The work of the Imperial Institute : address delivered at the Royal Institution of Great Britain before His Royal Highness the Prince of Wales, K.G., F.R.S., vice-patron, April 22nd, 1887 / by Sir Frederick Abel.

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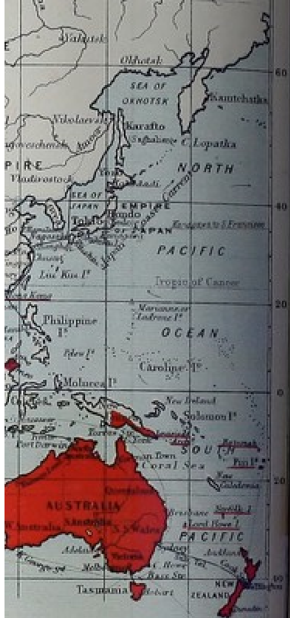

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SIR FREDERICK AB...

C.B., D.C.L., F.R.S., ETC.

LONDON:
...D BY WM. CLOWES AND SONS, LIMITED,
STAMFORD STREET AND CHARING CROSS.
1887.

THE WORK

OF

THE IMPERIAL INSTITUTE.

ADDRESS

DELIVERED AT

The Royal Institution of Great Britain

BEFORE

HIS ROYAL HIGHNESS THE PRINCE OF WALES, K.G.,

F.R.S., VICE-PATRON,

APRIL 22nd, 1887,

By SIR FREDERICK ABEL,

C.B., D.C.L., F.R.S., ETC.

LONDON:
PRINTED BY WM. CLOWES AND SONS, LIMITED,
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1887.

Royal Institution of Great Britain.

WEEKLY EVENING MEETING,

Friday, April 22, 1887.

H.R.H. The Prince of Wales, K.G., F.R.S.,
Vice-Patron, in the Chair.

Sir Frederick Abel, C.B., D.C.L., F.R.S., *M.R.I.*

The Work of the Imperial Institute.

The Colonial and Indian Exhibition, which owes not only its conception, but also its brilliantly successful realisation to your Royal Highness, will be pre-eminently remarkable in times to come, for having achieved many results of vital importance and highest benefit to Her Majesty's subjects in all parts of Her vast Realms.

The collection of all that is commercially valuable and scientifically interesting of the natural products of the great Indian Empire and of the Colonies in one exhibition, embracing as it also did very comprehensive illustrations of the development of commerce, of the arts and of certain industries, in the many countries beyond the seas which combine with the United Kingdom to constitute an Empire over nine million square miles in extent, afforded those at home an opportunity, surpassing all previous conception, of studying and comparing the natural history and resources of those distant lands, of which, attached though we might be individually to one or more of them by ties of friendship or of interest, the knowledge of many of us was of a very vague or partial character.

To the Colonists who visited us last year, the Exhibition has been of inestimable value, in affording them a most favourable and appropriate opportunity of becoming acquainted or renewing their old friendship with the Mother Country, and of examining the progress there made in industrial, educational, and commercial development; in leading to the cultivation of intimacy between Colonists from different sections of the Queen's Dominions; and in affording them invaluable opportunities of comparing the resources and state of development of their respective countries with those of other parts of Europe. No more convincing illustrations than were provided by this great Exhibition could have been conceived of the importance, to the Home Country, to each Colony, and to India, of fostering intimate relationship and unity of action. No more encouraging proof could have been afforded of the desire of all classes of Her Majesty's subjects at home to cultivate a knowledge of those far-off countries which the enterprise and perseverance of the British, and men of British offspring, have converted into prosperous and important Dominions, chiefly during the period of the Queen's reign, than was furnished by the interest which the thousands upon thousands, who

came from all parts, displayed in the study of the instructive collections in the galleries at South Kensington.

It was the success of the Exhibition which led to the definite formulation of the suggestion first made by your Royal Highness in a letter addressed by you in the autumn of 1884 to the Agents-General of the Colonial Governments, that a permanent representation of the resources of the Colonies and India, and of their continually progressing development, might with great benefit to the Empire at large, be established in this country. That the realisation of this idea upon a sufficiently comprehensive basis might constitute a worthy memorial of the accomplishment of fifty years of a wise and prosperous reign; a memorial not personal in its character excepting so far as it constituted an emblem of the love and loyalty of Her Majesty's subjects, but tending, as she would most desire, to serve the interests of the entire Empire, had only to be pointed out by your Royal Highness to be heartily concurred in by the Official Representatives of the Colonies and India, who were so intimately identified with the triumphs of the recent Exhibition.

The Committee to whom you, Sir, entrusted the elaboration of a scheme for carrying this conception into effect, became persuaded by a careful consideration of the subject that such an Institution as your Royal Highness desired to see spring into life, to be a memorial really worthy of the Jubilee of Her Majesty's reign and to fulfil the great purposes which you had in view, must not be confined in its objects to particular portions of the Queen's Dominions, but must be made thoroughly representative of the interests and of the unity of the whole Empire.

The outline of the scheme for the establishment of an Imperial Institute for the United Kingdom, the Colonies and India, which met with the cordial approval of your Royal Highness, was necessarily concise in dealing with the very wide extent of ground which the operations of the Institute are intended to cover; but those who have carefully considered it and rightly interpreted its proposals, have not failed to realise that it aims at very much more than the creation and maintenance of collections, illustrative of the natural resources of our Colonies and of India, and of the development and present condition of the chief industries of different parts of the Empire.

One of the primary objects of the Institute will certainly be the establishment of thoroughly well selected, carefully arranged, and efficiently maintained representations of the natural products which constitute the treasures, and are emblematic of the important positions in the Empire, of those great Colonial possessions which, during the fifty years of Her Majesty's reign, have, in many instances, experienced a marvellous development in extent, in commercial, social, and even in political importance.* The recent

* Statistical statements illustrating the development of the Colonies during the Queen's reign are appended.

Exhibition not only afforded conclusive demonstration of the great interest and value to the United Kingdom which must attach to such collections if properly organized; by such illustrations as the magnificent collections of valuable woods, from nearly every Colony, many quite unknown in England, and the great variety of valuable economic products from India, of the existence of which we at home had little idea, it also served to convince us that our knowledge of the great countries which constitute the chief portion of the Empire is very limited and imperfect, and that their resources are in many directions still in the infancy of development. Our Colonial Brethren cannot, on their part, fail to be greatly benefited by being thoroughly represented in a well-selected and carefully organized assemblage of illustrations of the sources of prosperity which constitute the sinews of their commerce, and upon a continued exploration and cultivation of which must depend the maintenance of their influence upon industrial and social progress. Neither can they fail to reap substantial advantages by pursuing a friendly rivalry with each other in demonstrating the advances made from time to time in the development of the resources of the respective portions of the Empire in which their lot is cast.

The hearty co-operation and important material support to which the great Colonies, through their representatives in London, pledged themselves when the scheme for the proposed Imperial Institute was in the first instance limited to this branch of the great work which it is now contemplated to accomplish, afforded conclusive evidence of their earnest desire to be in all respects thoroughly represented in the Mother Country, and to take their places permanently in our midst as fellow-labourers in the advancement of the prosperity of the Empire. In furtherance of this important end, a notable feature of that building which, in its character, will, it is hoped, be worthy of the momentous epoch it is destined to commemorate, will be, the attractions and conveniences presented by it as a place of resort and a *rendezvous* for Colonists visiting England, and, it is also anticipated, for the important Societies which represent the Colonies and Asiatic possessions in this Country, and the facilities which it will afford for reference to literature concerning the Colonies and India, for conferences on matters of common interest and value to the Colonists and those at home, for the interchange of information between the British manufacturer and those in the Colonies who are directly interested in meeting his requirements, and generally, for the cultivation of intimate relations and good fellowship between ourselves and our brethren from all parts of the Empire.

The Institute will, however, not only operate actively under its own roof in promoting the cultivation of a better knowledge of the geography, natural history, and resources of our Colonies, and for the advancement of the interests of the Colonists in this Country; it is also contemplated that representative collections of the natural products of the Colonies and India, carefully identified with the

more elaborate collections of the head establishment, shall be distributed to provincial centres, and that the provinces shall be kept thoroughly conversant with the current information from the Colonies and India, bearing upon the interests of the commercial man, the manufacturer, and the intending emigrant.

Although the formation, and maintenance up to date, of collections illustrative of the development and present condition of the important Industries of the Empire also forms, as I have stated, a part of the programme of the Institute, the scope of its activity in relation to industry will be of a much more comprehensive character; indeed, it is to be hoped that the work which it will achieve in furtherance of the development and progress of industries and their future maintainance in the United Kingdom at least upon a footing of equality with their conditions in the great Continental States, will be most prominent in securing to the Imperial Institute the exalted position which it should occupy as the National Jubilee Memorial of Her Majesty's reign.

