothed wheel was set to work. In 1813, Mr. Brunton, of Butterley, contrived a locomotive carriage to be propelled by levers, like horses' feet. In 1821, George Stephenson laid out a colliery railway from Stockton to Darlington. Mr. Pease contemplated using horse-power, but Stephenson assured him his Killingworth engine was worth fifty horses. This was adopted, Stephenson was appointed engineer, the line was opened in 1825, and the Locomotive did its work admirably. It was very clumsy and ugly, but it drew 30 tons at four miles an hour. Some improvements were made in this engine, and next year Stephenson built a Locomotive which contained the germ of all that has since been effected; "there being no material difference between the cumbrous machines that screamed and jolted along the coal tram-road in 1815, and the elegant and noiseless locomotives which now take out the express train, gliding smoothly and swiftly as a bird through the air." But Stephenson's Killingworth engine attracted little notice; though he confidently maintained that one day, such engines and railways would be known all over Britain. The No. 1 Darlington engine is at present on a pedestal at the Darlington

Station; and the Patent Museum only wants this engine to possess the most interesting group of Locomotives in the world. The Stockton and Darlington Railway was one of the first examples of Locomotive power on a railway for passengers. In 1814, George Stephenson constructed an engine for the Killingworth Colliery, near Newcastle, in which toothed wheels were employed to engage and turn all the four wheels of the engine, and so to utilize all their adhesive power, to "bite" the rails.

In the Patent Museum at South Kensington, may be seen a patriarchal Locomotive, rigged with iron beams and rods, which liken it almost to a ship. This is the premier Locomotive—a machine which heralded changes almost as momentous as the Steam engine itself. Compared with one of the splendid engines of the Great Western or North-Western, "Puffing Billy," the brainwork of William Headley, the Wylam Colliery viewer, and the handiwork of Jonathan Foster, the engineer or smith (for the two terms were almost synonymous in the year 1813), looks but a poor bungling piece of workmanship out of which it would seem hopeless to expect any good results. Yet this very engine was at work drawing eight wagon-loads of coals day by day from Lemington to the shipping port in the Tyne, eight miles distant, from the day she was set rolling until the moment she was finally taken off work for the purpose of being transferred to the Museum. In this engine the two great features which made the locomotive a success were first applied—the sufficiency for traction of the smooth rail and wheel, and the application of the steam-blast up the chimney. The sufficiency of the smooth rail and the wheel for traction was, indeed, *the* great principle, the establishment of which rescued the Locomotive from oblivion. The only means by which heavy loads had been drawn by locomotive power before Headley's time was by the employment of the toothed wheel and the racked rail, as introduced by Blenkinsop and Trevithick, but "the pull" tore up the racked rail, and consequently this system had to be abandoned for horses. It was in the year 1812, when the price of corn and all kinds of horse provender was so dear, that the necessity of substituting mechanical power for living muscle again thrust itself upon the attention of the Wylam viewer. Unless some saving could be made in the working of the colliery, the works must be closed, and himself and family deprived of bread. Thus stimulated to exertion, he brought out his plan of weighting the engine and of coupling the wheels so as to prevent any of them slipping. He proved this could be done experimentally, by constructing a wagon, weighting it with iron, and then propelling it by the power of several men seated upon it and working winches. The carriage thus weighted drew several loaded wagons well enough. In order to prove that it was the weight which caused the wheels to bite, in place of the iron load, were substituted a number of men who, at a given signal, left off working at the winches and jumped to the ground, when the wheels immediately began to slip round. The model of this experimental wagon, with the connected wheels, which thus solved the problem of making the smooth wheel adhere to the smooth rail, or, to use the language of Stephenson, of making "man and wife" of them, is in the Museum beside "Puffing Billy," and fully establishes the claim of William Headley to the discovery of this all-important principle.

We must now leave the Locomotive and return to the Railway, to describe in outline the construction of the Liverpool and Manchester line, sanctioned by Parliament in 1826. In the formation of this railway,—be it remembered, the first,—the engineer had almost every variety of difficulty to contend with. He had hills to surmount, flats to pass, and to make firm one of those loose morasses, which are not unfrequent in the north of England, but which had to be made as solid as the common ground before it would be able to sustain the ponderous weights which would have to pass over it. Chat Moss was notorious as one of the most dangerous and uncertain quagmires in the kingdom. Whether the instability of the ground for so many miles was owing to the filtering of the waves from the Irish Sea, or from the settling of the waters from the heights of Cumberland and Westmoreland, was, and is still, a problem. Many plans were followed, which proved unsuccessful; but at length the engineer decided upon throwing in bundles of "kids" or faggots, till at last a broad foundation, or floating basis, was established; as the workmen wrought higher and higher, the way gained hourly in solid character, and in the end, when the ballast for the rail was laid, a road firm, substantial, and enduring, was formed of the most fragile material upon which the engineer could lay his hand. Chat Moss was twenty to thirty feet deep, and four miles across. An eminent opposing engineer said, "No man in his senses would attempt a railroad over Chat Moss." He calculated it would cost 227,000*l.* to cross it; yet it was completed for 40,000*l.* George Stephenson organized all the work himself, there being then neither contractors nor navvies; he sent for his son Robert, who had been some years in America, for his co-operation in the great work.



SANKEY VIADUCT.

A viaduct, or elevated roadway, over Sankey Valley was another difficult work. For the security of this work, it was necessary to drive two hundred piles, varying from twenty to thirty feet in length, into the foundation of each of the ten piers: thus in all, two thousand piles had to be driven.

Mr. George Rennie has left some very interesting details of this Railway. The physical difficulties were great. The construction of the tunnel at Liverpool, on so great a scale, through the red sandstone rock; the crossing of the great Sankey Valley and its canal by a long and lofty viaduct, or bridge and embankment; also the Newton Valley, the bridge and embankment, beside other valleys of great length and depth; the construction of upwards of 100 bridges over and under the railway; the deep cutting through Olive Mount and Rainhill; the carrying the roadway over the much dreaded Chat and Parr Mosses; the determination of the width of guage, and distance between the lines of railway, &c., all of which subjects were scarcely known, involved difficulties of no ordinary kind; nevertheless they were deemed practicable. The duties of the Railway Engineer are very heavy. "He is responsible," says Mr. Fowler in his Presidential Address to the Institution of Civil Engineers, "for the vast number of objects required in the machinery for erecting and repairing shops for the engines and carriages, for the pumping and other fixed engines, and especially for the Locomotive engine itself, and for rolling and fixed plant generally."

The Liverpool and Manchester Railway was completed in 1829, and September in the following year was fixed for its being opened. There had been much debate among the Directors as to the means that should be employed for drawing the carriages, and a strong feeling existed in favour of employing stationary steam-engines, which should work ropes to and fro, at certain intervals along the line. Horse-power being evidently insufficient to keep up the speed which the Directors and the public desired, it was ultimately decided to use Locomotives, and the Directors offered a premium of 500*l.* for the best Locomotive that could be produced with certain conditions. These were: that the chimney should emit no smoke; that the engine should be on springs, not weigh more than six tons, or four tons and a half, if it had only four wheels; that it should be able to draw three-times its own weight, and not cost more than 550*l.*

Four engines, with the required qualifications, were produced on the day of trial, September 15, 1830. One of the engines was withdrawn. Of the others the first was the *Novelty*, constructed by Messrs. Braithwaite and Ericsson, which was exceedingly light, and it had its draft produced by means of a blowing-machine. The next was the *Sanspareil*, built by Mr. Hackworth, much on the principle of Trevethick's engine, but having two cylinders instead of one. The next was the *Rocket*, built by Mr. George Stephenson, and which gained the prize for lightness, power and speed, awarded by the Directors. It weighed 4 tons 5 cwt.; the tender following weighed 3 tons 4 cwt.; and two loaded carriages drawn by it on the trial, weighed 9 tons 11 cwts.: thus, the drawn weight was 12 tons 15 cwt., and the gross total 17 tons. It averaged a speed of 14 miles per hour; its greatest velocity was 29 miles an hour; and it evaporated 18¼ cubic feet, or

114 gallons of water per hour. The Novelty was driven on the trial by Sir Charles Fox, the engineer.

To recapitulate, Locomotives came into use in 1804, but their machinery was very imperfect. They were much improved in the next twenty years, and a speed of from 4 to 7 miles was attained, with a prospect of greater. High-pressure engines required to be used, but they frightened the ignorant; the very name was alarming. "The difficulty of arranging the parts of a high-pressure engine on a moveable carriage, and the apparent impossibility of furnishing enough of steam to make the wheels turn at the rate of 20 or even 10 miles an hour, retarded the progress of the Locomotive. If a wheel, 4 feet in diameter, turn 110 times in a minute, or travel at the rate of 15 miles an hour, each cylinder will take from the boiler 220 fills of steam per minute; and it is not surprising, therefore, that many thoughtful people, whose opinions were entitled to respect, regarded a speed of 15 or even 10 miles an hour as unattainable. Where learning failed, however, natural genius triumphed. George Stephenson, once a locomotive stoker in the north of England, and afterwards one of the most distinguished engineers of modern times, invented the tubular boiler, and raised the speed of the engine from 7 to 30 miles an hour. A large heating surface is indispensable to generate the heat required; but the space allowed for the whole engine on the carriage is necessarily limited, and Stephenson's ingenuity was exercised in providing the former without unduly increasing the latter. The flame and heated air leave the fire-box at a very high temperature, and much heat would be wasted if they were allowed to escape immediately into the atmosphere. Stephenson had already made an improvement on locomotives, which enabled him to supplement the ordinary operation of the furnace by this heated air." * If the steam, instead of being allowed to escape, were made to pass into the smoke-box, and then conveyed up the chimney, it would act as a powerful blast upon the fire. Instead of blowing the fire, it blows the chimney; and more air will, of course, enter the fire if the chimney be cleared more quickly. "This, then, was Stephenson's first great improvement, and it enabled him to give effect to another. Putting the chimney at one end of the boiler, and the fire-box at the other, he connected the two by a number of metal tubes passing from the back of the furnace to the smoke-box. Hot

* Mr. Syme; *Edinburgh Essays.*

air escaping through these tubes, heats the water by which they are surrounded, and enables engines to travel at the rate of 20, 60, or even 70 miles an hour. "The *Rocket* was constructed on this principle, and with this Stephenson gained the prize, and placed beyond doubt the propriety of using locomotives in preference to horses or stationary engines. The great object was now attained : a speed of 10 miles an hour, with ordinary loads, was certain, and 30 miles was not impossible. "George Stephenson came eminently at the right time in scientific history, gathering into one magnificent fact all the floating prophecies of possibilities, solving the problem, and setting the question of the Railway and the Locomotive Engine at rest for ever by his grand and masterly invention."

The *Rocket* was the produce of the locomotive works which Stephenson, with the aid of Mr. Pease, had established some years previously at Newcastle-upon-Tyne. It was the accurate workmanship of this engine, resulting from the trained hands in the Newcastle Locomotive Works, that stood Stephenson in good stead on the day of trial. The *Rocket*, which is now in the Patent Museum, presents very little difference in outward appearance from the engines of the present day, except in its small size. All the rods and working machinery, which heretofore, even in the Darlington engines, were carried high in the air over the boiler, were now placed lower down on either side of it near the centre of gravity, the cylinders being placed at an angle of 45°, and acting directly upon the driving-wheels, the spokes and fellies of which, strangely enough, are of wood! The *Sanspareil* has also been added to the Museum. After its defeat in the great trial, it was employed in the conveyance of passengers and general traffic on the Bolton and Leigh Railway until the year 1844, when, being found short of power for the rapidly increasing traffic, it was removed to Mr. Hargreaves's colliery at Cappul, near Chorley, where it was used as a fixed engine in winding and pumping. This work it did most satisfactorily until the end of the year 1863, when it was removed in consequence solely of the pit being exhausted. The engine is very similar in appearance to Mr. Headley's old Wylam engine, but it has one great improvement—the coupling of the wheels, instead of being accomplished by the cog-wheel arrangement underneath the boiler, was produced by a simple coupling-rod fixed upon the two wheels. In the perpendicular position of the cylinders, high up over the boiler, it resembled the Wylam engine, but the pistons worked from their under sides, and in fixed slides, being a grand improvement on the complicated system of rods in that old engine.*

By the great success of the *Rocket*, the key-note was struck. Constructors worked each in his own way, at the Locomotive, to improve the detail and increase the efficiency; and for many years the practice of builders was moulded into two general classes of engines, with two cylinders placed horizontally inside the smoke-box, under the chimney, and otherwise essentially similar to each other, except in one great feature, the number and disposition of the wheels. In one class there were six wheels, of which one pair was placed behind the boiler, typified in the engines of the day, made by Mr. Robert Stephenson; in the other class there were but four wheels, placed under the barrel of the boiler, leaving the fire-box overhung, typified in the engines made by Mr. Bury for the London and Birmingham Railway. Experience has demonstrated the disadvantage of an overhung mass, with a very limited wheel basis in the four-wheeled engine running at high speed; and it became the general practice to apply six wheels to all ordinary locomotive stock.

Here we must say something of the speed attained on Railways. The greatest speed of Trevithick's Engine was five miles an hour. The ordinary speed of George Stephenson's Killingworth Engine in 1814, was four miles an hour. In 1825, Mr. Nicholas Wood, in his work on Railways, took the standard at six miles an hour, drawing forty tons on a level; and so confident was he that he had guaged the power of the locomotive, that he said: "Nothing could do more harm towards the adoption of railways than the promulgation of such nonsense, as that we shall see locomotive engines travelling at the rate of 12, 16, 18, and 20 miles an hour." The promulgator of such nonsense was George Stephenson. In 1829, it was estimated that at 15 miles an hour the gross load was 9½ tons, and the net load very little; and that, therefore, high speed, if attainable, was practically useless. Before the end of that year, George Stephenson got with the Rocket a speed of 29½ miles per hour, carrying a net load of 9½ tons. In 1831, his engines were able to draw 90 tons on a level at 20 miles an hour. Nor were the engineers themselves alone mistaken in estimating the gigantic strength of the railway. A writer in a leading journal,

* Abridged from the *Times*.

the *Quarterly Review*, gravely observed: "As to those persons who speculate on the making of railways generally throughout the kingdom, and superseding all the canals, all the wagons, mail and stage coaches, postchaises, and in short every other mode of conveyance by land and by water, we deem them and their visionary schemes unworthy of notice;" and in allusion to an opinion expressed on the probability of railway engines running at the rate of 18 miles an hour, then in contemplation between London and Woolwich, the reviewer adds —"We should as soon expect the people of Woolwich to suffer themselves to be fired off upon one of Congreve's ricochet rockets, as trust themselves to the mercy of a machine going at such a rate." In two-and-twenty years afterwards, trains running at more than double this speed had become of daily occurrence, and nearly quadruple the speed which so alarmed the reviewer had been attained with perfect safety.

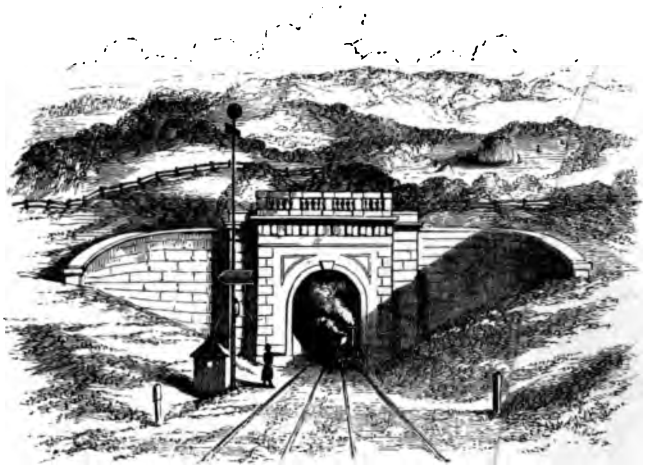
The advantages which had resulted from the Liverpool and Manchester Railway suggested the idea of uniting the metropolis with one of the great manufacturing cities: and Mr. Robert Stephenson was engaged to lay out and construct a line for that purpose between Birmingham and London. Few great undertakings ever excited so much controversy as this. The distance to be traversed was a hundred and ten miles. Lofty heights had to be surmounted, rivers to be crossed, deep valleys and ravines to be passed, and almost every difficulty that can be opposed to engineering skill had to be overcome. The preliminary proceedings cost the Company the enormous sum of 72,868*l.* The Railway was completed in 4 years 4 months; which, upon the whole distance of 112½ miles, gives, as the average rate of progress, one mile in every fortnight; the average cost per mile was 50,000*l.*, or more than double the estimate. The two greatest works are the Watford Tunnel, 1791½ yards (a mile and 31 yards in length), cost 140,000*l.*; and the Kilsby Tunnel, upon which 1,300 men were constantly employed, and 12 steam-engines were worked day and night. The Euston Terminus cost 800,000*l.*, and occupies 12 acres; the architectural gateway is pure Grecian Doric, and cost 80,000*l.*; its columns are higher than those of any other building in London. In the great Hall is Baily's colossal marble statue of George Stephenson, the originater of the railway system.*

* There are, unfortunately, in the histories of great inventions, many

The capital expended on the Liverpool and Manchester Railway had been upwards of a million and a half; that laid out on the London and Birmingham line, was more than seven millions and a quarter. Next came the design of uniting the old metropolis of the commerce of the Western Ocean, Bristol, with London, by the Great Western Railway. One of the most striking of the many engineering difficulties that had to be surmounted in the construction of this line, was the excavation through the solid rock of the celebrated Box Tunnel, which was satisfactorily accomplished under the direction of Mr. Brunel, the engineer-in-chief. This tunnel, which is ventilated by six shafts, varying from 70 to 300 feet in depth, is 3,175 yards in length. The Tunnel pierces through Box Hill, between Chip-

discrepancies in the statements of the precise share of merit due to the inventors. In some cases, the claim is altogether set at nought; in others two or more minds are shown to have been simultaneously at work upon the same idea, but separately; and in others claimants arise for a large share of the merit, to which the inventor believes himself to be wholly and solely entitled. Of the latter class is John Steele, who is stated to have assisted the Stephensons to mount the ladder of fame; and whose claim has been circumstantially urged by Messrs. Jeaffreason and Pole. John Steele (says Mr. Jeaffreason), one of George Stephenson's early friends, the son of a brakesman on the Pontop Railway, in his early childhood, displayed remarkable ingenuity in the construction of models of machines. His school-fellows at Colliery Dykes used to marvel at the correctness of his imitations of pit-engines, and remember how in school the master could never "set him fast" in figures. While he was still a school lad, his leg was accidentally crushed on the Pontop tramway. After leaving the Newcastle Infirmary, where the limb was amputated, he was apprenticed to Mr. John Whinfield, the ironfounder and engineer, of the Pipewell-gate, Gateshead. Here he attracted the attention of Trevithick, whom Steele joined, and assisted in the manufacture of the locomotive constructed by that original mechanician in 1803-4. He then returned to Gateshead, and there "built the first locomotive that ever acted on the banks of the Tyne." . . . When it was finished it ran on a temporary way laid down in Whinfield's yard, at Gateshead. John Turnbull, of Eighton Banks, living in 1858, remembered the engine being made while serving his apprenticeship at Whinfield's, and said that, when completed, "it ran backwards and forwards quite well, much to the gratification of 'the quality' who came 'to see her run.'" . . . "Every word that came from Steele—Trevithick's pupil and workman, who had himself, within six miles of Killingworth, built a machine which, with all its defects, had actually travelled under the influence of steam—George Stephenson stored up in his memory. Steele was never weary of prophesying that 'the day would come when the locomotive engine would be fairly tried, and would then be found to answer.'" No wonder that Stephenson caught enthusiasm from such a teacher. Poor Steele himself was eventually killed at Lyons by the bursting of the boiler of a steamboat, in the year 1825."

penham and Bath, part of which is 400 feet above the level of the railway. The number of bricks used in its construction was 50,000,000: a ton of gunpowder and a ton of candles were consumed every week for 2½ years: and 1,100 men and 250 horses were kept constantly employed.



BOX TUNNEL.

By the genius of Mr. Locke, the line between the banks of the Thames and Southampton has been rendered so safe, so speedy in transit, and so convenient, that the state dues of the latter place, which before the railway was made were only a few hundred thousand pounds, increased to upwards of four millions per annum, and it has become the third port in the kingdom, and head-quarters for the highway between Britain and the Southern World.

Upon this magnificent line was first constructed the Electric Telegraph—that offspring and independent companion of railways, and properly called "the silent highway," along which messages flash. To the working of railways the telegraph became essential: the needle is capable of indicating, at every station, whether the line is clear or blocked, or if accident has anywhere occurred. There can indeed be no doubt that but for the opportune invention of the electric telegraph, it would have been quite impossible for our railways to have been worked to the present extent with anything like the comparative safety and comfort now experienced. We have not space to detail the systems of signals upon the various railways: one of the most recent is Preece's series of appliances for showing how electric signals can be passed at pleasure along a railway train, from any one of the carriages or vans to another—from a passenger to the front and rear-guard at once, warning at the same time

RAILWAY EMBANKMENT NEAR BATH.

the engine-driver, or from a carriage which has broken away or dropped off. In the latter case the detaching of the coupling sets a bell ringing in the guard's van, and it continues to ring until the coupling is replaced; consequently it would be impossible for part of a train to become detached without the fact becoming known to the guard, who would immediately signal the engine-driver. Mr. Preece's system has already stood the test of experience on the South-Western line. From the great proportion of passenger traffic expected, it was proposed to travel at a higher speed upon the Great Western line than had hitherto been attained. With this view the permanent way was peculiarly laid—principally in fixing the gauge at seven feet, a much greater width than had hitherto been adopted, and by which greater steadiness could be ensured than otherwise consistent with high speed. The rails are bridge-shaped, with wide flanges, laid upon bearings of wood, instead of upon chairs; by which would be insured greater steadiness, less noise and wear and tear; the rails are mostly of Welsh iron. The whole length of the line is 118 miles 20 chains. The *broad gauge* of this line tripled the working power of the locomotive, and gave us 60 miles an hour, where we should have been lingering at 20. Thirty miles an hour was thought progress; an express at 35 miles an hour seemed to have reached the further limit; but in 1846, Brunel succeeded in working the express to Bristol in 2½ hours, and to Exeter in four hours. In the Great Western locomotives, cylinders were increased to 15 and 18 inches diameter; the fire-box surface in the *Rocket* was 20 square feet; in the broad gauge engines it has been increased to above 100 square feet.

It would far exceed our limit to attempt to sketch the varieties of railway construction; and we can only glance at a few of the more prominent instances. The Greenwich Railway, Landmann, engineer-in-chief, was the first completed line from the metropolis: opened Dec. 14, 1836: the rails are laid upon upwards of 1,000 arches, in building of which more than 70 millions of bricks were used. The Blackwall line, 3¾ miles, is carried nearly throughout on an arched viaduct of brickwork. Originally, the carriages were drawn by stationary engines, two at each end of the line; which, by means of ropes, dragged the up and down trains alternately, a mode of working ridiculed in Parliament as visionary and impracticable; the rope cost upwards of 1200*l.*, and the stationary engines 30,000*l.* each; but locomotives are now used; the line cost 311,912*l.* per mile.

The Atmospheric Railway consists of an iron pipe in the middle of the track, in which a piston moves with the velocity of from 20 to 30 miles an hour, by exhausting the tube in front of it, and admitting the air to press on the opposite side. A connexion is formed between this piston and the carriages by a rod passing through an opening on the top of the tubes, which is kept air-tight by a well-contrived valve that opens to allow the passage of the rod; the necessary vacuum is produced by air-pumps, worked by a stationary steam-engine.

In practically working the Atmospheric Railway, the obstacles were great. The amount of atmospheric pressure requisite in so small a tube was very great; and the leakage, waste of power, and first cost, were enormous. In the Pneumatic Railway of Mr. Rammell, C.E., the pressure is only 2½ oz. per square inch, whereas in the Atmospheric it was from 7 lb. to 10 lb. The Pneumatic principle had already been tested in a Dispatch tube, through which parcels were propelled on ledges or rails, cars filled with parcels, on the signal being given, by the exhaustion and pressure of the air in the tube, by a wheel worked by a high-pressure engine. This motive power is in the Pneumatic Railway applied to passengers in an enlarged tube. The principle of propulsion is very simple. It has been likened to the action of a pea-shooter, and the train the pea, which is driven along in one direction by a strong blast of air, and drawn back again in the opposite direction by the exhaustion of the air in front of it; the motion being modified by mechanical arrangements. The air is exhausted from near one end of the tube by means of an exhausting apparatus, from which the air is discharged by centrifugal force. The contrivance may be compared to an ordinary exhausting fan. The rails are *cast* in the bottom of the tubes; a few strips of vulcanized India-rubber screwed round the fore-end of the carriage constitute the piston, leaving three-eighths of an inch clear between the exterior of the piston and interior of the tube; there is no friction, and the leakage of air does not interfere with the speed of transit. The Whitehall and Waterloo Pneumatic Railway will extend from the station in Scotland-yard, carried in brickwork beneath the tunnel of the Underground District Railway, and then under the Low Level Sewer to the northern abutment, and from this iron tubes of 16 feet diameter are to be laid on the clay beneath the Thames.

The Subterranean Railway, beneath the crowded streets of London, Mr. Fowler, engineer-in-chief, extends from Paddington to Finsbury, 4½ miles: the difficulties of construction—through a labyrinth of sewers, gas and water mains, churches to be avoided, and houses left secure—was an herculean labour; but one of the greatest perplexities was to construct an engine of great power and speed, capable of consuming its own smoke, and to give off no steam. This Mr. Fowler surmounted by inventing an engine which, in the open air, works like a common Locomotive, but when in the tunnel, consumes its own smoke, or rather makes no smoke, and by condensing its own steam, gives off not a particle of vapour. It was next proposed, by extensions at either end of the underground line, and by a new line, to be called the "Metropolitan District Railway," to complete what will form pretty nearly an inner circle, but will also throw out branches to connect itself with the suburban systems north and south of the Thames; so that when the entire scheme is in working order we shall have something like a combination of two circles—the inner and the outer—as a thorough system for the metropolis. Of the progress of the works a specimen is afforded in 2,000 men, 200 horses, and 58 engines many months working, and whole terraces, streets, and squares in south-west London being tunnelled under almost without the knowledge of the inhabitants. The railway bridges across the Thames, and the magnificent stations upon the banks attest the completeness of the metropolitan system.

The first Railway constructed in the United States of America, was a line of about four miles for the conveyance of granite from the quarries at Irving to Boston harbour, which was first opened in 1827. The successful introduction of Steam locomotion in England was followed by the formation of numerous important lines in America; and in 1839, more than 3,000 miles were completed in the United States. Cheapness of land and timber made the average cost greatly below that of English railways; the average cost of several lines did not reach 5,000*l.* a mile. American practice, after having passed through various phases, has arrived at two great types of locomotive for passengers and for goods traffic, which are universally adopted in the United States. The passenger-locomotive has eight wheels, of which four in front are placed in a moveable frame, called a "bogie" or "truck," which swivels on a central pivot, and adapts itself to the curves of the lines; the four wheels behind are the "drivers;" they are larger than the front wheels, and of equal size and coupled. The cylinders are placed outside, just over the truck, horizontally. A "cab" or "house" is placed upon the hinder part of the machine, behind the boiler, for the protection of the engine-driver and the stoker from the weather, with ample glazed opening, to afford a clear view ahead. The chimney or "stalk" is in form externally like an inverted cone, expanding upwards; internally, it is cylindrical, and the space between the outer and inner chimneys forms a reservoir for cinders and ashes thrown up through the inner chimney, which are deflected by a baffle-plate at the top, and thrown over into the reservoir, trap, or "spark-catcher." This contrivance is specially designed for the use of wood as fuel, and to prevent the risk of conflagration arising from the numerous sparks which would otherwise be discharged in passing through forests and other ignitable districts. As a further precaution for the prevention of sparks, the top of the stalk is covered with a fine wire-net. The steam-whistle is situated above the boiler for ordinary use; and the bell is hung near to the cab, with ropes within reach of the engine-man. The bell is used in passing through the streets. The cow-catcher is hung in front of the engine, to ward off stray cattle, &c., and the American flag is hung behind it. The tender is carried on eight wheels, disposed under two trucks, fore and aft, to facilitate the turning of the tender on the curves.

