The development of the teaching of chemistry in England, 1799-1853

Byrne, Michael S.

ABSTRACT OF THESIS

THE DEVELOPMENT OF THE TEACHING OF CHEMISTRY *IN* ENGLAND, 1799-1853.

The thesis traces the development of chemistry teaching in England set against the scientific and educational development of the period. At the end of the eighteenth century, chemistry was little studied and then only as an adjunct to other professional studies. Chemistry as a profession did not exist and there were no laboratories in which a student could receive a practical training. The year 1799 marks the founding of the Royal Institution and from this time there was a considerable increase in the teaching of chemistry, partly as a result of the general educational progress which occurred during the first half of the nineteenth century.

The mechanics' institute movement enabled many to acquire a more scientific approach to their trade and the new institutions of higher learning, such as those at London, Manchester and Durham, early recognised the desirability of teaching chemistry and provided facilities for study to many who had for religious or financial reasons been excluded from Oxford and Cambridge. At the same time the teaching methods developed in Germany, and the success with which chemistry was being applied to agriculture caused great interest in England. Ultimately the wider knowledge of chemistry was reflected in its gradual introduction into schools. The lack of both governmental assistance and of an efficient central organisation for science, hampered the growth of chemistry teaching, but by 1853,

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BY

MICHAEL S. BYRNE.

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CONTENTS

INTRODUCTION

The subject of chemistry now forms an important part of secondary, further and higher education. It owes its position in the educational system to a general recognition of its value as an instrument of education and its importance in a modern industrialised society. At the beginning of the nineteenth century the profession of chemistry did not exist and the degree to which it was taught was minimal. This thesis constitutes an attempt to discover the ways in which chemistry became a part of English education and to what extent this had been accomplished by the mid-nineteenth century.

It has been attempted to set the developments against the background of general scientific and educational progress, and to indicate how the organisation of science in England, and Britain's advanced industrial position affected the development of chemistry teaching. The thesis begins with a consideration of the state of chemistry and its teaching at the end of the eighteenth century. Subsequently the development of chemistry teaching in mechanics' institutes, universities, scientific societies, and schools is dealt with. An attempt has been made to discover the nature of the chemistry taught and the teaching techniques through a study of the published work of the period.

A particularly interesting aspect of the study has been the development of laboratory teaching and the continental influences

which made this possible. The extent to which a practical training had become available by 1853 shows that chemical education had its roots in the first half of the nineteenth century. It is hoped therefore that this study of the period reveals something of the origins of chemistry teaching in England.

CHAPTER I.

CHEMISTRY AND EDUCATION

AT THE END OF THE EIGHTEENTH

CENTURY.

1. THE STATE OF CHEMISTRY.

In 1789, the French chemist Lavoisier published his Traité élémentaire de Chimie. This book popularised Lavoisier's discoveries which showed the true nature of burning, and led to the downfall of the phlogiston theory. These discoveries were the beginning of the development of modern chemistry. The book was translated into English in 1790. (1) The closing years of the eighteenth century were therefore mainly concerned with the diffusion of Lavoisier's researches which paved the way for the great advances of the nineteenth century. Consequently, this period saw no major advance in the progress of chemistry. (2)

The English scientist of the eighteenth century was usually neither a specialist nor a professional. That is to say his contributions usually ranged over a wide field, and that his scientific studies were independent of his occupation. It has been estimated that of 106 leading scientists of the century some 40-50 can be classified as amateurs or devotees. The three leading professions represented among the 106 scientists are medicine, technology and the Church and the percentage from each are 20, 15 and 10% respectively. (3) For example, Joseph Priestley (1733-1804), one of the most famous of English chemists had studied for the Unitarian ministry during which time he learnt Greek, Hebrew and Latin as well as undergoing a rigorous theological training. He became a tutor at the Academy at Warrington and later held several ministries. At

the time he began his researches his only knowledge of chemistry was that which he had acquired from some lectures given by a Dr. Turner of Liverpool. During his life he wrote on politics and theology and carried on his scientific work through gifts of apparatus and money from such friends as Josiah Wedgewood and the Earl of Shelburne. (4) Priestley's works included his History of Electricity published in 1767, and his Experiments and Observations on Different Kinds of Air, (3 vols., London, 1774-1777).

Similarly Henry Cavendish, the wealthy but eccentric scientist who had a formal education at Cambridge before devoting himself to science, had no training in science other than in mathematics, but nevertheless made important contributions to chemistry, heat and electricity. (5) Such men were typical of the English scientists of their time.