There is no need for me to recall to the minds of an audience in the Royal Institution the great strides which have been made during the last fifty years in the applications of science to the purposes of daily life, to the advancement of commerce, and to the development of the arts and manufactures. Nor is it necessary to dwell upon the fact that this country is the birth-place of the majority of the great scientific and practical achievements which have revolutionised means of intercommunication, and have in other ways transformed the conditions under which manufactures, the arts and commerce are pursued. These very achievements, of which we as a Nation are so justly proud, have led, however, by many of their results, to our becoming reduced to an equality of position with other prominent Nations in regard to important advantages we so long derived from the possession in this country of great material resources easy of access and application, and from the consequent pre-eminence in certain branches of trade and industry which we so long enjoyed.

In 1852, Sir Lyon Playfair, in one of a course of most interesting lectures on some of the results of the preceding year's great Exhibition, was impelled by the teaching of that great world's display, to point out that "the raw material, formerly our capital advantage, was gradually being equalised in price and made available to all by the improvements in locomotion," and "that industry must in future be supported not by a competition of local advantages, but by a competition of intellect." If this was already felt to be the state of the case six-and-thirty years ago, how much more must we be convinced of the full truth of this at the present day, by the conditions under which the British merchant and manufacturer have to compete with their rivals on the Continent and in the United States.

It is still within the recollection of many that almost the whole world was in very great measure dependent upon Great Britain for its supplies of ordinary cast iron. Even as lately as 1871, the

United States of America received from Great Britain nearly one-fifth of its total produce of pig iron; but from 1875 all importation of British iron ceased for over three years, and it was only in consequence of requirements in the States exceeding the capabilities of production, that some small demands arose in 1879, which were for some time maintained.

But while, in 1879, the pig iron produced in the United States amounted to little over 3,000,000 tons, in 1882 the make had increased by 70 per cent., viz. to over 5,100,000 tons. Since that time the actual make has not increased (in 1885 it amounted to 4,529,869 tons of 2000 lb.), but the *capacity of production*, which vitally interests the iron trade of this country, has risen enormously, the present capacity of all the American pig-iron works being estimated at over 8,900,000 tons, or nearly 300 per cent. greater than it was in 1879. So much regarding the United States; looking nearer home, we find that the iron of France, Belgium, and Germany not only competes with us in the open market, but that Belgian and German iron is actually imported into this country to a moderate extent.

As an instructive illustration of the advance and influence of the improvements which have been made in intercommunication upon the value of our natural products and their importance even in our own industries, I may, on the authority of Sir Lowthian Bell, state the astounding fact that in the opinion of competent authorities, the ore (hæmatite) especially suitable for steel manufacture by the Bessemer process can be brought over sea a distance of 1000 miles, landed close to mines furnishing the cheapest made pig iron of Great Britain, and converted into *steel* rails at a lower cost than the native ironstone of Cleveland can furnish similar rails in *iron*.

From time to time the ground which we have lost through the development of the resources of other countries has been more than retrieved temporarily by improvements effected through the more thorough comprehension and consequent better application of the scientific principles underlying processes of manufacture. Thus the quantity of fuel consumed in producing wrought-iron rails has been gradually reduced by improvements in the construction and working of furnaces, until less than one-half the amount is now required per ton of such rails than was employed fifty years ago; but, remarkable as it may seem, the ultimate effect of an advance of this importance is actually to improve the position, in relation to this manufacture, of other Nations less favourably circumstanced than Great Britain in the matter of coal, for, instead of having to multiply any difference in our favour in the cost of fuel required to produce a ton of rails by twelve, that difference has now only to be multiplied by three in order to arrive at the extent of our advantage.

The history of the development of steel manufacture during the last twenty-five years affords a most instructive illustration of the fluctuations which may ensue in the value of our natural resources, and the consequent condition of one or other of our important industries,

arising out of continued advances made in the application of science to the perfection or transformation of manufacturing processes, and of the stimulating effects of such fluctuations upon the exertions of those who are able to bring scientific knowledge to bear upon the solution of problems in industrial operations which entirely baffle the ordinary manufacturer. Within that period the inventions of Bessemer and of Siemens have led to the replacement of iron by steel in some of its most extensive applications. The Bessemer converter, by which pig iron is rapidly transformed into steel by the injection of air into the molten metal, has, so far as this country is concerned, to a very great extent, superseded the puddling furnace, in which pig iron is transformed by long-continued laborious treatment into steel or malleable iron. This important change in our national industry was, ere long, productive of a serious crisis therein, and for the reason that the pig iron produced from a large proportion of those ores which, from their abundance and the cheapness of their treatment, have been largely instrumental in placing Great Britain in her high position as an iron-producing nation, could not be applied to the production of marketable steel by means of the Bessemer converter. In the purification of this pig iron during its conversion in the puddling furnace into a suitable material for the production of rails, the elementary constituent phosphorus, which it had carried with it from the ore as a contaminating ingredient very detrimental to its strength, was eliminated, and by sufficient treatment a malleable iron of good quality was obtained; but in the production of steel from the same material in the Bessemer converter, the phosphorus is almost entirely retained in the metal, rendering it unsuitable for manufacture into rails or plates. Hence the application of this rapid steel-making process had to be chiefly restricted to particular kinds of ores, the supplies of which are limited to a few districts in this country. These had to be largely supplemented by importations from other countries; nevertheless the cheapness of production and superiority in point of strength, durability and lightness of the steel rails thus sent into the market from the Bessemer converter combined to maintain a supremacy of them over iron rails, &c., manufactured by the old puddling processes from the staple ores of the country.

The advantages presented by steel over the wrought iron of the puddling furnace for constructive purposes speedily became evident; combining as it does nearly double the strength with a more than proportionate superiority in elasticity and ductility, its value for shipbuilding purposes did not long fail to be realised. It was soon found more profitable to build a steel steamer, paying a price of nearly 9*l.* per ton for the material, than to construct one of iron which cost only 6*l.* 5*s.* per ton. The effect of the rapid displacement of malleable iron by steel produced from ores of a particular class has been, that at least 85 to 90 per cent. of the iron ores of Great Britain could no longer be applied to the production of material for rails and for con-

structive purposes, being unavailable for steel-making by any method which could compete with the Bessemer and Siemens processes. Great has been the apprehension among the owners of those ores, that the demand for iron which they can furnish could not revive, but the scientific metallurgist has successfully grappled, from more than one direction, with the great problem of restoring their commercial importance.

Modifications of the mode of working the rival of the Bessemer process, namely, the open-hearth (Siemens-Martin) process, have given successful results in the production of serviceable rails containing higher proportions of phosphorus than had before been admissible, and a simple alteration of the method of carrying out the Bessemer process has, within the last few years, led to really triumphant results, with the employment of those ores which, before, could only be dealt with by the searching operation of the old puddling furnace. By utilising the basic character of lime during the treatment of the melted pig iron, yielded by phosphoric ores, with air in the Bessemer converter, the phosphorus is fixed at the moment of its elimination by oxidation from the metal, and the objectionable impurity is held bound in the slag, while a steel is obtained rivaling in freedom from phosphorus the product furnished by the pure varieties of English and foreign ore which alone could previously be successfully dealt with by the Bessemer process. This modified treatment of iron for the production of steel, called the *basic treatment*, was soon applied also to the open-hearth (the Siemens and Siemens-Martin) processes of steel-making; thus a new era was established in steel manufacture by the quick processes, there being now but very few restrictions to their application to iron produced from all varieties of ores. Indeed, the treatment is actually being applied profitably to the recovery of iron from the rich slag forming the refuse-product of the puddling furnace in the production of malleable iron, which, containing as it did the phosphorus eliminated from the pig iron by the laborious purifying treatment, had been condemned to limited usefulness as a material for road-making, while now it ranks in market value with some ores of iron. Yet another most interesting and valuable result has been achieved by this simple application of scientific knowledge. The slag or refuse-product of the basic treatment of iron contains, in the form of phosphates of lime and magnesia, the whole of the phosphorus which it is the main function of that treatment to separate from the metal; it was soon found that the phosphoric acid which had been produced by the elimination of the pernicious element in the conversion of bad iron into good steel, existed in this refuse slag in a condition as readily susceptible of assimilation by plants as it is in the valuable artificial manure known as superphosphate; this refuse-slag, simply ground up, constitutes therefore a manure which is already of recognised value and commands a ready sale at very profitable prices.