In 1855, the number of miles of railway in the United States exceeded those in the rest of the world altogether by 2,550 miles. In 1837, the only railway in British North America was the Champlain and St. Lawrence line, 16 miles long, worked by locomotives. The longest line of railway in the world is the Grand Trunk Railway, which extends from Portland to Quebec and the river Du Loup, east, to Sarnia, at the foot of Lake Huron, west, with several branch lines, including a total of 1,396 miles, under one management.

The highest railway in the world is in Chili,* and has its terminus at an elevation of 4,075 feet above the sea level—a less height, of course, than that to which Trevithick worked the stationary engine in Pasco, but said to be one thousand feet higher than any other locomotive has reached. These summit levels teach engineers greater daring; and the Alps, Cordilleras, and Ghauts, even the mighty Himalaya itself, will no longer be considered bounds to the railway system. The summit of the Northern Bengal Railway, at Darjeeling, is as high as that of the Copiapo Railway.

Railway construction in India has been largely aided by the Government. At the commencement of the year 1866 there were 3,331 miles of railway open for traffic, and 306 miles since opened, making 3,637 miles of railway open in India. Of the 306 miles, 150½ miles belong to the Great Indian Peninsula, 47½ to the Great Southern, 30 to the Delhi, 34 to the Madras, 42 to the Indian Branch Railway, and two to the East Indian, which latter includes the girder bridge across the River Jumna at Delhi. The additions to the Great Indian Peninsula Rail

* *Vide infra*, p. 327.

way include the last section of the line to Nagpore, the present terminus of that line in the great cotton districts of Central India. 3,638 miles were open for traffic on the 1st of May, 1867, leaving 432 miles to be opened during the year, 464 miles in 1868, and 1,109 in 1869, and subsequently, together 2,005 miles remaining to be finished. The total amount advanced by the Government from the year 1849 to the end of 1866 for guaranteed interest was 18,929,576*l.*, and about 7,000,000*l.* had been paid back by the Companies from the earnings of the railways, making the debt of the railways to the Government nearly 12,000,000*l.*

Amongst the more prominent Railway works are Bridges of enormous span. The widest single span of any railway bridge in the world is 1,224 feet, carrying the Lexington and Danville Railway, at an elevation of 300 feet, over the Kentucky River, in the United States.

The next widest span is that of the Niagara Suspension Bridge, connecting the American and Canadian Railways at Niagara Falls; the clear span is 822 feet. The next widest are those of the Britannia Bridge, 460 feet each; the Saltash Bridge, two spans, 455 feet each; and the Conway Bridge, 400 feet.

The next is the immense bridge carrying the Royal Eastern Prussian Railway over the Vistula, at Dirshau; this is an iron lattice bridge, having six spans of 397 feet 3 inches each. The Nogat Bridge, on the same line, has two iron lattice spans of 321 feet, and one span of 53 feet 6 inches. The great railway bridge at Cologne has four lattice spans of 344 feet 6 inches each.

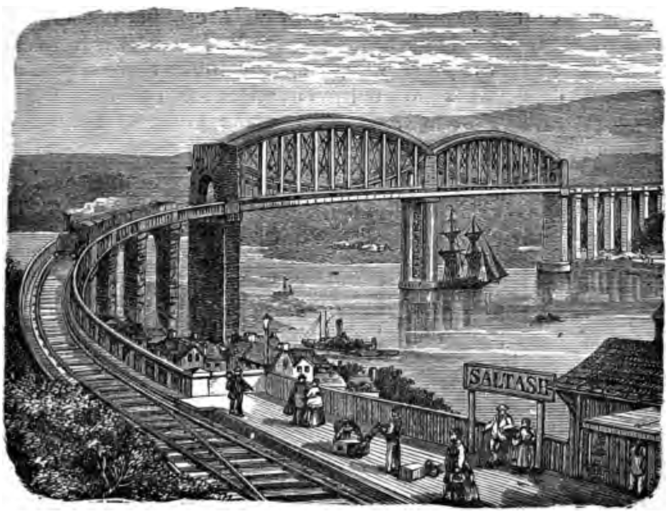
The middle opening of the Great Victoria Bridge at Montreal is 330 feet wide, the other twenty-four openings being each 242 feet.

The Chepstow Bridge has a span of 306 feet, besides three side spans of 100 feet each. The Boyne Viaduct has one lattice span of 264 feet, and two side spans of 138 feet 8 inches each.

The widest masonry span ever erected for railway purposes, is one of 180 feet, carrying the Glasgow and South Western Railway over the river Ayr.

The railway bridge across the Thames at Pimlico, has four cast-iron arches of 175 feet each, the widest yet employed.

The Saltash Bridge on the Cornwall Railway, I. K. Brunel, engineer is amongst the most remarkable achievements of skill. It consists of nineteen spans, seventeen wider than the widest arches of Westminster Bridge; while two, resting on a cast-iron pier of four columns, cross the whole stream of the Tamar at a leap of upwards of 900 feet, or a greater distance than the breadth of the Thames at Westminster. The total length of the structure from end to end, is 2,240 feet; its height from foundation to summit is 260 feet, or more than 50 feet higher than the Monument. The main pier, in the centre of the river, on which the great spans rest, has its foundation on solid

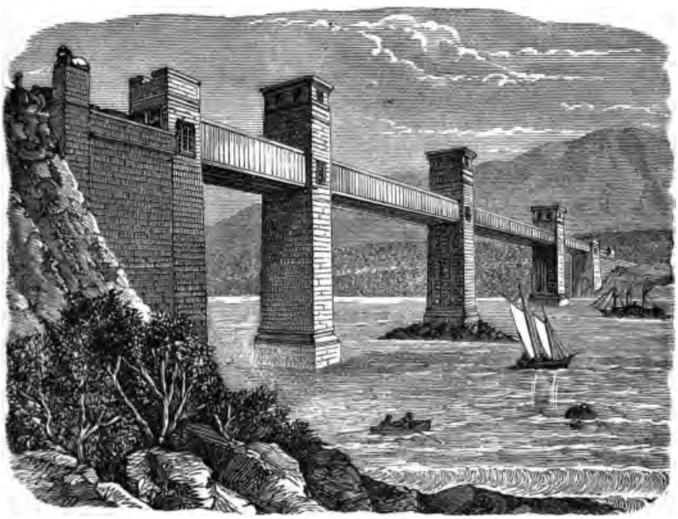


ALBERT BRIDGE. SALTASH.

rock, under some 70 feet of sea-water, with 20 feet of mud and concrete gravel. This was built on the coffer-dam principle: an immense wrought-iron cylinder of boiler-plate, 100 feet high, and 37 feet in diameter, and weighing upwards of 300 tons, was made and sunk exactly on the spot whence the masonry was to rise; then the water was pumped out, and the air forced in; the men descended, and working as in a gigantic diving-bell at the bottom of the river, cleared out the mud and gravel, until the rock was reached, and hewn into form, to support the cylinder evenly all round. Powerful steam air-pumps were necessary to keep the labourers supplied below, and they worked at an atmospheric pressure of upwards of 35 lb. to the inch. On this massive pile, built in the cylinder, the iron columns for the centre pier are raised. Until these ponderous masses were cast, metal works of such dimensions were seldom dreamt of. There are four octagon columns, 10 feet in diameter, and 100 feet high, and 150 tons weight. Each stands 10 feet apart from the other, in the centre of the granite, and all are bound together with a massive lattice-work of wrought-iron. The great spans, each end of which rests on two of these columns, is made on the principle of a double bow: the lower bow is of chains, carrying the roadway; the upper is a tube of wrought-iron, to which the lower is attached by powerful supports. Thus, a great weight on the lower bow only tends to give additional support by straightening the upper, and *vice versâ;* each, in fact, counteracts the effect of the other. Each arched tube is elliptical in form, and made throughout of inch boiler-plate, with inside wrought-iron diaphragms, with tie-rods and angle-irons. The pressure on the centre pier foundation is more than eight tons to the foot.

The great Tubular Bridges on the Chester and Holyhead Railway are also triumphs of engineering skill. When Mr. Robert Stephenson, the engineer for the line, proposed to span the Menai Straits by a tunnel of wrought-iron stretching from side to side, and allowing a passage for the trains to run through its interior, he confided the experiments to be made upon the strength of iron for that purpose, to Mr. Fairbairn, the eminent engineer of Manchester, who introduced wrought-iron girders, and found it more convenient and safe to make the top cellular, instead of using thicker plates than in the bottom. After many experiments, it was proposed to build "an iron box, 460 feet long, 30 feet high, and 14 feet broad, on the banks of the Menai Straits; to float this mass of 3,450 tons at high water to openings in piers for its reception; to lift it upwards of 100 feet, and build solid masonry underneath for its support; to rest it at its utmost height on cast-iron rollers, which would allow it to expand and contract, as the sun rose and set, or as summer advanced and waned, and then to make it a tunnel for the passage of railway trains, weighing perhaps, a hundred tons. Experience made Mr. Fairbairn confident that there was no danger of the bridge giving way under its own weight; and numerous experiments on a large scale proved the truth of his opinion. Chains were as unnecessary to support this bridge as intermediate piers, even if the latter could have been built. Its strength is derived from a different source from either. The roof consists of two platforms, divided into eight equal parts by partitions running from end to end of the bridge; and the cells thus formed keep the tube from giving way to compression in the top, where the material is most liable to be injured.

The first of these stupendous bridges was built on the Conway, in 1848. Two tubes of 400 feet span were required, one for each line of rails. A train of wagons, weighing altogether



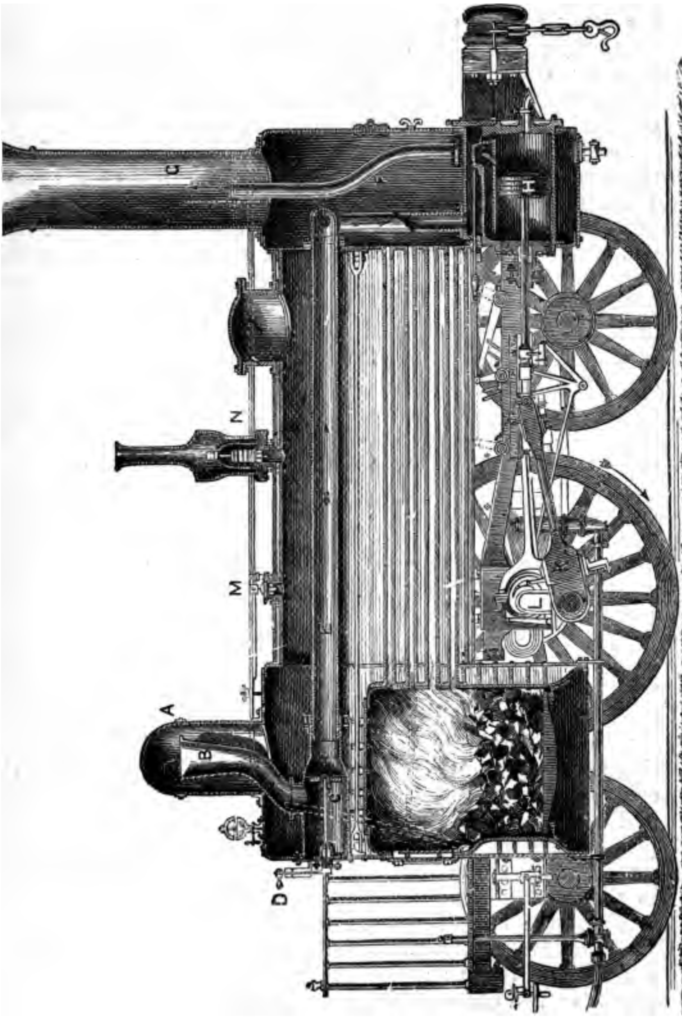
BRITANNIA BRIDGE, MENAI STRAITS.

301 tons, was placed in the middle of one of them; and the deflection in the centre amounted to 11 inches. The Britannia Bridge over the Menai Straits was finished about a year after, and is justly regarded as the greatest triumph of engineering that this or any other country has ever witnessed. A splendid tower rises to the height of 230 feet from a rock in the middle of the Straits; and four tubes, each 460 feet in length, stretch from it to smaller towers on the bank. Other four tubes, of 230 feet each, carry the railway to the high grounds on the east and west sides of the straits. This magnificent bridge was

the culminating point of railway enterprise and engineering; and half a century may elapse before necessity produces its rival." *

The modern locomotive is one of the most perfectly organized machines that human ingenuity has ever constructed; and though the general principle of its arrangement is simple and readily understood, the number of contrivances required for the proper performance of its functions, and for the due adjustment of the various subordinate actions, is very considerable indeed. An inspection of the cut on the opposite page, with the following explanation in reference thereto, will enable the reader who is already acquainted with the action of the stationary steam-engine, to form an accurate notion of the general construction of the locomotive. The cut shows a section of the machine through its centre, and though such a section would not pass through the cylinders, one of them is nevertheless shown in section. Its *piston* is seen at H, and the head of the *piston-rod* moving in slides, gives motion to the *connecting-rod*, which is connected with a *crank*, L, formed by forging the *driving-shaft* with a double bend. The boiler is cylindrical, and is traversed from end to end by a great number of brass tubes, from one and a quarter inch to two inches diameter, which pass from the *fire-box* to the *smoke-box*, F. The water in the boiler surrounds and covers these tubes, which, by the large extent of total surface they present, very quickly convey to the water the heat of the fire. The draught of the flame through these tubes is aided by the escape of the waste steam from the cylinders, through the *blast-pipe*, F, into the chimney, G; and, of course, the more rapidly the steam is consumed the greater is the draught, which thus regulates itself to the demand made on the machine. The steam leaves the boiler from the upper part of the *steam-dome*, A, where it enters the pipe, B, and then passes through the *regulator*, C, which can be closed or opened to any extent by the handle, D. The steam is conveyed towards the cylinders by the pipe, E, wholly within the boiler, until it reaches the smoke-box, where it divides into two branches, one for each cylinder. Each cylinder is provided with a slide-valve, by the action of which the steam is admitted on each side of the

* Mr. Syme; *Edinburgh Essays*. Mr. Fairbairn, it will be recollected, claimed *the idea* of the self-supporting Tubular Bridge, which Mr. R. Stephenson constructed. How fertile a principle this has proved need hardly be pointed out: it is to having been constructed on this principle that the *Great Eastern* steamship owes its enormous strength.



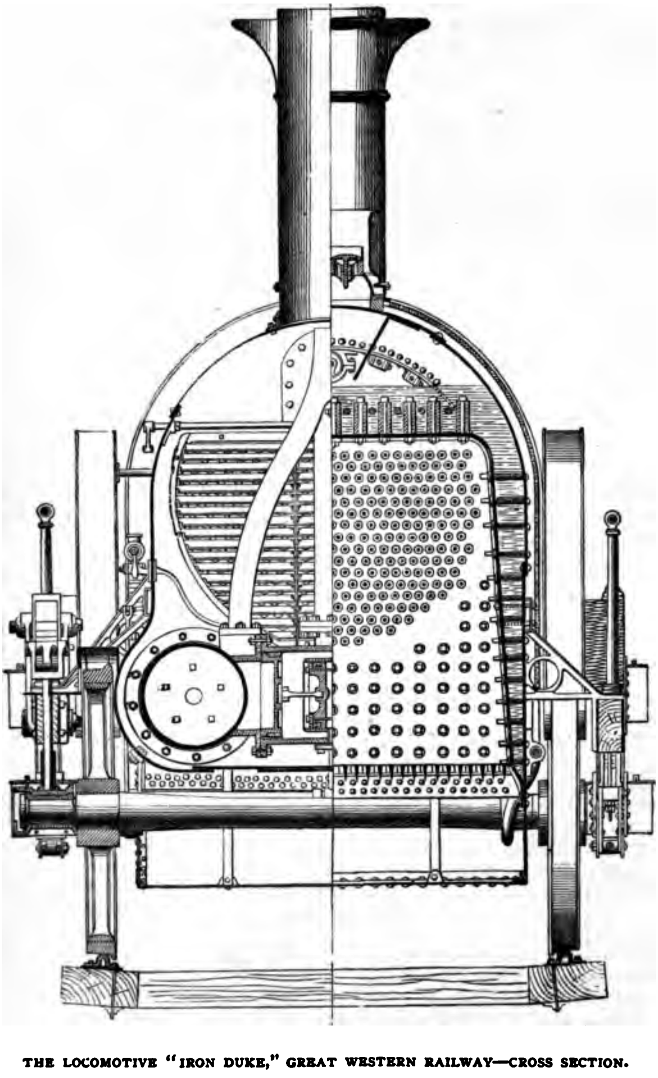
SECTION OF A LOCOMOTIVE.

piston alternately, at the same time that the communication on the other side is closed with the boiler and opened to the exhaust pipe, F. The outer surface of the boiler is shielded from the cooling contact of the external air by a covering of felt, or other bad heat-conductor, which is overlaid with strips of wood, and the whole is surrounded with sheet-iron.

Among the fine examples of the most powerful class of Locomotives is that constructed for the broad gauge of the Great Western Railway, which forms one of the illustrations of Mr. Bourne's *Recent Improvements in the Steam-engine.* In this engine, the "Iron Duke," the cylinders are 18 inches diameter and 24 inches stroke, the grate contains 21 square feet of area, and there are 305 tubes of 2 inches diameter in the boiler. The total heating surface is 1,952 square feet, and a cubic foot of water may be evaporated in the hour by every five square feet of heating surface. An engine of this class will exert 750 actual horse-power. The pressure in the boiler is 100 lbs. per square inch, and the initial pressure in the cylinder is about 10 lbs. less. But at high speeds the pressure in the valve-box is greater than that in the boiler, which may be imputed to the momentum of the steam when its continuous flow is arrested by the shutting of the slide-valve. At 60 miles an hour, when the handle which moves the link was in the first notch, and the steam was cut off at a quarter of the stroke, the back pressure, when the area of the blast orifice was one-sixteenth of the area of the piston, was 36 per cent. of the total pressure; and when the area of the blast orifice was enlarged to 1-10·7 of the area of the cylinder, the back pressure fell to 10 per cent.

"In the 'Iron Duke,' the steam is drawn from the water through a perforated steam-pipe, and its admission to the cylinders is regulated by a gridiron slide set in the smoke-box, and worked by a rod extending through the perforated steam-pipe to the front of the boiler. The damper consists of an arrangement of iron venetians set against the ends of the tubes in the smoke-box, each of which acts as a hanging-bridge in retaining the hottest smoke in contact with the tubes. These venetians are lifted or lowered by an appropriate handle, and the draught is thus regulated." * Mr. Gooch states that an engine of this class will evaporate from 300 to 360 cubic feet

* Abridged from *Recent Improvements in the Steam-engine.*



THE LOCOMOTIVE "IRON DUKE," GREAT WESTERN RAILWAY—CROSS SECTION.

of water in the hour, and will convey a load of 236 tons at a speed of 40 miles an hour, or a load of 181 tons at a speed of 60 miles an hour. The weight of this engine empty is 31 tons; of the tender 8½ tons; and the total weight of the engine when loaded is 50 tons.

The weight of engines of this class is, says Mr. Bourne, "very injurious to the railway; bending, crushing, and disturbing the rails, and trying severely the whole of the railway works. No doubt the weight might be distributed upon a greater number of wheels, but if the weight resting on the driving wheels be much reduced, they will not have sufficient bite upon the rails to propel the train without slipping. This, however, is only one of the evils which the demand for high rates of speed has produced. As, however, the attainment of a high rate of speed requires much power, and consequently much heating surface in the boiler, and as the number of tubes cannot be increased without reducing their diameter, it has been found necessary, in the case of powerful engines, to employ tubes of a small diameter, and of great length, to obtain the necessary quantity of heating surface; and such tubes require a very strong draught in the chimney to make them effective.*

We conclude with a few of the more striking Statistics of Railways, during the Ten Years from 1855 to 1865.

Mr. Robert Stephenson, in 1855, described our Railways as spreading like a network over Great Britain and Ireland, to the extent of 8,054 miles completed. In length they exceeded the ten chief rivers of Europe united; and more than enough, if single rails were laid, to make a belt of iron round the globe.

The Railway works had then penetrated the earth with tunnels to the extent of more than fifty miles. There were eleven miles of viaduct in the vicinity of the metropolis alone. The earthworks measured 550,000,000 cubic yards, which would form a pyramid a mile and a half in height, with a base larger than St. James's Park.

Eighty millions of train miles were run annually on the Railways, 5,000 engines and 150,000 vehicles composed the working stock; the engines, in a straight line would extend from London to Chatham; the vehicles from London to Aberdeen; and the Companies employed 90,400 officers and servants; while the engines consumed annually 22,000,000 tons of coals, so that in every minute of time, four tons of coal flashed into steam twenty tons of water, an amount sufficient for the supply of the town of Liverpool. The coal consumed is almost equal to the whole amount exported to foreign countries, and to one half of the annual consumption of London.

* *Catechism of the Steam-engine*, 1856.

Fortunately, the Railway System, since the introduction of the Locomotive engine, by Stephenson, gave it vitality, has been a complete success, in the reproduction of capital, in the enormous saving in the cost of transport; in the facilities it affords for the development of mines, and of nearly all branches of national industry.

The consumption of fuel had been diminished. Before 1829, it required about 5 lbs. to carry one ton a mile. In that year George Stephenson reduced it to 2·41 lbs. of coke. It can now be brought to less than a quarter of a pound per ton per mile.

In 1854, 11,000,000 of passengers were conveyed on Railways; each passenger travelled an average of twelve miles. The old coaches carried an average of ten passengers, and for the conveyance of 300,000 passengers a day of twelve miles each, there would have been required at least 10,000 coaches and 120,000 horses.

The Railway wear and tear is great: 20 tons of iron require to be renewed annually; and 26,000,000 of sleepers annually perished; 300,000 trees were annually felled to make good the loss of sleepers; and 300,000 trees can be grown on little less than 5,000 acres of forest land.

The Acts of Parliament which Railways had then been forced to obtain, cost the country 14,000,000*l.* sterling; and the legislation of Parliament had made Railways pay 70,000,000*l.* of money to landowners for land and property; yet almost every estate traversed by a railway has been greatly improved in value. Railway accidents occurred to passengers in the first half of 1854 in the proportion of one accident to every 7,195,343 travellers.

The results of Railways were then (in 1854) astounding: 90,000 men were employed directly, and upwards of 40,000 collaterally—130,000 men, with their wives and families, represent a population of 500,000 souls; so that 1 in 50 of the entire population of the Kingdom might be said to be dependent on Railways! The annual receipts on Railways had reached 20,000,000*l.*, or nearly half the amount of the ordinary revenue of the State. Had Railway intercourse been suspended, the same amount of traffic could not have been carried on under a cost of 60,000,000*l.* per annum; so that 40,000,000*l.* a year were saved by Railways to the public; "time is money," and in point of time a further saving was effected; for on every journey averaging 12 miles in length, an hour was saved to 11,000,000 of passengers per annum, which is equal to 38,000 years in the life of a man working eight hours a day; and allowing an average of 3*s.* per diem for his work, this additional saving was 2,000,000*l.* a year.

In 1865, the capital expended in this country on Railways had been upwards of three hundred and eighty-five millions sterling, or nearly half the National Debt.* This amount had been devoted to the construction of eleven thousand five hundred miles of Railway in the British Islands, which are now open for traffic. The works executed in connexion with these undertakings, says the *Railway News*, have been of extraordinary magnitude. Navigable rivers and even arms of the sea have been crossed over; hills have been pierced by tunnels and viaducts, embankments and cuttings made in all directions. All this has been accomplished within the lifetime of a single generation of men, who have not only executed the work, but pro-

* *Parliamentary Return.*

vided the means out of their own private resources, without any assistance whatever from the funds of the State. In a word, the Railway System of England has been the spontaneous outgrowth of the native industry, energy, and enterprise of its people. The rapid growth of the Railway System of the United Kingdom to its present dimensions must be accepted as a remarkable proof of the progress of the country. During the 41 years which passed since Stephenson ran his first train on the Stockton and Darlington line, the Railways of the kingdom absorbed 500,000,000*l.* of capital, and extended over more than 14,000 miles. In 1865, the length of lines was 13,289 miles, of which more than a third were single lines, and the rest double; this was an increase of 500 miles over the preceding year. The main trunk lines have now been laid out, and little more is wanted than lines and branches.

The statistics of a year's work on the existing Railways afford a striking illustration of the constant activity of our population, as well as of the important part which this means of communication plays in the social and industrial life of the nation. We find that in 1865, 3,448,509 passenger trains, carrying 251,862,715 passengers, travelled 71,206,818 miles; while 2,108,198 goods trains transported 15,179,000 horses, dogs, cattle, and other stock, 77,805,786 tons of minerals, and 36,787,638 tons of general merchandise over 68,320,309 miles. Thus, taking passenger and goods trains together, it appears that they travelled in the 12 months as great a distance as from the earth to the sun, and about half the way back again. In order to do this the Companies had to keep a rolling stock of 7,414 locomotives, 17,997 passenger coaches, and 233,260 goods waggons, trucks, &c. This, together with the cost of permanent way, management, servants, lawyers' bills, and compensation for accidents, involved an expenditure of 17,211,000*l.* On the other hand, there was received for passengers' fares 16,572,000*l.*, and for goods 19,318,000*l.*, together 35,890,000*l.*, which leaves a balance of profit for the Companies of about 18,679,000*l.*

What is implied by the Railway Interest—its hold on the country and monetary value—may be gathered from the following statistics:—The first Railway in the United Kingdom in length and revenue is the London and North-Western, extending over 1,274 miles, and drawing 6,276,879*l.* of annual receipts. Next comes the Great Western, 1,256 miles long, with 3,585,614*l.* of annual receipts; followed by the North-Eastern, 1205 miles and 3,529.288*l.* annual receipts; the Great Eastern, 756 miles, and 1,690,269*l.* receipts; the North British, 723 miles, and 1,309,865*l.* Midland, 700 miles, and 2,729,131*l.*; the London and South-Western, 576 miles, and 1,477,843*l.*; the Caledonian, 494 miles, and 1,432,445*l.*; the Lancashire and Yorkshire, 431 miles, and 2,150,643*l.*; the London and Brighton, 275 miles, and 1,055,116*l.*; the London Chatham, and Dover, 132 miles, and 446,896*l.* The profits of railway work, however, are not necessarily in proportion to length of mileage or amount of revenue.

Mr. Tidd Pratt states that upwards of 160,000 persons compose the general body of the working men on the Railways of this country. The public has a deep interest in the well-being and contentment of those who have the practical management of the railway traffic of the country, and in their being a faithful, vigilant, and well-conducted class of men, because upon them depends not only the safety of the lives of a great portion of the people of this country, but also the management and regular carrying on the commercial traffic of the kingdom.

The Army, Navy, and Volunteers, are services much indebted for their efficiency to the Railway System throughout the country. It has been stated at a Railwav inquiry, that whereas at one time it took nine days and many marches to bring a regiment from Manchester to London, it could now be accomplished in a few hours. In reference to the Navy, Railways have proved a most valuable boon, inasmuch as through their agency ships can be much more quickly served with stores and ammunition; and it may be truly said that the Volunteers are greatly benefited by the facilities they derive from the operations of the Railway System.

The longest railway in the world is the Illinois Central, which, with its branches, is 731 miles in length, and was constructed at a cost of 15,000,000 dollars.

Since page 317 was printed, stating the highest Railway in the World to be that in Chili, at an elevation of 4,075 feet above the sea-level, the line of Railway which had been in the course of construction for the last eighteen months over Mont Cenis, and which follows in the main the great road of the first Napoleon, was successfully traversed on the 21st of August, 1867, over its whole length, or 48 miles, by a locomotive engine. A train, composed of an engine and two carriages, left the St. Michel station at 6.30 A.M.