2. THE STATE OF CHEMISTRY TEACHING.

The origins of chemistry teaching were as a part of medical studies. In the eighteenth century the great source of instruction in the British Isles was the University of Edinburgh where medicine, chemistry, materia medica and botany were subjects of study. Joseph Black was appointed to the chair of chemistry in 1766 in which he remained until his death in 1799. His influence upon the teaching of chemistry is said to be greater than that of any other teacher in the eighteenth century. (6)

At Oxford, although the first chemistry laboratory had been opened in 1683, little of note had been accomplished with regard to teaching or research, and we get a glimpse of things in 1710 from the remarks of Uffenbach, a German traveller, who wrote: "The present Professor of Chemistry, Richard Frewin does not trouble much about it..." (7)

Martin Wall who was appointed Public Reader in Chemistry in 1782 gave a course of lectures which were similar to those given by Black. His audience was 14 or 15 and even less than this by the end of the course. (8) The appointment of Dr. Thomas Beddoes in 1789 brought a great revival of interest. He carried on both teaching and research but his political opinions together with his attempts to reform the Bodleian library were distasteful to the University and he resigned to found the Pneumatic Institution in Clifton. (9)

At Cambridge the first teaching of chemistry began about 1680. In 1766 a stipend of £100 per annum was contributed to the Professor of Chemistry by the Crown. In 1773 Isaac Pennington became Professor of Chemistry and when Pennington added to his duties by becoming Regius Professor of Medicine, he appointed Isaac Milner to lecture as his deputy. William Farish, who became seventh professor in 1793, lectured on "The Applications of Chemistry to the Arts and Manufactures of Britain", while Milner became the first Jacksonian Professor of Natural and Experimental Philosophy in 1783. While chemistry was kept alive in the University by these men there was

nothing in the nature of a laboratory which a student could attend.(10)

3. SCIENTIFIC PUBLICATIONS.

The last twenty years of the eighteenth century saw a considerable increase in chemical literature. Watt's Bibliotheca Britannica lists about one hundred works in English which are connected with chemistry, most of which were published in the last few years of the century when the impetus which Lavoisier had given to the subject is clearly discernable. (11) Major works which appeared during this period included, translations of Berthollet (1790 and 1791), the first part of a Dictionary of Chemistry (Birmingham, 1789) by James Keir, and a Dictionary of Chemistry (London, 1795) by William Nicholson. (12)

The first of the English scientific periodicals was the Philosophical Transactions which were begun in March 1665 by Oldenburg the second secretary of the Royal Society. The Philosophical Transactions published accounts of experiments, articles on scientific instruments and correspondence from the leading scientists of Europe. (13)

In 1797 Nicholson's Journal appeared. It was the first English scientific journal to survive which was published independently of a learned society. Its early numbers consisted largely of reprints and translations but in 1800 Nicholson and Anthony Carlisle published a paper on the electrolytic decomposition of water by the recently discovered Voltaic pile. The paper caused considerable interest and

for a time the Journal contained everything of value which was discovered through the use of the new scientific tool. The success of Nicholson's Journal and that of the Philosophical Magazine, which was founded by Alexander Tilloth in 1798, are indicative of the considerable amateur following which science enjoyed at the time. In 1813 Nicholson's Journal became incorporated in the Philosophical Magazine which still exists today. (14)

4. SCIENTIFIC SOCIETIES.

It was during the eighteenth century that men began to form societies for the purpose of teaching, experiment and discussion. One of the earliest and best known of these societies was the Lunar Society of Birmingham whose beginnings can be traced back to about 1765. Among its distinguished members were Erasmus Darwin, James Watt, Josiah Wedgewood, Joseph Priestley, Matthew Boulton and James Keir. (15)

The Manchester Literary and Philosophical Society, of which more will be said later, was founded in 1775 and grew out of a group of people who had met for several years previously. The conditions for membership included the publication of original work, and its honorary members included Franklin, Priestley and Volta. John Dalton held office in the Society from 1800 until his death in 1844 while another notable member was Joule who in common with Dalton published much of his work in the Memoirs of the Society. (16) Societies of this type

were also formed in other towns such as Bristol, Dublin, Edinburgh and Norwich, (17) but the Manchester and Birmingham Societies were the most important. More typical was the Derby Philosophical Society which was founded by Erasmus Darwin about 1873. The Society published little but seems to have acquired an impressive library. It existed until 1857 when it became amalgamated with the Derby Town and County Museum. (18)

Throughout this period there existed of course the Royal Society which had received its Royal Charter in 1662, but by the end of the eighteenth century its scientific work had become somewhat reduced. (19)

Not surprisingly the interest in science which had manifested itself in the growth of scientific societies also provided a rich field for another eighteenth century phenomenon: the peripatetic science lecturer. The first of these seems to have been Dr. J.T. Desaguliers who gave public lectures from about 1712 until 1742. (20) The most important chemical lecturer was Dr. Bryan Higgins, a former Professor of Chemistry at Dublin, who opened a school of practical chemistry in Greek Street, Soho in 1774. Lectures were given which were illustrated with experiments and these were followed by discussion. Subscribers were free to observe the experiments which were carried out in preparation for the lectures. (21) However these beginnings were soon to be outshone by an unobtrusive development which was to have a profound affect upon the progress of English

science and education. In 1799 the Royal Institution was founded: it was destined to house some of the finest scientific lecturers of the nineteenth century.

