

## History of Science as related to Civilisation.\*

By Sir Martin Forster, F.R.S.

IT was indeed a happy inspiration that led Mr. V. Subrahmanya Iyer, former Registrar of the University, to found a periodical celebration of an event so auspicious as the Silver Jubilee of the accession of His Highness the Maharaja, Founder and Chancellor of the Mysore University. I have been honoured by the University Council with an invitation to deliver the sixth of these commemorative lectures, whose declared purpose is to show how the application of scientific methods may "promote soundness of judgment, freshness of outlook and appreciation of higher human values".

On several recent occasions, attention has been directed to the value of the training offered to the non-scientific citizen by the history of science. This movement has its origin in an increasing suspicion that in England the time devoted to laboratory practice in schools is tending to become excessive; and as Indian educational methods are based largely upon Western usage, the growth of opinion which this view involves is deserving of close attention here. More particularly is this the case because the cost of providing laboratory instruction, whether in schools or universities, is very heavy; and at a time like the present, when every item of proposed expenditure, both private and public, demands careful scrutiny, the question whether substantial outlay on materials and appliances really achieves a commensurate benefit becomes important.

Stated otherwise the point is this. Although the current century has witnessed a greatly increasing occupational absorption of men trained in various branches of science, their fraction of those engaged in all employments taken together must remain very small. It is therefore reasonable to ask, is it profitable for the State to provide an expensive form of school-training framed as if all those who receive it were embryo professional scientists? There can be no question that every individual who is privileged to vote should have some knowledge of the fundamental relation of science to the State, but

cannot this be conveyed without giving him at the outset a training he might expect to receive if destined to embark on a scientific career?

The basic idea underlying the new movement is that a more generally useful approach to scientific method and scientific ways of thought is the historical one. Every intelligent mind finds attraction in biography, because when faithfully presented this offers the encouraging picture of shortcomings besides virtues, and thus makes us feel more at home even with outstanding personalities. An honest biography levels while it stimulates, and if with these effects the true bearing of science on civilisation be conjoined, this form of instruction can be made most fruitful. It fortunately happens that the history of science, more readily than general history, lends itself to this treatment because its duration, or at least the period of most flourishing development, extends over little more than a century. Consequently its basic facts are more surely ascertainable, many being within the recollection of living people. If this advantage were applicable to general history, much of the rubbish unseasonably uttered about the superiority of the "good old times" would be self-condemned, and much of the discontent prevailing now, as it has prevailed throughout the history of the world, being avoidable, might be avoided.

In designing a course on the history of science appropriate for students who will not for the most part become specialists in science it will be desirable to select the biographies of men whose discoveries may be definitely correlated with improvement in our ways of living and our outlook on life. If examined from this standpoint the whole subject will yield some surprises. Let us take an example that was very much in all our minds two years ago, being the centenary of Michael Faraday's discovery of electro-magnetic induction on 29th August, 1831. It has been claimed that "no other experiment in physical science has been more fruitful in benefit for mankind." All scientific men will agree that the claim is defensible, but the biography of Faraday may be less impressive in a course of science-history for the normal student than

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it is for the professed scientist. Because although his experiments were fundamental, an equally fundamental experiment in the same field had been made by the Danish philosopher Oersted in 1820, he having in that year discovered that a magnetic needle is deflected by a voltaic current; while several other contemporaries of Faraday, notably Arago, Ampère and Humphry Davy were fruitfully engaged in similar studies. In fact, Sir Ambrose Fleming has recorded that "nothing is more remarkable in the history of discovery than the manner in which Ampère seized upon the right clue which enabled him to disentangle the complicated phenomena of electrodynamics and to deduce them all as a consequence of one simple fundamental law, which occupies in electrodynamics the position of the Newtonian law of gravitation in physical astronomy."