Mr. Fell's system consists in the application of a central double-headed rail placed on its side in the middle of the way, and elevated about 14 inches above the ordinary rails. There are four horizontal driving-wheels on the engine, under the control of the engine-driver, which can be made by pressure to grasp the central rail so as to utilize the whole power of the engine, and so enable it to work up incredible gradients without slipping. The carriages also have four horizontal wheels underneath, which, with the central rail, form a complete safety-guard. In addition to the ordinary break there are breaks upon the central rail. It would appear, therefore, impossible for the engine or carriages to leave the rails where the central one is laid.

After leaving the deep valley in which St. Michel is situated, the line passes by a gradient of 1 in 30 to the Pont de la Denis, where an iron bridge spans the River Arcq, near the site of that which was carried away by the inundations of 1866.

The first very steep gradient of 1 in 10 was seen in passing Modane, and, foreshortened to the view, appeared on the approach as if impossible to surmount; but the engine, the second constructed on this system, had already proved equal to the task on the experimental line, and, clutching the central rail between its horizontal wheels, it glided quickly up, under a pressure of steam of not more than 80 lb. to the square inch, without apparent effort. The progress was purposely slow, because no engine or carriage had previously passed over the line, and also to give opportunity for examining the works. The train entered Lanslebourg station under a triumphal arch, having accomplished 24 miles of distance, and attained an elevation of 2,100 feet above St. Michel.

From this point the zigzags of ascent commence, and the gradients over a distance of four miles were for the most part 1 in 12. Looking down from the train near the summit, as if from a balloon, four of the zigzags were visible at the same instant to a depth of 2,000 feet. The power of the engine was satisfactorily tested in this ascent, and the summit was reached under salvoes of artillery from an improvised battery, and amid the cheers of French and Italians who had gathered to welcome the English on the frontier. The engine again came to a stand under a triumphal arch, at an elevation of 6,700 feet above the sea. Flags of the three nations, and a silk flag specially presented by Signor Ginaoli to Mr. Fell, waved over a sumptuous breakfast, also provided by that gentleman. The hospice, the lake, and the plateau of the summit, surrounded by snow-clad peaks and glaciers, rising to an elevation of from 10,000 feet to 13,000 feet, were passed, and the portion of the descent commenced from the Grand Croix. The railway here follows the old Napoleon road, which was abandoned long since for diligence traffic on account of the dangers from avalanche. Masonry-covered ways of extraordinary strength had here been specially provided for the railway.

The descent to Susa was a series of the sharpest curves and steepest gradients, on which the central rail had been continuously laid. Thus was completed a journey unexampled in its character both as respects the steepness of gradients, the elevation of the summit level, and the ease with which the curves and precipices were overcome.

To the foregoing account of the development of railways, some allusions to the changes in the most recent times must now be added. First, the railway over the Mount Cenis has been superseded by a tunnel, 8 miles in length, pierced through the mountain called the Grand Vallon. What renders the making of this tunnel remarkable is that it is bored through hard rock, and is provided with no natural ventilating shafts. The work was begun in 1857, completed in 1870; and was performed for the first four years by manual labour, but afterwards by specially-constructed boring-machines. It cost about 3,000,000*l.* sterling; but, from the experience acquired in its construction, it was calculated that similar work could afterwards be done for about half the cost. And, indeed, other very long tunnels have since been finished or projected, as, for instance, the St. Gothard—by which Italy and Switzerland are united by another route of railway. Still bolder is the enterprise—of which the initiatory stages are now in progress—of driving a tunnel beneath the Straits of Dover, so that England and France may be in direct railway communication. Fig. 14 is a chart of the proposed tunnel, which it is intended to drive through the lower or grey chalk—a formation known to extend beneath the bed of the Channel from shore to shore.

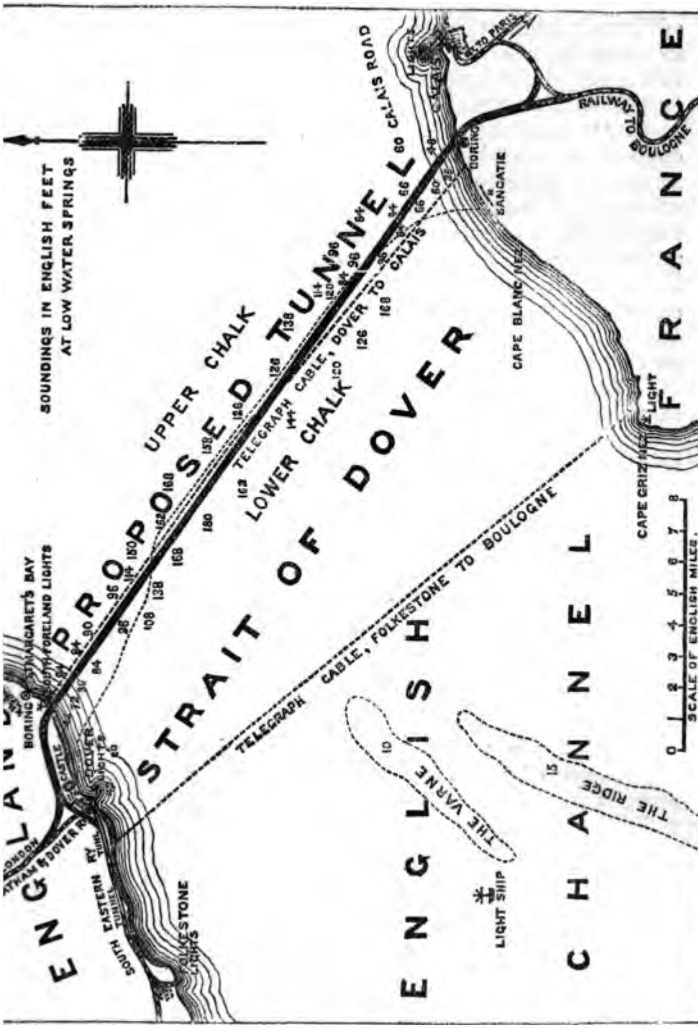


FIG. 14.—CHART OF THE CHANNEL TUNNEL.

It would, of course, be easy to extend the statistical account of British railways given on page 324 and following pages, so as to include the most recent returns; and although the figures would, in perhaps every case, show an increase, and, in some cases, a striking increase, they would probably have no particular interest for readers not specially devoted to the cultivation of this kind of science. The figures already given sufficiently serve to illustrate the magnitude of railway enterprise in this country. Nor will it be necessary to point out the extensions of the various railway systems which have been made either in Britain or abroad, although it may be noticed, in passing, that the Underground Railway in London has been extended beyond the limits named on page 315. Mr. Fell's system of railway has been applied in several localities where previously the construction of railways had never been thought of. The Righi in Switzerland, and Mount Vesuvius, are cases in point. The "Atmospheric" and "Pneumatic" railways, mentioned on pages 314 and 315, are abandoned, so far as regards the method of propulsion by atmospheric pressure or compressed air. The *broad gauge* has practically been given up upon the Great Western Railway, the rails being in some places retained in addition to those of the usual gauge, only in order that the existing rolling-stock constructed for the broad gauge might not be useless.

The application of steam, or other mechanical power, to the tram-cars, which now ply in the streets of all the large towns of Europe and of North America, is commencing; and when it is successfully carried out we may consider the result as essentially an extension of railways.

Some of the valuable improvements in the fittings and mechanism of the "rolling-stock," and which have tended towards the increased safety and comfort of railway travelling, will doubtless be known to our readers. We need but allude to the *continuous brakes*, the sleeping carriages, and Pulman cars; all of which are of recent introduction on British railways. The locomotive itself, though essentially the same as that already represented, has been in some respects modified in the adjustment of its parts, at the dictates of experience, and in more exact adaption to the special work required on different lines. Fig. 15 represents one of the latest types of locomotives, as constructed by the Great Northern Railway Company. This engine was put upon the rails for the first time to be shown at the celebration of the "Stephenson Centenary" at Newcastle, on the 9th of June, 1881, where the best and most modern typical locomotives were exhibited by the chief railway companies of England and Scotland. The engine shown in our figure has outside cylinders, and a single pair of driving wheels of very large diameter, namely, 8 feet 2 inches, so that each complete movement of the pistons will carry it forward nearly 26 feet. It is of the kind called a *bogy*-engine—the name bogy designating a framework capable of a certain amount of horizontal movement with regard to the engine, and bearing four wheels, as seen in the front part of our cut.

With regard to the question as to which is the longest and which the highest railway in the world (pages 317 and 327), it

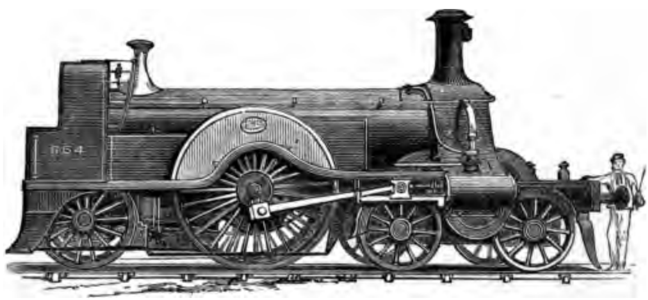


FIG. 15.—GREAT NORTHERN RAILWAY EXPRESS PASSENGER ENGINE.

may be stated that perhaps the Union Pacific line, from Omaha to Ogden, in the United States, a distance of 1,032 miles, may bear the palm for length. This line has been, within the last few years, supplemented by another—the Central Pacific—which carries the communication from Ogden to San Francisco, a further distance of 889 miles; so that a person may now travel in one and the same carriage completely across the American continent, from ocean to ocean. The whole distance from New York to San Francisco is 3,215 miles, and the journey occupies a week, the trains travelling night and day. The line between Omaha and San Francisco traverses some extraordinary scenery of wild and varied character. At one point the line crosses the Black Hills at an elevation above the sea-level

FIG. 16.—"CAPE HORN."

of 8,242 feet; and this is probably the greatest elevation yet reached by any railway. The line shows in places some of the most daring achievements of railway engineering. There is, for instance, the locality represented in Fig. 16, where the line is carried along the nearly vertical side of a mountain called "Cape Horn," at the height of 2,500 feet above the bed of the stream below.

A RAILWAY CUTTING.

IRON SHIPS OF WAR, GUNS, AND ARMOUR.

A CENTURY has rolled away since Edmund Burke, in fierce invective, taxed the invention of men with "sharpening and improving the *mystery of murder*, from the first rude essay of clubs and stones, to the present perfection of gunnery, cannoneering, bombarding, mining." Mr. Carlyle has said, in a more kindly vein :—"The true Epic of our time is not Arms and the man, but Tools and the man —an infinitely wider kind of Epic." Our machinery has been the making of us ; our ironworks have, in spite of the progress of other nations, still kept the balance in our hands. Smith-work in all its branches of engine-making, machine-making, tool-making, cutlery, iron ship-building, and iron-working generally, is our chief glory. All that we can attempt within our limited space is to *focus* the constructive character of these grand inventions. First, as to Iron Shipbuilding : "The future destiny of nations," says Mr. Fairbairn, "seems to be involved in the consideration of iron and its application to an entirely new system of construction in vessels of war, calculated to unite with equal facility the powers of attack and defence."

The history of Iron Ships dates from 1787, when Wilkinson, of Bradley Forge, built a canal-boat, drawing eight or nine inches when light. In 1815, Jevons, of Liverpool, built a small iron boat, and sailed her on the Mersey ; and in 1821, Aaron Manby designed an iron sea-going steam vessel, which was built by the Horseley Company, and sent to London in sections, re-constructed in one of the docks, and navigated across the British Channel to Havre, and thence up the Seine to Paris, under the command of Admiral Sir Charles Napier.

A second vessel was built in parts, and put together at Charenton. About 1830-38, an iron vessel, the *Manchester*, 84 feet long by 14 feet beam, with recessed paddle-boxes, was built at Manchester; and shortly after Messrs. Laird built the *Alburka*, a small iron vessel, for the Landers' exploration of the Niger. The strength and sailing qualities of these vessels were confirmatory of the great superiority of iron over wood for shipbuilding.

In 1834, the Admiralty undertook experiments to ascertain the resistance of iron plates to shot, when they condemned the use of iron of the thickness used for shipbuilding, and fell back upon the use of wood. In 1835, similar experiments were made at Metz, upon which General Du Bourg concluded that "of all steam vessels the most unfitted are those of iron." In 1839, Laird built the *Nemesis* and the *Phlegethon*, which took an active part in the Chinese war of 1842; they were of 660 and 570 tons burden respectively, and proved the power of iron vessels to bear the concussion of heavy guns fired from their decks. Next various target and other experiments were made; and General Paixhans expressed an opinion that vessels built of iron might be made shot-proof; but Sir Howard Douglas considered the proposition absurd.

During the Crimean war, Napoleon III. reopened the question by the construction of iron-plated floating batteries, when the shells and molten shot were destructive upon wooden sides. Next, the Minié rifle outranged field artillery: Whitworth invented a rifle more accurate and more powerful than Minié's; and Armstrong a rifled cannon that pierced every obstacle;—his 400-pounder, smooth bored, with 850 lb. bolt, and a charge of 50 lbs. of gunpowder, penetrated a target of 4½ inch plates, and 18 inches of solid teak backing. Whitworth's 120-pounder muzzle-loader rifled, with a flat ended cylindrical shell of homogeneous metal, and a charge of 27 lbs., pierced a 4½ inch target, at a range of 800 yards. It was evident that wooden ships could not stand such artillery. M. Dupuy de Loine, at the instigation of the French Emperor, designed, and constructed the *Gloire*, a timber-framed ship, plated with iron-rolled plates, 4½ inches thick; her plates weigh 800 tons, she throws a broadside weight of metal of 425 lbs., and carries 36 French 50-pounders. Her submersion is very great—the port sills hardly 7 feet out of the water, and the weight of her armour shakes her wooden frame. Next our Admiralty built the *Warrior*, a far greater success than the *Gloire;* her frame is of iron, with an iron inner skin, a backing of 18 inches of solid teak; and a broadside armour of 4½ inch plates, about one-third of her length. She had cross bulk heads of iron, fore and aft, she was built to carry 50 guns, but has only 13 68-pounder broadside. Our Admiralty then cut down some of our timber ships, and plated them with armour, and the *Royal Oak* surpassed the *Gloire:* she throws 400 lbs. more broadside of metal, but steams 0·7 knots less, and is 1,000 tons less displacement. But the *Gloire* and *Warrior* are only partially protected; and entire protection has been since substituted in all the frigates commenced. The extra weight of armour, however, involves the necessity of a vessel nearly twice the tonnage to carry the same battery; and this size and the extra draught of water are serious drawbacks.

The Cupola-ship or Turret-ship, designed by Captain Coles, supplied the wants required: the weight of armour on the top-sides is reduced; there are great facilities for working heavier guns, and moving them mechanically; and much greater range is obtainable, as well as high velocity, and keeping down the tonnage. Captain Coles claims for cupola-ships the power of carrying the heaviest ordnance that can be manufactured; throwing a far heavier broadside in proportion to tonnage, with greater rapidity and precision of fire, and greater extent of training. These vessels have superior speed, are better sea-going ships, are shorter and easier for turning and docking, spread more canvas, burn less fuel, and afford less chance of fouling the screw from there being no lower rigging; the ventilation is better, the crew are berthed more comfortably, the defensive power is greater, and the cost less. Still, it is contended that a man-of-war should be iron-clad throughout; and accordingly our Admiralty built the *Minotaur*, which is iron-plated from stem to stern; 100 feet length, beam 59 feet 3 inches, tonnage 6,621—only 50 tons more than that of the *Warrior;* she draws 26 ft. 2 in. water, and steams 14·3 in.; carries 13 68-pounders and 4 110-pounders on her broadsides, 704 men, and throws a broadside equal to 1,324 lbs.

Next, Mr. E. J. Reed, who had received the appointment of Chief Constructor of the Navy, submitted plans for the construction of armour-plated wooden ships of small dimensions and light draught; these were accepted: and he built the *Enterprise*, a sea-going ship, plated with 4½ inches of armour, with an upper deck nearly 8 feet, and a gunwale nearly 12 feet out of the water; well ventilated; having guns, engines, boilers, funnel, rudder, steering-wheel, shell rooms and magazines protected, and fitted with masts and sails. Mr. Reed has also built the *Favorite*, in opposition to which Captain Coles has designed the *Naughty Child*, said to out-distance Mr. Reed's system; for, with the same dimensions and the same speed, Captain Coles carries a crew of 40 less men, and throws a much heavier broadside—900 lb. against 356 lb. Nor is this all: the *Naughty Child*, working her guns upon the central system, has for her after-guns an arc of training equal to 154 deg., and for her foremost guns an arc of training equal to 310 deg.; while the *Favorite* has an arc of training of 50 deg. for her broadside guns, and of 12 deg. for guns when placed in her cross bulksides. Again, the guns of the *Favorite*, being placed nearly close to the broadside, have their muzzles immersed in water when the ship is inclined at an angle of 20 deg.; while the *Naughty Child* has her guns in a turret which is several feet within the line of the broadside, and consequently the gun's muzzle is clear of the water. An objection to the *Favorite* is the great area of her square battery, which presents a large surface for the enemy to aim at: whereas the areas of the *Naughty Child's* shields are much less, and would oblige the enemy to divide his fire and attention.

There are two great systems of arranging the iron intended to protect the sides of ships, the English and the American—the former by solid rolled plates in front, with wooden backing more or less interlaced with iron, and behind all an iron skin; the latter by laminated armour—*i. e.*, by thin plates laid one upon another till the required thickness is obtained; after that the backing and skin. For the attack there are likewise two systems of artillery fire—the English method of "punching" or driving shot and shell through the ship's defences, piercing holes in her sides to admit the water, destroying her guns and crew, and sinking or setting her on fire; and the American "racking"—*i.e.*, hurling heavy missiles against the opposing vessel with comparatively low velocity, thus shaking her sides, and perhaps in time shattering her plates. It appears most probable that the construction of the respective targets has governed the means employed for attacking them; but the Shoeburyness experiments have conclusively proved that English guns can pierce American ships' sides, while the effect upon our targets of the huge round shot projected from American ordnance remains to be shown.*

The history of the armour and armament of the broadside gun ships of our iron-clad fleet, may be summed up as follows. The *Warrior* and others designed about the same time were built to carry the then most powerful gun—the 95 cwt. 68-pounder, and were clothed with proportionately defensive armour of 4½ inches in thickness. But they were simply "box" armoured ships, carrying their guns behind their armour only amidships, and leaving their ends, with the water-line before and abaft the central box, unprotected by armour. With the *Hector* and *Valiant* class this defect was in a manner remedied, the former carrying a band of plating entirely round the main or gun deck, and the latter giving more protection to the water-line. Then came the wholly armoured ships, of iron and wooden construction respectively; the former represented grandly by the *Achilles*, *Minotaur*, &c., and the latter by the squadron of the *Caledonian* and *Royal Oak* class. With the iron ships was introduced an increase in the armour-plating to 5 and 5½ inches, and the *Achilles* was given as her armament the new wrought-iron 9-inch smooth-bore or "Somerset" gun in the place of the cast-iron 68-pounder and the 110-pounder breech-loading Armstrong, the latter never having been, at close quarters, with rapid firing, considered a match for the old cast-iron smooth-bore 8-inch. The trials of the *Royal Sovereign* and the feats of the American Monitors naturally gave birth to enlarged ideas on the arming and clothing of iron-clads. The turrets of the *Royal Sovereign* carried 12-ton guns, but it was also evident they could carry and work ordnance of double the weight; while the tremendous shot-resisting power which they must possess with their 10 inches of iron round the face of the turret round the gunports was very materially increased by the shot-deflective power given by their circular form.

Turret ships, low down in the water, present small marks, but it must not be forgotten that their decks are vulnerable, and at close range the taller-built broadsiders would send shot and shell through the decks, tearing a passage downwards and outwards below the water-line. A broadside ship carrying turrets also according to Mr. Reed's new plan will have this advantage, that as long as she steams straight at an enemy her

* *Times* Journal.

sloping bows will be almost invulnerable, and once within short range the number of broadside guns must tell. Commander John Rodgers, whose rough, sailor-like evidence before an American Committee in 1864 should be better known in England than it is, gave it as his opinion that turrets were better against ships, broadsides against forts; but his experience was confined to the laminated armour of the day, and, though the 15-inch gun on board his ship, the *Weehawken*, "broke a hole in the side of the *Atlanta* some 4 feet or 5 feet long, knocked in about a couple of barrels of splinters of wood and iron, wounded a whole gun's crew, and prostrated between 40 and 50 men, including those that were wounded," it must not be forgotten that the inclined sides of the *Atlanta* were protected by only 4½ inch thickness of laminated iron, a structure perfectly vulnerable to our old 68-pounder smoothbore, with a cast-iron shot.*

For some years past, in the progress of Gunnery, we have seen smooth-bored guns succeeded by rifled ordnance of strange powers and perpetually increasing dimensions; iron plates growing from a thickness of an inch and a half to that of 11 inches, and targets built up layer by layer till they arrived at the immense bulk intended for the defences of the *Hercules*, nearly four feet and a half of combined wood and iron. The *Hercules'* armour-plates were manufactured by Brown and Co., of the Atlas Works, Sheffield, where have since been rolled 13½ inch plates; and their machinery is capable of rolling plates of even greater thickness, and of cutting and shaping them afterwards. The practical result of the gun campaign of the year 1866 may be summed up in a few words—it consists in the adoption of what is now called the Woolwich, but what was previously known as the French gun. The *Hercules* target was subjected to the fire of three Armstrong 300-pounders or 12-ton guns, fired with 300 lb. rifled projectiles, and charges of 45 lbs., 55 lbs., and 60 lbs. of powder, when it proved quite impenetrable by any single shot. Subsequently, the 600-pounder Armstrong, or 22-ton gun, was brought to bear against it at 700 yards range, with rifled projectiles of from 575 lbs. to 585 lbs. weight, and 100 lbs. of powder, charges altogether unprecedented in any rifled gun. The target was still victorious, except where two shots happened to strike close together. The *Hercules* target is the only structure which has

* *Times* Journal.

foiled every attempt to penetrate it with a single shot. The exterior plates, 8 inches and 9 inches thick, were indeed pierced, but if the target opened its mouth it was to swallow up the huge projectiles one after another, till a space of 18·2 feet by 8 feet had received blows amounting to upwards of *seventy thousand foot tons*, and had only been penetrated once when a second shot struck close to one which had gone before. In its thickest part this target had 11½ inches of iron and 40 inches of wood, besides various iron ribs to bind the whole together.

The *Medusa*, built by Messrs. Dudgeon, her engines by James Watt and Co., is an armour-clad gunboat, 190 feet in length. Her hull is built of iron, with eight water-tight compartments, and is covered in with ¾-in. iron-plated deck, on which is laid the usual wood planking. Round the water-line of the hull is fixed a belt of armour-plating 4½-in. thick, and 4 ft. wide. The stem of the ship is fitted on the "ram" principle. In a central position on the hull is built up a square armour-cased battery, covered with 4½-in. armour-plating, and pierced with eight gun-ports. This battery mounts four ten-ton rifled Whitworth guns. The engines are ordinary direct acting, horizontal, the cylinders of 34 in. diameter, and the stroke 21 in. They drive a pair of independently working screws of 7 ft. 6 in. in diameter, and 11 ft. 6 in. pitch. The draught of water of the *Medusa*, with all on board and complete for active service, is stated at 8 ft. forward and aft.

The importance of having the vessels of our future Iron Fleet constructed on the double-bottom or unsinkable principle, is now admitted. The *Bellerophon* is constructed with water-tight internal walls, completing the double bottom; and thus is, in fact, a double ship from end to end. Unlike a wooden vessel of war, the bottom of an iron vessel is so weak in comparison with its other parts, and so liable to injury, that unless the ship is divided internally into numerous independent compartments or chambers, a comparatively slight touch of a rock, or other such injury below water, would expose her to the risk of almost instant destruction. In the new iron-cased ship *Bellerophon*, throughout the entire central portion, in which the engines, boilers, magazines, &c. are placed, the bottom of the ship is double, the inner and outer bottoms or hulls being placed from three to four feet apart, in order that there may be ample space between for cleaning and painting both when desirable.

The *Miantonomoh* (wood), the first American turret-ship that has visited the shores of Europe as a war-machine, for close heavy fighting appears perfect. The 15-inch Rodman guns are mounted on carriages and slides, very superior to anything before seen in England. The turrets are believed by the officers of the ship to be invulnerable to any gun that can be carried afloat. The sides of the ship are so low in the water that nothing remains for an enemy to hit but the turrets, and they, with their 250-pounders, hit very hard in return. Between decks the visitor is at first bewildered by the quantity of machinery scattered about. There are no less than seventeen steam-engines, large and small, on this deck. Six drive the blowers which receive the air from the main air-shaft, and distribute it along shaftings, and up through gratings in all parts of the ship; for at sea the ship is necessarily battened down fore and aft. Her guns, although of the immense diameter of bore of 15 in. at the muzzle, (the outer diameter was only 21 in.,) but the breech is immensely weighted with metal. The gun, however, is so evenly balanced upon its trunnions, that the captain of the gun can elevate or depress it with one of his fingers only on the screw-lever. During a visit of the Lords of the Admiralty to the *Miantonomoh*, the first gun fired was charged with a 35-pound powder cartridge and a *sabot* live shell, at extreme elevation. The effect was very grand as the vast globe of metal propelled from the mouth of the gun with a deep hoarse roar, went hurling on its course until it fell at an estimated distance of about 3,500 yards from the ship.

The following episode from the War of Secession in America, is calculated to show the terrific power of the iron-clad floating batteries in practice :—

On the afternoon of March 8, 1862, the *Merrimac*, one of the frigates which had been sunk in Norfolk Harbour, on the 21st of April, 1861, but which had been raised, repaired, replated with iron, and fitted with two iron beaks at the stem, attacked the Federal ships in Hampton Road, at the mouth of the James River. She was mounted with ten very large guns. The *Merrimac*, after firing two guns, ran into the *Cumberland*, a sloop-of-war carrying 24 heavy guns, striking her with the sharp bows, and making a large hole at the water mark. The *Cumberland* immediately began to sink, when the *Merrimac* backed a little, and ran into her a second time, making another large hole, and the

Cumberland heeled over, and finally sank. About 130 men were destroyed, most of them by drowning! The *Merrimac* next attacked the *Congress*, a 50-gun frigate, which, in less than an hour, hoisted a white flag. The officers and marines were taken prisoners, but the seamen were allowed to escape. At night the *Congress* was set on fire, and at midnight blown up. The *Minnesota*, a Federal steamer, carrying 40 guns, got aground, and could render no assistance. In the evening the *Monitor* arrived from New York, but was not then prepared to take part in the action. The *Monitor* was the first specimen of those iron-clad floating batteries, of which several others have since been constructed. It had a turret, which was in fact a revolving bomb-proof fort, carrying two 11-inch guns. On the morning of the 9th, the *Merrimac* came out and attacked the *Minnesota*, which would probably have been destroyed, had not the *Monitor* engaged the *Merrimac*. The action lasted a considerable time, the *Merrimac* both firing and attempting to sink the *Monitor* by running into it. The result was, that the *Merrimac*, considerably injured, was compelled to retreat into Norfolk Harbour; and on May 19 following, the Federals having taken possession of the City of Norfolk, the formidable *Merrimac* was blown up by the Confederates, on the opposite side of Elizabeth River.