CHAPTER II

THE TEACHING OF CHEMISTRY TO THE WORKING CLASSES.

1. THE EARLY HISTORY OF THE ROYAL INSTITUTION.

The Royal Institution was largely the creation of Count Rumford (1753-1814). As early as 1796 he had conceived the idea of a means by which a knowledge of mechanical things could be diffused. During his subsequent enforced stay in Germany, he had been in correspondence on this subject with Thomas Bernard, who was one of the founder members of the "Society for Bettering the Condition and Increasing the Comfort of the Poor."(22)

On arriving in London in September, 1798 Rumford had several meetings with Bernard, and a committee of eight members of the Society was appointed to confer with Rumford about the scheme. This committee which included the Earl of Winchelsea and William Wilberforce met Rumford on 31st January, 1799, and after receiving general support for the scheme, prepared a corrected plan for the consideration of the committee. (23)

The purpose of the Institution was to be "for diffusing the knowledge and faciliating (sic) the general introduction of useful mechanical inventions and improvements, and by teaching by courses of philosophical lectures and experiments the application of science to the common purposes of life." It was proposed that mechanical inventions and improvements should be on display, as far as possible in actual use. Included would be fireplaces, stoves, kitchens and, "a complete Laundry for a gentleman's family." In addition to these, there should be working models of ventilators, lime kilns, spinning wheels, bridges etc.

With regard to the teaching of the Institution, Rumford proposed that a lecture room together with an equipped laboratory be provided. The Institution was to be entirely privately financed by various kinds of subscription. (24)

At a meeting at the home of Sir Joseph Banks on 7th March, 1799, the first Committee of Managers was elected, and at the next meeting of Managers on 23rd March, Rumford was elected secretary. Subsequent negotiations led to the purchase of a suitable property in Albemarle Street.

On 30th April, 1799, a Mr. Webster was engaged as Clerk of the Works. At this time he had a small school for mechanics, and he proposed to Rumford that a similar school be founded at the Royal Institution. (25) In a letter to Rumford Webster says,

> "I think it extremely probable, that having once gained so much knowledge as such a course of education would afford, they would not stop here: but having experienced the Pleasure and Utility of Science, they would proceed to enrich their minds with other Branches of knowledge, by availing themselves of the Advantages which the Institution would afford them. Workmen so educated could not fail to become most valuable members of Society and repay by their Ingenuity and requirements the Trouble bestowed upon them." (26)

Webster's plan was for 18 - 20 young mechanics to be lodged for 3 - 4 months to learn geometry, mechanical drawing, mechanics, hydrostatics and then to branch off to studies directly related to their trades. (27) The scheme was enthusiastically received by Rumford, not surprisingly since he had done much philanthropic work for the poor in Germany; but from the beginning there was political

opposition, and as Webster wrote in 1837 in an account of his intentions, "I was not unaquainted with the political feelings of that time, but I did not think a little learning was a dangerous thing if judiciously bestowed....." Nevertheless the scheme was launched and workmen were sponsored by Lord Winchelsea, Lady Palmerston and others. (28)

The character of the Institution in these early years was almost wholly determined by Rumford. On 5th April, 1800 the first number of the Journal of the Royal Institution of Great Britain appeared. (It was 14 months before the next number was to appear and thereafter its appearance was spasmodic). (29) Thomas Garnett who had been a professor at Anderson's Institution in Glasgow, was appointed first Professor of Natural Philosophy on 23rd December, 1800. However due to a growing strain between Rumford and Garnett, intensified by Garnett's poor health, he gave only two courses of lectures, resigned in June 1801, and was succeeded by Dr. Thomas Young. In the meantime Humphry Davy had been engaged as Assistant Lecturer in Chemistry in February of that year, and it seems likely that Rumford secured his appointment with a view to encouraging the departure of Garnett. (30)

In a long report which was presented to the managers on 25th May, 1801, Rumford gives insight not only into the progress made but also his sense of priorities. Most indicative of this is that he devotes only four lines to the professors, lectures and lecture rooms, while he deals at great length with the chemistry laboratory, workshops,

education of mechanics, and plans for the repository. (31) By the end of 1801 Rumford had accomplished most of his objectives. He had included under one roof an industrial school for mechanics, a society for diffusing knowledge by lectures and publications, an exhibition of mechanical inventions and models, a school for cookery and a centre for the pursuit of scientific investigations. (32)

His achievement had been a considerable one, but from this time changes appeared in the affairs of the Institution. As Webster says in his recollections of 1837, "it was resolved upon that the plan must be dropped as quietly as possible. It was thought to have a dangerous political tendency, and I was told that if I persisted I would become a marked man!" and again later,