The organization of this latest advance in the development of

steel manufacture dates back only nine years, and already the year's product of the basic process amounts to over 1,300,000 tons of steel. But although it is to Englishmen that the owner of iron property and the steel-maker are again indebted for these important results, and to English manufacturers that the first practical demonstration of the success of this process is due, its application has been far more rapidly elaborated upon the Continent than here; in Germany the importance of the subject was at once realised, and it is there that considerably the largest proportion of steel is produced by the basic treatment; it is in Germany also that the value of the slag for agricultural purposes has been developed; the first steps in its utilisation being but just now taken, in Staffordshire.

I have already referred to the remarkable strides which have been made in the extension of iron manufacture in the United States: the development there of steel production has been no less marvellous. In 1879, 928,000 tons of Bessemer steel were produced; in 1885 the make amounted to 1,701,000 tons, while the productive capacity in that year was estimated at 4,102,000 tons. With other extensive steel-producing works in course of completion, provision is being made for increasing the power of production by another million tons. Looking to the fact that at the present time the railway mileage in the United States exceeds that of the whole of Europe, there being 1,300,000 miles of railway in operation, while at the beginning of 1865 there were only 34,000 miles, the causes of this enormous development of the iron and steel manufacture are evident; the resources of the country in ore and fuel are gigantic, and the systematic technical training of the people has made its influence felt upon the development of this as of every other branch of industry which our friendly rivals pursue. But it is not only in the United States that the development in the production of iron and steel has greatly increased of late years; thus, in Germany the increase in the production of pig iron alone, during the last twenty-one years, has been 237 per cent., in Austro-Hungary 152 per cent., while the increase in France and Belgium is 64 per cent., and therefore not greatly inferior to our own (75 per cent.).

Although, however, the increase in actual production of iron and steel in this country has not kept pace with that of some other countries, it is satisfactory to know that our *productive power* has very greatly increased in late years, and there is probably no one branch of our industries in which we have maintained our position so satisfactorily in regard to quality of product as that of iron and steel manufacture, even although, every now and then, we have indications that in the struggle with other Nations for superiority of product and for pre-eminence in continuity of progress, we have to look to our laurels. While the country owes a deep debt of gratitude to such men as Neilson, Mushet, Bessemer, Siemens, Thomas and Gilchrist, who by their brilliant discoveries and inventions have maintained Great Britain's posi-

tion as the leader in the origination of successive eras of advance in iron and steel manufacture, there is no question that the trade generally has in recent years derived the greatest assistance and benefit from the organization of the Society which, under the name of the Iron and Steel Institute, has brought the members of the trade to recognise that they themselves, and the country, reap incalculable benefit from their free interchange of knowledge and the results of experience, their candid discussion of successes, failures, and diversities of views and practice—the combination of friendly rivalry with hearty co-operation in the advancement of the science and practice of their important calling.

While we have succeeded in maintaining a foremost position in the iron and steel manufacture, there are some other important branches of industry, for a time essentially our own, the present condition of which, in this country, we cannot contemplate with equal satisfaction. Several instructive illustrations might be quoted, but I will content myself with a brief examination of one of the most interesting.

A glance at the history of the utilisation of some products of the distillation of coal will present to us an industry created and first elaborated in England, which has, on the one hand, by its development effected momentous changes in other industries and in important branches of commerce, while on the other hand it has been in great measure wrested from us in consequence of the systematic collaboration of scientific and practical workers on the Continent.

In discussing the recent advances made in chemical manufactures as exemplified by the Exhibition of 1851, Playfair, in the lecture to which reference has already been made, spoke of the great development of the value of the evil-smelling tar, which was then made to furnish the solvent liquids benzene and naphtha, and the antiseptic creosote, the residual material being utilised for pavements and for artificial fuel. The chemist little dreamt then that between 1851 and the year of the next great Exhibition, 1862, coal tar would have become a mine of wealth equally to science, to manufactures and to the arts, in which fresh workings have ever since continued to be opened up, and still present themselves for exploration. Hofmann, in his valuable report on the chemical products and processes elucidated by that Exhibition, dwells with the enthusiasm of the ardent worker in science upon the brilliant products obtained from coal tar, which had resulted from the labours of the scientific chemist and had already acquired an almost national importance, although this great industry was then still in its infancy. From the year 1856, when the first colouring matter known as *Mauve*, was discovered and manufactured by a young student at the College of Chemistry, Mr. Perkin, one of Hofmann's most promising pupils, to the present time, the production of new coal-tar colours or of new processes for preparing the known colours in greater purity, has progressed uninterruptedly, this industry having long since become one of the most important, and

also one of the most remarkable, as illustrating by each stage of its development the direct application of scientific research to the attainment of momentous practical results.

It is interesting to note that Perkin's discovery of mauve, as a product of one of the most important derivatives of coal-tar, called aniline, was arrived at in the course of an investigation, having for its object the artificial production of the invaluable vegetable alkaloid, quinine, the synthesis of which has been the aim of many researches during the past half century, and appears to be at length about to be achieved, as the result of a long chain of scientific research. The difficulties to be overcome before mauve could be produced upon a manufacturing scale were very great, and were only solved by a steady pursuit of scientific research, side by side with practical experiments suggested by its results. Aniline—the parent of the first coal-tar colour, a liquid organic alkali—a most fertile source of interesting and important discoveries in organic chemistry, which have made the names of Hofmann and others famous—was produced with difficulty by various methods in very small quantities, so as to be almost a chemical curiosity at the time of the discovery of mauve. Among the substances from which it had been prepared was the volatile liquid known as *benzene*, first discovered in the laboratory of this Institution in 1825 by Faraday, in the liquid products condensed from oil gas, but afterwards obtained by Mansfield, in the College of Chemistry, from coal-tar naphtha, which also furnished in his hands a series of homologous liquids, many of them now of great importance as the raw materials from which dyes are obtained.

The conversion of benzene into aniline, which had been effected on a very small scale in different ways by German and Russian investigators, was accomplished as a manufacturing process after many difficulties by Perkin, and within a year after the discovery of mauve by him, it was in the hands of the silk dyer. Perkin's success led other chemists at once to pursue researches in the same direction, especially in France, where the next important coal-tar colour, *magenta* or fuchsine, was obtained, by M. Verquin, the successful manufacture of which in a pure state was, however, first accomplished by English chemists, with Mr. E. C. Nicholson at their head, whose magnificent specimens in the 1862 Exhibition excited universal admiration. In 1861 beautiful violet and blue colours were produced, again by French chemists (Girard and De Laire), but were manufactured shortly afterwards in a pure state by Nicholson. This brought the coal-tar dye industry down to the year 1862, and Hofmann, in congratulating his young pupil Perkin (in his Jury Report) upon the splendid industrial result achieved, in having first manufactured a colour from coal-tar, which had been arrived at by purely scientific research, expressed the hope that the commercial success of his enterprise might not divert him from the path of scientific inquiry—a hope which he has lived to see fully realised, as the long series of fresh contributions, made almost without inter-

ruption since that time by Perkin to our knowledge of organic chemistry have been among the most brilliant and important achieved by chemists of the present day, and have continued to influence in a most important manner the branch of industry which he created.

The six years succeeding those which formed the first period (1854–1862) of existence of this industry were fruitful, not only of new colours but also of progress made in England, as well as on the Continent, in the development of the manufacture, and of our knowledge of the constitution, of the beautiful dyes which outvie each other in brilliancy. Important researches by Hofmann, which, while establishing the correctness of his scientific conceptions of the real nature of magenta, led to the discovery, by him, of a matchless violet dye, were followed by the production, at the hands of Perkin and Nicholson in England, and of several workers on the Continent, of the well-known gas-light greens, of Bismarck brown, and of some eight or nine other important dyes; blue, yellow, orange, and scarlet.