Composite-built hulls for gunboats, is a new phrase in naval architecture.* A composite twin-screw gun-vessel has been

* After much controversy, it has been decided that to Mr. Assheton Smith, of Tedworth, is due the invention of the Gun-boats now generally introduced into the English and French navies; and of which our fleet stood in such sore need while it lay helplessly idle off Cronstadt during the Russian war. The origin is thus told in Mr. Smith's Memoirs :—" Some years ago, when the Duke of Wellington was staying at Tedworth, Mr. Smith communicated to the great captain his notions respecting gun-boats. The Duke listened, as he always did, with attention to the squire's remarks, but gave no opinion at the time respecting the subject of them. Next morning as they were both walking on the terrace after breakfast, the Duke said 'Smith, I have been thinking that there is a good deal in what you said last night about those gun-boats, and I should advise your writing to the First Lord of the Admiralty,' then Lord ———, which Mr. Smith accordingly did, but received no answer. Some time after, when walking down Regent-street, he met the First Lord, whom he knew personally, and asked him, in the course of conversation, if he had received his letter containing suggestions for the introduction of gun-boats. The First Lord replied that he had, but that the Admiralty could not pay attention to all the recommendations made to them. Upon this, Mr. Smith took off his hat, and turning away from him with a stately bow, observed, 'What His

built by Messrs. Dudgeon, of Millwall, a firm to whose unaided exertions and enterprise the country owes the introduction of the twin-screw principle of propulsion into the Royal Navy. This new vessel, the *The Eugénie*, has a tonnage of 315, builders' measurement, with an extreme breadth of 22 ft., and a moulded depth of 10 ft. Her draught of water, with crew, stores, armament, and everything on board, is 7 ft. 6 in. Her guns on board consist of one 70-pounder rifle muzzle-loader, one 40-pounder breech-loader, and two 20-pounder breech-loaders. She has a frame of angle-iron of 3½ in. by 3 in., with diagonal tie-stamps 6 in. by 6-8ths, the latter extending from the bilge to the upper stringer, and forming squares of about 8 ft. apart. The upper deck has also tie-plates of similar strength. The iron frame is completed with the usual centre and floor plates, and wrought-iron deck beams, and has five water-tight bulk-heads. The stem and sternpost are built up of wood, and the entire hull is sheathed with two thicknesses of teak of 2¾ in. and 2 in. thickness. Her machinery consists of two pairs of direct-acting inclined cylinder-engines of 30-horse power, nominal, each. The cylinders stand at an inclination of 35 deg., almost touching each other at the top; and the space between them below is occupied by the condenser and hot well, which also forms part of the framing of the engines. The cylinders have a diameter of 25½ in., and a length of stroke of 14 in. The screw shafting is carried out under each quarter in two brass tubes, each of these brass tubes being enclosed in other tubes, which are built out as part of the iron frame of the ship. Both are finally enclosed in the outer wooden tube on the plan patented by Messrs. Dudgeon. The shafting carries two three-bladed screws, each having a diameter of 5 ft. 10 in., and a pitch of 9 ft. 6 in. Its rate of speed, by a vessel of 315 tons, having a propelling

Grace the Duke of Wellington has considered worthy of attention, I think your Lordship might have at least condescended to notice.' Yet within ten years from this interview, one fleet of our formidable 'vixen' craft was at sea, and another being fitted out for service. Little perhaps did the spectators, who proudly gazed upon the goodly swarm of these dark hulls at Spithead, know that the projector of them was a foxhunter, and that to a foxhunter's clear head and far-seeing eye was the gallant Wildman mainly indebted for 'the single little vessel' (the Staunch) with which he demolished four large junks in the Chinese seas. Yet it has been said that Mr. Smith was a foxhunter and nothing more. The verdict of true Englishmen will be very different."

power of only 60-horse, has never yet been equalled by any gun-vessel of similar tonnage and power afloat.

The British navy now possesses two very formidable armoured ships in the *Devastation* (Fig. 17) and the *Thunderer*. Each of these has two turrets, 24 feet 3 inches in diameter inside, constructed of teak and iron. Inside there is, first, a lining of 2⅝ inch iron plates; then 6 inches of teak, in iron frames; next, 6-inch armour plates; then 9 inches of teak;

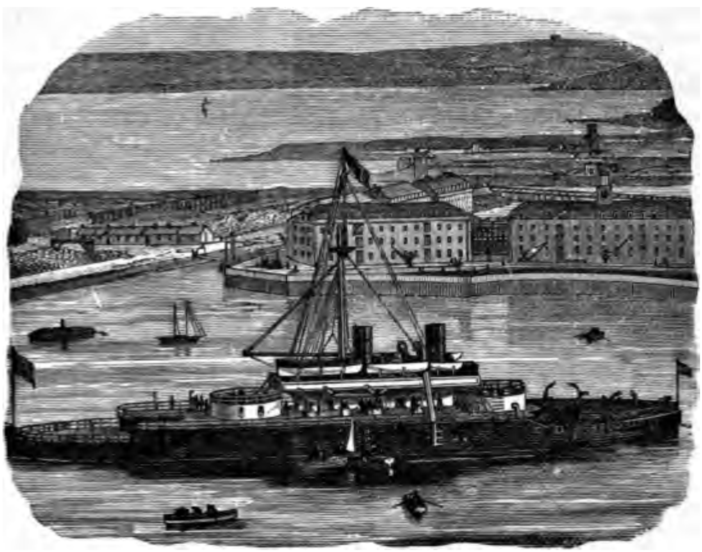


FIG. 17.—H.M.S. *Devastation* IN QUEENSTOWN HARBOUR.

and, outside of all, 8 inches of armour-plates. Each turret carries two 35-ton Fraser muzzle-loading rifled guns, and can be turned either by hand or by steam power. These vessels are propelled by twin-screws, worked by independent engines, capable of indicating 5,600 horse-power. Each ship can carry no less than 1,800 tons of coal, and can steam at the rate of nearly 14 miles an hour. It is 285 feet long, 58 feet wide, 26 feet draught. The hull is double, the distance between the outer and inner skins of the bottom being 4 feet 6 inches, and the outside very heavily plated. As there are no masts or sails, a clear range is afforded for the guns fore and aft.

We now proceed to the question of *Forts*. The stone sea-ports of Sebastopol had beaten off the combined navies of England and France, and borne almost unscathed the impact of 50,000 shot and shell, according to General Todleben's estimate. Stone, therefore, and, above all, granite, seemed sufficient security against attack from the sea. Experiments have since taught us that iron ships can be constructed capable of carrying enormous guns, and of keeping the sea in the roughest weather; and since granite has been found to crumble before 300-pounder shot and shell, we now know that iron must be met by iron, that *forts must be plated as well as ships*. The most important experiment carried on against granite was that by the Ordnance Select Committee in December, 1865, against a granite casemate for two guns, erected at Shoeburyness to test the resistance of iron and granite. There were two iron shields on the east and west embrasures. That on the east was 21 in. thick. In front three slabs of rolled iron 4 in. thick, behind them 8 in. in depth of $\frac{7}{8}$ in. iron plates placed vertically on their edges, then a 2-inch solid plate, next 6 in. of teak, and finally a 1-inch iron plate; the whole bolted together from front to rear, and secured to a strong iron girder-frame, the base of which turned back horizontally, and was strongly attached by nuts to vertical bolts let into the granite. The west shield consisted of a solid rolled iron plate $13\frac{1}{2}$ inches thick, and was carefully secured. The east shield received 13 blows, chiefly from a steel shot of high calibre, amounting, on the whole, to 424 foot tons to every square foot of its actual surface, deducting the porthole. The west shield was struck nine times. The total blows upon it averaged 800 foot tons to every square foot of its surface, deducting the porthole. Both shields continued to afford a fair amount of protection to the guns behind them. Against the granite were fired altogether 65 rounds, giving an average blow of 302 foot tons per square foot of surface, while the average against the iron was 520 foot tons per square foot. Moreover, almost all the shots fired at the iron were of steel, while cast-iron shot and shell were almost exclusively used against the granite. One projectile was on an average planted on every five square feet of iron shield, and on every eight square feet of granite.

The demolition would have caused the abandonment of the two casemates attacked before the firing ceased; they were quite untenable after the 54th hit. The injury done to the stonework was irreparable; nothing short of complete reconstruction would restore it; whereas a structure of iron would admit of easy repair by recasing the wounded parts, which always serve as support, and might be actually rendered stronger than before by the accumulation of thicknesses of plate, and it was observed that the dust, grit, and fine splinters of granite sent into the work were sufficient to amount to annoyance, if not to an actual obstruction of the working of the gun. The experiment has proved that while the attack of a properly-constructed iron-built battery would be hopeless, except with steel or hardened shot, at a range not much exceeding 600 yards, the destruction of a granite fort may readily be effected with cast-iron shot at 1,100 yards. This appears to settle the question of iron *versus* granite, as far as protection to guns is concerned; but there is another aspect of the case which requires consideration. It is now acknowledged that shields are absolutely necessary to the safe working of guns engaged with iron-clad ships.

Engineers of all schools seem satisfied that old strongholds may now be considered to be in their dotage, and that they must be protected by a rising young family of detached forts, built so as to guard their parent as long as possible from rude contact with the besiegers' shot and shell. Further than that, the opinion gains ground that, while brick and stone can be crumbled into ruinous heaps at long ranges, earthworks, unless of huge capacity, are almost equally vulnerable to large shells containing good bursting charges of powder. Iron therefore is loudly called for to protect the guns, and here the controversy of turrets *versus* broadside runs as high as it does in the navy. We have projects for masonry casemates with iron shield by Captain Inglis, R.E., first proposed in 1862; iron casemate by Lieutenant Collinson, R.E.; iron casemate by Captain Schuman, of the Prussian Engineers; iron embrasure in earth and iron movable chamber for one gun by the same ingenious officer. Which of these or other inventions may prove best, time and experiment alone will show. Every experiment made on this subject points to the lesson that where defensive works have to be overcome, no effort should be spared to bring up guns of the largest possible calibre; one of these being able to perform work of a nature impossible to any number of its lighter brethren.

These results rendered necessary the covering of the principal forts of the Isle of Wight with iron round their whole circumference, because they are exposed to attack on all sides; the rest, iron towards the sea, granite casemates, with iron shields, towards the land. The Horse Sand Fort affords a type of the whole cluster. The bottom of the foundation is 11 feet below low-water, ordinary spring-tides. Here is laid a ring of masonry, outside granite, inside concrete, in blocks. The breadth of the ring where it rests on the ground is 54 feet; the upper part, 1½ feet above high water, is 40 feet 8 inches thick. The central hollow is filled in, first with clay and shingle, and, lying flat upon the bed thus made, a thick layer of concrete. Down through the centre of the solid mass sinks an iron shaft 6 feet in diameter, to a depth of 54 feet below the bottom, yet these works are but the foundations for the fort. An outer wall of granite and Portland stone 16 feet high and 14 feet 6 inches thick is then built round the circumference, its foot set back 18 inches to leave room for a facing of iron, backed by concrete. Holes are left in the wall to take the bolts necessary for supporting the iron plates and backing. Behind the wall, in the interior of the fort, are magazines, shell stores, provision stores, water-tanks, and ablution-rooms for the men. Now we come to the main alterations. The fort has an uniform face of grey metal, pierced with two rows of mere holes, and for many feet of granite, 15 inches of wrought iron. All architectural features disappear, and the Noah's-Ark like structure bears about the same relation to the first design, that a Monitor does to a handsome wooden three-decker. The ark is not wanting in chimneys; four large truncated cones crown the roof, but their tops are covered with heavy iron plates, and the smoke that curls from their sides will be the breath of 600-pounders. Each turret revolves upon an iron cylinder; and if huge gaps were made in the exterior, the eight guns within it would stand as firm as ever. The total number of guns mounted in each of these two formidable forts will be 63, all of high calibre; their smooth sides cannot be scaled in the darkness of night, nor can they even be approached in time of war, for iron gun-vessels will creep round the water-line, and torpedoes nestle at their feet. Nothing can compare with these works for strength: they are Cyclopean, yet equally remarkable with their vastness is the amazing facility with which they are carried on. Huge blocks of granite or concrete weighing several tons are picked up from barges underneath the circular stages erected over the site of the foundations, moved from place to place, and slung down to their beds as easily as a mason lays the single bricks with which he works. There is something very fascinating about the apparatus, which in a day of ten hours, and with an expenditure of about 6 cwt. of coal, can lift and deposit some 1,000 tons of material, under the guidance of one man. Nor is another mechanical feat unworthy of English engineering, unsuggestive of English resources. A few years ago Yorkshire stone frequently took several weeks to travel from the mouth of the Humber to Portsmouth. Now, 48 hours by railway suffice to transfer a block from the quarry to its final resting-place in the fort.*

Next, of *Guns*. Mindful of present economy rather than desirous to obtain a weapon of increased strength, many European nations have retained the old material in their service. Austria, France, Spain, Italy, and the other copyists of *La Grande Nation* still use gun-metal for their field artillery; Prussia and Russia† go hand in hand in this as in other military matters, employing steel for their light as well as their heavy ordnance; England devotes herself to wrought-iron, having caught the trick of its manufacture, and her Armstrong field-guns are practically everlasting.

We have not space to detail how first long narrow projectiles of hard and tough material, called shells by courtesy because their interior could contain a small bursting charge, were slipped through the *Warrior* target; how these were followed

* Abridged from the *Times* Journal.

† In the *Proceedings of the Royal Artillery Institution*, vol. i., we find the following "Return of the daily amount of shot and shell thrown into Sebastopol by the British Siege Train." This contains a ghastly catalogue of killed and wounded in the bombardments. During the siege a total of 253,042 rounds of shot and shell were thrown into the city from the English batteries alone, and in the last four days' bombardment 24,732. No wonder the Russians called it a *feu d'enfer*. All honour to them for their long resistance, and to our own troops for their determination to push on in spite of all the difficulties with which they were surrounded, and notably the presence of a large Russian army always endeavouring to break the siege. Three hundred and sixty-seven pieces of heavy ordnance were employed in the reduction of the place by the British forces, 238 of them were worn out or placed *hors de combat* by the fire of the enemy, so that there remained 129 serviceable at the end of the war.

by larger missiles with increasing bursting charges; how the fierce heat of the shock was found enough to ignite the powder without any fuzes; how Sir W. Armstrong and Captain Alderson, R.A., invented their respective solid-headed shells, so that the massive iron plate being overcome, destruction of the wood and skin might follow as a matter of course. Suffice it to say that the *Warrior*, and vessels of even higher strength, are vulnerable to shells fired from the weakest of our present M. L. ship guns, and that we know of no foreign iron-plated ship through whose sides our artillerists will not pledge themselves to drive these terrible projectiles of one calibre or other at ranges of 500 to 1,000 yards.

What is the best material for projectiles intended to penetrate iron plates, and what form should we give them? Common cast-iron is cheap, and always to be found in any quantity; but when it came to be used against wrought-iron plates it was found to be quite ineffective, because so large a portion of its "stored up work" was expended in dashing itself to pieces that the target suffered but little. In the absence of better material, however, it is well to know that cast-iron shot will give their maximum effect when fired with a very high velocity, because the indent or penetration is effected before the shot has had time to fly in pieces, or the rest of the plate to reinforce the part attacked. A cast-iron *shell* is of about as much use against a good iron plate as a pat of butter would be. Hence, for a long time, steel was always used for penetrating purposes. But steel is very expensive, and when in the form of a shell resists too strongly the explosive force of the bursting charge.

Spherical shot have less range and accuracy than elongated projectiles: they experience more resistance in proportion to their "work," and are, therefore, ill adapted for penetration; they break up more easily on impact, and the capacity of the spherical shell is much less. The form must therefore be elongated, but with what shape of head? Mr. Whitworth long advocated a flat head, which is that best adapted for punching a clean hole. But then we do not want to punch a clean hole; and, besides, the piece driven out of the iron plate has to be carried by the shot through the wooden backing, at the expense of much force, so, on the whole, a conical or elliptical form of head has the superiority, for it tears through the plate, and is free to wedge itself through the wood behind, without carrying any weight but its own. The latest form of head, and that found best hitherto, is called "ogival pointed," and combines the strength of the curve with the penetration of the wedge.

The two great rivals, Armstrong and Whitworth, contest the palm of excellence. When England awoke from her peaceful sleep in 1859, the Armstrong gun was the only one offered to her at once successful and complete. Mr. Whitworth* had a system of rifling and a shape of projectile, but his guns were not then forthcoming. Before he was ready, many hundreds of his rival's guns were actually mounted behind the parapets of fortresses at home or in the colonies, and forming the armaments of war ships. The Whitworth gun ought not to suffer in the eyes of the world because it was rejected. What could be more wonderful than its accurate shooting at long ranges? What more encouraging to Englishmen than to see two rival inventors producing weapons which, after firing more than 3,000 rounds with service charges and all sorts of projectiles, were subjected to every means that could be devised to burst them, and yet remained unburst at last?

The Armstrong 23-ton gun shown at the Paris International Exhibition, was by far the finest and most complete solution of modern military *matériel* displayed. There were heavy guns and light, carriages of iron and of wood, projectiles adapted for dashing through iron plates, tearing the side of a ship to pieces, setting it on fire, smothering men with pestilential vapours, or sweeping them down in heaps by showers of leaden and iron balls; and, among them all, turned out from the same arsenal, and by the same hands, was the life-saving apparatus for the succour of shipwrecked sailors. Everything was provided to save life and to kill it. The idea of the Armstrong gun is no novelty. Coiled ropes and even coiled iron bars were wrapped round the weak interior tubes of guns ages ago, but Sir W.

* In Mr. Whitworth's built-up steel guns, the breech is screwed in, being formed of one, two, or three concentric cylinders, so exquisitely perfect in manufacture that every thread of them all fits into its appointed groove with the nicest accuracy, never failing to run smoothly with the others. This perfection of accurate proportions is Mr. Whitworth's speciality. Much modern work has only been rendered possible since he invented an apparatus for measuring the millionth part of an inch, and produced absolutely true planes which may float on each other, separated by a thin film of air; or, if this film be pushed aside by sliding the top plate forwards instead of placing it at once face to face with the lower one, the two will adhere together, as if made of one piece. Mr. Whitworth has not yet constructed a gun of very high calibre.

Armstrong not only adopted the idea, but carried it out with all the perfection of workmanship possible only since modern machinery was invented. All improvements since introduced in the Government manufactories are but modifications of his system. The aim of Krupp's method is to produce solid steel guns, and other continental makers have followed in his track. It is only in his heaviest ordinance that he supplements the steel gun by external rings of steel, shrunk on while hot. Armstrong builds up all his guns coil by coil, cylinder by cylinder, ring by ring. Mr. Fraser, of the Royal Arsenal at Woolwich, takes cheaper iron, coils several bars one over another without cooling, turning, or boring, and then welds them together, building up the gun at last of only three or four pieces. He thus gains cheapness of construction, with probably little difference in strength.

Krupp's 15-inch rifled breech-loading gun is entirely made ot steel, in three principal parts—the inner tube which extends from end to end of the piece, and two layers of superimposed steel hoops. Considered as a grand mass of worked metal nothing can be finer than this huge monster; but as a piece of artillery it is certainly defective. The weight of the huge gun is, roughly, 50 tons, and the weight of the projectile is said, in Mr. Krupp's list of his contributions, to be 1,000 Prussian lbs., or half an English ton. The charge is to weigh about 1 cwt.

Next are Palliser's new guns, in which a coiled wrought-iron double tube takes the first shock of the gas, and is surrounded by a mass of iron cast over it in a mould as the French guns are cast round their cores. This is theoretically the right way to apply the two forms of iron, if cast-iron is to be used at all. The gun exhibited by Major Palliser at Paris has a 9-inch bore, and throws a shot of 250 lb. weight, It has been fired twenty times with 43 lb. of powder; four times with 55 lb.; eighty-seven times with 45 lb., its service projectile being used throughout the proof.*

The results of recent Gunnery experiments in England have established that—

For actual perforation of iron-plated targets of modern construction heavy guns are required, and as these must be capable of throwing a projectile with a high velocity, they must be strong enough to stand large charges of powder. The projectiles must be of hard material. Palliser's chilled iron

* Abridged from the *Times* Journal.

shot and shell are equal, if not superior, to steel, and far cheaper. Shells should be so constructed that the bursting charges may act in a forward direction; their heads must be solid, and the best form is the "ogival pointed." With hard projectiles, the *perforation* is directly proportional to the "work" attained, and inversely proportional to the diameter of the shot or shell. The resistance of wrought-iron plates equally well made varies as the square of their thickness. Placing them at an angle to the line of fire diminishes the effect of the shot in the proportion of the sine of the angle of incidence to unity. The resistance of plates to perforation is hardly effected by a backing of wood simply, but much increased by a rigid backing of iron combined with wood, or of granite, iron, brick, &c., much of the shot's effect being transferred to the backing, which suffers proportionately. Iron-built ships with compact oak or teak backing are stronger than similarly clad wooden ships; the best form of backing being wood combined with horizontal plates of iron, as in the *Chalmers*, *Bellerophon*, and *Hercules* targets. Palliser's bolts are found to be the best for securing iron plates. An inner skin of iron is almost essential, for it not only renders the backing more compact, but prevents many splinters from passing into the ship. Every ironclad, whether built of wood or iron, should therefore have an inner iron skin. Laminated armour is much inferior to solid armour.

Nothing seemed available to match the rapidity of a shot moving at the rate of 1,000 feet a second. The power of electricity came at last into the hands of the philosophers. Professor Wheatstone proposed in 1840 to set the new spirit a task that had baffled the most powerful of its predecessors, and thus to utilize a velocity in comparison to which the motion of a shot was but as the creeping of a tortoise to the flight of a falcon. A variety of suggestions were soon made by scientific men, but the first instrument actually constructed and practically used in 1849 was invented by an ingenious Belgian artillery officer—Captain Navez.

The great improvement of *rifling* guns, that is spirally groove-bored, has been described as that final touch without which the most monstrous cannon that ever was forged is only a Samson shorn of his locks; and must stand before a 9-inch rifled gun as Goliath did before David, its ponderous bulk but a gigantic target, unable to reach its despised foe before receiving the fatal missile. Not that rifling a gun of necessity increases its range. A round ball discharged from a rifle goes no further than the average of a number of similar balls fired from a smooth-bore. But it can be trusted to strike its mark, and its range is uniform or nearly so; whereas an unrifled shot may go left, right, over, or under a target, even in the hands of the most perfect marksman. It is only from a rifled gun that an elongated shot can be fired and sail smoothly through the air, unchecked by the medium which its narrow body and pointed head cleave as a fish cleaves the water which detains the ship's log. From the same weight of gun, therefore, if rifled, you can fire a shell which will range further, go straighter, and pierce a stronger target than if the bore were left smooth. The elongated shell will also contain more powder or bullets, as the case may be, than the round shell.

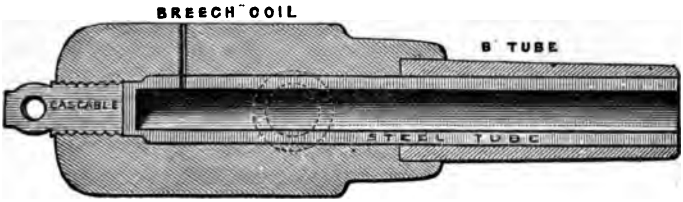


FIG. 18.—SECTION OF 9-INCH FRASER GUN.

The guns now made at Woolwich are built up of the several parts which are indicated in the section (Fig. 18). These are, 1st, the steel barrel; 2nd, the B tube; 3rd, the breech coil; 4th, the cascable screw. The inner barrel is made of a steel cylinder, which, after having been roughly turned and bored, is subjected to a process called *toughening*, by which its

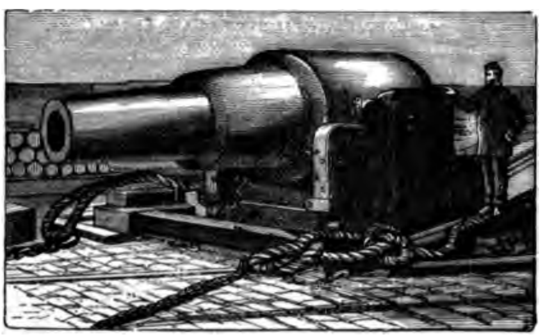


FIG. 19.—THE 35-TON FRASER GUN.

tenacity is greatly increased. The B tube is made by winding a red-hot iron bar spirally, and afterwards forging the coils into one mass. The breech coil is similarly made from iron bars;

and the several pieces of the gun are fitted to each other with the utmost accuracy, the outer ones being shrunk upon the inner. The grooves of the rifling are cut by means of ingeniously contrived machinery, by which most remarkable accuracy is obtained. One of the 35-ton guns constructed on this plan is shown in Fig. 19. These pieces of ordnance have, however, been surpassed by the 81-ton guns that have more recently been made at Woolwich on the same general plan. The comparative size of these pieces is shown in Fig. 20. Yet more recently Sir W. Armstrong has made still heavier cannon for the Italian Government, the weight of each gun being about 100 tons. He has also constructed equally heavy guns for some of our own coast defences. The force of the projectiles discharged from such guns is enormous. Thus, for example, the 1,200 lb. shot of the Woolwich 81-ton gun leaves

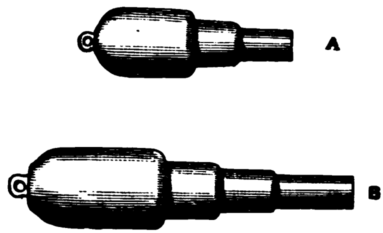


FIG. 20.—COMPARATIVE SIZES OF 35 AND 81-TON GUNS.
A. 35-ton. B. 81-ton.

the muzzle with such a velocity that the projectile possesses an energy of more than 14,000 foot-tons; and at long range it will completely penetrate an iron plate 20 inches in thickness. One of Sir W. Armstrong's improvements in artillery is a system of handling large guns by means of hydraulic machinery. The training and loading of the heaviest ordnance are, by this system, performed with the greatest ease by the mere touching of handles connected with certain valves in the apparatus, and the method is applicable to naval guns as well as those in forts. The arrangements are such that the operations are performed under cover, so that the artillerymen are not exposed to any special danger in loading and training the piece.

As, whatever, may be its strength, the "life" of a piece of ordnance is limited, so that after a certain number of rounds it becomes unsafe or useless the first cost of a gun becomes a matter of consideration. This cost is great in any case, but it varies much from one system to another, according to the nature of the material and the workmanship required. Thus, for example, a 35-ton gun constructed on Sir J. Whitworth's plan would cost 6,000*l.*, while Sir W. Armstrong's estimate is 3,500*l.*, and the gun is made at Woolwich, on Mr. Fraser's plan at a calculated expense of 2,500*l.*

Of Small Arms, the Breech-loader is stated to multiply the fire of an army three or four fold, placing as it were three or four rifles in each soldier's hand. The Dano-German war proved the value of the system, of which the famous needle-gun was but an indifferent exponent; and on July 11, 1864, a Government committee reported that "it was desirable to arm the whole of our infantry with breech-loading rifles;" which thereby signed the death-warrant of muzzle-loaders for British soldiers. Captain Majendie states that the Snider gun is proved "to be fifty per cent. quicker than its rivals, as well as stronger; it is simple and apparently durable; the breech arrangement being well adapted to sustain any number of discharges, from the fact of those shocks being sensible only." In answer to the exaggerated reports of its failure, Captain Majendie states that its general use in Canada, at Hythe, and at Aldershott has been reported to be highly successful: and he adds that out of 50,000 rounds of ammunition fired by himself, only 1 in 300 failed from any cause.

Mr. Kenneth Cornish, in his new Breech-loader, has simplified the mechanism of the breech in a wonderful manner. Imagine a child's cross-bow, minus the arc and string; and that is the shape of the stock and barrel of the rifle. A bullet put in at the muzzle would run down the barrel and out in a straight line along the groove upon the stock; for what in the cross bow is the place for introducing the arrow is in this rifle the place for dropping or pushing in the cartridge. Across the barrel, at a point somewhat higher up than where this joins the stock, is the breech-piece, not a solid hinged block, as in the Snider rifle, but a species of flap, set on edge, and in shape and action not unlike the knife of a guillotine. This is simply lifted up or pressed down as occasion may require: and when raised, by pulling it open somewhat further than it would go of its own accord, the extraction, worked by a sere spring, is set in motion and draws: or, if the motion communicated be quick and sudden, throws out the copper-based cartridge from the barrel.