> "No notice was ever given publicly that the idea of instructing the mechanic was abandoned, and I have no doubt but that in many parts of the kingdom the Institution got the credit of great liberality long after the mechanic's school had become extinct." (33)

On 9th May, 1802 Rumford left for Bavaria and never returned to the Royal Institution. In his last report of 3rd May he says at the request of the Managers he has made several new arrangements for the running of the Institution. The Journals were to be put into the hands of Young, Davy, and Savage the printer, the workshops were to be let to a tradesman to carry on his trade at his own expense, and similarly the modelmaker was to carry on a private business. (34) Following his departure those parts of the Institution which were nearest to Rumford's heart were gradually

to disappear. Whether the reasons were political as Webster indicates or financial as Bence Jones states (35) is conjectural but one thing is likely: that Webster's school for mechanics preceded and influenced Birkbeck's work in founding mechanics institutes.(36)

The Institution was now entering upon the second phase of its history. The idea of a mechanics school had come to nothing and the next few years were to see the Institution develop as a centre for the dissemination of middle class culture. During 1803 progress was made on the library and in a report laid before the managers at the end of April, it was suggested that the workshop should be attached to the laboratory and equipped for chemical processes. The report goes on to say, "This laboratory will be equal, or indeed superior, to any in this country, and probably to any on the Continent." It also suggested that chemical operations should be taught in the laboratory. (37) This emphasis on chemistry must have been in some measure due to the great success of Davy as a lecturer. On 31st May, 1802, he had been made Professor of Chemistry, and in October of that year he wrote to Davies Gilbert, "My audience has often amounted to four or five hundred and upwards, and amongst them some promise to become permanently attached to chemistry. This science is much the fashion of the day." On 17th November, 1803 he was elected a Fellow of the Royal Society.(37)

Within a few years the Royal Institution became firmly established as a fashionable centre for the spread of science and the arts among the cultivated sections of society, and the aims of its

founder were forgotten.

2. THE MECHANICS INSTITUTE MOVEMENT.

The mechanics' class at the Royal Institution was not altogether an isolated experiment. As early as 1717, artisans were meeting on Saturday evenings at the Spitalfields Mathamatical Society. It did not however retain its working class character until the time that mechanics' institutes were being formed. (38) Similarly the Birmingham Sunday Society, established in 1789, had closely allied to it a class, some of whom were skilled workmen, who constructed apparatus for the purpose of carrying out experiments in mechanics, hydrostatics, electricity, pneumatics and astronomy.(39) In 1796 the Society reorganised as the Birmingham Brotherly Society and offered instruction in elementary subjects.

More important than either of these ventures were developments which were occurring in Glasgow at about this time. John Anderson who had been Professor of Natural Philosophy at the University from 1757 to his death in 1796, provided in his will for an institution to be founded which was to be known as Anderson's University. It seems that some years previously Anderson had encouraged the attendance of mechanics at his lectures on experimental philosophy. These lectures he illustrated with experiments and adopted to the special needs of his audience. (40) Anderson, however, left only £1,000 which was quite inadequate for his grandiose scheme, but his

trustees, determined to carry out his wishes as far as possible, made a start by appointing Thomas Garnett as Professor of Natural Philosophy in 1796. Garnett was a great success, the total attendance in his first series of lectures being 972. Following his departure for the Royal Institution, a body which at this time was similar in its aims to Anderson's Institution, Dr. George Birkbeck (1776-1841) newly graduated in medicine at Edinburgh, but with a keen interest in science, was appointed to the vacant chair in November, 1799. (41) On his appointment Birkbeck found himself unable to secure the services of a scientific instrument maker in Glasgow, and had to have his apparatus constructed by a number of craftsmen. Birkbeck found these "unwashed artificers" showing such an intelligent interest in the construction of his apparatus that he determined to start a free course of lectures on simple scientific topics. (42) Like Websters plan it was not without opposition and Birkbeck relates that:

> "They predicted, that if invited, the mechanics would not come; that if they come, they would not listen; and that if they did listen, they would not comprehend."(43)

Birkbeck seems to have been mainly concerned with adding interest to the mechanics' work and occupying their leisure hours rather than stimulating invention.(44) Certainly he does not seem to have believed that the movement "...will send hundreds, nay thousands, of a new set of labourers into the boundless and half-cultivated fields of science; to explore new tracts, find new riches, and add to the heap of existing knowledge", as later

advocates were to claim. (45)

The courses proved popular with the Glasgow artisans. The attendance swelled from seventy five on the first night to five hundred by the fourth evening. The class continued with great success during the following two sessions, but in the session 1802-1803, difficulties arose over the Managers' proposal to charge a fee of five shillings. In addition to his lectures to the mechanics' class, Birkbeck carried on the lecture courses begun by Garnett. In the fourth session he reorganised his course, substituting two consecutive courses in chemistry for his morning course on natural philosophy. However after the 1803-1804 session which was poorly attended, and having to take the risk of the expenses upon himself, he resigned and after some lecturing in Birmingham and other places, he settled in London in 1806 to build up a medical practice. (46) Birkbeck was succeeded by Dr. Andrew Ure, whose primary interest was chemistry and from that time chemistry became the subject for which the Institution became especially famous. The "mechanics' class" continued, and purchased books in order to form a library. (47) The seeds of the Mechanics' Institutes had been sown but 20 years were to pass before they were to come to fruition. Independent experiments continued to be made. Thomas Dick of Methven, Perthshire, established a "peoples library" and wrote a series of articles in the Monthly Magazine of 1814, advocating the formation of similar institutions.

