public by his invention of weaving." There were only 2300 power-looms at work in Great Britain in 1813. In 1833 there were 100,000. At the present time, they are as universal as spinning machines,—very different in their beautiful construction from Cartwright's invention, but the same in principle. The Returns of the Factory Inspectors for 1856 show the employment of 369,205 power-looms, of which 298,847 were for weaving cotton. Such has been the progress of an idea casually impressed upon the active mind of a scholar, who was previously conscious of no aptitude for mechanical pursuits. His parliamentary reward did not repay his expenses in working out his scheme.

The history of the cotton-manufacture, as of most other arts, abounds with examples of the struggles of inventors, if not against neglect and fraud, against the almost insuperable difficulties of carrying forward an invention to commercial success. Bentham has expressed a great truth in forcible words; "As the world advances, the snares, the traps, the pitfalls, which inexperience has found in the path of inventive industry, will be filled up by the fortunes and the minds of those who have fallen into them and been ruined. In this, as in every other career, the ages gone by have been the forlorn hope, which has received for those who followed them the blow of fortune." * Dr. John Roebuck, "who may be said to have originated the modern iron manufacture of Britain, though his merits as a great public benefactor have as yet received but slight recognition," † was one of those who encountered the snares and pitfalls in the path of inexperience. We have shown what the iron manufacture was in 1740. ‡ In 1774, we find it alleged that "there is no room to doubt, that in every one of the three kingdoms there may be enough iron found to supply all the British dominions, and yet we import very large quantities from the North, from Spain and from America. The reason of this is, because the inhabitants of these countries can make it cheaper." They had a great command of fuel for charcoal. "It is earnestly to be wished," says the writer, "that, as it hath been often proposed and promised, the use of pit-coal could be generally introduced, so as to answer in all respects as well as charcoal." He adds, "at this time, as I have been well informed, iron is wrought with pit-coal at the Carron Works in North Britain." § The founder of these Carron Works, and the inventor of the economical processes which first gave cheap iron to our country, in many forms of utility, was Dr. John Roebuck.

The man who succeeded in proving, by the commercial results of his processes, that iron could be smelted by pit-coal, everywhere

* "Manual of Political Economy."
† "Quarterly Review," vol. civ. p. 78.
‡ *Ante*, vol. iv. p. 396.
§ Campbell, "Political Survey," vol. ii. p. 43.

in abundance, instead of by charcoal from woods that were disappearing through the advance of agriculture, was a physician at Birmingham. He was a scientific chemist, as far as the science of chemistry was understood in the middle of the eighteenth century; and he was connected with a chemical manufactory, to which he devoted himself with the ardour of an experimentalist. By his improvements in the production of sulphuric acid (then called vitriolic acid), the use of which was even then extensive in manufactures, he reduced the price of that article to a fourth of its previous cost. He was one of those who led the way in those great chemical discoveries which have produced as wonderful changes in the productive power of the country as machinery has produced. Sulphuric acid, after Roebuck's time, partially did the work of bleaching that the sun and air were necessary to complete. But his attempts to connect bleaching processes with the vitriol works that he established at Preston Pans were not successful. Having abandoned his practice as a physician, and settled in Scotland, he turned his thoughts to smelting and manufacturing iron. At Carron, in the parish of Tarbert, in Stirlingshire, there were the great requisites for this manufacture. There was abundant coal, and ample command of water-power. Some iron-stone and lime were to be found within a mile; some was to be procured from places ten miles distant.* Workmen were brought from Birmingham and Sheffield; and on the banks of a river, renowned in Scottish history, was the famous foundry established in 1759, which sent cheap grates into the homes of England, and cast the guns for Wellington's battery-train. To Dr. Roebuck has been assigned the honour of inventing the process of converting cast iron into malleable iron. But it is enough to give him an enduring name in the history of manufacturing industry, that he first brought about that marriage between the neighbours coal and iron which time can never dissolve—that union which made iron "the soul of every other manufacture;" which, when the iron railing round St. Paul's was still pointed out as a great feat of charcoal-smelting, enabled a daring engineer, within fifteen years of the time when the first furnace was lighted at Carron, to throw a cast-iron bridge over the Severn of a hundred feet span; and which, during the lapse of a century, has covered our country with works that are amongst the noblest triumphs of a great era of the Sciences and Arts; compared with which structures the once famous Coalbrook Dale bridge appears a toy. Dr. Roebuck called Smeaton to his aid as an engineer, and he invited Watt to experiment upon the employment of his steam-engine in

* "New Statistical Account of Scotland—Stirlingshire," vol. viii. p. 373.

blowing the furnaces. He was at one time associated as a partner in the great career that was opening to Watt. But he became involved in other undertakings beyond his capital; and had the common fate of those who undertake mighty enterprises without an adequate command of the sinews of all enterprise, whether of war or of peace.