The advantages of breech-loaders are chiefly these: 1, *Multiplication of fire*, so that for all contests, not actually hand to hand, the number of men are practically multiplied, say, three-fold; but every loss of a soldier is in such a case equal to the loss of three; 2. *Facility of loading in all positions* and in all weathers; this enables the soldier to seek any cover—a stone, a log, even a sod of earth behind which he can lie and maintain a steady fire, without exposing body or limbs. At close quarters, too, his bayonet need never be moved from the line with his enemy's breast, while he puts in the cartridge which will settle matters between them; 3. *Reduction of fatigue;* joined with No. 2 this improves the actual shooting; there are few rifles that are not more accurate than the average soldier who points them; 4. *Ease of repair and cleaning;* an oiled rag has only to be drawn through the barrel to clean it, and a damaged breech apparatus is readily replaced in all systems worth naming.

The history of the Needle-gun presents more than one claimant to the invention, and possibly each claimant may be entitled to share the merit. It was first patented in 1831, by Moser, an engineer, of Kennington. It originated in the method of igniting the charge by passing a needle through the cartridge to strike the detonating gunpowder, and thus ignite the powder in front of the charge, instead of behind it, as in the ordinary percussion-gun; Moser's drawings also show a cartridge containing an elongated bullet for a musket. This was the needle-gun in its original form. But Moser could not get his invention investigated in practical England; his plan was tried in Prussia, and eventually adopted; and in 1835, Dreyse, a gunmaker, of Sommerda, applied the breech-loading arrangement. The gun was definitively introduced in the Prussian service in 1848. The mechanism at the breech of the gun resembles the ordinary bolt of a street-door, and has a large projecting knob or handle, by which it is moved into or out of the grooved catch which fastens it. In the body of this bolt, the arrangement for cocking and discharging the needle is enclosed; and this part of the contrivance is as simple as the mechanism of the interior of an ordinary child's toy-gun, in which the spiral spring which fires the wooden pellet, and the method of maintaining it and discharging it by the direct action of the trigger, are precisely similar to the lock of the needle-gun. In 1850, several rifles on this model were made at the Government factory at Enfield, and condemned partly from the supposed danger of having the fulminate contained in the cartridge, but mainly from the escape of gas round the needle. Various improvements have been made in the Prussian weapon; but in all the various patterns, the principles of Moser's invention are retained in the position of the fulminate and the elongated projectile. In the cartridge a new and very doubtful principle is, however, introduced. The bullet, which fits into a pasteboard *sabot*, or shoe, containing the fulminate to be exploded by the touch of the needle, is made so small that it *does not touch the barrel* in its passage through it, the rotation of the rifling being communicated by the sabot only. Thus perfect cleanliness is ensured, and absence of fouling. The Prussian needle-gun will not compare with the muzzle-loading Enfield for precision to 500 yards; and its maximum of efficiency, even against masses of troops, is 700 yards, the Enfield being effective at 900. In short, in this arm the main feature is quickness. In the converted Enfield Rifle we have succeeded in obtaining the same rapidity, with increased solidity and much greater accuracy.

The cartridge was said to be so great a secret that it could only be manufactured in Prussia; but this was untrue. The smaller diameter of the bullet was a secret, as also the composition of the percussion-powder, which is generally the fulminate of mercury intimately combined with meal-gunpowder; but it is mixed with collodion, and moulded into the cartridge whilst moist. The collodion adds nothing but combustible matter (gun-cotton) to the mixture.

We have already named one claimant to the Needle-gun. Mr. Hanson, of Folly Hall, near Huddersfield, states himself to be the inventor, and to have given the secret to a townsman of his, Mr. Golden, gunmaker, of Huddersfield, who patented it, and made some of the guns. These were but rook-guns of small range. The specifications of English patents find their way abroad; and, in consequence, Mr. Golden received an order from the King of Prussia for two of his patent needle-guns. They were duly sent to his Majesty, through his Ambassador in London; as three letters of correspondence, with the large Prussian seal upon them, now in the possession of Mr. Golden, will testify. This is how the needle-gun got into Prussia. In two years after, this gun, with some little modification, and made larger for military purposes, was introduced into England as the Prussian needle-gun. It was exhibited daily at the Polytechnic Institution, and caused a great sensation. Happening to be in London at the time, Mr. Hanson went to see it, and was astonished to see his needle-gun there—not the identical gun sent to Prussia, but on the same principle, as proved by the specification and drawings.

The invention of the needle-gun has been claimed by the Prussians, the French, and the Belgians. According to the Prussians, Nicholas Dreyse, already named, presented this gun to the King in 1844; some years afterwards it was introduced into the regiments of the Guard, and for twelve years it has been in use in the whole army (infantry, cavalry, and engneers). In 1848, when the Berlinese attacked the arsenal, they managed to get hold of a dozen of these guns; and in 1850 one of these very guns is said to have been exhibited at Paris at the shop of a *marchand d'armes*.

Others attribute the invention to a M. Descoutures, an old member of the Polytechnic: he presented this gun to Napoleon III., who was struck with its advantages, and charged Colonel, now General Favé, to make experiments; and the same having proved successful, the Emperor placed it in the special armoury, and even proposed to give it the name of *Fusil Napoléon*. But its employment was objected to by the Minister-of-War and others, and Descoutures carried the invention to Prussia, where it was adopted. In Belgium it is maintained that the ignition of the cartridge by the needle is due to Montigny, a gunmaker at Brussels, who, in 1832, produced the first breech-loading gun ignited by a needle. The Belgian Government refused to entertain the invention. Montigny next went to St. Petersburg, and proposed it to the Czar; the trials were successful, but the artillery department opposed it, and Montigny was so disappointed that he died of grief in 1845. Next we have a parallel case of defeated hope.

In the conversion of the Enfield musket, Jacob Snider's cartridge, which contained ignition, was chosen; but the Ordnance Committee then employed their own officers; Snider was offered a very inadequate remuneration, which he refused to accept, and while the matter was in dispute, the poor inventor died!

An improvement on the Prussian Needle-gun has been patented by Sears and Hunt: it can be loaded and fired six times in one minute, if necessary, and without any alteration in its position after firing; its range and accuracy are stated to be equal to those of any gun in existence, while its accuracy is not to be surpassed. The escape of gas is prevented, and it can be fired hundreds of times without fouling; it can be taken asunder and again put together in less than one minute; and the cartridge is most easily made.

The Chassepot musket is said to insure great rapidity of fire. A man with a lot of loose cartridges besides him can fire this improved musket twelve times in one minute; but that rate the most skilful and robust soldier cannot keep up beyond about thirty rounds; past that the fire perceptibly slackens. The cause is purely physical, *i.e.*, the fatigue of the man, whose arm has often to support unaided the whole weight of the weapon. The Chassepot Musket may sustain very advantageously a competition with the Needle gun. Its superiority arises chiefly from the more perfect closing of the breech, which is complete, whilst it is very defective in the needle gun. All the gases developed by the ignition of the charge are utilised to propel the bullet, which adds to its range and pene-

FIG. 21.—THE CHASSEPOT RIFLE.—SECTION OF THE BREECH.

trating power. The firing of the Chassepot rifle astonished the late Emperor of the French by its destructiveness. In two minutes a battalion of 500 men, at 600 yards from the mark, had fired 8,000 balls, of which 1,992 had struck the line of aim. The ground in front of the mark was so cut up that not a blade of grass could be seen; and the Emperor is reported to have exclaimed, "It is frightful! It is a massacre!"

The mechanism of the Chassepot rifle is shown in Fig. 21, where B corresponds with the part called, in the old percussion-cap lock, the "hammer." When B is drawn out it is retained by the catch C, connected with the trigger. B has a rod with a coiled spring, which, when released by pulling the trigger, darts forward the needle, which enters the base of the cartridge and explodes the *fulminate* in its centre. The lever E enables the breech-piece F to be withdrawn for the introduction of the cartridge.

The rifle of the British army is now the Martini-Henry (Fig. 22), so called because it is a combination of Martini's breech-loading mechanism with Henry's system of rifling. The barrel is of steel, and the twist of the rifling is one turn in 22 inches.

FIG. 22.—THE MARTINI-HENRY RIFLE.
A, ready for loading; B, loaded and ready for firing.

The charge consists of 85 grains of powder, and a bullet weighing 480 grains. The cartridge is of the same general construction as that used in the Snider rifle; but the Martini-Henry is, in every respect, a superior weapon—in accuracy, and rapidity of fire, length of range, penetrating power, and simplicity of mechanism.

Among the new weapons must be mentioned that of which so much was heard at the commencement of the Franco-Prussian war under the name of *mitrailleur*, or mitrailleuse. It was a battery of rifles united in one machine, and the details of the construction were at first kept concealed. Weapons on the same principle have since been added to the armament of other nations. The form of mitrailleur adopted in the British service, about 1870, is that known as the Gatling gun, which is represented in Fig. 23. The Gatling gun has ten distinct and separate barrels, which are screwed into a solid revolving piece at the breech end, and near their muzzles pass through a circular plate, by which they are kept parallel to each other. The weapon is made of three sizes, the largest firing half pound bullets 1 inch in diameter, and the smallest bullets of ·45 inch diameter. The small Gatling is said to be effective at a range of more than a mile and a quarter, and it can discharge 400 bullets in one minute. The main features

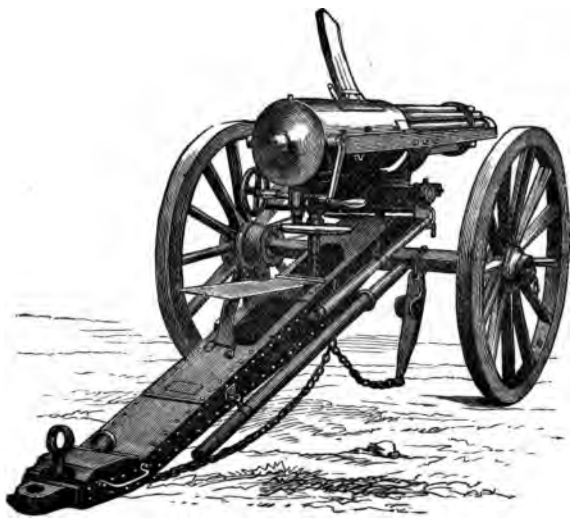


FIG. 23.—THE GATLING BATTERY GUN.—REAR VIEW.

of the gun may be thus described: each barrel is provided with its own independent lock or firing mechanism. When the gun is kept in operation by turning the handle, all the locks and barrels revolve together; and the whole operation of loading, closing the breech, discharging and expelling the empty cartridge-cases, is continuously conducted by rotatory movement. There is, therefore, no pause in the several operations. As only four men are needed for working the gun, the exposure of life is far less than in the case of infantry having the same firing power; and Mr. Gatling contends that, shot for shot, his machine is more accurate and steady.

Torpedoes, explosive engines fired by electricity, were employed with various success in America during the late Civil War.* Drifting torpedoes were first tried by the Confederates, but unsuccessfully. The Federals placed nets which caught the drifters, when the boats of the fleet disposed of them easily. The Southerners then devised stationary torpedoes under the water. These were of three distinct classes. 1. Torpedoes fixed at the end of spars anchored in a stream, or on piles driven into the bed: these were called stake-guns. 2. Torpedoes moored at the bottom, and floating below the surface, arranged to be fired by contact or by electricity. 3. Torpedoes at the bottom, arranged to be fired by electricity. Torpedoes of the first class appear to have been employed chiefly upon the Mississippi, and without much effect.

Those of the second were very successful on the Roanoke River, in 1864. Though out of 100 torpedoes laid, only about thirty remained in position, they managed to blow up three out of nine Federal gunboats. Four other gunboats were so seriously damaged that they could not be employed again. Many torpedoes with detonating apparatus were used, because the shores of some of the southern rivers are so pestilential that men could not remain permanently in charge of the apparatus required for exploding the mines by electricity. "The mosquitoes and snakes alone would, probably, have driven off the torpedo detachment sent for observation and to fire the mines." The banks of the James River being occupied in force, the mines could generally be fired by electricity, whether they were of the second or third class. Here is a sickening picture of the fate of a Federal gunboat on James River, in the year 1864. On the explosion taking place the gunboat appeared to rise and then bend a little in the middle. The movement was followed almost immediately by the explosion of the boilers, which sent everything into the air. The explosion must have been an awful sight to witness, for the air seemed filled with burning bodies. This, to a certain extent, was the case, for all the crew were blown up with the vessel; but their apparent number was enormously increased by the

* Torpedoes are named from the Torpedo, Electric Ray, or Cramp-fish, from the Latin *Torpeo*, to benumb; the engineer having imitated the apparatus in the fish, in which resides its electric or galvanic power.

stores of clothing that happened to be on board being set on fire and driven about by the explosion. The affair was followed by a most remarkable stillness, only broken by the splash of the falling bodies and fragments. The officers and crew of the gunboat numbered 151, and the greater portion were killed outright! The number of Federal ships actually destroyed by Confederate torpedoes of one class or another was *thirty-nine*, besides some damaged and forced to go into dock for repairs. The American Government became so thoroughly impressed with the value of these strange and insidious defenders of coasts and rivers that they equipped five large vessels with torpedo arrangements, and have built some small rams.

Land torpedoes seem also to have acted a very important part in the defence of Richmond and other places. The known presence of a large number of them in front of the works withheld the Federals from attacking at a time when the parapets were guarded by but few troops. Like watchdogs, they scared away the would-be intruder without need of touching him.

At the Paris International Exhibition were shown two torpedoes from Austria :—1. *Such as are fired from the shore*, depending, therefore, for their certain action upon an accurate knowledge of the attacking ship's position. The channel of Malamocco, just outside Venice, was provided with these. Their obvious disadvantage is that on a dark night it would be impossible to know the position of the vessel doomed to destruction, and the whole apparatus would become almost useless, unless the defenders were prepared to waste their whole line of torpedoes upon a single pilot vessl. 2. *Self-acting torpedoes*, which explode on being struck by the ship attempting to pass. Pola was defended by a double line of these. They were connected with a magnetic arrangement on shore. The advancing vessel strikes upon one of a numerous array of studs projecting from the case containing the powder, or, still better, gun-cotton. The blow overcomes the force of a spiral spring, which, however, pushes back the stud as the torpedo yields or the ship moves on. The current is thus broken and remade, and the fierce gas dashes through the bottom of the ship, or breaks her back by the concussion. "Of all the operations of war this mining is, perhaps, the most terrible. From without the fortress the attackers burrow towards the defenders' works. As they approach nearer they speak no word, and work as quietly as may be, for they know that the enemy is listening intently for the sound that may betray them. If they can but escape his observation the defences will surely fall before them, but if detected they are lost. He hears their advance, lodges his charge, and fills in his gallery. But two thin wires lie hidden in the mass of earth, and when the time has come—just, perhaps, as the besiegers are placing their powder at the end of their painfully achieved task—a muffled sound is heard, the solid earth heaves above their heads or beneath their feet, and then closes slowly in upon the wretches, burying them alive in the grave which their own hands have dug."

Torpedoes have also been invented at Woolwich, for destroying an enemy's ship; they explode by the slightest contact.

Here, also, in the Gun Factories, may be witnessed the manufacture of various portions of the Fraser Gun, recently introduced as the new service gun for sea and land use. As you are conducted from forge to forge, you see the various modes which the section and coils of the gun have to undergo before being brought under the huge Nasmyth hammer to be wrought into proper shape; and finally, the method of welding the coils to form the tube, and transpose the whole into a solid and combined mass, completing the gun in a rough state, which is then left to cool. In the Royal Laboratory nearly 400 persons are employed. In the Boxer cartridge factory, upwards of 300,000 cartridges are turned out per day. In the Shell Foundry are the Boxer and other solid shot broken for the purpose of exhibiting the quality of the metals of which they are composed, and the manner of fracture. Of the 8-inch, 10-inch, and 12-inch Palliser shot 500 are produced per day. Stamping trucks into shape is now used, instead of the old system of casting, which was not sufficiently durable for the present heavy guns; and there is a new process of cutting an inch slad of iron with the band saw which is very efficient.

THE ELECTRIC TELEGRAPH.

THE applications of electricity to the arts of life, are, in themselves, of such romantic, if not poetic character, as to lead to their fancied predictions being traceable in the higher regions of embellished thought. Contemplating these marvellous results, it is asked, might we not exclaim, after the inspired author of the book of Job, "Canst thou send lightnings, that they may go, and say unto thee—Here we are?" There is a fancied allusion to the application of electrical power in *Hudibras*, where Sidrophel knows how to

—fire a mine in China, here,
With sympathetic gunpowder.

And even Puck's fairy boast of putting a girdle round about the earth in forty minutes, has been almost reduced to practice; one of our most profound electricians having exclaimed, "Give me but an unlimited length of wire, with a small battery, and I will girdle the universe with a sentence in forty minutes." And this is no vain boast; for so rapid is the transition of the electric current along the lines of the telegraph wire, that, supposing it were possible to carry the wires eight times round the earth it would but occupy *one second of time*. And the anticipation of covering the earth with the iron net-work, *like a spider's web*, recalls Pope's couplet:—

"The spider's touch, how exquisitely fine!
Feels at each thread, and lives along the line."

The learned Italian Jesuit, Strada, in one of his *Prolusiones Academicæ*, in 1617, has a sort of prevision of the *instantaneous transmission of thoughts and words between two individuals, over an indefinite space*, by supposing the existence of "a species of loadstone which possesses such virtue, that if two needles be touched with it, and then balanced on separate pivots, and the one turned in a particular direction, the other will sympathetically move parallel to it." Each of these needles was to be poised and mounted parallel on a dial having the letters of the alphabet arranged round it. Accordingly, if there be two persons at a distance, and each has a dial, and there be a pre-arrangement as to details, a correspondence could be kept up between them by simply pointing the needles to the letters of the required words. Strada's conceit was, however, too much for Bishop Wilkins, who believed in the possibility of our flying, and he took care to caution his readers against Strada's delusion. It slept altogether for nearly a century, when, in 1712, Addison, in the *Spectator*, revived the story of the sympathetic needles, and their conversation across a whole continent, and the conveyance of their thoughts to one another in an instant over cities, or mountains, seas or deserts. Yet, Addison only quoted Strada's proposition in playful suggestion of having in place of the letters on the dials certain amatory words, which should abridge "the lover's pains in this way of writing a letter, as it would enable him to express the most useful and significant words with a single touch of the needle." But when Strada wrote, and Addison quoted, it never entered into the mind of either to expect its almost ultimate realisation.

Then we read of one of the Brethren of the Charter-house beguiling his time by making electrical signals through a wire 765 feet long. And next, 25th November, 1731, on the same night that Dr. Frobenius's experiments cost the Royal Society ten guineas for the phosphorus employed in them, the Charterhouse Brother, above mentioned, showed the learned Fellows the facility with which electricity passes through great lengths of conductors, "which experiment succeeded, notwithstanding the largeness of the company." This was repeated in 1745, when Dr., afterwards Sir William Watson, assisted by several Members of the Society, caused the shock to pass across the Thames on Westminster Bridge, the circuit being completed by making use of the river for one part of the chain of communication. Upon making the discharge the shock was felt instantaneously by the observer on each side of the river.*

* At the opening of George the Third's Museum, at King's College, London, in June, 1843, an interesting experiment was performed before Prince Albert by Professor Wheatstone, with one of his Telegraphs, so as

Subsequently the same parties made experiments near Shooter's Hill, when the wires formed a circuit of four miles, and conveyed the shock with equal facility. In the paper detailing these experiments, printed in the 45th volume of the *Philosophical Transactions*, occurs the first mention of Dr. Franklin's name, and of his theory of positive and negative electricity.

In the *Scots' Magazine* of March, 1753, appeared a distinct proposition for a system of telegraphic communication, by as many conducting wires as there are letters in the alphabet; and Cavallo, in his treatise on electricity, records a similar system of telegraphing, invented by a Jesuit at Rome.

In 1787, Arthur Young, while travelling in France, in his Diary, dated October 16, made an entry which goes a great way towards establishing the fact that a French mechanic, M. Lomond, had then, in actual operation in Paris, an Electric Telegraph. The entry is as follows:—

"*Oct.* 16, 1787.—In the evening to Mons. Lomond, a very ingenious and inventive mechanic, who has made an improvement of the jenny for spinning cotton. In electricity he has made a remarkable discovery. You write two or three words on paper; he takes it with him into a room and turns a machine enclosed in a cylindrical case, at the top of which is an electrometer, a small fine pith ball; a wire connects with a similar cylinder and electrometer in a distant apartment, and his wife, by remarking the corresponding motions of the ball, writes down the words they indicate; from which it appears that he has formed an alphabet of motions. As the length of the wire makes no difference in the effect, a correspondence might be carried on at any distance—within and without a besieged town, for instance. Whatever the use may be, the invention is beautiful."

Sir Bernard Burke, in communicating the above to the *Times*, in 1866, asks, "Is it not possible that the poor French mechanic may have perished in the Revolution, and his mighty invention with him?"

to form a communication between the College and the lofty Shot-tower on the opposite bank of the Thames. This was done by laying the wire along the parapets of the terrace at Somerset-House and Waterloo-bridge, and thence to the top of the tower, about 150 feet high, where one of the telegraphs was placed. The wire then descended, and a plate of zinc attached to its extremity, was plunged into the mud of the river, whilst a similar plate was attached to the extremity at the north side, and was immersed in the water. The circuit was thus completed by the entire breadth of the Thames, and the telegraph acted as well as if the circuit were entirely metallic.

Volta's discovery of the development of electricity in metallic bodies, animal electricity as it is called, causing convulsions in the limbs of frogs when the divided nerves were connected by a metallic wire, gave a new turn to the researches. Next, Reizer, in 1794, constructed his apparatus. Wire was the conductor, as in the present telegraphs, but the electric spark, elicited by friction, was the only agent. The wire conducted to a darkened room, around which were placed pieces of tin-foil inscribed with letters, and fixed on plates of glass. The spark, it was found, in leaping across the glass plates to pursue its course along the wire, illuminated the pieces of tin-foil, and thus the letters could be read.

Soemmering next, in 1809, exhibited to the Munich Academy, an apparatus in which the signalling was by gas-bubbles, from the decomposition of water in glass tubes, each of which denoted a letter of the alphabet; subsequently he dispensed with the tubes.

Three years later, Francis Ronalds, employing frictional electricity, constructed a telegraph of a single insulated wire, the indication being by pith balls, in front of a dial. When the wire was charged, the balls were divergent; but collapsed when the wire was discharged; the signals were clocks with lettered dials. Ronalds succeeded, and exhibited his telegraph at Hammersmith; the Government witnessed the trials, but declined to accept the invention, as they had already done in the case of a Voltaic Electric Telegraph, devised in 1813, by Mr. Hill, of Alfreton, in Hampshire. In the same year that Ronalds exhibited his telegraph, its success may have prompted Andrew Crosse, the electrician, to utter his prediction: "I prophesy that by means of the electric agency we shall be enabled to communicate our thoughts instantaneously with the uttermost parts of the earth."*

Next, in 1820, M. Oersted, of Copenhagen, made his celebrated discovery of Electro-magnetic action, for which he received the Copley Medal of the Royal Society. When Oersted discovered that the connecting wire of a voltaic circuit acts

* A few copies of the remarkable pamphlet on this subject, entitled, *Description of an Electric Telegraph*, by Francis Ronalds, 1823, may be still obtained from Mr. Spon, of Charing Cross. Mr. Ronalds himself lately was living at Battle, in Sussex, and his portraits may be obtained from Messrs. Maull and Polyblank. His pamphlet is one of very great interest, and well worth reading.

upon a magnetic needle, he found that the needle had a tendency to place itself at *right angles* to the wire; a kind of action altogether different from any which had been suspected. "This observation," says Dr. Whewell, "was of vast importance; and the analysis of its conditions and consequences employed the best philosophers in Europe immediately on its promulgation."

A single wire has but small power on the needle; but Professor Schweiger invented the "multiplier," as he called it, in which the needle, being surrounded with many successive coils of insulated wire, is acted upon by the joint force of all. Another important discovery was made shortly after, by Oersted, Davy, Arago, and others. They succeeded in rendering iron magnetic, by the passage of a galvanic current through a wire coiled round the iron. It was found that provided the iron to be magnetised were perfectly soft and pure, the magnetised property remained only during the actual transmission of the electricity, and was lost immediately on the interruption of the electric circuit. If the iron to be exposed to the galvanic current were combined with sulphur, carbon, or phosphorus, the magnetic power became more or less permanent.

Professor Owen has eloquently said of Oersted's discoveries: "Remote as such profound conceptions and subtle trains of thought seem to be from the needs of every-day life, the most astounding of the practical augmentation of man's power has sprung out of them. Nothing might seem less promising of profit than Oersted's painfully-pursued experiments, with his little magnets, voltaic pile, and bits of copper wire. Yet out of these has sprung the Electric Telegraph! Oersted himself saw such an application of his convertibility of electricity into magnetism, and made arrangements for testing that application to the instantaneous communication of signs through distances of a few miles. The resources of inventive genius have made it practicable for all distances, as we have lately seen in the submergence and working of the electro-magnetic cord connecting the Old and the New World of the geographers."

According to the statement of Dr. Hamel, of St. Petersburg, Baron Schilling was the first to apply Oersted's discovery to telegraphy, by greatly simplifying the means. Next, in 1835, Gauss and Wöher established communication between the Observatory and University at Gottingen, the former under Professor Gauss. In the following year, 1836, Professor Munck, of Heidelberg, who had imported Schilling's telegraphic apparatus, explained the value to William Forthergill Cooke, who had long been studying electrical communications. He returned to England early in 1837, and in June, with Professor Wheatstone, took out a joint patent for the first Electric Telegraph, which was laid on the London and Blackwall Railway. The wires employed were of copper, inclosed in an iron tube, each wire being separated from its neighbour by some non-conducting material. A much smaller number of needles, to denote all the required signals, was used than hitherto; the temporary magnetism excited by the current in soft iron, to ring an alarm, either directly or indirectly, by veritable machinery; and the reciprocal arrangement; by which the invention was rendered applicable to a long line of communication. At one terminus, five needles were arranged, with their axes in a horizontal line. When at rest, those needles hung vertically, by reason of a slight preponderance given to their lower ends. At the other terminus, five pairs of finger-keys, resembling those of a pianoforte, were placed over a trough of mercury, to which a voltaic battery was attached. On depressing the keys, the wires belonging to them, respectively, were brought into connexion with the trough, and receiving the voltaic current, it flowed along them with the rapidity of lightning, and caused the needles to deflect at the other terminus. Letters were indicated by the movement of the needles, and a communication could thus be carried on rapidly with certainty. The instruments at the two termini were also rendered reciprocating; a set of finger-keys and a voltaic battery being placed at each station, so that either could transmit or receive a signal. The bell or alarum, rung to draw attention at either terminus, was of two kinds; a hammer was impelled against the bell by magnetic attraction, or a catch was released from a train of clockwork, which, by the usual intervention of a wheel and pallets, rang the bell, as in common alarums.

In the beginning of 1838, Messrs. Cooke and Wheatstone obtained a patent for improvements which rendered it possible, not merely for the two extreme termini, but for any number of intermediate stations, to hold communication. The five needles were now reduced to two; and some important improvements made in insulating and protecting the wires, which were to be laid beneath the earth in tubes of wood, iron, or earthenware. In 1839, this improved telegraph was brought into actual operation on the Great Western Railway, and the inventors were gratified by seeing their scheme triumphantly successful.

One of the most simplified descriptions of the Electric Telegraph is the following by Mr. Alfred Smee, F.R.S., to whom science is indebted for a battery of great value in experimental researches when the most speedy and energetic electric action is needed, such as the production of the electric light, deflagration of metals, ignition of gunpowder for mining purposes, &c. Mr. Smee's simplification is as follows:—"A magnetic needle, suspended in such a manner that it is free to turn in any direction, takes a position from north to south, with a little deviation. By simply being able to understand the property of this needle, man can steer his course over the vast expanse of the ocean, even when he is unable to see the land. By it, man can traverse the densest forest, or the most dreary desert, when neither sun, moon, nor stars are visible for days and days.