Similarly Timothy Claxton, finding himself debarred for social

reasons from philosophical societies, founded in 1817 a "Mechanical Institution". It came to an end in 1820. Another individual enterprise was that of James Beaumont Neilson (or Nelson), manager of a Glasgow gas works who instituted the Glasgow Gas Workmen's Library in 1821 for the employees. A laboratory, workroom and apparatus were later added. (48)

A more significant development and one which derived its inspiration more directly from Birkbeck's work at Glasgow was the founding of the Edinburgh School of Arts in April 1821. This was founded by Leonard Horner, the object being, "the instruction of Mechanics in such branches of physical science as are of practical application in their several trades. "Despite the fact that the control of the school was entirely in the hands of the leading citizens of the town, within a month of the opening, 450 students each paying an annual subscription of fifteen shillings had enrolled. (49)

Meanwhile in Glasgow, the mechanic's class after a disagreement with the managers over the ownership of the library and apparatus, seceded to form an independent school in July 1823. In the first year courses were given in natural philosophy, chemistry, mechanics, mathematics and astronomy and a class of over 1,000 students was enrolled. By the end of the year mechanic's institutes had been established in Kilmarnock and Greenock. (50)

Birkbeck had not lost his interest in adult education. He was a member of the London Institution, a middle class body founded

in 1805 with at that time a character similar to the Royal Institution. He had also continued his friendship with Henry Brougham, the champion of popular education whom he had known since their student days together at Edinburgh. (51)

Birkbeck was the moving spirit behind the founding of the London Mechanic's Institution in 1823. This was founded in response to an appeal from the newly founded Mechanic's Magazine. A meeting was held on 11th November, 1823 at which over two thousand people attended, a subscription list was opened and among the donors were Birkbeck, Brougham, Francis Place, T.C. Hansard and the editor of the Morning Chronicle. Despite the opposition encountered due to the supposed revolutionary character of the Institution, (The Examiner of 16th November records that "not a single Tory attended the meeting or contributed to the support of the Mechanics' Institution.") the movement fostered by the Mechanics' Magazine quickly spread throughout the country.(52) At the close of 1823 there were six mechanics' institutes in existence, fourteen more (including four in Scotland and one in Wales) were founded in 1824, and about seventy new institutions in 1825. In 1824 sixteen thousand copies of the Mechanics' Magazine were sold. (53)

The organisation of the Institutes varied considerably both from one to another and from time to time. The best were usually equipped with a library, reading room and museum of models and apparatus. The apparatus was for the dual purpose of illustrating the lectures and allowing the members to perform experiments.

Teaching was by means of lectures to large audiences on mathematics, natural and experimental philosophy, and drawing; with some literary subjects such as English and foreign languages. (54) At the other end of the spectrum we read that the Wellingborough Institute was established in a workhouse and that the villagers of Ripley met in a hayloft. (55) At Newcastle upon Tyne a schoolroom in Pilgrim Street provided the first home of the Institution, and George Stephenson became its first president. (56)

Some indication has been given of the enthusiasm with which the institutes were received by the mechanics. It is interesting to try to discover the reasons for their sudden flowering at this time. Undoubtedly the renaissance of scientific interest which occurred in the second half of the eighteenth century, which had expressed itself in the founding of Literary and Philosophical Societies, and the influence of the Industrial Revolution in stimulating interest in mechanical subjects were contributary factors. At the same time the Industrial Revolution created an increasing need for skilled workers possessing a basic scientific knowledge. Hence employers were often associated with the founding of mechanics' institutes, and even those who did not approve of attempts at elementary education were not opposed to giving some education which would make workmen more effective in industry. As H.C. Barnard says it was thought that the "education would not be of the kind to enable them to climb out of that state of life into which it had pleased God to call them, but would merely enable them

to do their duty in that state of life more efficiently." (57) Engels saw the mechanics' institutes merely as a means of using the working class to provide inventions to benefit the rich. (58)

Another important factor was the growing awareness of the need to provide elementary education to the great mass of the people. The end of the eighteenth century saw the Sunday school movement started by Stock and Raikes in 1770, and later the monitorial schools of Bell and Lancaster laid the foundations of a national system of education.