The historian who has brought so large a fund of good sense and liberality to his narrative of English affairs from the peace of Utrecht to the close of the American war, says that the year 1763 "was distinguished by an event of more real importance than the rise or the resignation of lord Bute."* That year is considered memorable for the production of a new kind of earthenware, remarkable for fineness and durability. This ware was soon to remove the pewter dishes from their dingy rows in the tradesman's kitchen, and to supersede the wooden platter and the brown dish of the poor man's cottage. The artisan of Burslem, in Staffordshire, who brought about this change, was Josiah Wedgwood. We have already briefly indicated the condition of the Staffordshire Potteries at the beginning of the eighteenth century.† Dr. Campbell, in 1774, makes this statement: "In the space of about sixty years, as I have been well informed, the produce of this ware hath risen from 5000*l.* to 100,000*l.* per annum. These are entered by the thousand pieces for exportation, which is annually about forty thousand."‡ In 1857 there were a hundred million pieces of British earthenware and porcelain exported to every European country (with the exception of France), and to America, the United States being by far the largest importers. It is to Josiah Wedgwood that the creation of this great manufacture and commerce is to be principally attributed. England had produced its Bow china, its Worcester china, and its Chelsea china, which was held to equal that of Dresden. But these elaborate tea-services and ornaments were for the luxurious. Palissy gave France the lead amongst industrious nations in her manufacture of expensive porcelain. But Wedgwood in his ware combined the imitation of the most beautiful forms of ancient art with unequalled cheapness. In his workshops we may trace the commencement of a system of improved design, which made his ware so superior to any other that had been produced in Europe for common uses. England, by the discovery of a contemporary of Wedgwood, Mr. Cooksworthy, of Plymouth, was found to possess, in the Cornish clay, a material equal to that of the Sèvres and Dresden manufactories. His patent was transferred to the Staffordshire Potteries in 1777,

* Lord Mahon—"History of England," vol. v. p. 2.
† *Ante*, vol. iv. p. 400.
‡ "Political Survey," vol. ii. p. 18.

and from that time we went steadily forward to the attainment of our present excellence in the production of porcelain, upon a scale commensurate with the general spread of the comforts and refinements of society.

The transference of power to Mr. Pitt, in 1784, and the firmness with which he was enabled to hold its possession, presented opportunities for wise endeavours to place the commerce of the kingdom upon a broader foundation. The first object attained was the removal, in 1785, of an odious system of restrictions and disabilities in the trade between Great Britain and Ireland. In the preliminary inquiries by a committee of the House of Commons, some interesting details of manufactures were elicited. Mr. Wedgwood pointed out how greatly the industry of the Potteries multiplied the industry of others besides that of the twenty thousand persons directly employed; the quantity of inland carriage it created; the labour it called forth in collieries, and in raising the raw material of earthenware; the employment of coasting vessels in the transport of this material from the Land's-End to different parts of the coast: and the re-conveyance of the finished goods to those ports "where they are shipped for every foreign market that is open to the earthenware of England." In 1787 the government carried through a bold measure of commercial freedom in a treaty of commerce and navigation with France, which opened new ports, not only to the earthenware of England, but to her woollens, her cottons, her hardware and cutlery, her manufactures of brass and copper. Previous to this treaty, most of the staple productions of Britain had been prohibited for so long a period in France that the notion of exchange, under a system of moderate duties, had ceased to be contemplated by the merchants of either country. The political arguments by which this great measure was supported, and those by which it was opposed, will be noticed in a subsequent chapter. We introduce the subject here, because the debates in both Houses of Parliament supply some general views of the commercial policy of a period, when, as we have seen, the industry of this country had received an extraordinary impulse from new inventions, and from increased energy in the long-established modes of production. The general argument for the treaty was put with great force by Mr. Pitt: "France was, by the peculiar dispensation of Providence, gifted, perhaps more than any other country, with what made life desirable, in point of soil, climate, and natural productions. It had the most fertile vineyards and the richest harvests; the greatest luxuries of man were produced in it with little cost, and with moderate labour. Britain was not thus