In the next period of six years (1868–1874) another great stride was made in the coal-tar colour industry, due to important scientific researches carried out by two German chemists, Graebe and Liebermann, which led them, in the first place, to obtain an insight into the true nature of the colouring matter of one of the most important staple dye-stuffs, namely the Madder root. They found that this colouring matter which chemists call *Alizarine* was related to *Anthracene*, one of the most important solid hydrocarbons formed in the distillation of coal, a discovery which was speedily followed by the artificial formation of the madder dye, alizarine, from that constituent of coal-tar. At first, this achievement of Graebe and Liebermann was simply of high scientific interest, but Perkin, who was pursuing research in the same direction, soon discovered two methods by which the conversion of anthracene into the madder dye could be accomplished on a large scale, and one of these, which was also arrived at by the German chemists simultaneously with Perkin, is still used for the manufacture of alizarine, which was for some time most actively pursued in this country, with very momentous results, as regards the market value of the madder root. The latter has long been most extensively cultivated in Holland, South Germany, France, Italy, Turkey, and India, the consumption of madder in Great Britain having attained to an annual value of as much as 1,000,000*l.* sterling. Playfair pointed out in 1852 that important improvements had been attained in the extraction of the red colour or alizarine from the madder root, the refuse of which, after removal of the dye in the ordinary way, had been made, by a simple treatment, to furnish further quantities of the colouring matter. This result, most valuable at the time of the first great Exhibition, became insignificant when once the dye was artificially manufactured from anthracene; the price paid for madder in 1869 was from 5d. to 8d. per pound, but now the equivalent in artificial madder dye, or alizarine, of one pound of the root, can be obtained for one-halfpenny. The latter is still used by the most conservative

section of the dye-trade, the wool-dyers (and in some respects it appears to present in this direction a little advantage over the artificial colour), but the value of its present annual consumption in Great Britain has become reduced from one million to about 40,000*l*. During the development of the artificial alizarine industry within this third period of six years, the continued researches of Perkin, Schunck, Baeyer, Caro, and others have led to the development of further important varieties of coal-tar dyes, the most valuable of which, discovered by the two last-named chemists, was a beautiful *cerise* colour, called eosine.

With the discovery of artificial alizarine the truly scientific era of the coal-tar industry may be said to have commenced, most of the commercially valuable dye-products, obtained since that time, being the result of truly theoretical research by the logical pursuit of definite well understood reactions. The wealth of discovery in this direction made during the last thirteen years is a most tempting subject to pursue, but I am compelled to refrain from entering upon it, further than to point out that the practical significance of beautiful scientific researches of many years previous became developed—that one of the results was the production of very permanent and brilliant scarlet and red dyes, the manufacture of which has greatly reduced the market value of cochineal—that the careful study of the original coal-tar colours led to their production in a state of great purity by new and beautifully simple scientific methods (which include the extensive employment as an invaluable practical agent in their production, of the curious gaseous oxychloride of carbon, until lately a chemical curiosity, produced through the agency of light, and hence christened *phosgene gas*, by its discoverer, John Davy, in 1812); and lastly, that even the well-known vegetable colouring matter, *indigo*, one of the staple products of India, now ranks among the colours synthetically obtained by the systematic pursuit of scientific research, from compounds which trace their origin to coal-tar.

The rapid development of the coal-tar colour industry has not failed to exercise a very important beneficial influence upon other chemical manufactures; thus, the distillation of tar, which was a comparatively very crude process, when, at the period of the first Exhibition, benzene, naphtha, dead-oil and pitch were the only products furnished by it, has become a really scientific operation, involving the employment of comparatively complicated but beautiful distilling apparatus for the separation of the numerous products which serve as raw materials for the many distinct families of dyes. Very strong sulphuric acid became an essential chemical agent to the alizarine manufacturer, and, as a consequence, the so-called anhydrous sulphuric acid, the remarkable crystalline body which was for many years prepared only in small quantities from green-vitriol, and of which minute specimens carefully sealed up in glass tubes were preserved as great curiosities in my student's days, is now

made at a low price upon a very large scale by a beautifully simple process worked out in England, by Squire and Messell. The alkali and kindred chemical trades have been very greatly benefited by the large consumption of caustic soda, of chlorate of potash and other materials used in the dye manufactures, and the application of constructive talent, combined with chemical knowledge, to the production of efficient apparatus for carrying out on a stupendous scale the scientific operations developed in the investigator's laboratory, has greatly contributed to the creation of a distinct profession, that of the chemical engineer.

One of the most beneficial results of the rapid development of the coal-tar colour industry has been its influence upon the ancient art of dyeing, which made but very slow advance until the provision of the host of brilliant, readily applicable colours completely revolutionised both it and the art of calico printing.

In endeavouring to furnish some idea of the magnitude of the coal-tar colour industry, I may state that the total value of the coal-tar colours produced in 1885 amounted to about 3,500,000*l.* The value of the alizarine and its related dyes which are used with it for obtaining various shades of colour, now amounts to about one-half of the total produce of the coal-tar colour industry. Their manufacture in England in considerable quantities still continues, but it is a suggestive fact that the value of the artificial alizarine imported into this country from the Continent last year, was 259,795*l.* Taking the average value of madder at 5*d.* per lb., and the cost of its equivalent in artificial alizarine at one-halfpenny, the quantity imported, if valued at 5*d.* per lb., would represent about 2,597,950*l.*

I venture to think that it will be interesting at this point, to quote some words of prophecy included in Professor Hofmann's important 'Report on the Chemical Section of the Exhibition of 1862,' and to inquire to what extent they have been verified. In commenting upon one of the features of greatest novelty in that world's show, the exhibition of the first dye products derived from coal-tar, he says :—

"If coal be destined sooner or later to supersede, as the primary source of colour, all the costly dyewoods hitherto consumed in the ornamentation of textile fabrics ; if this singular chemical revolution, so far from being at all remote, is at this moment in the very act and process of gradual accomplishment ; are we not on the eve of profound modifications in the commercial relations between the great colour-consuming and colour-producing regions of the globe ? Eventualities, which it would be presumptuous to predict as certain, it may be permissible and prudent to forecast as probable ; and there is fair reason to believe it probable that, before the period of another decennial Exhibition shall arrive, England will have learnt to depend, for the materials of the colours she so largely employs, mainly, if not wholly, on her own fossil stores. Indeed, to the chemical mind it cannot be doubtful, that in the coal beneath her feet lie waiting to be drawn forth, even as the statue lies waiting in the quarry, the fossil equiva-

lents of the long series of costly dye materials for which she has hitherto remained the tributary of foreign climes. Instead of disbursing her annual millions for these substances, England will, beyond question, at no distant day become herself the greatest colour-producing country in the world; nay, by the strangest of revolutions, she may ere long send her coal-derived blues to indigo-growing India, her tar-distilled crimson to cochineal-producing Mexico, and her fossil substitutes for quercitron and safflower to China, Japan, and the other countries whence these articles are now derived.

"Coal and iron, it has been said, are kings of the earth, and our latest chemical victories seem destined to add another vast province to the dominion of coal, and a fresh element of commercial predominance to its already powerful possessors."

So far as concerns the displacement of madder, cochineal, quercitron, safflower, and other natural dye materials from their positions of command in the markets of England and the world, Hofmann's predictions have been amply fulfilled, and it appeared, in the earlier days of the coal-tar colour industry, as though he would be an equally true prophet in regard to England becoming herself the greatest colour-producing country in the world. But, although Germany did little in the days of infancy of this industry, beyond producing a few of the known colours in a somewhat impure condition, many years did not elapse ere she not only was our equal in regard to the quality of the dyes produced, but, moreover, had outstripped us in the quantities manufactured and in the additions made to the varieties of valuable dyes sent into the market. The following is the estimated total value of coal-tar colours manufactured in the several producing countries as far back as 1878:—Germany, 2,000,000*l.*; England, 480,000*l.*; France, 350,000*l.*; Switzerland, 350,000*l.* These figures show that the value of the make of colours in England was less than one-fourth that of Germany, and that even Switzerland, which, in competing with other countries industrially is at great natural disadvantages, was not far behind us, ranking equal to France as producers. The superior position of Germany in reference to this industry may be in a measure ascribable to some defects in the operation of our Patent Laws and to questions of wages and conditions of labour; but the chief cause is to be found in the thorough realisation, by the German manufacturer, of his dependence for success and continual progress upon the active prosecution of scientific research, in the high training received by the chemists attached to the manufactories, and in the intimate association, in every direction, of systematic scientific investigation with technical work.

The young chemists which the German manufacturer attracts to his works rank much higher than ours in the general scientific training which is essential to the successful cultivation of the habit of theoretical and experimental research, and in the consequent appreciation of, and power of pursuing, original investigations of a high order. Moreover, the research laboratory constitutes an integral

part of the German factory, and the results of the work carried on by and under the eminent professors and teachers at the universities and technical colleges are closely followed and studied in their possible bearings upon the further development of the industry.

The importance attached to high and well-organized technical education in Germany is demonstrated not only by the munificent way in which the scientific branches of the universities and the technical colleges are established and maintained, but also by the continuity which exists between the different grades of education; a continuity, the lack of which in England was recently indicated by Professor Huxley with great force. Nearly every large town in Germany has its "Real Schule," where the children of the public elementary schools have the opportunity, either by means of exhibitions or by payment of small fees, of receiving a higher education, qualifying them in due course to enter commercial or industrial life, or to pass to the universities or to the polytechnic or technical high schools, which, at great cost to the Nation, have been developed to a remarkable extent in recent years, and have unquestionably exercised a most beneficial influence upon the trade and commerce of the country. A most important feature in the development of these schools is the subdivision of the work of instruction among a large number of professors, each one an acknowledged authority in the particular branch of science with which he deals. Thus, at the Carlsruhe Polytechnic School—one of the very earliest of its kind—which was greatly enlarged in 1863—the number of professors is 41; and at Stuttgart the teaching staff of the polytechnic school amounts to 65 persons, of whom 21 are professors.