In addition to these philanthropic endeavours the Whig-Radical reform group of Bentham, Place, Brougham, Whitbread and others saw educational reform as taking its place alongside law and parliamentary reform.

Finally the Radical agitation of Paine, Cobbett and others saw the mechanics' institutes as a means of teaching politics and economics and furthering adult education which was an important part of its programme. All of these factors contributed to the development of the Institutes at this time, but not least of the reasons for this early rapid growth was the very real desire of the mechanics for scientific knowledge. So much so that in 1824 Francis Place could describe with obvious satisfaction the sight of "from 800 to 900 clean respectable-looking mechanics paying most marked attention to a lecture on chemistry" (59)

The attention which had been drawn to the mechanics' desire for education was further focused by the appearance in 1825 of

Brougham's Practical Observations upon the Education of the People addressed to the Working Classes and their Employers. This led to the formation of the "Society for the Diffusion of Useful Knowledge" in 1827. This society in which Brougham was the leading figure published a number of popular works such as The Penny Magazine and The Library of Useful Knowledge. (60)

In the quarter of a century following the founding of the London Mechanics' Institution there was a considerable development of the movement. The enthusiasm of the first few years was not however maintained. It seems that the period 1826-31 was mainly one of decline. The reasons were various but included the economic depression of 1826, the lack of qualified lecturers, the lack of interest shown in science by the mechanics, and the small amount of time available for study. (The machine operatives commonly worked from 6 a.m. to 7 p.m.) Probably the most important factor was the lack of elementary education of the mechanics. (61) This aspect of the problems was aptly summed up in the words, "We have tried to form colleges before we have had schools." (62)

Finally there were political difficulties. The Radicals lost interest because politics was rigidly excluded, while the Tories (with a few exceptions like Huskisson) and the Established Church distrusted them as centres of Radlicalism.

Undoubtedly the aims of the founders had been pitched much too high but it is wrong to suppose that the movement ceased to grow. In fact from 1832 onwards there was a steady increase in the

numbers of mechanics' institutes. Kelly has calculated that the number of mechanics' institutes rose from 101 in 1831 to 261 in 1841, while the more middle class Literary and Philosophical Societies rose from 6 to 44 in the same period. (63)

During this period the Institutions had changed in character. Popular science, literary and philosophical subjects crept in although politics and religion were still too inflammatory to be included. The Institutions took on a more club-like atmosphere and exhibitions, soirées and visits became popular. Also the membership at this time was more middle class. However the membership had not changed as much as has often been supposed. The members were still broadly working class and if there were few unskilled workers it is fair to recall that Birkbeck's first attempts were directed at skilled craftsmen. So that while there had been an increase in clerical workers, by and large the Mechanics' Institutes continued to cater for those for whom they were founded. (64) Certainly one historian's description of them as "play-centres for serious clerks" seems a little harsh. (65)

What the best of the institutes were doing is illustrated by this extract from the report of the Edinburgh School of Arts.

> "In chemistry, Dr. Reid is the lecturer, who not only performed experiments himself before his pupils, but enabled the students to perform them themselves: several of them, he says, performed nearly two hundred" (66)

Another extract tells us that a similar state of affairs existed in the natural philosophy class. (67)

And again in a report presented to the Quarterly General Meeting of the London Mechanic's Institution on Wednesday, 6th September, 1843 we learn that,

> "In June last a Chemical Class was established upon the following plan: That a teacher should be appointed to give a short introductory lecture on each class evening. That each member of the Class, having been previously supplied with a complete set of apparatus, shall perform the requisite experiments to illustrate the introductory lecture." (68)

That a practical training in chemistry could be received at the larger of the Mechanics' Institutes is further testified to by Hudson when he refers to "the general taste for chemical science" as shown by successful chemical laboratories at the mechanics' institutes at Leeds, Bradford, Wakefield, Manchester, Westminster, York, Glasgow and Newcastle. (69)

Even where the teaching of science had been less successful, the excellent libraries continued, and the lectures had been largely replaced by class-room teaching. So the Institutes were now supplying a real educational need in providing elementary education. A further attack on the problem of elementary education was the opening of day schools, some of which were short lived, but others such as that opened by the Liverpool Mechanics' Institute in 1835 had long and successful careers. (70)

After Birkbeck's death in 1841 the movement showed a spasmodic development. The years 1849-52 were a boom period and it has been estimated that in 1851 there were some 698 mechanics' and literary

and scientific institutions. (71) One of the factors contributing to this was the formation of powerful unions. This removed one of the main difficulties that of finding sufficient lecturers. The first of these unions was the West Riding Union of Mechanics' Institutions formed in December 1837. (72) Other unions followed, some short-lived, but others such as the powerful Northern Union (1848) comprising Northumberland and Durham existed for many years. (73) What were then the achievements of the Mechanics' Institutes with regard to the teaching of chemistry, in this period? Perhaps most important was that they showed that among many of the less privileged members of society there was a very real interest in, and a desire for, a knowledge of science. The Mechanics' Institutes provided with varying degrees of success some knowledge of chemistry. In the best they gave a practical training which was many years in advance of Oxford, Cambridge and the schools, and if they did not produce a great harvest of Stephensons and Brindleys as their more enthusiastic founders hoped, they did produce a few, as is shown by the example of John Glover, who learnt his chemistry at the Newcastle Mechanics' Institution and lived to revolutionise the manufacture of sulphuric acid. (74) Finally they sometimes formed valuable libraries of chemistry books.