"Now, we find that, if we have a magnetic needle, and pass a current of electricity parallel to it, the needle is deflected across the current of electricity. By taking advantage of a knowledge of this deflection, Cooke and Wheatstone have far outstripped the velocity of the carrier-pigeon, the swiftest horse, or the most rapid railway-train, in the rate at which messages may be transmitted from place to place. For the purpose of working the telegraph, they place along the railway-lines wires, which extend in one continuous length from station to station. Whenever the voltaic force passes, it acts upon the needles at the opposite end. This action represents a sign; and by using these signs upon a pre-concerted plan, the messages are sent."

Other discoverers were in the field, as well as our two meritorious countrymen. Dr. Steinheil, of Munich, substituted for the ordinary voltaic battery the magneto-electric machine, in which, according to Faraday's great discovery, the electric current was derived by induction from a permanent magnet. He also contrived an apparatus by which, instead of merely indicating letters, the needle could be made to drop ink on paper, so that, from the number and arrangement of the dots, a communication could be fixed on a strip and afterwards read; but the communication was slow. Professor Morse also turned his attention to making the electric telegraph a registering instrument. In his scheme a pencil was, at first, substituted for ink; and then was added a steel point, which pressing the paper into a groove, made an indentation; and from the number of marks, letters and figures were denoted.

Early in 1840, Professor Wheatstone patented his Electro-magnetic Telegraph* with movement signals, which could be applied to most important purposes. The "communicator" is a thin disc of wood, turning horizontally upon a pillar or axis, its circumference being divided into equal spaces, alternately filled up with metal or ivory. The metal divisions communicate with a central column, and through it with one pole of a battery, the other pole of which is connected with the return wire, or with the earth. Against the circumference of the disc rests a spring, from the foot of which proceeds a wire to the line or long conductor. As the disc revolves on its centre, the spring rests alternately on metal and ivory, and were there no break in the magnetic current at the distant station, the current from the battery would be transmitted or intercepted accordingly. Over each division of the circumference is placed a letter or figure, so that by bringing one letter after the other opposite a dot fixed near to the disc, the galvanic circle is opened or completed alternately with each succeeding letter. For the ease of turning the disc, it is provided with spokes or arms, radiating around its upper surface.

The Telegraph operated upon by this communicator, possesses great simplicity both in its principle and combination. Opposite and near to the poles of a temporary or voltaic magnet, is placed a small armature of soft iron. When the iron is rendered magnetic, the armature is attracted to it; but, on interrupting the galvanic circuit, the magnetism of the iron

* Faraday was the first to elicit the Electric Spark from the magnet; he found it visible at the instant of breaking and renewing the contact of the conducting wires, and only then:

"Around the magnet, Faraday
Is sure that Volta's lightnings play;
But *how* to draw them from the wire?
He took a lesson from the heart:
'Tis when we meet, 'tis when we part,
Breaks forth the electric fire."

Blackwood's Edinburgh Magazine.

ceases, and a small reacting spring throws the armature back to its original position. The armature itself turns on an axis, which carries a pair of pallets, taking into the teeth of an escapement-wheel and moving the wheel onward, one tooth at a time; or a spring-barrel and fuzee are employed to turn the escapement-wheel, and the pallets merely control its revolutions, like the same parts in a common clock. The object is to communicate to a light paper or mica dial, bearing letters around its circumference, a step by step motion, wholly under the control of the operator at a distant station; so that he may bring any figure or letter on the dial to a small opening in a screen, through which it will be visible to the observer. The number and order of the signals upon the paper disc, correspond with those on the "communicator," so that the operator sees on his own dial the signals he makes on his correspondent's apparatus. To reduce the chance of an error, each word, as it is completed, is acknowledged by the correspondent, through a signal, before the next word is commenced.

Two of the important applications of the principles of this invention of Professor Wheatstone, must be mentioned. The multiplication of "Telegraph Clocks," to any number, by their connexion through a single wire with one governing chronometer at a central point, so that the indication of time, in every part of a country, might be the same precisely; and a contrivance for enabling the telegraph to print its own intelligence, instead of rendering it visible, or to do both at the same time. For the latter purpose a type disc is made to rotate, precisely as the paper dial or the index would do, in front of a cylinder covered with white paper; there being interposed between the type and cylinder, a sheet of the copying or transfer paper well known as the carbonic ink paper. The slowness with which signals would be rendered, as compared with the needle instrument, prevented this grand invention of Wheatstone's from being brought much into use.

The relative positions of Messrs. Cooke and Wheatstone, in connexion with the invention of the Electric Telegraph, have been much disputed. The award of Sir M. I. Brunel and Prof. Daniell says, "Whilst Mr. Cooke is entitled to stand alone as the gentleman to whom this country is indebted for having practically introduced and carried out the Electric Telegraph, as a useful undertaking, promising to be a work of national importance,—and Prof. Wheatstone is acknowledged as the scientific man whose profound and successful researches had already prepared the public to receive it as a project capable of practical application,—it is to the united labours of two gentlemen so well qualified for mutual assistance that we must attribute the rapid progress which this important invention has made during the five years since they have been associated."

This award, it is contended, refers only to the *first* patent in which Mr. Wheatstone was associated with Mr. Cooke. Prof. Daniell, too, contends that the document has been misinterpreted: he maintains that "the applications which Prof. Wheatstone has made of the almost instantaneous transmission of this wonderful power to unlimited distances in telegraphic purposes, are far more wonderful, ingenious, and practically useful than anything which has yet been contrived for the concentrated action of the force. Like the Daguerreotype and the Voltatype, they have sprung from scientific principles to perfection. It is not difficult to foresee, that these modes of distant communication will rank, ere long, amongst the necessary conveniences of a highly civilized community."

And, M. de la Rive contends that Mr. Wheatstone was led to this beautiful result by the researches that he had made in 1834 upon the velocity of Electricity—researches in which he had employed insulated wires of several inches in length, and which had demonstrated to him the possibility of making voltaic and electro-magnetic currents to pass through circuits of this length. Vice-Admiral Smyth bears this testimony: Prof. Wheatstone "has had much obfuscation to put up with; though he is, undoubtedly, the first contriver of the Electric Telegraph in the form which made it available for popular use."*

In 1843, Mr. Cooke introduced the most important improvement, regarded in a commercial point of view. This was the suspension of the wires, in the air, upon posts or standards, for insulation, instead of conveying them under ground. The wires do not come in contact with any part of the standard, but pass through rings of earthenware. Iron wires of a large size can thus be used instead of copper.

* See the Memoir of Professor Wheatstone, which contains circumstantial details collected at considerable pains, and is accompanied by an engraved portrait of Professor Wheatstone, in the *Year Book of Facts*, 1867.

Here are two of the early applications of this marvellous power:

The first newspaper report by Electric Telegraph appeared in the *Morning Chronicle*, May 8, 1845, detailing a railway meeting held at Portsmouth on the preceding evening. On April 10, in the same year, a game of chess was played by Electric Telegraph, between Captain Kennedy, at the South-Western Railway terminus, and Mr. Staunton, at Gosport; the mode of playing was by numbering the squares of the chess-board and the men; and in conveying the moves, the electricity travelled backward and forward during the game upwards of 10,000 miles.

In 1845, by the Electric Telegraph then laid from Paddington to the Slough station, on the Great Western Railway, John Tawell was captured on suspicion of having murdered Sarah Hart at Salt-hill, on Jan. 1. Tawell left Slough by the railway on that evening; and at the same instant, by telegraph, his person was described, with instructions to the police to watch him on his arrival at Paddington: he was accordingly followed, apprehended and identified.

Dr. Lardner in 1850, shared with Leverrier, the Astronomer, and some other men of science, a series of experiments made with the view of testing "the efficiency of certain telegraphic apparatus." Two wires extending from Paris to Lille, were united at the latter place, so as to form one continuous wire, extending to Lille and back, making a total distance of 336 miles. This, however, not being sufficient for the purpose, several coils of wire wrapped with silk, were obtained, measuring in their total length, 746 miles, and were joined to the extremity of the wire returning from Lille, thus making one continuous wire, measuring 1082 miles. A message consisting of 282 words, was then transmitted from one end of the wire. A pen attached to the other end immediately began to write the message upon a sheet of paper moved under it by a simple mechanism, and the entire message was written in full before the committee of scientific persons present.

"This might well be looked upon as a feat sixteen years ago, but the science of Telegraphy has made such wonderful progress, that at the present time the two Atlantic Cables, when joined end to end, so as to form one unbroken length of nearly 4,000 miles, can readily be worked at a speed far greater than through the comparatively small length of line referred to in the foregoing experiment. Each cable can easily pass fifteen words per minute, or upwards of forty average messages per hour between Europe and America.

This speed of transmission is greatly exceeded in the working of short land-lines." *

We have already spoken of the earth being used with great advantage for one-half of the telegraphic circuit. This property is a most extraordinary phenomenon, and still remains a paradox to scientific men, and plays a most important part in telegraphy throughout the world. The writer on mathematical and physical science in the *Encyclopædia Britannica*, eighth edition, vol. I., p. 986, observes, under the head of "The Earth Circuit,"—"There is one circumstance connected with the electric telegraph deserving of particular notice. I mean the apparently infinite conducting power of the earth when made to act as the vehicle of the return current. Setting all theory aside, it is an unquestionable fact that if a telegraphic communication be made, suppose from London to Brighton, by means of a wire going thither passing through a galvanometer, and then returning, the force of the current shown by the galvanometer at Brighton will be almost exactly doubled if instead of the return wire, we establish a good communication between the end of the conducting wire and the mass of earth at Brighton, the whole resistance of the return wire is at once dispensed with. This fact was more than suspected by the ingenious M. Steinheil, in 1838, but, from some cause or other, it obtained little publicity; nor does the author appear to have exerted himself to remove the reasonable prejudice with which so singular a paradox was naturally received. A most ingenious artist, Mr. Bain, established for himself the principle, and proclaimed its application somewhat later, and, in 1843, perhaps the first convincing experiments were made by M. Mateucci, at Pisa." Again, Lardner observes that "of all the miracles of science surely this is the most marvellous. A stream of electric fluid has its source in the cellars of the Central Electric Telegraph Office, Lothbury, London; it flows under the streets of the great metropolis, and, passing on wires suspended over a zigzag series of railways, reaches Edinburgh, where it dips into the earth, and diffuses itself upon the buried plate. From that it takes flight through the crust of the earth and finds its own way back to the cellars at Lothbury."

We now proceed to detail a few of the amplifications and modifications, which it is anticipated by some writers upon

* The Electric Telegraph, by Lardner and Bright, new edit. 1867.

the subject, "will enable the telegraph to print its message, and even to speak it." Morse's instrument requires four waves for each letter, and the dial seven; still, Mr. D. E. Hughes has produced a Telegraph that requires but one electric wave. It has twenty-eight keys, like those of a piano, each of which corresponds to a letter, or number, or stop. When one of these keys is depressed, it brings a detent in contact with a pin corresponding to that letter on the circumference of a revolving type-wheel, stops it, and at the same time sends an electric wave to the distant station; here an electro-magnet detaches a similar detent, and, after stopping the same letter, a revolving cam presses a slip of paper against the type and takes off an impression. The keys may be touched, one after the other, with this result, nearly as quickly as one would touch those of a piano; they will render four words per minute a length of 2,800 miles, or six words in the same time a distance of 2,000 miles, or ten words per minute 1,000 miles, or twenty-four words per minute a length of 500 miles.

Bonelli's Telegraph consists of two tables of cast-iron placed inversely to each other at the corresponding station: each is provided with a miniature railway—over which run two wagons, one containing the type-set message, the other the paper—and two combs formed by the extremities of the wires of the line, one of which touches the type at one station, while the other passes over the prepared paper at the other. A spring catch to each of the wagons sets them free to move by the closing of an electrical current. Mr. W. Cooke, who furnished particulars of this instrument to the Bristol Association, asserts that a well-considered system of counter-currents had completely annihilated the inconveniences which, from the time of Bain to the present moment, had existed in electro-chemical telegraphy, and that no difficulty could be experienced in working it either on long or short distances.

Mr. W. Ladd proposed to convey from station to station a musical note or sound which, divided into various lengths and combinations, would form a sound alphabet similar to the signals written by Morse's Telegraph. Reiss's instrument consists of two pieces of apparatus, the one for transmitting the signal having a small mouth-piece. When a sound is made into the mouth-piece, the membrane vibrates and breaks contact between the pin and plate in its centre, causing the iron coil in the receiving instrument to be magnetized and demagnetized according to the number of vibrations with a musical sound. The production of exact *fac-similes* of pictures, or music, or writing, is another phase of this wondrous power. M. Casselli has elaborated Mr. Bakewell's principle by the contrivance of two cylinders moving at the two stations synchronously by mechanical means of his own invention. For the purpose of transmitting short-hand accounts of speeches at public meetings, or other news, this Telegraph would appear to be useful.

We read also of a Telegraph Printing instrument, producing letters printed in ordinary type by means of pressing small keys bearing the respective letters. It is worked by a combination of clockwork and electricity, and is stated to have been in use for some weeks without a single derangement. A very simple apparatus, invented about 1861, is described in the *London Review* as follows:—"In order to apply the current to the purpose of transmitting signals, the mechanism of the communicator is so arranged that when any one of the keys or buttons is depressed by the finger, the passage of the electric current is cut off along the line; and when any other key is similarly depressed, the action of a simple piece of mechanism causes the former key to be elevated, open the electrical circuit, and allow the induced current to flow through the instrument, along the wire, and to the distant station. In this way a message is readily transmitted. The person sending it with one hand keeps the handle of the box revolving; and with a finger of the other hand depresses by turns and successively the keys opposite the several letters required to spell the words. It needs no skilled operator to use the instrument; a child who knows his letters may send a message to his playmate who is just able to read, though he may be a hundred miles away from him. But how can the person to whom the message is sent receive and understand it? By means of what is termed the 'indicator.' This apparatus is something like a watch, placed on a small stand in any convenient position for observing the dial. The face of this dial is spaced and lettered in the same manner as that of the 'communicator.' To the hand of this indicator a step-by-step motion is given by means of an electro-magnetic apparatus, the details of which it is not necessary to explain, but so arranged as to be set in motion by the electric current sent along the wire from the communicator. The hand or pointer of this indicator moves precisely as the hand moves on the dial-plate at the other extremity of the line. The apparatus is not only simple, but it is so efficient, that with a small amount of practice a hundred letters may be transmitted within the minute; and it has this further recommendation, that it does not require the employment of any galvanic apparatus or corrosive acids."

Mr. A. Bain proposed to the Society of Arts, in January 1866, to form a complete system by the composing machine and the transmitting and receiving apparatus combined in the following manner. There should be only two wires at most on one line of posts, one to be called the up-wire and the other the down-wire, so that messages can be transmitted in both directions at the same time. The action is as follows:—The current passes from the battery to the main wire, from thence to a spring, through the perforations of the paper to a roller, then to the frame of the clockwork, and from thence to the main wire; but at each of the intermediate stations, when they are necessary, a portion will pass down through the ends of the branch circuits to the frames, through the styles to the chemical paper, and will return by the end to the main wire. In this way the currents are made to write a copy at every station on the line; but at the stations where copies may not be desired all that the operator has to do is to lift up the pen from the paper, or he may turn back the penholder frame altogether away from the disc. Mr. Bain showed a method by which a despatch could be transmitted from a central station, say from London, to any number of telegraph lines simultaneously, so that the despatch may be received and written at any number of towns on each line, in the way already described. This system has been proved electrically, chemically, and mechanically in England, France, and America. It can transmit intelligence from London to the farthest corner of England or Scotland at the rate of, in round numbers, 6 words per second, 333 per minute, 20,000 per hour, and with a degree of accuracy never before attained by any other system; and, further, it can automatically transmit despatches of any length from any place, say from London, to all the principal towns of England simultaneously, at the above-named degree of celerity.

"The Nerves of London" is the term applied to the system of wires which may be seen stretching across the sky-line of great thoroughfares, and visibly triangulating the town in every direction. By a simplified apparatus messages are sent along these lines at the rate of 100 letters a minute; the process of reading or renewing the message is, of course, proportionally rapid; and the new instruments for this purpose bear the same relation to the old ones that the works of a watch bear to the stronger machinery of an eight-day clock. A twofold advantage accrues from this. On the one hand, a means of producing the electro-motive power far simpler and more convenient than the voltaic battery, with its solutions and manipulation, can be employed; for a feebler current will do the work with these than with the heavier instruments. Likewise, from feebler currents being employed, and from the comparatively short distances these have to traverse in order to connect the furthest-sundered limits of even this metropolis, wires of far smaller dimensions can be employed to convey these currents. The use of copper for the material of the wire is also rendered possible and convenient by this great diminution in the size of the wire; and copper is a far less sluggish conductor than iron, pure copper standing at the head of all conducting substances.

The battery employed to transmit the electric impulse along this delicate thread of metal is a form of the magneto-electric machine—one of the most beautiful of Faraday's splendid gifts to science. By the converse proposition to that established by Oersted, that a magnet tends to place itself athwart a wire along which an electric current is passing, Faraday was enabled to show that a current having all the characters of one of voltaic electricity can be induced in a wire running athwart or winding round a magnetized bit of iron, so often as the magnetic repose, so to say, of the particles of that magnetic system is interrupted —as, for instance, by the sudden removal or replacement of its armature. By rapid rotation such a removal and replacement of a piece of iron before the poles of a magnet can be made to produce a series of electric impulses along a wire coiled around it; and electric impulses of this kind can be produced from a very small magnet, which yet possess sufficient power to work the delicate instruments that have been described, even after traversing some 150 miles of the ordinary coarse iron wire, or twelve miles of the extremely fine copper wire now used by Mr. Wheatstone in his new cables.

But it is to the construction of these cables, and to their distribution over London, that the business-world is to look for the effective working of the new system. The fine copper wires that have been mentioned as the conductors of the current would be too frail to resist the strain imposed on the iron lines now used. They are, therefore, merely suspended without strain, and at short intervals, from iron wires previously stretched tightly from post to post. But as each wire is to be, so to speak, a separate nerve attached to some special house, the demand from many householders would require the supply of a corresponding number of wires. Hence twenty, fifty, a hundred, or even many hundreds of these little nerves are connected into a system. Each is carefully wound with a thin, almost invisible, ribbon of the purest caoutchouc—and telegraphy is much indebted to the progress that has been made in the purification and treatment of that wonderful gum. Almost any number of these wires, thus varnished and protected from the damp, which in wet weather dissipates to a serious extent the electricity in the ordinary wires, are then united into one compact cable. This system of wires is then hung as has been described, and as may be seen vexing the eye at St. Clement Danes and St. Mary-le-Strand, the wires that sustain it being strained from poles from the house-tops. The area of London being divided by a system of triangulation, the posts that form the meeting-points of three series of cables become the points at which all these multitudinous wires have to be distributed, at intervals carefully selected. Such is a general sketch of this system of telegrams for the million, by Mr. Wheatstone's new scheme; and evidence of its general popularity may be gathered from the good-natured readiness with which householders have permitted the posts to be erected on the roofs of their dwellings.*

The varieties of the Electric Telegraph are so numerous that it may be convenient here to recapitulate those most extensively adopted, as stated by a contemporary. The apparatus employed to transmit intelligence by means of Electricity may be divided into two great classes—Telegraphs whose signals are transient, and must be read off one by one as they appear; and those which record their signals permanently, so that they can be read at leisure.

The instruments used in this country of the first class are the double and the single needle Telegraphs of Cooke and

* Abridged from the *Saturday Review.*

Wheatstone, used by the Electric Company and the South-Eastern Railway Company,—the single needle requiring one wire and the double needle two,—and a modification of the single needle used by the Magnetic Telegraph Company. Instruments of this class indicate letters by the separate or combined movements of their needles or pointers, are very simple in their construction, little liable to get out of order, and therefore are most suitable for the business of a railway, where skilled clerks cannot be employed.

The Telegraph of Professor Wheatstone, in which a hand points to the letter itself on a dial, is gaining ground for private use; and the Bell Telegraph of Sir Charles Bright, which reproduces the signals of the Magnetic Company's needle instrument by strokes upon two bells of different pitch, one of which represents the movements of the needle to the left, the other the movements to the right, is extensively used by the Magnetic Company, and has the advantage of leaving the hands free to write down the message as received.

The instruments of the second class are the so-called Printing Telegraphs of Morse and Bain, which *record* the signals received in an alphabet composed of dots and strokes. These instruments are used on all the important circuits of the Electric Company, and Morse's system is generally employed throughout Europe.

The Type-printing instrument of Professor Hughes has been introduced; but it is said not to be very successfully worked at present. It records the message in ordinary letters, which can, of course, be read by any one.

Professor Wheatstone has also introduced a Type-printing instrument for private use. To him Electro-telegraphy owes much; but his latest achievement (1867) excels all we have yet heard of. With his improved automatic instrument, properly manipulated, he can transmit 600 distinctly legible signs or letters in a minute.

The commercial value of an instrument does not depend upon the use of the ordinary alphabets, but upon the amount of work it will turn out, and its accuracy and freedom from derangement. The Morse instrument is at present unsurpassed in these respects, and it has been found that its introduction upon a circuit previously worked by the needle system reduces error to a very considerable extent. This arises from its signals being *recorded:* they can be read calmly and without flurry; and should an error arise, it can be traced to the person in fault, thus inducing a far greater sense of responsibility.

The speed attained by the double needle and Morse instruments in the highest speed on a circuit of a little under 200 miles was—

Double needle	35 words per minute.
Printing	38 ,,

Average of between two and three hours' continuous work reporting a speech—

Double needle	24·3 words per minute.
Printing	26·5 ,,

And for a circuit of more than 400 miles:—

Printing, average speed . . . 24·5 words per minute,

clerk reading from the manuscript of the *Times* reporter—not always very legible.*

The following results among what may be termed the *curiosities* of Batteries are very striking. "To show how thoroughly perfect the insulation of the Atlantic Cables is, Mr. Latimer Clark had the extremities of the two conducting wires which now stretch across the Atlantic joined together in Newfoundland, so as to form an immense unbroken loop-line of 3,700 miles. He then put some acid in a lady's silver thimble with a small piece of zinc, and another of copper, and by this simple agency he actually succeeded in passing signals through the entire length of both cables in little more than a second of time.

"To show how exceedingly small an electric charge may be made to produce signals through the Atlantic Cables, during the experiments carried on by Dr. Gould at Valentia, Mr. Collett, the superintendent at Newfoundland, actually sent a message with a battery composed of *a copper percussion-cap and a small strip of zinc, which was excited by a drop of acidulated water, the simple bulk of a tear.*"

We quote the above from Mr. E. B. Bright's excellent

* From *A Handbook of Practical Telegraphy*: by R. S. Culley, *Telegraphic Engineer*. Published with the sanction of the Chairman and Directors of the Electric and International Telegraph Company, who have adopted it for the use of their staff. Reviewed in *The Builder*.

Additions to the Electric Telegraph, by Dr. Lardner, reprinted in 1867. The *thimble* battery reminds us of the elementary galvanic battery which Dr. Wollaston, many years ago, formed out of a silver thimble with its top cut off. It was then partially flattened, and a small plate of zinc being introduced into it, the apparatus was immersed in a weak solution of sulphuric acid. With this minute battery he was able to fuse a wire of platinum one-three-thousandth of an inch in diameter, a degree of tenuity to which no one had ever before succeeded in drawing it.

Mr. E. Highton, C.E., has made a battery which exposes a surface of only one-hundredth part of an inch: it consists but of one cell; it is less than one-ten-thousandth part of a cubic inch; yet it produces electricity more than sufficient to overcome all the resistance in the patent gold-leaf Telegraph of the inventor's brother, and works the same powerfully. It is also a battery which, although it will go through the eye of a needle, will yet work a Telegraph well. Mr. Highton had previously constructed a battery in size less than one-fortieth part of a cubic inch. This battery he found would ring a Telegraph-bell ten miles off.*

Within the last few years some very remarkable discoveries have greatly added to the resources of telegraphic art. The Morse printing, the single needle, the bell sounder, and, in some cases, the alphabetic dial instrument, still keep their ground as the most generally used for land lines; and these forms appear, indeed, to have practically superseded all the other numerous, and often highly-ingenious, forms of electric communication that have yet been proposed.

That one and the same wire could be used for two messages simultaneously, in opposite directions, would have, at one time, appeared to the ablest electrician a sheer impossibility. Yet this has been practically accomplished by ingeniously devised plans, which, however, would require for their explanation too much technical detail for these pages. This method of *duplex* telegraphy is in daily operation, and by its means double work is obtainable from each wire. Even this has been surpassed; for an extended application of the same principle makes it possible for *four* different telegraphic messages to be simultaneously traversing the same wire.

* Paper read before the Society of Arts.

Still more recent is the wonderful realization of a long-desired achievement, namely, the transmission of sounds, or the production of articulate speech at an indefinite distance. This is what has been accomplished by the *telephone*, invented by Mr. Graham Bell, in 1876. It is not a little remarkable that the instrument by which you may converse with a person a hundred miles away, is, of all the instruments for communication at a distance, one of the very simplest. Externally it presents the appearance of a wooden handle, to which two wires are attached. Fig. 24 is a section through the centre of it; where N S represents a steel magnet, B a coil of silk-covered

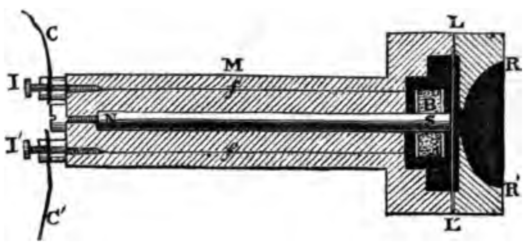


FIG. 24.

copper wire surrounding one end of the magnet, and having the terminals I I′, to which are attached the wires C C′, going to a receiving instrument of identical construction. L L′ is a thin circular metallic plate, and in front of it is the bell-shaped opening R R′. Into this opening you speak in your usual tone, and your correspondent at the distant end of the line, holding his instrument close to his ear, distinctly hears the words and even recognizes the sound of your voice. Many different forms of speaking-instruments have lately been devised, and some have given very wonderful results; but their description would carry us far beyond the limits prescribed for this article.

OCEAN ELECTRO-TELEGRAPHY.—THE ATLANTIC CABLES.

THE establishment of submarine telegraph lines, which enable instantaneous communications to pass between distant lands, is an achievement perhaps even more calculated to strike the public mind than the system of electric communication by land, where the visible connections between the stations have become familiar to our eyes. If we ask for the first inventor or projector of the submarine electric telegraphic line, we meet with the difficulty which also arises in other cases, from the fact that all such inventions are really developments, and that the palm can at best be awarded only to him who has made the widest step. For instance, as regards the invention we are now discussing, we find that, in firing mines by electricity, Schilling used submerged conductors as early as 1812. In 1839 Dr. O'Shaughnessy, superintendent of our Indian telegraphs, is said to have established a communication by a submerged wire across the River Hoogly; and it seems certain that, as early as 1837, Professor Wheatstone had conceived the idea of a submarine telegraph between Dover and Calais, and he had, in 1840, sufficiently matured his plans to bring before a Committee of the House of Commons a project for thus electrically connecting England and France. But it was, as we shall presently see, at least ten years later before the idea was successfully carried out.