To avoid misunderstanding, I must emphasise the point I desire to make, namely, that the transcendent importance of Faraday's work is not so readily appreciable by the normal citizen as by the professional student of science. Although the group of inventions developing the modern dynamo are actually derived from his great discovery that by cutting lines of magnetic force with a conductor, a current of electricity is generated in that conductor, the effect of this discovery on social conditions was long delayed. The modern power-machine, or dynamo, converts mechanical energy into electrical energy, but its development into a form providing cheap and abundant electric light involved numerous factors with which Faraday was not concerned. These depend first on finding the most convenient arrangement of the conductor as related to the magnet, and may be said to have reached their commercial stage in the Gramme-machine of 1870; but they required also those improvements of the arc and the incandescent electric lamp which took place during the ten years following. The scientific men engaged in these developments were very numerous indeed, and therefore, while Faraday's discovery serves to focus the public mind on the benefits accrued, the history of its application is too complicated for general assimilation.

In striking contrast with so devious and highly technical a chapter in science-history are the profound and clear-cut social effects resulting from the discoveries of Pasteur. These originated in a chance appeal for

advice from a distiller regarding his fermentation process, which led Pasteur, then Dean of the Faculty of Sciences in Lille, to observe under the microscope that when fermentation was healthy the yeast globules were almost round, but that an acid fermentation was accompanied by elongated cells. This occurred in the summer of 1856, and thereon he wondered whether he might not be confronted with a principle common to all fermentations, namely, that each fermentation arises from its own type of micro-organism.

The consequences of pursuing this idea represent a startling revolution in common thought and in surgical practice throughout the world, because, after a bitter controversy and by methods of experimentation both careful and convincing, Pasteur finally demolished the hypothesis of spontaneous generation. On 7th April, 1864, he concluded a famous lecture at the Sorbonne with these words: "There is now no circumstance known in which it can be affirmed that microscopic beings come into the world without germs, without parents resembling themselves. Those who affirm it have been duped by illusions, by ill-conducted experiments, spoilt by errors that they either did not perceive, or did not know how to avoid."

The fundamental experiments of Pasteur founded the modern science of bacteriology, which he himself did so much to develop until his death in 1895, and their social effect was immediate. The British surgeon Lister had assimilated the idea that infection of surgical wounds—then causing frightful mortality in even the best-conducted hospitals—might be due to the action of living organisms, and beginning in 1864 he proceeded to verify this theory by his aseptic treatment of wounds, using for that purpose carbolic acid. All the antiseptic methods in practice to-day are the direct results of his teaching. It will thus be recognised that for the normal citizen, whose main concern lies in the civilising or socially ameliorating effects of scientific discovery, the biography of Pasteur will be found more impressive than that of Faraday.

For it follows that not only surgery, but general pathology, has profited incalculably and speedily by his work and teaching. While studying anthrax, he introduced the now common method of successive bacterial cultures outside the tissues infected,



and in 1877 elucidated a tangle of observations connected with this venomous disease. About the same time Koch improved that method by adopting solid culture-media in bacteriological technique, in 1882 isolated the tubercle bacillus, and identified the cholera bacillus in the following year. It should now be common knowledge that plague, typhoid, rabies, diphtheria, tetanus and various other pestilences have been very substantially mitigated in consequence of these pioneer investigations, and it will be agreed that the biographies of those patient and courageous men who have provided their fellow-creatures with weapons to combat such fell diseases and thus to preserve many millions of lives, are as worthy of attentive study by the youth of the world as are the biographies of the kings, emperors, generals and ecclesiastics who have destroyed millions.

Social consequences to a scientific discovery of another type cluster round the hydrocarbon benzene. By a coincidence, Faraday figures here also, because he discovered it in oil-gas in 1825; but that chapter in the history of civilisation which might appropriately be called the "Benefits of Benzene" was actually opened by W. H. Perkin in 1856. In this year, while hoping to synthesise quinine, he discovered by accident the artificial colouring-matter, mauve, which paved the way to a vast series of new products contributing inestimably to the comfort, health and æsthetic satisfaction of mankind.