CHAPTER III.

CHEMISTRY TEACHING AT

THE ANCIENT UNIVERSITIES.

1. THE ANCIENT UNIVERSITIES IN THE FIRST HALF OF THE NINETEENTH CENTURY.

By the end of the eighteenth century the Universities of Oxford and Cambridge were in a state of decline. The Scottish universities on the other hand had steadily improved during the eighteenth century. While in England the colleges had become so powerful as to gain predominance over the universities, in Scotland the universities, more subject to Continental influences, had evolved a system of professorial teaching. Consequently, the English universities became more insular at a time when their northern counterparts were developing close relations with Dutch and other Continental universities. (75) Clearly the English universities were ripe for criticism and it is not surprising that it emanated from Scotland. Early in the nineteenth century the Edinburgh Review was founded and it soon became the organ of Whig reformers who used it to mount attacks on the English universities. The first of these came in a review by John Playfair of Laplace's Traité de Méchanique Céleste.(76) Playfair commented on the lack of British names among the mathematicians and astronomers who had made significant contributions in the last seventy years or so. (77) For such an advanced work as the Méchanique Céleste, Playfair considered that he was being generous in assuming that there would be a dozen people in Britain who could read it with reasonable ease. (78) One reason for this, according to the writer, was the failure to embrace the more rigorous analytical methods in mathematics; but the major share of criticism is reserved

for the English universities.

> "In one of these, where the dictates of Aristotle are still listened to as infallible decrees, and where the infancy of science is mistaken for its maturity, the mathematical sciences have never flourished; and the scholar has no means of advancing beyond the mere elements of geometry. In the other seminary the dominion of prejudice is not equally strong.....Mathematical learning is there the great object of study: but still we must disapprove of the method in which this object is pursued." (79)

The criticism seems to have been justified. Charles Babbage, the Lucasian Professor of Mathematics at Cambridge commented on the decline of mathematics (80) and even after 1850 we are told that an earnest student could be discouraged from reading the Méchanique Céleste or any other advanced work, on the grounds that it had no bearing on the Tripos Examination. (81)

This was followed by a similar attack on classical education. (82) Although the tone of the writing is immoderate, the general theme of the article (i.e. that other studies should be afforded equal facilities for study) is soundly argued. As for classics:

> "We would place it upon a footing with many other objects of study; but allow it no superiority. Good scholars could as certainly be produced by these means, as good chemists, astronomers, and mathematicians are now produced, without any direct provision whatsoever for their production." (83)

Such criticisms were not allowed to pass unanswered and Oxford found a defender in Edward Copleston, Fellow of Oriel and later Bishop of Llandaff. In his Reply to the Calumnies of the Edinburgh Review against Oxford, containing an account of Studies pursued in

that University (Oxford 1810), he made a spirited defence and was able to refute some of the wilder assertions of the critics of the universities. For example he claims that Aristotelian physics has not been taught for over one hundred years other than to illustrate the progress of science. (84) Professor Archer however considers that Copleston's replies "are stronger evidence of the justice of the attacks than anything contained in the attacks themselves."(85) The reviewers were quick to reply (86) and a series of exchanges was carried on until 1811.

The matter then seems to have been dropped but under the influence of the reforming atmosphere of 1831 the Edinburgh Review returned to the attack. Between 1831-1836 Sir William Hamilton who had studied at Oxford and Edinburgh and had experience of Continental universities, mounted a new series of attacks. (87) The first article (88) criticised the degree of control which had been acquired by the colleges at Oxford and Cambridge. In the opinion of the writer this had been to the detriment of the universities as a whole. (89) Clearly the writer favoured professorial teaching of the Scottish variety. Further articles (90) attacked the religious tests at the universities and urged the entry of Dissenters.