blest by nature; but on the contrary, it possessed, through the happy freedom of its constitution, and the equal security of its laws, an energy in its enterprises and a stability in its exertions, which had gradually raised it to a state of commercial grandeur. Not being so bountifully gifted by Heaven, it had recourse to labour and art by which it had acquired the ability of supplying its neighbour with all the necessary embellishments of life in exchange for her natural luxuries. Thus standing with regard to each other, a friendly connection seemed to be pointed out between them, instead of the state of unalterable enmity which was falsely said to be their true political feeling towards each other." * The principle laid down by Pitt has a permanent importance. The national and commercial jealousies by which the principle was assailed are simply curious, as an exhibition of plausible fallacies. Bishop Watson,—one who had rendered good service to the arts of his country, by making chemistry popular in his amusing "Essays,"—maintained that, as in the time of Charles II., the trade with France was held to be detrimental to our interests because it showed a balance against us "by which we lost a million a year," such a trade would not be lucrative and safe in the time of George III.: that is, because the British consumer of the seventeenth century had paid in money to the French producer a million a year above what the British producer received, "we lost a million a year," the satisfaction of the wants of the consumer being nothing in the account. All this dust, which, from time immemorial, had been thrown into the eyes of the nation, is now scattered to the winds. But the anxious prelate thought that if our home market, the richest market in Europe, was opened to France, her own industry and ingenuity would be dangerously stimulated. France, he said, was ambitious to rival us in its rising manufactures of cotton, cutlery, hardware, and pottery. If she were to cultivate manufactures in the same degree as we had done, our ruin would be inevitable. France, Dr. Watson maintained, had abundant pit-coal; was casting pig-iron; was making cutlery at Moulins cheaper and neater than that of Sheffield; and, notwithstanding a recent law of England, prohibiting the exportation of tools and machines, France had got models of them, and would soon copy our tools, and not take our manufactures. The bishop proclaims, in his despair, that "every tool used at Sheffield, Birmingham, and Manchester, might be seen in a public building at Paris, where they were deposited for the inspection of their workmen." † Great manufactures are not created

* "Parliamentary History," vol. xxvi. col. 395. † *Ibid.*, vol. xxvi. col. 523, and col. 543.

simply by possessing copies of another country's machinery. The French government obtained, in 1788, models of the cotton-spinning machines used in England; but whilst a peaceful intercourse enabled us to send France cotton fabrics, she did not attempt to manufacture for herself. Cotton-mills were established in Normandy and at Orleans when the continent was shut out by the war of the Revolution from commercial exchange with England.* But there was a power possessed by our country that France and other continental nations did not possess, and had not capital and trained workmen to acquire by imitation; a power, of which it was said in 1819 that it had "fought the battles of Europe, and exalted and sustained, through the late tremendous contest, the political greatness of our land;"—a power which upon the return of peace, "enabled us to pay the interest of our debt, and to maintain the arduous struggle in which we were engaged with the skill and capital of countries less oppressed with taxation." † That great power was "our improved steam-engine."

In the year 1757, over the door of a staircase opening from the quadrangle of the college of Glasgow, was exhibited a board, inscribed "James Watt, Mathematical-Instrument Maker to the University." In a room of small dimensions sat a young man in his twenty-first year, filing and polishing quadrants and sectors, to sell for his livelihood. He had come in his eighteenth year from his paternal home, at Greenock, where his father carried on the business of a ship-chandler, to endeavour to learn the art of a mathematical-instrument maker; but he could find no one in Glasgow capable of instructing him. By the advice of a kinsman of his mother, who was a Professor in the Glasgow University, he went to London with the same object. For a year he worked with intense application in a shop in Finch Lane, Cornhill; but his health failing, he returned to Glasgow, having become a skilful mechanic, and possessing the far greater advantage of a sound mathematical education. He endeavoured to establish a shop in that city. The worshipful Company of Hammermen,—in that spirit of exclusiveness which the lapse of a century has scarcely eradicated, where Guilds and Corporations have any remnant of antiquated privileges,—resolved to prevent James Watt exercising his art. He was, however, employed within the precincts of the University to repair some astronomical instruments; and several of the Professors took the ingenious young man under their protection, and gave him a workshop within their walls. Here he soon attracted the notice

