origin—that is to say, steel which had never been in a fluid condition. It would consist of two varieties differing really only in the amount of hammer work put upon them when in a red or yellowish plastic condition, and both made from a common material—viz., cemented, converted, or blister bar iron. The basis metals before carburization by charcoal in the cementation furnace would be the nearly pure irons wrought in the charcoal forges of Spain, Sweden, Styria, Flanders, and possibly Russia, and brought to Sheffield via Hull. The transit from Hull or Goole before the Don was navigable would be by packhorse. No wonder such irons cost about £145 per ton.

Probably each cutler had his own small cementing chest, because it was as late as 1759 that the Cutlers' Company erected on a large scale what would doubtless be a co-operative cementation furnace, in the chests of which many tons of iron could be converted at one operation. The nearly pure imported irons, however, all contained slag, consisting very largely of oxide of iron, the result being that when the carbon by what may be called carburization in the dry way permeated the iron the oxide of iron in the slag areas was reduced to metal with an evolution of carbonic oxide gas, which blew bubbles or blisters on the surfaces and in the interiors of the plastic bars. When the blister bar, which was very brittle, was heated and hammered into merchant sizes it was known as blister or tilted steel.

But for the highest quality of cutting implements, especially those required for clothiers' shears or for table blades, the blister bar was worked in a much more drastic fashion. Blister bar was broken into suitable lengths and each length was heated and somewhat hammered out to confer toughness on the brittle bar and to flatten down the blisters. Several bars were then piled and welded under a thin protective covering of suitable flux. The welded pile was next drawn down to a small rectangular faggot somewhat oblong in shape, so that in subsequent working the flats and edges of the welds could always be distinguished. The above faggot or small bloom was then worked into merchant sizes, and cutting articles made from it were branded with a rude representation of one pair of clothier's shears. Hence the name single shear steel.

For a still higher quality of steel a faggot of single shear steel was nicked, bent back upon itself, welded, and again worked down to the original size. Articles made from this steel, after it had been worked into merchant sizes, were branded with rude representations of two pairs of clothier's shears and were called double shear steel. Shear steel is the purest steel made, being practically iron and carbon. It is necessarily limited to relatively small sections; thus bars several inches in diameter sold as shear steel are sold under a false trade description. It is impossible to make such large round bars in shear steel.

Towards the middle of the 18th century Mr. Benjamin Huntsman, a Doncaster clock-maker, finding that worked blister bar was not sufficiently free from blister and weld lines for delicate clock springs, made experiments to find out a process which should give him a weldless steel; and in 1740 he discovered and established the crucible process at Attercliffe, Sheffield. Steel manufactured by this "fluid" method still further enhanced the reputation of Sheffield, and founded an industry which is now producing in Sheffield alone about 50,000 tons of cutting steels every year. About the middle of the 19th century this costly steel was used for structural steel, ranging from railway tires to heavy guns. But for the rails and armour of this period wrought iron was used, and there were consequently in the Sheffield district hundreds of puddling furnaces, which have now virtually disappeared.

In the early sixties the Bessemer, or to be quite just the Bessemer-Mushet, process firmly established in Sheffield those titanic operations known as the "heavy lines." For instance in less than 20 years Sheffield had become a great steel-rail manufacturing centre. Indeed, in 1879 Messrs. Brown, Bayley, and Dixon made in one week a world's record in rail rolling, turning out nearly 2,000 tons, a figure at which one now smiles. To-day only one firm, Messrs. Steel, Peach, and Tozer, make rails, the trade having on account of carriage charges perforce migrated to the coast so as to secure water carriage. To a great extent also the Bessemer process has been superseded by large Siemens-Martin furnaces on the regenerative principle—not because of any inherent fault in the method just named, but because the Siemens steel can be produced of even quality without that drastic scientific control necessary to obtain regular Bessemer results. This still important but waning method deserves a consideration based upon practical as well as scientific knowledge it has not received from authors of text-books, who probably have never made a heat of Bessemer steel in their lives.

Many text-books state that Mushet conceived the brilliant idea of adding spiegel or ferro-manganese, and so introducing carbon in such a way as to convert Bessemer's blown metal into steel. The facts are as follows:—Bessemer thought out and carried to a successful issue the grand conception of oxidizing the carbon and silicon in molten pig iron by a blast of air and so producing nearly pure iron. But his nearly pure iron contained several tenths per cent. of dissolved oxygen, which rendered his material so red-short as to be commercially worthless. Had carbon been able to remedy this fatal defect, half a ton of Swedish white iron would have put matters right. But such an addition to blown Bessemer metal would not render it forgeable. The patent of Mushet embodied a treatment of vast importance in steel metallurgy to-day. It was to add metallic manganese, which combined with the dissolved oxygen in the blown metal, rendering it insoluble, and so fluxing it into the slag. In the early days of the Bessemer process it was not realized that an excess of about 1 per cent. of manganese in the finished steel was necessary to get easily rolled ingots, and the slow process of the Bessemer method in its early days was largely due to the fact that an excess of only about 0.3 per cent. of manganese was left in the finished steel, a quantity far too small to cleanse the metal from dissolved oxygen. The carbon added by the ferro-manganese or spiegeleisen was necessary to produce steels of varying hardness, but it had little to do with rendering Bessemer's blown metal a commercial product. The honor of this achievement is due almost entirely to Mushet's manganese.

Another class of industry which has during the last quarter of a century enormously developed in Sheffield is the manufacture of steel castings in which the toughness brought about in worked steels by hammering, rolling, or pressing is secured by flame-annealing. For instance, the East Hecla Works of Messrs Hadfield, devoted mainly to this industry, cover 90 acres. Their relatively small Hecla Works, covering about four acres, are engaged chiefly in the manufacture of projectiles, of which they have supplied to various governments a number approaching 1½ millions. The manufacture of naval and military guns, carried out mainly by firms like Messrs. Vickers, Messrs. Firth, and Messrs. Cammell, Laird, has assumed enormous proportions. As to armour several firms have huge departments for the production of face-hardened armour plates. To give an idea of the vast concentration of the steel industry round Sheffield it may be stated that there are about 400 firms engaged in the manufacture or working of steel, or both.