The important part taken by the German universities in the training of young men for technical pursuits has often been dwelt upon as constituting a striking feature of contrast to our university systems. The twenty-four universities in the German Empire, each with its extensive and well-equipped science departments and ample professional staff, contribute most importantly to the industrial training of the Nation in co-operating with the purely technical schools. The facts specified in the Report of the Technical Education Commission that, in the session 1883–4, there were 400 students working in the chemical laboratories at Berlin, and that, during the same session, 50 students were engaged in original research at Munich (where the traditions of the great school of Liebig are worthily maintained), illustrate the national appreciation of the opportunities presented for scientific training; and the expenditure of 30,000*l.* upon the physical laboratory, and 35,000*l.* upon the chemical department, of the New University of Strasbourg, serves to illustrate the unsparing hand with which the resources of the country are devoted to the provision of those educational facilities which are the very life-spring of the industrial progress whence those resources are derived.

In France, higher education had been allowed to sink to a low ebb after the provincial universities had been destroyed in the great

Revolution, and the University of Paris had been constituted by the first Napoleon the sole seat of high education in the country. Before the late war, matters educational were in a condition very detrimental to the position of the country among Nations. There was no lack of educational establishments, but the systems and sequence of instruction lacked organization.

Since the war, France has made great efforts to replace her educational resources upon a proper footing. The provincial colleges have been re-established at a cost of 3,280,000*l.*, and the annual budget for their support reaches half-a-million. The organization of industrial education has now been greatly developed, though still not on a footing of equality with that of Germany. The practical teaching of science commences already in the elementary schools, and the groundwork of technical instruction is afterwards securely laid by the higher elementary schools, of which so many excellent examples are now to be found in different parts of France. Every large manufacturing centre has its educational establishment where technical instruction is provided, with special reference to local requirements; the Institute Industriel, at Lisle, and the Ecole Centrale of Lyons, are examples of these. In order to render these colleges accessible to the best talent of France, more than 500 scholarships have been founded, at an annual cost of 30,000*l.* The Ecole Centrale des Arts et Manufactures, of Paris, still maintains the reputation as the great technical university of the country, which it earned many years ago, and receives students from the provincial colleges, where they have passed through the essential training preliminary to the high technical education which that great institution provides.

Switzerland has often been quoted as a remarkable illustration of the benefits secured to a Nation by the thoroughly organized education of its people. Far removed from the ocean, girt by mountains, poor in the mineral resources of industry, she yet has taken one of the highest positions among essentially industrial Nations, and has gained victories over countries rich in the possession of the greatest natural advantages. Importing cotton from the United States, she has sent it back in manufactured forms, so as to undersell the products of the American mills. The trade of watch-making, once most important in this metropolis, passed almost entirely to Switzerland years ago; the old established ribbon trade of Coventry has had practically to succumb before the skilled competition of Switzerland, and although she has no coal of her own, Switzerland is at least as successful as France in her appropriation of the coal-tar colour industry and her rivalry in rate of production with England, the place of its birth and development. Comparative cheapness of labour will not go very far to account for these great successes; they undoubtedly spring mainly from the thoroughly organized combination of scientific with practical education of which the entire people enjoys the inestimable benefit.

From the age of six to twelve, or thirteen, the children must attend primary schools, where, as the pupils advance in age, the instruction becomes more practical. The application of the knowledge acquired in these primary schools, is cultivated for three years at the so-called "Improvement Schools," and upon these follow the Cantonal High Schools, which are divided into trade- and classical schools, and of which there are sixty-seven in the little canton of Zurich alone. Above those there are five universities and the Zurich Technical Institute, which is supported by the Federal Government, the Canton itself subscribing liberally to its aid. It owns a very numerous staff of professors and teachers, and the number of students attending is so large that, magnificent as was the accommodation which it already afforded, no less than 50,000*l.* have recently been spent upon additional chemical laboratories. Although the Germans have so many technical colleges and chemical schools they go in large numbers to the Zurich Institute, and even a few English appreciate the great advantages which must accrue from the thorough training attainable in this world-renowned school of technics.

Holland furnishes another brilliant example of the success with which a Nation brings the power of systematic technical education to bear in securing and maintaining industrial victories in the face of most formidable disadvantages, while the United States of America, so rich in natural resources, have long since realised the immensity of additional advantages to be gained over European Nations in the war of industry by a wide diffusion and thorough organization of technical education. So long as forty years ago the States already possessed several excellent educational institutions established upon the basis of the Continental polytechnic schools, but it was not until about fifteen years later that the great advances achieved by Germany in technical education, made America, like France, anxious concerning the progress and development of some of her industries.

The subject was at once made a thoroughly national one, and it is now just upon a quarter of a century ago since Congress ordained that each State should provide at least one college, having for its leading objects the diffusion of scientific instruction in its relations to the industry of the country, and decreed that public lands should be granted to the States and Territories providing such colleges. In accordance with the system adopted for the regulation of these grants, the State of New York received close upon a million acres of land, and out of this grant grew the University of Cornell, which could be called upon to educate 500 students free of charge under the conditions of the grant, and which was already at work in 1867, having in the meantime received most important aid from an endowment of 100,000*l.* by a private citizen, Mr. Cornell. The combined effect of this State action and of great private munificence, was a remarkably rapid development of scientific and technical education throughout the country; besides some fifty colleges, with

eight or nine thousand students, which sprang out of the Land Grant Act for Industrial Education, there are now in the States about 400 other universities and colleges (with 35,000 students, and between 5000 and 6000 teachers), in a large proportion of which efficient instruction in applied science is provided.

Among the more prominent of America's technical schools are the Stevens Institute of Technology, New Jersey; the Pennsylvania Polytechnic College, Philadelphia; the Lawrence Science School, in connection with Harvard University; the Columbia College and School of Mines, New York; the Massachusetts Institute of Technology, Boston; the Engineering School of the Michigan University; the Lafayette College, Pennsylvania; the Mechanical College of Louisiana University; the Brown University, Rhode Island; Washington College, Virginia; Union College, Schenectidy; and the Shipley School, in connection with the Cornell University. To the useful work accomplished within a few years by these and many other highly important educational institutions, which have placed the acquisition of scientific knowledge within the reach of the very humblest, the enormous strides made by the United States in the development of home industries must unquestionably be in the main ascribed.

While extolling the comprehensive and well-organized systems of technical education existing in all parts of the Continent and the United States, let us not undervalue the great progress which has been made in recent years in Great Britain in the advancement and extension of technical instruction. The Royal Commission on the Depression of Trade and Industry state, as the result of evidence collected by them, that "It would be difficult to estimate the extent to which our industries have been aided in various ways by the advance of elementary, scientific, and technical education during the last twenty years."

The important influence exercised by the admirable work which the organization of the Science and Art Department has accomplished, upon the intellectual and material progress of the Nation, is now thoroughly recognised. Professor Huxley, the Dean of the Normal School of Science, in his recent important letter "On the organization of industrial education," has reminded us that "the classes now established all over the country in connection with that department, not only provide elementary instruction accessible to all, but offer the means whereby the pick of the capable students may obtain in the schools at South Kensington as good a higher education in Science and Art as is to be had in the country," and "that it is from this source that the supply of science and art teachers is derived, who in turn raise the standard of elementary education" provided by the School Boards. The extension of facilities for the education of those engaged in art-industries is constantly aimed at, as was recently demonstrated by the creation of free studentships for artizans in the Art Schools at South Kensington.

The necessity which has gradually made itself felt in the manufacturing towns of the United Kingdom for encouraging the study of science in its application to industries, by those who intend to devote themselves to some branch of manufacture or trade, has led to the establishment in about twenty-five towns in England and Scotland, and in two or three in Ireland, of colleges of science corresponding more or less to the Continental polytechnic schools, and accomplishing important work in training students in the different branches of science in their applications to manufactures and the arts. A number of these, such as the Owen's College, Manchester, the Yorkshire College, at Leeds, the Glasgow and Bradford Technical Colleges, the Firth College at Sheffield, and the Mason's College at Birmingham, have established a high reputation as schools where science in its applications to productive industries is most efficiently taught and importantly advanced.