* Say—"Cours d'Economie Politique," tome i. chap. xix.
† Jeffrey—"Character of James Watt," 1819.

and received the kind attentions of men whose names will be held ever in veneration—Adam Smith, Robert Simson, and Joseph Black. To these eminent philosophers even the members of the Company of Hammermen would lowly bow; as they bowed to the magnates of Glasgow, the tobacco-lords who walked in scarlet cloaks and bushy wigs apart at the Cross, and to any one of whom no tradesman dared speak till he caught the great man's eye, and was invited by him to come across the street and impart his humble request.* Watt had an ardent friend in a college student, John Robison, about the same age with himself, who had also a genius for scientific pursuits. He has recounted that when he first went into Watt's little shop, and expected to see only a workman, he was surprised to find the quadrant-maker his superior in philosophy. But Robison left the University; went to sea as a midshipman; and was in the boat on the St. Lawrence with Wolfe, on the morning on which the Heights of Abraham were scaled. The friends had conversed about steam-engines before Robison's departure. When the young man returned in 1763,—having been employed by the Admiralty to take charge of Harrison's chronometer on a voyage to Jamaica, to test its sufficiency for determining the longitude of a ship at sea,—he found that his old companion in the College workshop had been making more rapid advances in scientific attainments than himself; and had been long engaged in trying experiments in the construction of a steam engine, upon principles different from that in common use. He had lighted upon the same principle as that now employed in a high-pressure engine. In that year of 1763 a small model of Newcomen's engine was put into the charge of Watt to repair. The imperfections of that invention, known as "the atmospheric engine," were evident to him; and he long laboured unsuccessfully to discover how its defects could be remedied. The radical defect was, that three times as much heat as was necessary for the action of the machine was lost. If one-fourth of the heat could generate an equal amount of available steam, the saving of fuel alone would ensure the adoption of an engine constructed to produce such an important economy. Newcomen's machine was used in draining mines, in raising water to turn water-wheels, and in blowing furnaces for iron-smelting. But its expense of working was enormous. Its construction was clumsy and imperfect. We may imagine Adam Smith telling Watt the story which he has so well told in the "Wealth of Nations," of the first fire-engine; in which "a boy was constantly employed to open and shut alternately the communication between the boiler

* "New Statistical Account—Lanarkshire," p. 232.

and the cylinder, according as the piston either ascended or descended;" and how the boy, wanting to play, found out that "by tying a string from the handle of the valve which opened this communication to another part of the machine, the valve would open and shut without his assistance."* Improvements such as this had been accomplished by accidental observation. What improvements might not be effected by careful examination, grounded upon scientific knowledge. The experimental philosopher was still working in the dark, when he discovered that water converted into steam would heat about six times its own weight of water at 47° or 48° to 212°. He mentioned this fact to Dr. Black, who then explained to him his doctrine of latent heat, with which Watt had been previously unacquainted. He says of himself that "he stumbled upon one of the material facts by which that beautiful theory is supported." Amongst the principal features of scientific progress at this period, sir John Herschel includes "the development of the doctrine of latent heat by Black, with its train of important consequences, including the scientific theory of the steam-engine."† The ceaseless preparatory labour of thought was now to produce its results. In a solitary walk, Watt solved the great problem upon which he had been so long intent. The necessity of working for his bread, whilst he eagerly desired to bring his ideas into a practical shape, was still forced upon him. But he saw his way. The invention was complete in his mind. To have a model constructed was a work of great diffculty. He had no capital to employ in engaging better workmen than the blacksmiths and tinmen of Glasgow. He struggled against these difficulties till he found a zealous and powerful ally in Dr. Roebuck. At length, in May, 1768, Watt had the happiness of congratulating his friend on the achievements of their mutual hopes: "I sincerely wish you joy of this successful result, and hope it will make you some return for the obligations I ever will remain under to you."

It was agreed that a patent should be taken out; and Watt repaired to London to accomplish this business. On his way thither he had an interview, at Birmingham, with Matthew Boulton, who desired to join in the speculation. This eminent manufacturer, in every quality of sterling integrity, of generous feelings, of skill in organization, of prudent enterprise, was worthy of being the associate of a man of genius like Watt, who was timid, and sometimes desponding. Their partnership was unfortunately deferred till 1773, for Roebuck would not admit Boulton to a share of the patent, except upon terms to which the prosperous and ingenious

* "Wealth of Nations," book i. chap. i.