The great impetus given by Perkin to civilisation arose from the fact that he founded, with his own hands, that branch of manufacture known as the organic chemical industry. Prior to 1856, the so-called heavy chemical industry was well established, flourishing predominantly in England. It embraced the large-scale production of acids, alkalis, bleaching-powder and soap, but the colouring-matters, drugs and perfumes then in common use, being all derived from natural sources, were limited and, compared with current prices, costly. When Perkin found mauve to be an excellent dye for silk, he found also that in order to produce it in marketable amounts he would require large quantities of nitrobenzene and aniline, which hitherto had been handled only in the laboratory. Mansfield had just devised the principle, still followed, by which benzene could be obtained commercially from coal-tar naphtha, when the skill

and enterprise of Perkin enabled him to produce from benzene on an industrial scale first the nitrobenzene, and thence the aniline required for manufacturing his new artificial dye. He developed this novel industry during the succeeding years, being instrumental in marketing artificial alizarin among other colouring-matters. About 1874, however, competition by factories established on the Rhine a few years earlier, compelled him to dispose of his own factory, to which he could not bring the necessary increased capital, and for which he could not find suitably trained subordinates. Until his death in 1907 he successfully devoted his energies to purely scientific research.

Meanwhile there had sprung into being an entirely new manufacturing technique, the ramifications of which became incredibly wide-spread. A contributory factor of great importance was the prodigal employment of university-trained chemists by the German factories above mentioned, at that time a new principle. The heavy chemical industry itself received a stimulus from the observation that for many purposes the organic chemical industry found fuming sulphuric acid more convenient and efficient than oil of vitriol, and satisfaction of this demand led to an increased interest in catalysis as a principle having wide industrial application, the full effects of which were demonstrated by the European War most disastrously prolonged for three years by its incidence.

Probably the first noticeable result of Perkin's discovery was a multiplication of new dyes and the displacement of madder (since 1868) and of indigo (since 1897) by the corresponding products from coal-tar; but these were only the superficial signs. The outstanding characteristic of the organic chemical industry, distinguishing it from all other industries, lies in the bewildering number of by-products associated with many of its operations. To maintain economic levels of production, uses for these by-products must perforce be found, and the search for remunerative applications has led to the manufacture of numerous new drugs, dyes and photographic materials. This has involved the development of an entirely new, and in some cases very complicated, manufacturing technique, because organic compounds, or the compounds of carbon, require very delicate handling compared with that applied to the materials concerned in the heavy chemical



industry and in metallurgy. This arises from their sensitivity to heat, and the fact that the solvents from which they are crystallised for purification belong to their own class in preference to water. Concurrently, the application of trained minds in rapidly increasing hundreds to the problems involved has given birth to great new industries, such as artificial silk and plastics, or synthetic resins typified by bakelite; besides improving beyond expectation the purification of natural products such as petroleum and sugar.

Another chapter of science-history revealing immediate and far-reaching social results from an accidental discovery is provided by the life of Henry Bessemer. This is admirably described in his autobiography published in 1905, seven years after his death at the age of 85. The three classes of iron known at the middle of the nineteenth century were not then producible in large quantities, and their cost was so high as to preclude their use for many purposes to which they are now freely applied. They were called wrought iron (almost free from carbon), steel (with a medium carbon-content reaching 2.2 per cent.) and cast iron (with increasing amounts of carbon up to 5 per cent.). Wrought iron was too malleable for many purposes, cast iron was too brittle for anything, and steel was found to be greatly hardened by sudden cooling and yet remained malleable on slow cooling. The great contribution to social welfare by Bessemer in 1856 was the discovery that molten cast iron may be deprived of its carbon by a blast of air; and that when thus purified in a suitable converter, iron may be heated easily to a temperature above the melting point of steel. Thus there could be produced in rapidly increasing quantities a new class of iron called mild steel, free from slag, and by early improvements in manufacture almost free from the highly deleterious phosphorus and sulphur.

The results of this discovery during the succeeding fifty years have been magical, because the abundance and improved quality of steel produced in England and the United States led to its adoption for constructional purposes of every kind, while the consequent facility with which other metals, notably manganese, nickel, chromium and tungsten may be added in amounts producing remarkable and convenient changes in the properties of steel has led to an enormously

expanded variety of application. The machine-shop in particular has benefited by one of these in the shape of high-speed steel, containing quite large percentages of chromium and tungsten, which by causing the steel to retain its hardness at elevated temperatures enables a cutting-tool to be used in the lathe at greatly increased speeds. Thus the advantage to engineering practice has been incalculable.