The wealthier of the City Companies, some of which had long been identified with important educational establishments, associated themselves with the Corporation of the City of London nearly ten years ago to establish an organization for the advancement of technical education, which has already carried out most important work. The Society of Arts, which initiated the system of examinations, afterwards so successfully developed by the Science and Art Department, set on foot and conducted for several years examinations of artizans in a few branches of technology. This useful work was relinquished in 1879 to the City and Guilds' Institute, and its extension since that period has been most satisfactory. The number of candidates then presenting themselves was 202, distributed over twenty-three centres where examinations were held, four years afterwards (1883) the number presenting themselves for examinations was 2397, and last year they amounted to 4764. The centres where examinations are held have been increased to 186, and the number of subjects dealt with, from thirteen to forty-eight. The beneficial influence exercised by these examinations upon the development and extension of technical instruction in the manufacturing districts throughout the country is already very marked. The adoption of the system, originated by the Science and Art Department, of contributing to the payment of teachers in proportion to the successes attained by their pupils, is operating most succesfully in promoting the establishment and extension of classes for instruction in technical subjects, in connexion with Mechanics' Institutes and other educational establishments in various centres of industry. In 1884, the number of classes in different parts of the country and metropolis which are connected with the examinations of the Institute was 262, having 6395 students, and this year the number of classes has risen to 357, and that of students to 8500.

The Technical College at Finsbury was the first great practical outcome of the efforts made by the City and Guilds' Institute to supplement existing educational machinery, by the creation of techno-

logical and trade schools in the metropolis, and the results, in regard to number and success of students at the day and evening schools of that important establishment, have afforded conclusive demonstration of the benefits which it is already conferring upon young workers who, with scanty means at their command, are earnest in their desire to train themselves thoroughly for the successful pursuit of industries and trades. The evening courses of instruction are especially valuable to such members of the artizan classes as desire, at the close of their daily labour, to devote time to the acquisition of scientific or artistic knowledge. The system of evening classes, which was pursued, in the first instance, at King's College and one or two other metropolitan schools, was most successfully developed by the Science and Art Department, and, being now supplemented by the important work accomplished at Finsbury College, is really, in point of organization, in advance of similar work done in other countries.

Another department of the City and Guilds' Institute, of a somewhat different character, but akin to that of the Finsbury College in the objects desired to be achieved by it, is the South London School of Technical Art, which is also doing very useful work, while the chief or central Institution for Technical Education, which commenced its operations about three years ago, if it but continue to be developed in accordance with the carefully matured scheme which received the approval of the City and Guilds' Council, and with that judicious liberality which has been displayed in the design and arrangement of the building, bids fair to become the Industrial University of the Empire.

As one of the first students of that College of Chemistry which became part-parent of our present Normal Schools of Science, and the creation of which (forty-two years ago) constituted not the least important of the many services rendered towards the advancement of scientific education in this country by His Royal Highness the Prince Consort, most vividly I remember the struggling years of early existence of that half-starved but vigorous offspring of the great school of Liebig, born in a strangely unsympathetic land in the days when the student of science in this country still met on all sides that pride of old England, the practical man, enquiring of him complacently: *cui bono; quo bono?* That ardent lover of research and instruction, the enthusiastic and dauntless disciple of Liebig—my old master—Hofmann, loyally supported through all discouragement, and in the severest straits, by a small band of believers in the power of scientific research to make for itself an enduring home in this country, succeeded in very few years in developing a prosperous school of chemistry which soon made its influence felt upon British industry; and it is not credible that less important achievements should be accomplished, and less speedily, in days when the inseparable connection of science with practice has become thoroughly recognised, by an Institution created, and launched under most auspicious circumstances, by those powerful representatives of the commercial and industrial

prosperity of the Empire, who, before all others, must realise the vital necessity for ceaseless exertions, even for much self-sacrifice in the immediate present, to recover our lost ground in the Dominions of Industry.

It has been already demonstrated by the rapid increase which has taken place in the number of young men who, qualified by their preliminary education for admission as matriculated students, go through the complete curriculum of the Central Institute, that the combination of advanced scientific instruction with practical training which that course of study involves, will be much sought after by young men whose preliminary education has qualified them for admission, and whose probable future career will be interwoven with the advancement of one or other of the great industries of our country. But, one of the most important functions of the Central Technical College should consist in the thorough training of teachers of applied science. The statistics furnished by the technological examinations show that, while their successful organization has led to the establishment of classes of instruction, supplementary to the general science teaching in every large manufacturing centre, the increase in the number of candidates examined has been accompanied by an increase in the percentage of failures to pass the examinations, and that the supply of a serious deficiency in competent teachers was essential to a radical improvement in technical education. The work of the City and Guilds' Institute in this direction has already been well begun, and it is in the furtherance of this, by the organization of arrangements for facilitating the attendance of science teachers for sufficient periods at the Central Institute, or at more accessible provincial technical colleges, that the Imperial Institute may hope to do good work.

Without taking any direct part in the duty of education, it is contemplated that the Imperial Institute will actively assist in the thorough organization of technical instruction, and its maintenance on a footing, at least of equality, with that provided in other countries, by the system of intercommunication which it will establish and maintain between technical and science schools; by the distribution of information relating to the progress of technical education abroad, to the progressive development of industries, and the requirements of those who intend to pursue them; by the provision of resources in the way of material for experimental work, and illustrations of new industrial achievements, and by a variety of other means.

The provision of facilities to teachers in elementary schools to improve their knowledge of science and their power of imparting information of an elementary character to the young, with the aid of simple practical demonstrations of scientific principles involved in the proceedings of daily life, constitutes another direction in which important progress may be made towards establishing that continuity between elementary and advanced education which is so well developed on the Continent. The organization of facilities, combined

with material aid, to be provided to young artizans who shall afford some legitimate evidence of superior natural intelligence and a striving after self-improvement, to enable them to abandon for a time the duty of bread-winning, and to work at one or other of the technical schools in London or the provincial centres, will be another object to which the resources of the Imperial Institute should be applied very beneficially. Not only will the intelligent workman's knowledge of the fundamental principles of his craft or trade be thereby promoted; his association in work and study with others who are pursuing the acquisition of knowledge in different directions, which at first seem to him alien to his personal pursuits and tastes, but come in time to acquire interest or importance in his eyes, will bring home to him the advantages of a wider and more comprehensive scope of instruction, and the enlargement of his views regarding the value and pleasure of knowledge will, in turn, exercise a favourable influence in the same direction upon those with whom he afterwards comes into contact. The cramping influence which the great subdivision of labour, resulting from the development of mechanical, physical, and chemical science, is calculated to favour, must thus become counteracted, and the workman will realise, that if he is to rise above the level of the ordinary skilled labourer, mere dexterity in the particular branch of that trade which he has made his calling must be supplemented by an acquaintance with its cognate branches, by some knowledge of the principles which underlie his work, and by some familiarity with the trades allied to his calling.

The importance of bringing technical instruction within the reach of the needy scholars of the lower middle class need not be dwelt upon, and there can be no question that one of the most powerful means of promoting the extension of technical education will be the well organized administration of a really comprehensive system of scholarships, to be judiciously utilised in connection with the well-established colleges and schools of science and technics throughout the country, in such proportions as to meet local requirements and changing conditions. That a good foundation for such a system of scholarships is likely ere long to emanate from the resources of the Royal Commission of 1851, has already been officially indicated in one of its reports; may we not also hope that many will be found in our Empire ready to follow the example of the late Sir Joseph Whitworth, and to act in emulation of the patriotism of those men who, by munificent donations or endowments in aid of the work of bringing industrial education within the reach of all classes in the United States, have helped to place our Cousins in the position to hold their own and aspire to victory, in the war of industry? The thoroughly representative character which it is intended to maintain for the governing body of the Imperial Institute, will secure the wise administration by it of funds of this kind, dedicated to the extension and perfection of national establishments for technical education, and to the encouragement of its pursuit, in the ways above indicated, by

those whose circumstances would otherwise prevent them from enjoying the advantages secured to their fellow-workers in other countries. Several other directions readily suggest themselves in which the judicious administration of resources in aid of the technical training of eligible men of the artizan class could well form part of the organized work of the Imperial Institute.

By the establishment of an Education branch of the Intelligence Department, which will form a very prominent section of the Imperial Institute, the working of the colleges and schools of applied science in all parts of the United Kingdom will be harmonised and assisted, and the information continuously collected from all countries relating to educational work and the application of the sciences to industrial purposes and the arts will be systematically distributed. A well-organized Enquiry Department will furnish to students coming to Great Britain from the Colonies, Dependencies and India the requisite information and advice to aid them in selecting their place of work and their temporary home, and in various other ways. The collections of natural products of the Colonies and India, maintained up to the day by additions and renewals at the central establishment of the Institute, will be of great value to students in the immediately adjacent educational Institutions, and will moreover be made subservient to the purposes of provincial industrial colleges by the distribution of thoroughly descriptive reference catalogues, and of specimens. Supplies of natural products from the Colonies, India, or from other Countries, which are either new or have been but imperfectly studied, will be maintained, so that material may be readily provided to the worker in science or the manufacturer, either for scientific investigation or for purposes of technical experiment.