† "Discourse on the Study of Natural Philosophy."

proprietor of the works at Soho could not agree. Watt, meanwhile, had to maintain himself by the superintendence of several canals then in course of construction. The employment was disagreeable to him. He had no advantage from working his patent, for his partner, Roebuck, was engaged in too many losing undertakings to advance more capital. At length that partner, in whose misfortune Watt deeply sympathized, agreed to sell his property in the patent to Boulton. In 1774 Watt went to Birmingham to superintend the construction of his machines; and he wrote to his father, "the fire-engine I have invented is now going, and answers much better than any other that has yet been made." There was very soon a change in the character of Boulton's manufactory. Dr. Johnson kept a Diary of a tour in Wales in 1774. On the 20th of September is this entry: "We went to Boulton's, who, with great civility, led us through his shops. I could not distinctly see his enginery—Twelve dozen of buttons for three shillings—Spoons struck at once." In 1776, Johnson and Boswell made an excursion to Oxford, and also saw Birmingham, of which Boswell has this record: "Mr. Hector was so good as to accompany me to see the great works of Mr. Boulton, at a place which he has called Soho, about two miles from Birmingham, which the very ingenious proprietor showed me himself to the best advantage. I wished Johnson had been with us; for it was a scene which I should have been glad to contemplate by his light. The vastness and the contrivance of some of the machinery would have matched his mighty mind. I shall never forget Mr. Boulton's expression to me,—'I sell here, sir, what all the world desires to have—Power!'" *

It is unnecessary, for our purpose, that we should pursue the history of the final establishment of the steam-engine of Watt to be the great operative power of the larger industries of Britain. It quickly superseded Newcomen's machines in draining the Cornish tin and copper mines. It multiplied cotton-mills in the towns of Lancashire and of Scotland, without reference to the previous necessity of choosing localities on the banks of the Irwell or the Derwent, the Tweed or the Clyde. It was blowing the iron furnaces of Dudley, and hammering steel at Sheffield. It was forging anchors and impelling block-machinery at Portsmouth. Yet it was ten years before Boulton and Watt derived any profit from the discovery. They had to struggle, in the first instance, against the common prejudice which attaches to every new invention. All the business sagacity of Boulton was necessary to encourage its use by the most moderate price; or by stipulating only for a royalty upon the amount of fuel which it saved, charging nothing for the engine. The partners had to contend, in actions at law, against unscrupulous pirates. But Parliament, in 1775, had granted an extension of the patent, and the reward to the inventor and his admirable associate would come in time. They would be repaid, however tardily, by the pecuniary fruits of their skill and perseverance, before the invention was thrown open to the world. But even before that period what mighty effects had been produced upon British industry by this crowning triumph of an enterprising age! Without its aid the energy of the people had more than counterbalanced the waste of the national resources by an obstinate government in a foolish and unjust war. The steam-engine of the "Mathematical-Instrument Maker to the University of Glasgow" gave a new impulse to the same energy in another war against a gigantic military despotism, wielded by a man originally as humble as himself—a student of the Military School of Brienne. Captain Sword and Captain Steam were to engage in a struggle not less arduous than that of "Captain Sword and Captain Pen." The one was to lay prosperous cities in ashes; the other was to build up new cities in desolate places. The one was to close the havens of ancient commerce; the other was to freight ships with products of such surpassing excellence and cheapness, that no tyrannous edicts could exclude them from oppressed nations. The one was to derange every effort of continental industry; the other was to harmonize every form of British labour and invention, by lending to each an intensity and a concentration previously unknown. The one was to attempt the subjugation of the intellect of brute force; the other was to complete "the dominion of mind over the most refractory qualities of matter:"

"Engine of Watt! unrivall'd is thy sway,
Compared with thine, what is the tryant's power?
His might destroys, while thine creates and saves,
Thy triumphs live and grow, like fruit and flower,
But his are writ in blood, and read on graves." *

* It has been said that Boulton, upon being asked by George III. what he dealt in, replied, "What kings delight in,—Power!" Boswell's story is more probable.

* Elliott.—"Steam at Sheffield."