Professor Morse claims the credit of having made the first practical experiment on the mode of crossing rivers or other bodies of water by electricity. In 1842 he conceived his subaqueous plan, which in December, 1844, he submitted to the United States House of Representatives. In the autumn of the former year the Professor connected, at New York, Governor's Island with Castle Garden, a distance of one mile. For this purpose he laid his wires, properly insulated, beneath the water. He had scarcely begun to operate when a part of his conductor was destroyed by a vessel which drew the wires up on her anchor, and cut them off.* The Professor, however, persevered, and next so arranged his wires along the banks of the river, as to cause the water itself to conduct the electricity; and the law of its passage was next ascertained. This plan was also put in practice by Captain Taylor, in his telegraph laid across the English Channel, by which instantaneous communication was made from coast to coast across the harbour of Portsmouth, from the house of the Admiral, in the Dockyard, to the railway terminus at Gosport; and thus a direct communication was made from London to the official residence of the Port Admiral at Portsmouth.

As soon as it had become known that Morse's experiments had proved the practicability of submarine telegraphs, many schemers came forward with their plans for a line between Europe and America. On the other hand, there were not wanting voices loudly to proclaim the impossibility, or at least improbability, of success in such an enterprise. The wire, it was said, would be frayed on rocks, or divided by the constant agitation of the waters, or it would be broken by the impact of great fishes, &c., &c. When, in spite of these prophecies of evil, the first submarine cable had been constructed and laid across the English Channel, or sunk in the bed of the Atlantic Ocean, the earlier experience seemed, as we shall presently show, to realize these unfavourable predictions. That the projectors should have recognized in these first failures merely the consequences of preventible accidents, shows their entire confidence that their enterprise was founded on just principles and would ultimately succeed. When a concession had been

* Professor Wheatstone made a similar experiment, and with a like result. Mr. George Cruikshank tells us that Mr. Wheatstone, when first appointed Lecturer at King's College, having seven miles of wire in the lower part of that building, which abuts on the river Thames, for the purpose of measuring the speed of the electric current, said to Mr. Cruikshank, "I intend one day to lay some of this wire across the bed of the Thames, and to carry it up to the top of the shot-tower on the other side, and so make signals." This was explained to Prince Albert on his visit to the College in 1843: the wire was duly laid, but was broken and swept away by a Thames barge. The experiment was, however, repeated with entire success. This was about eight months after Morse's experiment.

obtained from the Governments, authorizing the laying of a submarine cable, it was found that at first the public confidence in the success of these enterprises was so small that the necessary funds were not forthcoming.

Then a bold American schemed a telegraph across the Atlantic, to bring England and America within a speaking distance. He proposed to run a copper wire, well covered, and as large as a pipe-stem, from Nova Scotia to the coast of Ireland. This he thought might be accomplished by winding the wire upon reels, and arranging it on board a steamer, so as to be reeled off as fast as the boat's progress, and dropped the whole width of the Atlantic. A more confident experimenter claimed a telegraph "right-of-way" across the Atlantic. He proposed to carry the necessary wire part of the distance on board a steamer, and reel it off in a spool in its wake; maintaining that the wire of its own weight would sink down to a point where from the solidity of the water (!) it would remain in suspension; being at the same time below the *line of travel* of the monsters of the sea and the currents of the deep.

Next, Mr. C. V. Walker, superintendent of telegraphs to the South-Eastern Railway, having assisted in perfecting a wire covered with gutta-percha for use in tunnels, employed it for insulation in wet tunnels, and this suggested a submarine experiment. On January 9, 1849, having tested two miles of copper wire, insulated with gutta-percha, it was wound upon a wooden drum, mounted on a frame, and thus conveyed to Folkestone Harbour. Here a pole was set up in the sands, but above high-water mark, by which a wire was led from the telegraph office to the margin of the sea, thus completing the communication with the metropolis, by conversing with the clerks. Mr. Walker shortly afterwards laid down a chart of soundings, and traced upon it the line of a cable between Dover and Calais, nearly that actually adopted.

In the meantime Mr. Jacob Brett, of Hanover-square, had patented his "Subterranean and Oceanic Printing Telegraph," by which he and his brother, in 1845, had proposed to the British Government to put the metropolis in connexion with the various Colonial and Channel Islands. This line being combined with Brett's Patent Printing Telegraph, any communication could be instantly transmitted and delivered, in an unerring printed form, almost at the same instant of time, at the most distant part either of the United Kingdom or of the colonies.

Next, Mr. Brett and his partners obtained the right to establish an electric telegraph between France and England, by a submarine communication across the Channel: the points selected were from the beach at Dover to Cape Grinez, near Calais; the vessel employed was the *Goliath.* The experiment succeeded; but within a week the wire was cut asunder among the sharp rocks at Cape Grinez, and all communication between coast and coast was suspended. The experiment, so far as it went, proved the resistance of the gutta-percha to the action of salt water, and its perfect insulation; and that the weights on the wire were sufficient to prevent its being drifted away by the currents.

It appears, however, that in January, 1849, Mr. John Jos. Lake, of the Ordnance Office, Plymouth, proposed, to prevent the injury to telegraphs from the nature of the bottom of the sea, to suspend them by corks, placed at intervals, and to secure them to the bottom by anchors or a dead weight, at certain greater distances. "Had this plan been adopted," says Mr. Lake, "the injury to the wires off Cape Grinez could not have occurred, as no part of the wire would have touched the bottom."

In estimating the helps and appliances to the success of the Electric Telegraph, it is scarcely possible to overrate the properties of Gutta-percha, the discovery of which new substance dates within the decade of the Telegraph. It would seem almost as though one were sent to perfect the other. It was first employed in electrical experiments by Faraday, in 1848, who stated its use to depend upon the high insulating power which it possesses under ordinary conditions, and the manner in which it keeps this power in states of the atmosphere which make the surface of glass a good conductor. The telegraph-wire is not

SUBMARINE CABLE BETWEEN DOVER AND CALAIS.

only coated with gutta-percha, but inclosed in tubing made of it. For this purpose the gutta is dissolved in bisulphuret of carbon; the wire is passed over pulleys through the solution, and then through a tube lined with brushes, which remove anything superfluous; and by the time the wire reaches the second pulley, the bisulphuret has evaporated, and left a thin coating of gutta. Where the wire is to be roughly used, it is covered with cotton, and then passed through the gutta solution; but the tubing is more effective. A great feat of dispatch has been accomplished in this application. One day, in 1849, a coil of copper wire, 12,240 feet long, was delivered at the Gutta Percha Company's Works, City-road, at 4 P.M., to be covered with sulphuretted gutta for the Russian Government, with a strict injunction that it must be dispatched by the Hamburgh mail on the following day; and the coil was shipped within twenty-four hours of its arrival at the works. Such expedition is worthy of the Electric Telegraph itself.

To return to its early progress. The Dover and Calais cable had resolved the doubt which had been held as to the possibility of sufficiently insulating a wire for any considerable length under water; and the experimental line had failed by accident. Another cable was accordingly commenced at the Millwall manufactory, as suggested by Kuper—namely, a colliery rope, with outside iron wires laid spirally around the conducting wires covered with gutta-percha, instead of over the usual hemp core: by this means great strength was combined with an armour protection; and every subsequent cable upon this plan has proved a perfect success. The Dover and Calais cable was laid in 1851: notwithstanding the enormous traffic up and down Channel, this cable has been seldom injured during upwards of fifteen years' service, and has been easily repaired on each occasion; and in January, 1867, it was in a perfect state of insulation as regards the whole of its four conducting wires. The success attending the Dover and Calais cable led to the execution of further works of the kind, to connect England with Ireland, Belgium, Holland, Hanover, and Denmark, and subsequently for the Mediterranean and other seas and channels. In all, there have been no less than seventy-four important cables constructed in this country alone.*

* Dr. Lardner's *Electric Telegraph*, revised and rewritten by E. B. Bright, 1867. This work contains a list of the above Submarine Cables; the year

Before the close of 1855 the practicability of uniting the British Islands (the extreme west of Ireland) and Newfoundland (North America), nearly 2,000 miles apart, became more evident; and all doubts were removed by experiments upon underground lines in a continuous circuit of upwards of 2,000 miles, transmitting signals at the rate of 210, 241, and 270 per minute. Soundings had been taken, which proved that a gently undulating plateau of great breadth extends nearly the whole of the distance between Ireland and British North America, at depths of from 1,700 to 2,300 fathoms; and it was noted that the microscopic shells upon the surface of this plateau are so fragile that a breath would destroy them, thus affording proof that there are no currents moving here; "for had the shells been rolled to and fro, their delicate organism would have been bruised to pieces." *

The Governments on both sides encouraged the project, and the Atlantic Telegraph Company was formed, nearly the whole of the capital—350 shares of 1,000*l.* each—being subscribed for in this country in a few days. The engineer-in-chief was Sir Charles (then Mr.) Bright; the electrician, Mr. Whitehouse. The cable was manufactured by Glass, Elliot, & Co., of Greenwich, and Newall, of Birkenhead. The cable, with massive ends, weighing 10 tons to the mile, and encased with wires of great thickness, was in August, 1857, taken by the *Agamemnon* and *Niagara*, and paid out successfully to the extent of 335 miles. Then, great was the consternation occasioned by the discovery that the electrical continuity was lost. To the inexpressible delight, however, of everybody on board, the electricity suddenly returned, just as the scientific authorities were going to give the order to cut the cable and wind in. Before morning their joy was turned to sadness, for the brakes were applied to stop the cable from running out too fast, and as the stern of the ship rose from the trough of the sea the strain was too sudden, and the cable parted.

Such was the failure of the first attempt to span the Atlantic. The cable had been manufactured after experiments on upwards of sixty kinds of cables. The expedition started from

when laid; the number of conducting wires; number of outer iron wires; total length; weight per mile; and remarks. Those cables in *italics* (27 in number out of 74) have failed. Thus at a glance we see the progress which has been made in Submarine Telegraphy to January, 1867.

* Dr. Lardner's *Electric Telegraph*, p. 110.

Valentia, Ireland, where the shore-end being landed, there was a ceremonial inauguration of the enterprise. The Lord Lieutenant, the Earl of Carlisle, received the extreme end of the cable, and drew it into a hut, where electric batteries had been placed, on the beach of Valentia Harbour. Great was the enthusiasm of the poetic temperament of his Excellency; as well as the earnestness of the people, and of the practical men who accompanied the ships to sea, paying out the cable as they went. When they had reached 200 miles, messages were conveyed to and from land and the ships with the utmost facility.

Mr. Whitehouse, the electrician, now resumed his experiments with a view to a renewed attempt to lay the cable. In the ordinary wires by the side of a railway the electric current travels on with the speed of lightning; but when a wire is encased in gutta-percha, or any similar covering, for submersion into the sea, new forces come into play. The electric excitement of the wire acts by induction, through the envelope, upon the particles of water in contact with that envelope, and calls up an electric force of an opposite kind. There are two forces, in fact, pulling against each other through the gutta-percha, as a neutral medium,—that is, the electricity in the wire, and the opposite electricity in the film of water immediately surrounding the cable; and to that extent the power of the current in the enclosed wire is weakened.

A submarine cable, when in the water, is virtually *a lengthened-out Leyden jar;* it transmits signals while being charged and discharged, instead of merely allowing a stream to flow evenly along it; it is a *bottle* for holding electricity rather than a *pipe* for carrying it; and this has to be filled for every time of using. The wire being carried underground, or through the water, the speed becomes quite measurable—say a thousand miles in a second, instead of two hundred thousand—owing to the retardation by induced or retrogade currents. The energy of the currents and the quality of the wire also affect the speed. Until lately it was supposed that the wire acted only as a *conductor* of electricity, and that a long wire must produce a weaker effect than a short one, on account of the consequent attenuation of the electrical influence; but it is now known that, the cable being a *reservoir* as well as a conductor, its electrical supply is increased in proportion to its length.

As a consequence of these properties, the signals are not received at the end of a long submarine cable with the promptitude and decision which characterize the working of a land line. Indeed, but for such delicate instruments as those invented by Sir W. Thomson, it would have been impossible to work long submarine lines except with great slowness. There are two instruments of Sir W. Thomson's particularly used for submarine lines, namely, the *mirror galvanometer*, and the *syphon recorder*. The former is represented in Fig. 25. The general principle on which it acts is the same as that of the single needle instrument, but the magnet is very small, light, and delicately suspended, and carries a little mirror, by which a ray from a lamp, D, is reflected on a screen, C, and appears as a spot of light. The slight movement of the mirror is greatly magnified in the movement of the spot of light, which may be

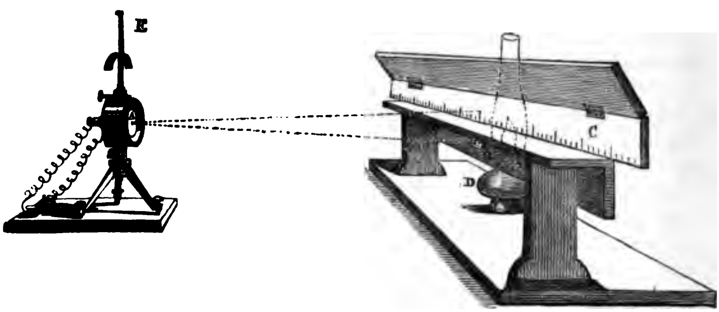


FIG. 25.—THE MIRROR GALVANOMETER.

considered as practically a long, *weightless* pointer for indicating the motion of the magnet. The messages are received by watching the movements of the spot of light, and in these movements, which, closely observed by a bystander, would appear merely irregular starts or stoppages, the telegraphic clerk recognizes distinct signals from the other end of the line. The other instrument is, as its name imports, a recording one, that is, it writes the message in a permanent form.

The next attempt, early in 1858, was made under the immediate direction of Mr. Cyrus W. Field, who from the commencement greatly promoted the scheme, and now accepted the post of general manager, generously refusing a proffered salary.

Mr. Everett had now designed a paying-out machine on a new principle; and Mr. Appold had invented "self-releasing brakes," so constructed as to give way when the strain exceeded a ton and a half. As the cable was calculated to support a strain of something over three tons, the recurrence of the accident of the previous year was thus rendered impossible. On this occasion, the laying of the cable was commenced in mid-ocean, the *Niagara* and *Agamemnon* proceeding in opposite directions after splicing their respective portions. Twice the cable broke when the ships had not long separated, and twice the gallant ships met again and renewed the splice. The third time the ships receded from one another as far as 200 miles, when the electric current again ceased to flow. This time the cable was found broken within 20 feet of the *Agamemnon!* No one could then guess the cause of the disaster; and by experiments, which were made before cutting off the now useless remnant from the *Niagara*, it appeared that the cable, or what remained of it, was capable of supporting a strain of four tons for an hour and forty minutes.

Notwithstanding this failure, the ships, after re-coaling, started for another and this time successful effort; and the cable was laid between the two continents on the 5th of August, 1858, by Sir Charles Bright, and his staff of engineers, after eight days, during which 2,022 miles of cable were placed. After transmitting messages for nearly a month, some defect in the insulation of the conducting wire put an end to the further working. The testing showed a fault at about 270 miles from Valentia, the electrical leakage having been augmented by the strong currents used to pass signals through the cable. During the working period, 97 messages had been forwarded from Valentia to Newfoundland, and 269 messages from Newfoundland to Valentia. "Among these may be instanced the message from her Majesty to the President of the United States, and his reply; messages stopping the departure from Canada of two regiments for this country, thus saving at least 50,000*l.* unnecessary expense to our Government; and messages announcing the safe arrival of the steamer *Europa*, with mails and passengers uninjured, after her collision with the *Arabia*." * Mr. Cyrus Field, on the 5th of August, from the *Niagara*, Trinity Bay, Newfoundland, telegraphed to the Associated

* Dr. Lardner's *Electric Telegraph*, edited by Bright, p. 115.

Press, New York, that the Atlantic Telegraph was completed. No words can express the enthusiasm with which Mr. Field was received as he steamed in triumph into New York. Alas! on the very day which had been set apart to do him special honour, the speaking, living existence of the cable was at an end, and it lay along the bed of the Atlantic an inanimate and useless mass! Several attempts were made to pick up the cable to see where the faults were, but were unsuccessful. Just 111 years previously, on the 5th of August, 1747, Dr. Watson astonished the scientific world by practically proving that the electric current could be transmitted through *a wire hardly two miles and a half long.*

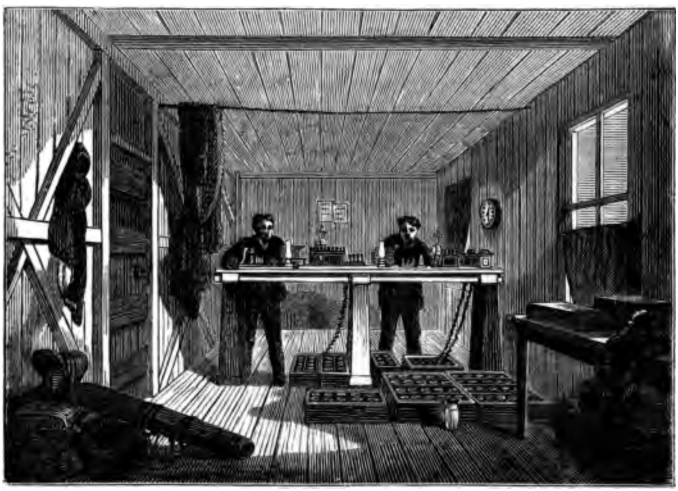
From the above time to 1865, a period of seven years, no fresh attempt was made. Valuable experience had, however, been gained. It was ascertained that it was advisable to construct a cable proportionately stronger and specifically lighter than the first Atlantic line, so that it might be recoverable from great depths. A larger conductor and more perfect insulation were requisite for so long a circuit, to insure greater speed with a less intense current. Meanwhile, the Atlantic Company survived, and at length the cable of 1865 was proposed. Sir Charles Bright recommended the combination of iron wire and hemp for the outer protecting strands, by which the specific gravity was reduced, and greater strength gained; while casing the wires in hemp, saturated with tar, would preserve them from rust. The weight and bulk of the cable were so enormous, that the *Great Eastern* was taken up for its shipment, and prepared accordingly; huge tanks were built within her to receive the cable, and keep it saturated with water. Here is a description of the work as it lay in the *Great Eastern,* prepared for the Expedition:—"The Atlantic Cable is just 2,200 nautical miles, or in round numbers, about 2,600 miles long. The central conductor is composed of seven fine copper wires, twisted into one complete strand, insulated with Chatterton's patent compound. Outside this come four distinct layers of gutta-percha, each also insulated with the same material that encloses the conductor. Outside the gutta-percha again are wound eleven stout iron wires, each of which, before being twisted on, is itself carefully wound round with strands of hemp, soaked with tar. Thus, then, there are no less than 25,000 miles of copper wire in the conductor, about 35,000 miles of iron wire in the outside covering, and upwards of

400,000 miles of strands of hemp, more than enough in all to go 24 times round the world. In strength the cable is equal to bearing a strain of $7\frac{3}{4}$ tons, while its specific gravity is so low that it can with safety be depended on to support 11 miles of its length in water. It has been made mile by mile, joined up in long lengths of 700 and 800 miles, and shipped on board the *Great Eastern* into three enormous wrought-iron tanks: the first holding a coil of 630 miles of cable, the second one of 840, and the third one of 830. The tanks themselves, with water and their contents of cable, weigh in all upwards of 5,000 tons. To shore them up with cross-beams, struts, and braces, no less than 400 loads of timber were consumed. The mere cable, was but an item in the mass of heavy weights the *Great Eastern* had to carry on this occasion. Her draught of water was rather over than under 30 feet, and, all told, her weights, when starting from Valentia, came near the stupendous mass of 18,000 tons."

Dr. Field, of New York, has published a *History of the Electric Telegraph*, which a reviewer in the *Athenæum* states to contain a "personal narrative, which the author can only have derived, as a whole, from the actual promoters of the scheme," and upon which the reviewer founds the following:—

"It was while turning round a globe, and meditating on Mr. Gisborne's proposition for a telegraph from Newfoundland to New York, that a young merchant, who had retired from business with an ample fortune, was led to ask himself the question, Why should not there be a wire across the Atlantic Ocean itself? The subject had occupied other people's minds; and Lieut. Berryman, sent out by the Navy Department to study winds and currents, had already reported the existence of the deep sea plateau. Accordingly, when Mr. Field wrote to the National Observatory at Washington to ask for scientific advice as to the feasibility of the telegraph scheme, Lieut. Maury answered,—'Singularly enough, just as I received your letter I was closing one to the Secretary of the Navy on the same subject.' He inclosed a copy of this official letter, and it contained the following remarkable words:—'Whether it would be better to lead the wires from Newfoundland or Labrador is not now the question; nor do I pretend to consider the question as to the possibility of finding a time calm enough, the sea smooth enough, a wire long enough, a ship big enough, to lay a coil of wire sixteen hundred miles in length. . . . A wire laid across from either of the above-named places on this side will pass to the north of the Grand Banks, and rest on that beautiful plateau to which I have alluded, and where the waters of the sea appear to be as quiet and as completely at rest as it is at the bottom of a mill-pond.' Strange that this 'beautiful plateau' should occur at the narrowest part of the ocean, and between countries which are both occupied by energetic Anglo-Saxons! Here then was sufficient encouragement: other men, to whom science was a regular pursuit, had prepared the course, Cyrus Field was the man to run the race. He at once set to work with extraordinary energy, and, with his own example to back his arguments, succeeded in inducing four other men of large fortune to enlist themselves in the enterprise. With some little trouble a very liberal charter was obtained from the Government of Newfoundland, and at six o'clock, one Monday morning, at the house of Mr. Cyrus Field's brother, a company was organised with five directors, the charter was formally accepted, and a capital of a million and a half of dollars was subscribed."

The accompanying Illustration shows the reception of the Telegrams, and the interior of the Instrument-room of the Telegraph-house at Foilhommerum, Valentia: the instruments are Professor Thomson's.

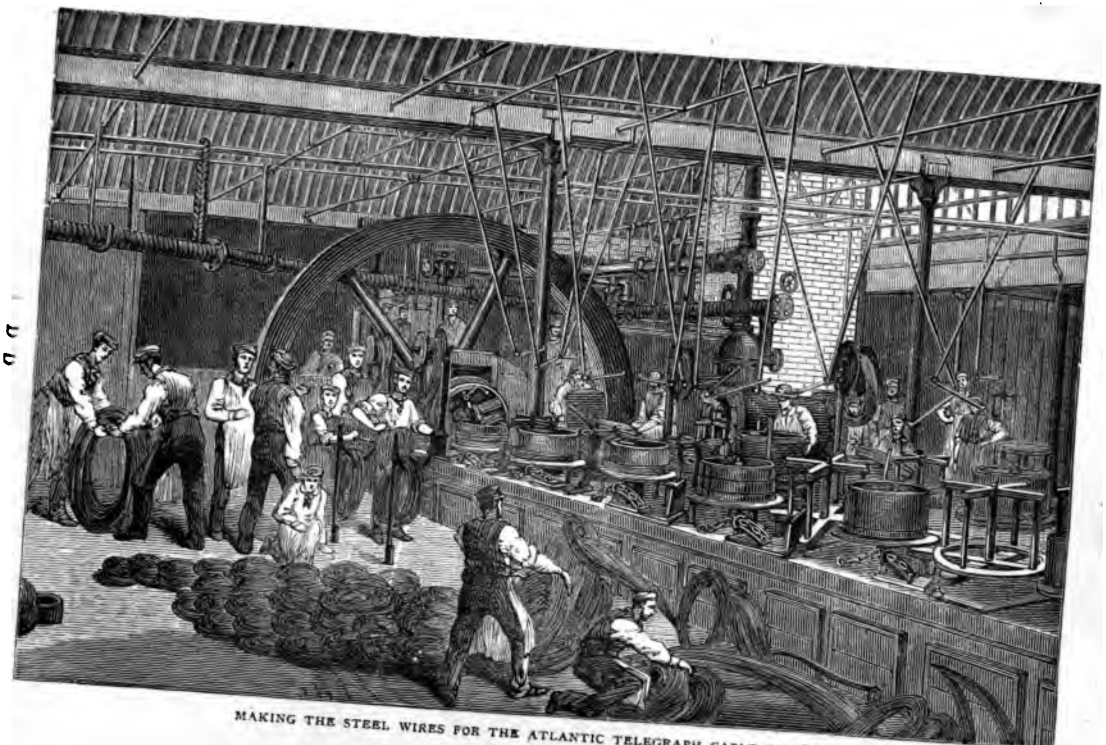


RECEIVING MESSAGES FROM THE GREAT EASTERN IN THE INSTRUMENT-ROOM AT VALENTIA.

The introduction of the cable to the telegraph station in 1865, is thus described by the artist of the *Illustrated London News*:—"The shore-end of the cable was taken up by Mr. Glass, and handed to Sir Robert Peel, who passed it through a hole left for the purpose in the building which forms *pro tem.* the station, where it was speedily connected with the batteries in the instrument-room. A signal was then interchanged with the *Caroline*, proving that the electric communication was perfect. Mr. Glass formally announced the success of the test that had been applied, and then the men returned to the beach, and filled in the trench in which the cable lay. The *Hawk* having arrived from Kingstown, towed the *Caroline* out of the bay to lay the cable, which was done under the direction of Mr. Canning." We now return to the details of the manufacture of the cable.

The cable of 1865 was constructed by Messrs. Glass and Elliot, at their factory at Morden Wharf, East Greenwich. The metallic wire wound spirally around the cable to protect it from damage, was manufactured at Birmingham, by Webster and Horsfall, of Hay Mills. The engraving on the next page represents the large range of shopping, showing the men at work, each superintending a drum on which the wire is coiled, as it is drawn down from one size to another; this wire being used for binding round the core containing the copper wire along which the electric current is transmitted. This portion of the manufacture has just been described at page 370. Messrs. Glass and Elliot having combined their works with those of the Gutta Percha Company, the insulation of the conducting wire was proceeded with, *pari passu*, under the careful superintendence of Mr. Chatterton and Mr. Willoughby Smith. The eight separate insulating coatings reduced incalculably the chance of any defect occurring at one point in all, and resulted in the insulation being far superior to that of any previous cable.

The *Great Eastern* sailed from Valentia on the 23d of July. On the second day after starting from the Irish coast, a fault in the electric insulation of the cable was detected: a tiny piece of loose iron wire had forced its way through the outer covering and the gutta-percha surrounding the electric wire, so as to come in contact with the latter; and, when this piece was cut out and a new splice made, the fault was effectually cured. The cable had again to be raised and examined in the same way, on the 29th, when the ship was in 2,000 fathom water, 636 miles from Valentia, and 1,028 miles from Newfoundland. A total loss of electric insulation, or "dead earth," as it is called, was discovered about one o'clock that afternoon. The ship was stopped at once, and, as soon as the picking-up machinery could be put in gear, the end of the



MAKING THE STEEL WIRES FOR THE ATLANTIC TELEGRAPH CABLE OF 1865.

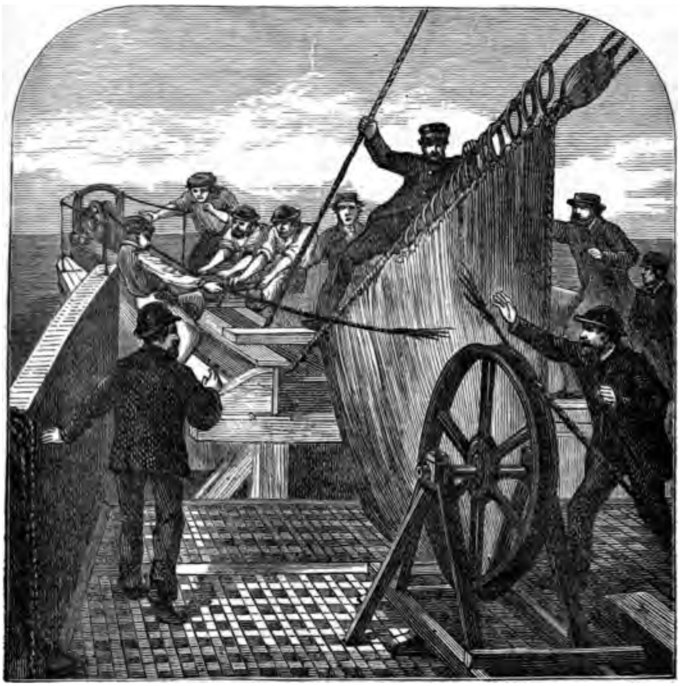
cable was hauled in again over the bows, and the faulty portion having been cut off and laid aside for a minute examination, the remainder was spliced afresh, and the operation of paying-out over the stern of the ship was recommenced next morning.