The existence of those collections and of all information relating to them, as well as of the libraries of technology, inventions, commerce and applied geography, in immediate proximity to the Government museums of science and inventions, art, and natural history, to the Normal School of Science, and to the Central Technical Institute, present advantages so obvious as to merit some fair consideration by those who have declined to recognise any reason in favour of the establishment of the Imperial Institute at South Kensington.

In the powerful public representations which have of late been made on the imperative necessity for the greater dissemination and thorough organization of industrial education, the importance of a radical improvement in commercial education, as distinguished from what is comprehended under the head of technical training, has scarcely received that prominence which it merits. It is true that, in some of our colleges, there are courses of instruction framed with more especial reference to the requirements of those who propose to enter into mercantile houses, or in other ways to devote themselves to commercial pursuits; but as a rule the mercantile employés, embraced under the comprehensive title of clerks, begin their careers in life but

ill prepared to be more than mechanical labourers, and remain greatly dependent upon accident, or upon their desire for self-improvement which directs them in time to particular lines of study, for their prospects of future success in commercial life.

This impressed itself strongly upon the Royal Commission on the Depression of Trade and Industry, who state as the result of evidence collected by them that our deficiency in the matter of education as compared with some of our foreign competitors relates "not only to what is usually called technical education, but also to the ordinary commercial education which is required in mercantile houses." The ordinary clerk in a merchant's office is too often made to feel his inferiority to his German colleague, not merely in regard to his lamentable deficiency in the knowledge of languages, but in respect to almost every branch of knowledge bearing upon the intelligent performance of his daily work and upon his prospect of advancement in one or other branch of a mercantile house. The preliminary training for commercial life on the Continent is far more comprehensive, practical and systematic than that which is attainable in this country, and the student of commerce abroad has, afterwards, opportunities for obtaining a high scientific and practical training at distinct branches of the polytechnic schools and in establishments analogous to the technical colleges, such as the High Schools of Commerce in Paris, Antwerp, and Vienna.

It will be well within the scope of the Imperial Institute as an organization for the advancement of industry and commerce, to promote a systematic improvement and organization of commercial education by measures analogous to those which it will bring to bear upon the advancement of industrial education.

The very scant recognition which the great cause of technical education has hitherto received at the hands of our administrators has, at any rate, the good effect of rousing and stimulating that power of self-help which has been the foundation of many achievements of greatest pride to the Nation, and we may look with confidence to the united exertions of the people of this country, through the medium of the representative organization which they are now founding, for the early development of a comprehensive national system of technical education, of the nature foreshadowed not long since by Lord Hartington, in that important address which has raised bright hopes in the hearts of the Apostles of education.

In some of the views which have been of late put forward regarding the possible scope of the Imperial Institute, the antagonism which has been raised and fostered against its location in the vicinity of some of our National Establishments most intimately connected with the educational advancement of the Empire, has developed a tendency to circumscribe its future sphere of usefulness, and to place its functions as a great establishment of reference and resort for the commercial man in the chief foreground. I have endeavoured to indicate directions in which its relations to the Colonies and India,

to the great industries of the country, and to the advancement of technical and commercial education, cannot fail to be at least as important as its immediate connection with the wants of the commercial section of the community, and those are most certainly quite independent of the particular locality in which it may be placed, excepting in so far as the command of ample space, and the advantages to be derived from juxta-position with the great National establishments to which I have referred, is concerned. At the same time, there is not one of the directions in which the development of the resources and activity of the Institute has been thus far indicated, which has not an immediate and important bearing upon the advancement of the commerce of the Empire. There are, however, special functions to be fulfilled by the Institute, which are most immediately connected alike with the great commercial work of the City of London and with that of the provincial centres of commerce. The provision, in very central and readily accessible positions, of commercial museums or collections of natural or import products, and of export products of different nations, combined with comprehensive sample-rooms and facilities for the business of inspection or of commercial, chemical or physical examination, is a work in which the Institute should lend most important aid. The system of correspondence with all parts of the Empire which it will develop and maintain will enable it to collect, and form a central depot of, natural products from which local commercial museums can be supplied with complete, thoroughly classified economic collections, and with representative samples of all that, from time to time, is new in the way of natural products from the Colonies and Dependencies, from India, and from other countries. In combination with this organization, the distribution, to commercial centres, of information acquired by a central department of commercial geography will constitute an important feature in the work of the Institute, bearing immediately upon the interests of the merchant at home, in the Colonies, and in India.

The formation of specially commercial institutions, of which enquiry offices, museums, and sample rooms with their accessories, will form a leading feature, and which will supply a want long since provided for by the Nations with whom we compete commercially, is already in contemplation in the Cities of London and Newcastle; other great commercial centres will also doubtless speedily take steps to provide accommodation for similar offshoots from the central collections of the Institute. So far as the Indian Empire is concerned, the organization of correspondence by provincial committees which already exists in connection with economic and geological museums established in the several Presidencies, affords facilities for the speedy elaboration of the contemplated system of correspondence in connection with the Institute, and the establishment of similar organizations in the different Colonies will, it is hoped, be heartily entered upon and speedily developed.

The system of correspondence to which I have more than once alluded in indicating some of the work of the Institute, in relation to technical education and industry, and which will form a most important part of the main groundwork of its organization, is not in the least theoretical in its character. Its possible development has suggested itself to many who have given thought to the future sphere of action of the Institute in connection with commerce and industry; to myself, who for many years have been, from time to time, officially cognizant of the work performed by what are called the Intelligence Departments of the Ministries of War abroad and at home, the direct and valuable bearing of such a system upon the work of the Institute, suggested itself as soon as I gave thought to the possible future of this great conception, and to Major Fitzgerald Law belongs the credit of suggesting that the well-tried machinery of the War Office Intelligence Department should serve as a guide for the elaboration of a Commercial Intelligence Department. This Department, which will, it is hoped ere long commence its operations by establishing relations with the chief Colonies and India, will be in constant communication with the Enquiry Offices to be attached to the local commercial establishments and to other provincial representations of the work of the Institute, systematically distributing among them the commercial information and statistics continually collected. It will be equally valuable to the Colonies and India by bringing their requirements thoroughly to the knowledge of the business men in the United Kingdom, and by maintaining that close touch and sympathy between them and the people at home which will tend to a true federation of all parts of the Empire.

In no more important direction is this system destined to do useful work than in the organization of emigration, not only of labour, but also of capital. The establishment of emigration enquiry offices at provincial centres in connection with a central department at the Institute, will be of great service to the intending emigrant, by placing within his reach the power of acquiring indispensable information and advice, and by facilitating his attainment of the special knowledge or training calculated to advance his prospects in the new home of his choice. Similarly, the capitalist may be assisted in discovering new channels for enterprise in distant portions of the Empire, the resources of which are awaiting development by the judicious application of capital and by the particular class of emigration which its devotion to public works or manufacturing enterprise in the Colonies would carry with it. The extent to which the State may aid in the organization of systematic emigration, and the best mode in which it may, without burden to the Country, promote the execution of such public works in the Colonies as will open up their Dominions to commerce and at the same time encourage the particular class of emigration most advantageous to the Colonies themselves, are subjects of great present interest; but, in whatever way these important questions may be grappled with, such an or-

ganization as the Institute should supply, cannot fail to accelerate the establishment of emigration upon a sound and systematic footing, and to co-operate very beneficially in directing private enterprise into the channels best calculated to advance the mutual interests of the capitalists and the Colonies.

I have already indicated that it is not only in connection with purely commercial matters that the Intelligence Department of the Institute will occupy itself. The prospects of its value to the Colonies and to India in promoting the development of their natural resources and the cultivation of new fields for commercial and industrial activity are well illustrated by the valuable work which has been accomplished upon similar lines by the admirably directed organization at Kew.

By the systematic collection and distribution of information relating to industries and to education from all countries which compete with ourselves in the struggle for supremacy in intellectual and industrial development, the Institute will most importantly contribute to the maintenance of intimate relationship and co-operation between educational, industrial, and commercial centres, between the labourer in science and the sources through which his work becomes instrumental in advancing national prosperity; between the Colonies and the Mother-Country, between ourselves and all Races included in the vast Empire of Her Majesty.