The foregoing examples of science-history within reach of the normal citizen, and illustrating how his comfort and security have been augmented by scientific investigation, relate to periods just beyond the life-time of the present generation, but one which will naturally occur to many present as having taken place under their own eyes will be found in the principle of internal combustion, to which is due the tremendous development of motor-traffic. This hinges on consuming the fuel within the motive power-cylinder instead of outside, as in the steam-engine, and began with the Otto gas-engine of 1876, still used for stationary purposes. Extension of this principle to an internal combustion motor using petroleum vapour instead of coal-gas, effected by Daimler in 1885, was the first step towards the complete revolution in road transport witnessed by the present generation, accomplished by constant improvement in mechanical details of the engine, in the method of igniting the explosive mixture of petroleum vapour with air, in lubrication and in the character and quality of tires for the wheels.

Concurrently with this revolution has proceeded a revolution in the oil and rubber industries. The United States petroleum industry began in 1859 with the discovery of rock-oil in Pennsylvania, and rapidly grew to enormous proportions, products from the fractional distillation being universally adopted for heating, lighting and lubrication. The transformation of this industry due to the multiplication of motor-vehicles is two-fold, firstly in the methods of purification and distillation, secondly in the practice of cracking, the process by which fractions of high boiling point may be converted into motor-spirit. A third phase in this transformation now impending, is the production of oil by the hydrogenation of coal and coal-tar. This phase is at the development stage, but in the last few weeks a conditional remission of petrol tax by the British Government has led the Chairman of



Imperial Chemical Industries to announce that his company will proceed with a plant for hydrogenating coal at an outlay of 2½ million pounds: this follows an expenditure of one million pounds on the preliminary experiments.

It must be remembered that crude petroleum is a very complicated mixture of chemical individuals, ranging from gases of the methane type through the diminishingly volatile hydrocarbons of the paraffin series to low-melting solids like vaseline. The composition of these mixtures varies greatly with geographical origin, Borneo petroleum, for instance, being rich in benzenoid hydrocarbons. Before the more volatile fraction called petrol, or gasoline in the United States, was applied to motive internal combustion engines, it was a dangerous component of the illuminating fraction, and went largely to waste. For many years past, however, all the ingenuity of the manufacturer has been directed to conserving this volatile fraction, increasing its supply and producing it in a more highly purified condition. The demand for motor-spirit has led to these vast improvements in manufacture and to the introduction of cracking, while the resultant purity of the more volatile fraction has been an important factor in the development and multiplication of air-craft. A moment's reflection on the colossal advantages arising from the growth of motor-traffic in this country will convince you of the beneficent relation borne by scientific discovery and invention to the State, particularly as this demonstration has progressed under your own eyes.

Another revolution still in progress relates to the preservation and transport of food as effected by canning and refrigeration. Although having less practical interest for the people of this country than for Europeans and Americans, whose customary diet has been vastly improved and varied by these processes, it nevertheless will benefit indirectly the population of India because it has developed a food-science, including recognition of the vitamin principle and a more scientific evaluation of nutritional factors, which cannot fail ultimately to improve the public health. The speed of development and widening scope of this new knowledge form a separate chapter of science-history, but an illuminating example is given by the history of solid carbon dioxide, known as Dry Ice in the States and

Drikold or Cardice in England, in which countries it is now increasingly used as a refrigerant. The commercial production of this material began only in 1924, and the manufacturing tonnage for the United States is as follows:— 1925, 170; 1926, 525; 1927, 1,715; 1928, 7,000; 1929, 22,000; 1930, 40,000.

Enough has now been said to demonstrate the very direct bearing on our individual modes of living effected in recent years by scientific discovery and invention; and to show that in many cases this may be recognised and traced by the normal citizen untrained in scientific practice. Many other examples will occur to your minds, such as line and wireless telegraphy and telephony, motion-pictures, hydro-electric power generation and non-ferrous metallurgy. A distinct, but very important section of science-history lies in the realm of ideas as a stimulus to experiment. This may be illustrated by the theory of evolution as taught by Darwin and his followers; the cell-theory as developed by Schleiden for plants (1838) and by Schwann for animal tissue (1839); and finally, the conception of the atom as formulated by Dalton and replaced in very recent years by the captivating theories of Rutherford and Bohr.