We abridge from Mr. Russell's Diary, his very able account of the actual breaking of the cable, on Wednesday, the 2d of August, which he has justly called "a sad and memorable day." "While Mr. Cyrus Field was on watch in the tank, a little before the time of the accident, a grating noise was audible as the cable flew over the coil. One of the experienced hands immediately said, 'There is a piece of wire,' and called to the look-out man above to pass the information aft, but no notice appears to have been taken for some time of the circumstance. After the ship had been stopped, and the remainder of the fluke in which the fault was supposed to have occurred had been paid out, a piece of wire was seen projecting out of the cable in the fluke. It was nearly three inches long, and evidently of hard, ill-tempered metal, which had flown out through the strands of the cable in the tank. The discovery was in some measure a relief to men's minds, because it showed that one certainly, and the second possibly, of the previous faults might have been the results of similar accident. It was remarked, however, that this fault occurred on the same watch as all the previous misfortunes had occurred.

"With less difficulty than usual, the cable was hauled in over the bows at 10.8 A.M. Greenwich time. It was fortunate that we had not got a few miles further, as we should have then been in the very deepest part of the Atlantic plateau. As far as could be ascertained, the ship was now over a gentle elevation, on the top of which there were only 1,950 fathoms of water. The picking-up was, as usual, exceedingly tedious, and one hour and forty-six minutes elapsed before one mile was got on board; then one of the engine's eccentric gear got out of order; next, the supply of steam failed, and when the steam was got up it was found that there was not water enough in the boilers, and so the picking-up ceased altogether for some time, during which the ship forged ahead and chafed against the cable.

"After two miles of cable had been picked up, the *Great Eastern* was forced to forego the use of her engines because the steam failed, while her vast broadside was exposed to the wind, which was drifting her to the larboard or the left-hand side, till by degrees an oblique strain was brought to bear on the cable, which came up from the sea to the bows on the right side. Against one of the hawsepipes at the bows the cable now caught, while the ship kept moving to the left, and thus chafed and strained the cable greatly against the bow, for now it was held by this projection, and did not drag from the V-wheel in front. The *Great Eastern* could not go astern lest the cable should be snapped, and without motion some way there is no power of steerage. At this critical moment, too, the wind shifted, so as to render it more difficult to keep the head of the ship up to the cable. As the cable then chafed so much that in two places damage was done to it, a shackle chain and a wire rope belonging to one of the buoys were passed down the bow over the cable and secured in a bight below the hawsepipes. These were hauled so as to bring the cable, which had been caught on the left-hand side by the hawsepipes, round to the right-hand side of the bow, the ship still drifting to the left; while the cable, now drawn directly up from the sea to the V-wheel, was straining obliquely from the right with the shackle and rope attached to it. It was necessary to do this instead of veering away, as we were near the end of the cut of cable.

"The cable and the wire rope together were now coming in over the bows in the groove in the larger wheel, the cable being wound upon a drum behind by the machinery, which was once more in motion, and the wire rope being taken in round the capstan. Still, the rope and cable were not coming up in a right line, but were being hauled in, with a great strain on them, at an angle from the right-hand side, so that they did not work directly in the V in the wheel. Still, up they came. The strain was shown on the dynamometer to be very high, but not near breaking-point. At last, up came the cable and wire rope shackling together on the V-wheel in the bow. They were wound round on it, slowly, and were passing over the wheel together, the first damaged part being inboard, when a jar was given to the dynamometer, which flew up from 60 cwt. —the highest point marked—with a sudden jerk, 3½ in. In fact, the chain shackle and wire rope clambered, as it were, up out of the groove on the right-hand side of the V of the wheel, got on the top of the rim of the V-wheel, and rushed down with a crash on the smaller wheel, giving, no doubt, a severe shock to the cable to which it was attached. The machinery was still in motion, the cable and the rope travelled aft together, one towards the capstan, the other towards the drum, when, just as the cable reached the dynamometer, it parted, 30 feet from the bow, and with one bound leaped, as it were, into the sea."



THE BREAKING OF THE ATLANTIC TELEGRAPH ON BOARD THE GREAT EASTERN.

This is the scene on board represented above, from an engraving, drawn by Mr. Robert Dudley, the artist who accompanied the Expedition, to sketch its many incidents for the *Illustrated London News.* Mr. Canning, the chief engineer of the work, was standing close by. Mr. Russell goes on to say:—"It is not possible for any words to portray the dismay with which the sight was witnessed and the news heard. It was enough to move one to tears, and, when a man came aft with the inner end still lashed to the chain, and we saw the tortured strands, torn wires, and lacerated core, it is no exaggeration to say that a strange feeling of pity, as though for some sentient creature mutilated and dragged asunder by brutal force, passed through the hearts of the spectators. But of what avail was sentimental abstraction, when instant, strenuous action was demanded? Alas! action? There, around, spread the placid Atlantic, smiling in the sun, and not a dimple to show where lay so many hopes buried. However it was something to know, though it was little comfort, that we had at noon run precisely 116·4 miles since yesterday, that 1,186 miles of cable had been paid out, that we were 1,062·4 miles from Valentia, 606·6 miles from Heart's Content, that we were in lat. 51 deg. 25 min. long. 39 min. 6 min. our course being 76 deg. S. and 25 deg. W. The *Terrible* was signalled 'The cable has parted,' and was requested to bear down to us, which she did, and came-to off our port-beam. After a brief consideration Mr. Canning, whose presence of mind and self-possession never left him, came to the resolution to seek for the cable in the bottom of the Atlantic, and to get out his grapnels and drop down on it and pick it up again."

There were men on board who had picked up broken cables from the Mediterranean, full 600 fathoms down. It was settled that the *Great Eastern* should steam ten or twelve miles to windward and eastward of the position in which she was when the cable went down, out with the grapnels and wire rope, and drift down across the track in which the cable was supposed to be lying. The grapnels were two five-armed anchors with flukes, with sharply-curved, tooth-like ends, the hooks with which the engineer was going to fish from the *Great Eastern* for more than a million. The ship lay-to, in smooth water, with the *Terrible* in company. The grapnel, weighing three cwt. shackled and secured to a length of wire buoy-rope, of which there were five miles on board, was brought up to the bows, and thrown over. At first, the iron sank but slowly, but soon the picking-up machinery lowered length after length over cog-wheel and drum, till the iron wires, warming with work, heated at last so as to convert the water thrown upon the machinery into clouds of steam.

Still the rope descended, and the strain was diminished, when at 2,500 fathoms, or 15,000 feet, the grapnel reached the bed of the Atlantic; and as the ship drifted across the course of the cable, there was just a surmise that the grapnel might catch it. In the search from August 3 to August 11, the cable was grappled three times—on the 3d, 7th, and 11th; it was lifted each time a considerable way from the bottom: but the grapnel, ropes, and lifting machinery, were not sufficient to bring it to the surface. On the first attempt, the grapnel having been let down overnight, they began to haul in the rope early next morning. At eight o'clock, 300 fathoms were in, and it was evident to all on board that the grapnel was holding on, and lifting "something" from the bottom. Presently the upper wheel of the picking-up apparatus broke, and the operation of taking in the rope became dangerous.

The weather, which had hitherto been very thick and hazy, now settled down into a dense fog, and the *Great Eastern* lost sight of the *Terrible;* but the conviction was that the cable was really once more attached to the *Great Eastern*, no matter how precariously, or how far off. The hawser toiled and pulled as if it were a living thing, and struck out a considerable angle from the bows, as if it were towed by some giant force underneath and away from the steamer. When 500 fathoms were inboard, the most sceptical admitted the cable must be on the iron hooks; but all hopes and fears were now abruptly ended. The drum flew round rapidly, the tail of the rope flourished in the air, as it flew inboard, and with a light splash the other end of the rope dived into the Atlantic. One of the iron swivels had yielded to the strain. The rope used was divided into lengths of 100 fathoms, each having a shackle at the end, with a heavy iron swivel. The head of the bolt of one of these had been drawn right through the iron collar, as 900 fathoms had been secured. Not a moment was to be lost. It was clear that the grapnel could pick up the cable in more than 2,000 fathoms, and the only question now was whether the wire rope would bear the purchase and weight of hauling up from such vast depths. There was fortunately wire rope enough left to make another attempt, and it was then resolved to steam forthwith to a point two miles eastward of the extreme end of the cable, so as to have only a mile or so of it to lift up in the bight when the ship drifted over it; as the broken part would, it was hoped, in coming up on the grapnel, twist round the other portion of the cable. A fog came on that afternoon, and the *Great Eastern* lay for the night in a smooth sea. Next day she drifted 34 miles, which, with 12 miles steamed, made 46 miles from the position where the cable parted. A raft was then made, and on it was placed a buoy to slip over with 2½ miles of cable, itself attached to a mushroom anchor, as soon as they reached the spot where they had grappled the cable the day before. This was done, and the big ship steamed off again; the fog continued two days, and she drifted still about.

On Monday, Aug. 7, between 11 and 12 o'clock, the weather having cleared, the grapnel, with 2,500 fathoms of cable, was hove over. The machinery was so much improved, that the grapnel was only half the time in reaching the bottom, and the diminished strain soon showed that it was resting on the ooze. The day was fine, a steady breeze from the north drifting the ship towards the cable, at the rate of a mile an hour, broadside on. At noon the position was at lat. 51° 27′, long. 48° 42′. For several hours the grapnel dragged the bottom without obstruction. At 6.15 the strain increased from 45 cwt. to 48 cwt. and soon began to rise steadily to 55 cwt. and thence to 60 cwt. Presently was observed a slight tendency in the ship to come round to the wind, and in an hour and a half the cable was caught again. The ship's head was brought round to the wind by the screw, and the capstan engine was set to work to aid the new machinery of the picking-up gear to haul up the cable. At half-past 11, 500 fathoms were hauled in. All seemed going on hopefully till next morning. Between five and six o'clock, A.M., it was calculated that the grapnel, with the cable, was then rising from the bottom. The rope had come steadily on at an average during the night of 150 fathoms an hour; and there was consequently great gladness on board. The one mile mark was hauled in, and it was demonstrated that a ship could pick up a cable in 2,500 fathoms of water, and pull it one mile from the bottom. The cable was now suspended 1,500 fathoms, or one mile and a half below in ocean. This good news was signalled to the *Terrible*, and in an instant the flags were flying, and all was over. One of the shackles and swivels which joined each length of wire rope to the other, had come over the bow, had passed over the drum, and was in the third round of rope taken in by the capstan, when the head of the swivel-pin gave way, and quick as lightning, with the end flourishing, the iron shackle like a mailed fist in the air, right and left, as if menacing with death any one in its way, glanced aloft, and leapt exultingly into the sea, to join the cable and the 1500 fathoms of wire rope which still hung from the grapnel. Now all these shackles and swivels were examined before they were put over to prevent the recurrence of accident; the strain was not near that put down as the breaking point, yet such was the sad result. The news was signalled to the *Terrible*, and her boat put off to learn what was to be done. At 9.50 a second buoy, secured on a raft of casks, was lowered with 2,500 fathoms of telegraph cable moored to a broken spar-wheel, the buoy being let go as close as possible to the spot where the grapnel-rope sank. Almost in despair the operators resolved on one more attempt.

August 9 and 10 were employed in re-adjusting and fortifying the picking-up machinery and the grapnel-tackle. The anchor capstan was enlarged and strengthened with huge beams of oak, and an iron casing all round it, forming a huge drum of twice the diameter of the ordinary capstan for winding on the wire rope and great hawsers more rapidly; while "the slack" was to be taken in from this drum as fast as it accumulated, and passed along a line of men to the place where it was to be coiled on deck.

August 11 was the last day of painful trial, the final yield-to the disaster. Not satisfied with the progress of the work, the operators drew up the grapnel to examine it, and found it defective. The stock of wire being diminished by all these mishaps, hempen rope was added to supplement it. Another grapnel was lowered, and another attempt was made to catch the cable. Nearly a mile was hauled on board, when the hempen rope snapped, and for the fourth time the cable went to the bottom. All was over. There were not materials enough on board for a fifth attempt.

The *Terrible* steamed on to America to announce the failure to those who were anxiously waiting the result at Newfoundland; and the *Great Eastern*, after lowering a third buoy, returned home. Nearly 1,200 miles of the cable now lay along the bed of the Atlantic Ocean; one end attached to the shore at Valentia, the other submerged under 1,950 fathoms of water, and resting on a soft, oozy bottom. A length of

5,500 miles of cable altogether had been made for this great Atlantic enterprise from 1857 to 1865, and nearly 4,000 miles had been swallowed up in the ocean; a million and a quarter had been sunk; but the grand hopes were not crushed.

The various telegraphic companies interested in the completion of the undertaking wisely concluded to resume operations forthwith. Their first intention was to construct all the necessary mechanical appliances and send back the *Great Eastern* in October to pick up the broken cable, splice it with what remained on board, and finish the work which accident had suspended. On consultation with Captain Anderson, however, they substituted for this plan a much wiser one. The three companies, Atlantic, Construction, and Great Ship, agreed on the general basis of a new scheme: the Construction Company undertook both the raising of the old cable, and the making of a new one. The Great Ship Company agreed to make any needful alteration in the ship, to be chartered by the Construction Company, who were to receive 600,000*l.* if the enterprise succeeded, 500,000*l.* it it failed. The new cable, placed by the side of that of 1865, is stronger, lighter, and more flexible, giving it an immense aggregate superiority, and enabling it at any point to resist a strain of eight tons. The length shipped was 2,730 miles; that of 1865, was 2,300 miles. The new cable was made by the Telegraph Construction and Maintenance Company, at their works in the City Road, and at East Greenwich.

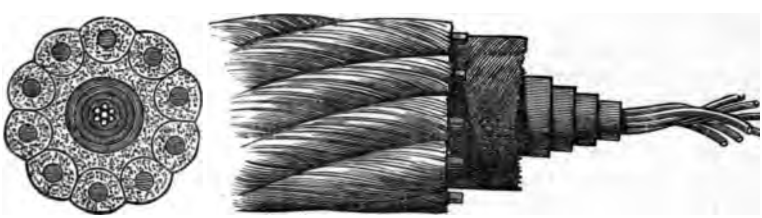
Should hauling in become necessary, it could now be done either from the head or stern of the *Great Eastern*. From the stern it might be effected by the paying-out machinery, the drums of which were altered and strengthened, and reversing gear was added; so, in fact, the machine could be used either in paying out or hauling in. The machinery for this purpose in the bows of the ship was entirely new; it had double drums, and was calculated to work up to a strain of sixteen tons, and would not give way under a pressure of considerably more than thirty tons. It was specially constructed with a view to grappling for the old cable, and was to be worked by a double-cylinder trunk-engine of 40-horse power, nominal. The dynamometers for the picking-up as well as for the paying-out machinery were fitted with adjusting weights, and had larger scales attached, so that more delicate observations would be attainable. A "crinoline" guard, weighing

17 tons, over or around the screw-propeller of the *Great Eastern*, to prevent entanglement with the cable during its descent from the stern of the ship. If a fault should occur the screw might be backed, and the cable hauled in, to examine the cause of fault, with great quickness, by the alterations thus made in the apparatus.

The electricians were at work during the winter of 1865-6, in the wooden shanty, the telegraph-room at Valentia, working and watching the exquisite apparatus connected with the end of the 1865 cable. Impulses were driven through the eleven or twelve hundred miles of submerged cable twice or thrice every day, to see whether insulation and conductivity were at all injured. Of course, no messages could be sent or received, because the other end of the cable was down two miles deep at the bottom of the Atlantic; but Professor Thompson, Mr. Willoughby Smith, and Mr. Varley, had so improved the apparatus, that they could tell at once whether an impulse was going through the wire or not. Every test showed that the cable was as perfect from end to end as when first laid down, in all electrical qualities. There was a minute mirror attached to a magnet, and a graduated scale on which reflected light from the mirror fell; if an electric current through the cable affected the apparatus, the minutest oscillation of the magnet moved the mirror at the same time, and caused a moving spot of light to travel along the graduated arc; the extent of the oscillation being measured by the range of travel over the graduations.

On Sunday, July 1, the *Great Eastern*, with her costly burden, left the Nore, and on the 7th arrived at Belhaven, a small but fine anchorage at the south-west of Ireland; and the *William Corry* having arrived, everything was got ready for splicing the shore-end with the main cable. On the 13th of July, the shore-end being buoyed up, it was easily found and taken up by the *Great Eastern*. The sea-end of this massive shore-cable was then carefully spliced to the end of the main cable, an operation which occupied about five hours. Then the real start began, the much-prized cable uncoiling itself from the tanks, and dipping into the sea, amid the firing of cannon, hoisting of flags, the playing of music, &c. On the 14th and 15th, two telegrams were received. On the 17th they finished paying out the portion of the old cable of 1865, having spliced it to the new. On the morning of the 27th, the *Great Eastern* sighted Newfoundland ; at 9, the cable was cut, preparatory to splicing it to the massive shore-end. There the important voyage practically terminated ; for all else was mere handicraft work. On the 28th the main cable was carefully spliced to the shore-end : the men jumped into the water and carried or dragged the cable about twenty yards. The first trial with the electric instruments showed that the insulation and conductivity of the cable were excellent. Europe was once again united with America, as she had been for a brief period in 1858. Even before the *Great Eastern* entered the harbour it had received a telegram through the cable from the Queen for transmission to President Johnson, to which was transmitted a reply. "On the 1st of August, political and commercial telegrams were sent from New York to London, being the practical commencement of the system for which the whole eventful enterprise had been undertaken. Shortly afterwards, a telegram was transmitted, certainly the most remarkable which, up to that time, had ever been achieved. It was from New York to Bombay. It went across a wide stretch of America, then spanned the Atlantic, then crossed Ireland and England, with the intervening bit of sea, then the continent of Europe, the Bosphorus, Asia Minor, Mesopotamia, the Persian Gulf, and the Indian Ocean, to Kurrachee." (*Companion to the Almanac*, 1867.)

Then commenced the second part of the final work, the recovery of the old cable. The storms of twelve months had passed over it: that it had not drifted was thoroughly believed. The naval commanders had made accurate observation of the exact latitude and longitude of the spot where



ATLANTIC TELEGRAPH CABLE, 1866.

the end of the cable finally disappeared in August, 1865; and, as the same nautical instruments, applied in the same way, would find the same spot again, this was the test, and the only test relied on. On the 9th, the *Albany* hooked the cable, and tried to raise it, but on the 11th a $\frac{7}{8}$ inch mooring-chain broke, and two miles of grapnel-rope were lost. The *Great Eastern* and *Medway* arrived on the 12th at the cable-fishing ground. We have not space to detail the series of snatchings, losings, raisings and breakings, dodgings and fishings, of the vessels engaged in this cable-craft; but pass on to the 16th, when while hauling up the grapnel, the splice between the grapnel-rope and the buoy-rope broke, and down went rope, grapnel, cable, and all. The position being a good one, another grapnel was put forth; it was dragged; the strain on the dynamometer (the instrument that shows the amount of force or weight pulling at the grapnel-rope, in addition to its own weight) indicated that the grapnel had got hold of the cable; it was hauled in; and lo, on the 17th up came to sight the actual cable itself! This was in lat. 51° 29′, long. 38° 48′. By 10.30 A.M. 2,300 fathoms of grapnel had come on board, and there now remained but 15 fathoms of the $1\frac{1}{8}$ chain attached to the grapnel. Nearly every one on board the ship crowded to the bows to see the grapnel come up over the water. The lost cable of 1865, lifted from its oozy bed two miles beneath the surface of the Atlantic Ocean, now made its appearance, attached to the flukes of the grapnel, amid a spontaneous cheer; the sound of this, however, had scarcely passed away, when the fact became known that the cable had quietly and easily disengaged itself from the flukes and springs of the grapnel.

On the appearance of the cable all were struck with the fact that one half of it was covered with ooze, staining it a muddy white, while the other half was just in the state as it left the tank the year before, with its tarred surface and strands unchanged, which proved that the cable simply lay in the ooze, only half imbedded.

Next week, the three ships in different changes of their respective positions, attempted to lay hold of the cable, and to suspend it from the buoys, in the form of a bight or festoon, so that it might be taken up within the bight and raised to the surface, thus bearing, of course, with a greatly diminished weight on the lifting apparatus. The weather was very unsettled, and on Sunday, the 26th, when the *Great Eastern* let down her grapnel for the tenth time, having twice drifted over the cable without catching it, there was a general gloom on board ship, with a determination, however, to persevere so long as a bit of rope was left. Just before dinner-time the *Medway* came up and brought the bad news that she had broken the cable south-west of the buoy. Success at length came, thus recorded:

"Sunday morning, 3.45, Sept. 2.—We have succeeded. The Atlantic Telegraph cable of 1865 has been raised to the surface, and in a few minutes afterwards communication established with Valentia. It is impossible adequately to describe the enthusisiastic joy which prevails on board the ship at the present moment.

"The picking-up went on with its usual certainty and precision, and by twelve o'clock (midnight) the bows of the ship were crowded, not only by those actually on the watch, but by nearly all the hands, who turned out to see the result of this attempt to recover the cable. Precisely at 12.50 this morning the cable made its appearance upon the grapnel, and, save when the voice of Captain Anderson or Mr. Canning was heard giving an order, one could almost hear a pin drop, such was the perfect silence which prevailed. No excitement, no cheering, as there was on the Sunday when we lifted it before; all was calm and quiet, the men scarcely spoke above their breath. After some precautionary operations, the signal being given to haul up, the western end of the bight was cut with a saw, and the cable then rose over the bows of the *Great Eastern*, slowly passing round the sheave at the bow, and then over the wheels on the fore-part of the deck."

The old cable of 1865 was found, not merely bodily, but with all its electric qualities in full efficiency. The cable itself told the tale. Mr. Willoughby Smith entered the testing room of the *Great Eastern*, bringing in carefully the end of the long cable. There it was—the copper in the middle, then the gutta percha, then the iron wires, and then the outer covering of Manilla hemp. The problem to be solved was, whether the cable, after being twelve months at the bottom of the Atlantic, would transmit an electric message to Valentia. Mr. Smith applied the end of the cable to his delicate instruments, amid the breathless silence of those around him. Presently he took off his hat, and gave a cheer—*the cable spoke!*

Rockets announced the triumph, and there was cheering everywhere. During these anxious moments, Mr. May, a careful observer in the Telegraph room at Valentia, was watching for any indications of life in the 1865 cable, the shore end of which was connected with instruments in the room. Suddenly, at a quarter to six, on that eventful Sunday morning, he observed a peculiar movement in the apparatus, which showed that a message was about to arrive through the cable; then the movements assumed all the regularity of letter-by-letter and word-by-word transmission; and then he read off: "Sunday, 5.40 A.M. Signals through 1865 cable, which is all right. Now splicing. Please inform directors;" and then Mr. Canning sent a message to Mr. Glass, the managing director of the Telegraph Construction and Maintenance Company, expressing the pleasure he felt at speaking to him through the cable of 1865, and the operator at Valentia telegraphed back his congratulations.

These messages or telegrams came with a distinctness and precision greater than even those through the new cable; showing that the old ocean-washed messenger had been improved rather than injured by its long submersion. The news was known in London by nine o'clock the same morning; before noon the *Great Eastern* received a congratulatory telegram; and the morning journals of next day, September 3d, published the information.

The long-sought cable having been brought to the surface of the water, a splice was soon made to a sufficient length of new or additional cable; and the *Great Eastern's* prow was once more turned westward, to submerge the 600 miles of new cable from the place of pick-up to Heart's Content. Not the least among the wonderful feats connected with the expedition was this: that when Greenwich time was flashed from Valentia to the ship, on the morning of the 2d, Commander Moriarty was able to detect so small an error as *six-tenths of a second*, accumulated in twenty-six days, in the admirable chronometer supplied by M. Barraud.

The ship went on westward, paying out the cable. On September 2d, the *Great Eastern* submerged 29 knots by noon; and on each of the next five days the length submerged averaged 135 knots per day, about 5⅝ knots per hour. On the 3d, the cable had to reach the profound depth of 2,424 fathoms—almost precisely 2¾ English miles—equal to 40 times the height of St. Paul's Cathedral. By noon, on the 7th, the ship was 115 miles from Heart's Content, and in 154 fathoms of water. On the 8th of September, the *Great Eastern* finished her grand labours. She came into harbour, and spliced her main cable to a new massive shore-end, and trusted the submersion of the latter to the *Medway*, aided by the boats of the *Terrible*. The cable was landed at 4 P.M. and in the presence of the Governor, the Bishop, and other notabilities of Newfoundland, a telegram was flashed to Valentia, speedily followed by a congratulatory reply. On the 9th of September the *Great Eastern* turned her head to the east, and amid the cheers of the Newfoundlanders, began her return voyage to England, bringing with her most of the persons who had been engaged in the noble work.

In commemoration of the event her Majesty was pleased to confer the honour of a baronetcy in two cases, and of knighthood in the four others:—1. Sir Daniel Gooch, Bart., M.P., the first engineer who has received a baronetcy, and once the locomotive superintendent of the Great Western Railway. 2. Sir Curtis Miranda Lampson, Bart., deputy-chairman of the original Telegraph Company. 3. Sir Richard Atwood Glass, Knt., who designed and made the cables of 1865 and 1866. 4. Professor Sir William Thompson, Knt., the famed electrician. 5. Sir Samuel Canning, C.E. Knt., engineer-in-chief of the Telegraph Construction and Maintenance Company. 6. Captain Sir James Anderson, Knt., commander of the *Great Eastern*.

"This last great telegraphic triumph is simply one of engineering skill, care, and perseverance. But a wonderful triumph it is. The difficulties to be overcome were neither few nor small. Think of the difficulty of encasing a bundle of thin wires of more than two thousand miles in length, in a tube of gum, and that without the slightest fissure or most minute pin-hole in the whole of that length. And then to case this with a material sufficiently strong to protect this inner core from strain or friction; and, lastly, to deposit it at the bottom of the Atlantic, in many places more than two miles in depth. Think of these things, and then say if the men who have done this are not worthy of all praise. But they have done more. They have taken up the loose end of last year's cable, and spliced it, and successfully laid the remainder. May these cables be more durable than many others that have been laid! There is every reason to hope they will. They have been much more carefully made."* Here we see the result of the long course of experiences which attended this herculean labour.

The eventful feat has been signalized and chronicled most worthily. Mr. Russell's "Diary of the Cable," originally written for the *Times* journal, has not only the attraction of brilliancy, but the greater value of a minute record of a scientific labour, in such language "that he may run that readeth it." This is one of the most complete chronicles of its kind which has ever appeared in any public journal. The numerous incidents of trial and endurance are suggestive throughout of the many difficulties which beset labours undertaken without the advantage of experience to aid in the attainment of precise results. The greatest successes are achieved by such means, though they are often mistakenly attributed to fortuitous turns. Mr. Russell's *Diary* has taken the more permanent form of a handsome folio volume, with truly artistic Illustrations, such as only the Art of the present day could produce.

Among the commemorations was a Banquet given by the Lord Mayor of London, at the Mansion-house, to which men of science associated with this triumph were invited; thus celebrating this truly British achievement in a characteristic British manner.

The reader is probably already aware of the great development of submarine telegraphy which has taken place since 1866. Cables connecting shore with shore lie upon the beds of seas and oceans in every direction, and the Atlantic itself is now traversed by three working cables, while others are being projected to extend still more the electric communication between the Old World and the New.

FINIS.

INDEX.

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ERRATA.

In the diagram fig. 2, p. 108, the point on the extreme right should be marked *b*, that on the left, *a*.

Page 115, line 4, for Hook, *read* Hooke.
,, 116, lines 4 and 11 from bottom, for Debrell, *read* Drebbel.
,, 291, *delete* the foot-note.

THE END.

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