In conclusion, I venture to express the belief that the organization which the Imperial Institute will have the power of developing, with a wisely constituted governing body at its head, may accomplish, and at no distant date, most useful work, which has been already publicly indicated as destined to have an immediate bearing upon the federation of England and her Colonies. Professor Huxley, in his last Presidential Address to the Royal Society, uttered most suggestive words, indicative of the value and the possibility of a *scientific* federation of all English speaking Peoples; and this subject is now receiving the careful consideration of that Society. It is firmly believed by leading men of science, that such a federation of at any rate the Colonies and Dependencies with us will be brought about, and it is in harmony with that belief that the Imperial Institute should be expected, through its organization, to afford important aid in the application of the principle of federation to the geological and topographical survey of the Colonies, in the establishment of a system of interchange of meteorological and scientific observations, and in the promotion, in various ways, of thorough co-operation between particular Colonies or groups of Colonies, for applying the results of scientific research to the mutual development of their natural resources.

It may be that the programme of which I have given a very imperfect exposition, as indicative of the work which the Imperial Institute may be called upon to accomplish, will be regarded as almost too ambitious in its scope for practical fulfilment. The outline

of this programme has been drawn by a combination of abler hands than mine; I have but ventured to sketch in some of the details as they have presented themselves to my mind, and to the minds of others who have given thought to this great subject; but I dare to have faith in its realisation, and to believe that, if the work be taken in hand systematically and progressively, the nucleus being first thoroughly established from which fresh lines of departure will successively emanate, the Imperial Institute is destined to become a glory of the land. And, as one whose mission it has been, through many years of arduous work, to assist in a humble way in the application of the resources of some branches of science to the maintenance of the country's power to defend its rights and to hold its own, I may perhaps be pardoned for my presumption in giving expression to the firm belief that, by the secure foundation and careful development of this great undertaking, and by its wise direction by a Government truly representative of its Founders—all Nations and Classes composing the Empire—there will be secured in it one of the most important future Defences of the Queen's Dominions; one of the most powerful instruments for the maintenance of the unity, the strength, and the prosperity of Her Realms.

THE BRITISH COLONIES.

ILLUSTRATIONS OF THEIR DEVELOPMENT DURING THE QUEEN'S REIGN.

IMPORTS AND EXPORTS.

		IMPORTS. £	EXPORTS. £
American Dependencies	1837 ..	5,200,000	5,000,000
	1885 ..	25,700,000	21,500,000
Australasia	1837 ..	1,500,000	1,300,000
	1885 ..	63,500,000	52,000,000
Africa	1837 ..	2,000,000	1,500,000
	1885 ..	10,000,000	12,000,000

All the Imports and Exports taken together were ELEVEN TIMES larger in 1885 than they were in 1837.

British Shipping Trade with Colonies ..	1837 ..	3,700,000 tons.
	1885 ..	56,600,000 „
British Export to Colonies	1837 ..	11,300,000*l.*
	1885 ..	54,500,000*l.*

POPULATION.

Of all the Colonies existing in 1837 ..	1837 ..	4,204,700
	1881 ..	12,753,277*
Of all the Colonies in 1881		15,763,072*

* These numbers must have considerably increased since 1881.

RATE OF INCREASE FROM 1837 TO 1881.

In European Colonies	SLIGHT.
In Ceylon	TWICE as large as it was.
In the Great Asiatic Colonies ..	About the SAME.
In the Cape of Good Hope	EIGHT TIMES as large as it was.
In Canada	THREE TIMES as large as it was.
In the West Indies	NOT quite TWICE as large as it was.
In Australia	Nearly TWELVE times as large as it was.

	How and when Acquired.		Area.	
			Square Miles.	
British Isles	..	..		120,8
Indian Empire (including Burmah)	..	1757–1858		1,574,5
Dominion of Canada :—				
Quebec	Conquest, Treaty Cession	1759-63		
Ontario				
New Brunswick	Treaty Cession	1763		
Nova Scotia	Conquest, Treaty Cession	1627–1713		3,470,3
British Columbia	Transfer to Crown ..	1858		
Manitoba	Settlement	1813		
North-West Territories	Charter to Company ..	1670		
Prince Edward's Island	Conquest	1756–63		
Newfoundland	Settlement, Treaty Cession	1550–1713		40,2
Australasia :—				
New South Wales	Settlement	1787	311,098	
Victoria	Settlement	1834	87,884	
South Australia	Settlement	1836	903,690	
Queensland	Settlement	1824	668,497	
Western Australia	Settlement	1826	1,060,000	
Tasmania	Settlement	1803	26,215	
New Zealand	Purchase	1840	104,458	
Fiji	Cession from Natives ..	1874	7,740	
New Guinea	Annexation	1884	86,360	
				3,255,9
South Africa :—				
Cape of Good Hope	Treaty Cession (finally)	1815	219,700	
Bechuanaland	.. ..	1885	185,000	
Natal	Annexation	1843	18,750	
				423,4
St. Helena	Conquest	1673		
Ascension	Annexation	1815		
Ceylon	Treaty Cession	1801		25,3
Mauritius	Conquest and Cession ..	1810–14		7
Straits Settlements	Treaty Cession	1785–1824		1,4
Hong Kong	Treaty Cession	1841		
Port Hamilton	.. ..	1884		
British North Borneo	Cession to Company ..	1877		30,0
Labuan	Treaty Cession	1847		
British Guiana	Conquest and Cession ..	1803–14		109,0
West Indies :—				
Jamaica	Conquest	1655	4,362	
Trinidad	Conquest	1797	1,754	
Windward Islands	Cession	1783	784	
Leeward Islands	.. ..	..	665	
Bahamas	Settlement	1629	5,390	
				12,9
Bermudas	Settlement	1612		
British Honduras	Conquest	1798		6,4
West Africa :—				
Sierra Leone	Transfer from Company	1807	468	
Gambia	.. ..	..	69	
Gold Coast	Conquest and Cession ..	1663–1871	18,784	
Lagos	Cession	1861	1,069	
				20,3
Gibraltar	Conquest	1704		
Malta	Treaty Cession	1814		1
Cyprus	Convention with Turkey	1878		3,5
Heligoland	Treaty Cession	1814		
Falkland Islands	Treaty Cession	1770		6,5
				9,101,9

THE BRITISH EMPIRE.

ng of 1886.)

Population.		Imports.		Exports.	
	35,241,482	Total. £390,018,569	From Colonies. £95,812,911	Total. £295,967,583	To Colonies. £88,303,634
	253,982,595	Total. 68,156,654	From British Isles. 49,711,562	Total. 89,098,427	To British Isles. 36,984,034
	4,324,810	23,917,200	8,921,510	18,782,156	8,986,897
	179,509	1,682,457	642,528	1,368,153	322,527
921,268		22,826,985	11,423,047	18,251,506	7,683,886
961,276		19,201,633	9,149,076	16,050,465	7,745,415
312,781		5,749,353	2,983,296	6,623,704	4,081,864
309,913		6,381,976	2,520,863	4,673,864	1,715,391
31,700		521,167	222,940	405,693	279,660
130,541		1,656,118	642,102	1,475,857	359,708
564,304		7,663,888	4,934,493	7,091,667	5,158,078
128,614		434,522	..	345,344	35,542
135,000		..	..	..	..
	3,495,397				
,249,824		5,260,697	4,023,819	7,031,744	6,602,193
..		..	..	..	..
424,495		1,675,850	1,310,452	957,918	721,190
	1,674,319				
	5,024	63,786	27,931	23,406	1,164
	200	..	..	..	..
	2,763,984	4,811,451	1,315,345	3,161,262	1,852,829
	377,373	2,963,152	692,430	3,941,757	508,331
	540,000	18,676,766	4,282,920	17,260,138	3,845,362
	160,402	4,000,000	3,218,946	2,000,000	1,052,302
	2,000	..	..	..	..
	150,000	96,282	..	52,551	..
	6,298	84,869	1,554	85,741	..
	264,061	1,999,448	1,099,504	2,322,032	1,777,376
585,536		1,595,262	910,194	1,518,024	643,971
153,128		3,083,870	887,011	2,769,727	863,290
311,413		1,611,483	670,955	1,834,388	797,194
119,546		476,457	207,637	466,759	160,903
43,521		181,494	37,329	122,351	35,771
	1,213,144				
	13,948	283,440	75,416	88,622	2,557
	27,452	237,538	127,602	317,449	205,032
60,546		455,424	323,572	377,055	156,730
14,150		212,122	87,099	199,483	18,753
408,070		537,339	403,788	467,228	330,997
75,270		538,221	338,318	672,414	249,794
	558,036				
	18,381	..	..	..	..
	149,782	13,343,789	122,899	12,908,492	3,120,319
	186,173	304,375	..	287,521	..
	2,001	..	..	..	..
	1,553	67,848	60,962	101,338	98,468
	305,337,924	£220,752,916	£111,377,100	£223,134,236	£96,397,528

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