

and out of place in a zoo, aquatic circuses with performing dolphins are legitimate and laudable.

The translation seems to be excellent—I have not checked it with the original—but, because it was done by zoologists, it is free from those dreadful technical blunders often made by translators unfamiliar with the subject of their work. The numerous photographic illustrations are well chosen and informative. Hediger's book should be carefully studied by all who have anything to do with the management of zoos; zoo visitors who are seriously interested in what they see will find it a revelation.

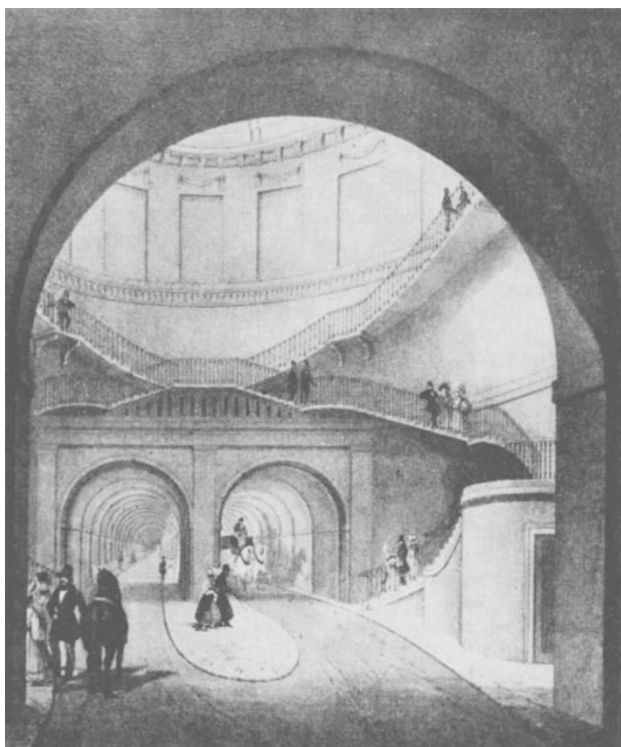
L. HARRISON MATTHEWS

## FOUNDER OF MASS PRODUCTION

Marc Isambard Brunel

By Paul Clements. Pp. xv+270+37 plates. (Longmans: London, January 1970.) 65s.

SINCE Samuel Smiles laid down his pen, the lives of great engineers have received only perfunctory attention from biographers. So great a confidence as the Victorians had was certain to lead to a reaction which swept away their achievements along with their lace antimacassars and their pompous architecture. Fortunately, Victoriana is back in fashion, and Marc Brunel, though formed in an earlier age, was in many ways a typical Victorian—high-principled, determined, superbly self-confident and apparently insensitive to the horrors of nineteenth century England. "A splendid establishment indeed!" he recorded in his diary after a visit to Bedlam, and the poor unfortunates who dug his famous tunnel under the Thames were lucky if they finished the job with their lungs and their minds intact. The foul air, the constant danger of explosion from marsh gas or of flood from the river, and the sheer discomfort of the working conditions must have made "the Great Bore" (as it was called) one of the least favoured working places in London.



Brunel's projected view of the south side entrance to the Thames tunnel (from *Marc Isambard Brunel*, plate 37).

Nevertheless, in spite of all the natural obstacles, and the unnatural ones planted in its way by a reluctant and suspicious Treasury, the tunnel was finished in 1843, 18 years and 43 days after the ceremonial stone had been laid at Rotherhithe. It was, I suppose, Brunel's greatest achievement, but the tunnel never became the success he had expected. Within a few years it had become, in Paul Clements's words, London's cheapest doss-house. In 1865 it was bought by the East London Railway Company, and now forms the crossing-point for an undistinguished stretch of the Metropolitan Line between Whitechapel and New Cross.

I would prefer to honour Marc Brunel as the founder of mass production—an achievement which in the long run has proved far more significant than the four hundred yards between Wapping and Rotherhithe. In 1800 he developed a series of machines to automate the production of pulley blocks used in the rigging of warships. Each 74-gun ship needed 922 blocks, and the annual naval requirement was about 100,000 a year. Brunel reduced the processes of production to a series of separate operations, and devised and had built a series of machines which could carry out each operation without skilled attention. By 1803, ten unskilled labourers at the naval dockyard at Portsmouth were turning out as many blocks as had 110 skilled craftsmen at the sub-contractor's factory at Southampton. Brunel built to last; his machines made blocks used in landing craft which ferried troops across the Channel on D-Day, and even now are pressed into action to make blocks for Nelson's Victory when the need arises.

Paul Clements has written an admirable account of Marc Brunel's life. Together with L. T. C. Rolt's life of Isambard Kingdom Brunel, it provides a readable and fairly complete account of two of the nineteenth century's most remarkable figures. Paul Clements writes: "It seems miraculous that the most original engineer of the first quarter of the nineteenth century should have been followed by a son who added lustre to his name". It does indeed. For most people Isambard is likely to remain the more charismatic figure; but this book emphasizes just how much he owed to his father. NIGEL HAWKES

## FROM INVENTION TO INNOVATION

The Economics of Technological Change

By E. Mansfield. Pp. x+257. (Longmans: London, December 1969.) 50s.

Industrial Research and Technological Innovation

An Econometric Analysis. By E. Mansfield. Pp. xviii+235. (Longmans: London, December 1969.) 65s.

THE two books overlap to a considerable extent, the first being a less technical and more readable presentation of the econometric studies described in detail in the second. The first book also covers a wider spectrum of topics, including automation and government policy.

Throughout the 1960s economists have been stimulated by a steady flow of papers from Mansfield on industrial research and innovation, and it is valuable to have these two books which draw together the results of many of his previous studies and relate them to a wider framework of economic analysis and policy.

Until recently the industrial innovation process, although always the subject of considerable public interest, suffered from neglect by professional economists and scientists. This gave free rein to a mythologizing process consisting in about equal proportions of biographical anecdotes of famous innovators and proverbial management wisdom of unproven validity. It is surprising how few of these generalizations and anecdotes stand up to critical scrutiny or test. Even some of those generalizations which seem most plausible are surprisingly difficult