The conclusion that I now submit is this. If civilisation be defined as reclamation from barbarism, as a process of developing the arts and refinements of life, no century in the world's history has been more fruitful in civilising agency than the last hundred years. In that period have been recorded unhappily the average number of human conflicts, political and martial, differing only in their weapons and their staging from the ceaseless human discords common to general history. On this murky background, however, has been painted with radiant brush the promise of a colourful era which the nations may enter when they unite in recognising political quarrels to be less advantageous than the co-operative harvesting of Nature's gifts as a consequence to elucidation of natural laws. This desirable step towards popular enlightenment would be hastened if the more fundamental of these laws, and the history of their application to modern progress, were allowed increasingly to replace general history in the school curricula, so that the changes now rapidly transforming the art of living may be brought into proper perspective and healthily developed.



Prominent in the study of these changes must be the life-history of the people most concerned in them. The lesson from all these lives, for all of us, is their thoroughness and beneficence. If half the attention of schools, colleges and mature citizens that has been given to Alexander, Cæsar and Napoleon had been devoted to Faraday, Pasteur, Lister and Bessemer, the world would be a different and a better world

to-day. Because, not only were these men remarkable discoverers, to whom we owe far greater security and amenity of life than our forefathers could enjoy, but their methods of work and their outlook towards their fellow-beings display just those qualities most needed for smooth and continued progress of civilisation; patience, honesty and thoroughness in their labour combined with inexhaustible goodwill towards mankind.

### Letters to the Editor.

#### On the Discovery of *Prothallus* in Indian *Ophioglossums*.

THE genus *Ophioglossum* has interested a number of botanists in India and abroad on account of its peculiar systematic position in the Pteridophyta. Attempts are often being made to throw more light upon its life-history simply by the study of the sporophyte generation. But the gametophyte generation has not been so well studied owing to several difficulties in its way. It is, however, to be noted with satisfaction that it was studied in a few species of *Ophioglossum* during the latter half of the last century and in the beginning of the present century by some eminent workers. Mettenius, for instance, studied *O. pedunculatum* as far back as 1856, while Dr. Lang studied prothalli of *O. pendulum* in 1902; and Bruchmann studied the *Ophioglossum vulgatum* in 1904. Later on Dr. Campbell confirmed the results of these authors by his study on *O. moluccanum* and *O. pendulum* in 1906. Since then no attempts appear to have been made either by way of confirmation of old results or by way of investigation of new ones.

It was in 1930 that my attention was drawn to this subject by some remarks on *Ophioglossum* made by Prof. Dixit in his book and I began to study it, more critically since 1931. My observations by the cultural methods—later on confirmed by the gametophytes that I could obtain in nature—I have been able to discover the prothalli of some four Indian species which appear to be different from those that have been studied by previous botanists such as Dr. Lang and others.

The peculiar methods used in obtaining them have been summarised in my "*Rationale* of the germination of the spores in

*Ophioglossum*" which will soon appear elsewhere.

My further researches on this structure have given me a wealth of new facts and allowed me to throw a good deal of light on some previously unsolved points. It was very kind of Prof. Dixit to confirm my results later and I offer my sincere thanks to him and to my two colleagues Messrs. Deshpande and Kanitkar.

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#### Theory of Parallel Deposits of Solute by Evaporation from the Walls.

D. OWEN before the Physical Society of London, 22nd May 1932, gave a demonstration of the difference of heights to which (1) fuchsin, (2) salt solution, and (3) a mixture of the two solutions respectively would rise in a strip of filter paper dipping into these solutions.

In repeating the experiment, we noted the formation of very beautiful parallel deposits. One of us, in a paper on the variability of Avogadro's Number (S. Ray in *Zeit.f.phys. Chemie*, 128, 186, 1927) has shown that in a solution or sol the concentration variation with height follows a curve as in Fig. 1 while in another paper on A Physical Factor in Liesegang Phenomenon (*Koll. Zeit.*, 44, 277, 1928) the same author has shown that this concentration distribution has the possibility of explaining Liesegang phenomena. Thus, if in the graph, AB is a line parallel to OY, the Y axis, such that tangent at C is parallel to the tangent at D, it means at these two points not only are