This stream of external criticism had been sufficient to generate activity in Parliament and several attempts were made to introduce bills which provided for the admission of Dissenters. However the attempts were dropped when the universities intimated

that they were prepared to make their own reforms.(91)

Just as the universities had found a defender in Copleston in the early years of the century so they now found another in William Whewell (1794-1866). He was born of humble parentage but went on to become Master of Trinity in 1841. For many years he was a regular attender of the meetings of the British Association, being president at the Plymouth meeting of 1841. (92) In 1835 he published his Thoughts on the Study of Mathematics as a part of a Liberal Education. (93) In this Whewell outlined the importance of mathematics and condemned certain modern tendencies in its teaching which he considered laid insufficient emphasis on teaching the student to think. He did however wish to reform certain aspects of the teaching, notably by the inclusion of mechanics and hydrostics in the course. This provoked the Edinburgh Review to further comment and it accused the University of Cambridge of pursuing the study of mathematics to the detriment of other subjects. (94)

Whewell's views on education as expressed in his works are marked by their thoughtfulness and are indicative of a careful study of the subject. He distinguished between the permanent and the progressive studies. The permanent studies he considers to be classics, geometry, mechanics and hydrostatics, while the progressive studies include such modern subjects as botany, zoology, geology, chemistry and the more modern branches of mathematics such as algebra and differential calculus. The permanent studies must come

first in any system of education for it is essential that an appreciation of the "force of Reason and the beauty of language" be given before a student could proceed to studies which would help him to justly estimate the progress of mankind. Chemistry and its allied sciences of electrochemistry and minerology, he considers, because of their state of development, to be less satisfactory progressive subjects than natural history. (95) Any professional education must follow a liberal education and any practical studies such as engineering must be learnt by professional men and by practical studies. (96)

Whewell implies that the professional studies are not the province of the university and no doubt it was this kind of reasoning which made the entry of science into the universities such a formidable problem. It is interesting however to see that Whewell appreciated the educational value of science and did not, as did most of the other protagonists of science teaching, stress only the utilitarian aspects.

With the internal examination reforms which are discussed in the next section, and the Royal Commissions of the mid-century the universities gradually acceded to the demands of their critics and by the eighteen-fifties had laid the foundations for the development of the great laboratories, in which discoveries were to be made which revolutionised the course of science.

2. CHEMISTRY TEACHING AT OXFORD.

As has been said, by the end of the eighteenth century the University of Oxford was in a state of decline. Dissenters and Roman Catholics were still barred from matriculation and the curriculum was predominantly classical. The examination system was ludicrous in that the examination time was often spent in gossip or newspaper reading and the attainment of a degree a mere formality. (97) Numbers had declined during the protracted wars at the end of the century and science could find little part to play in a university education. (98)

Science teachers were attached to the Faculty of Medicine and chairs of medicine, natural philosophy, botany and geometry had existed since the seventeenth century. (99) Dr. Beddoes had been succeeded in 1793 by Robert Bourne. He made no important contributions to chemistry and like all his eighteenth-century predecessors was a physician. (100)

In 1800 the examination system was reformed and in 1807 a School of Mathematics and Physics appeared in addition to the School of Litterae Humaniores.(101) At this time we have evidence that the teaching of science was at an extremely low ebb, for we read that the average attendance at public lectures on natural and experimental philosophy had been nearly 50 in the years 1773-7, while by 1809 the attendance had dropped to 14 in the Lent term no class being held in the other terms due to the low attendance. There

was a similar decline in the attendance at chemistry lectures.(102) Another factor which detracted from science was that there was not the stimulus of fellowships for work in natural science. (103)

In 1803, the Aldrichian professorship of chemistry was endowed. The first occupant, Dr. John Kidd lectured on three evenings a week during a two term course and it may well be that the poet Shelley attended his courses. (104) Kidd seems to have been a man of wide interests and a scientific and medical reformer. He had a large medical practice and after adding readerships of minerology and anatomy to his duties he resigned in 1822 to become Regius Professor of Medicine. (105)

Kidd was succeeded by Dr. Charles Daubeny. After being an undergraduate at Magdalen, he had studied medicine at Edinburgh, and his interests included botany and the study of volcanoes. He was actively engaged on research on several topics during his tenure, his most important chemical work being his Introduction to the Atomic Theory (1831) (106) Although Daubeny was obviously more of a specialist than many of his predecessors, his period of office was one of decline. According to his evidence to the Royal Commission (1852) the attendance at his lectures, "averaged from the years 1822-1830, 31 per annum; from 1831-1838, 16 per annum; from 1838 to the present time, only 12;..." (107) It is not surprising that faced with this kind of audience the science professors should make a plea for more science teaching in the University. In 1839

an Examination Statute was presented to Convocation. It proposed that no student should be awarded a degree unless he had attended two courses of lectures from those set out in a schedule. Arts subjects were available for candidates for Litterae Humaniores, but the courses available for degrees in Mathematics and Physics were: geometry, astronomy, natural philosophy, experiemental philosophy, anatomy, chemistry, botany, minerology and geology. The statute was rejected. (108)

In 1834 Daubeny was appointed Sherardian Professor of Botany and henceforth he devoted much of his time to his Physic Garden. In 1840 he added a third professorship that of rural economy. From this time much of his scientific work was concentrated on agricultural science, in which he was influenced by his friend Liebig. Indeed it has been suggested that the founding of the Daubeny Laboratory may have occurred to him as a result of Liebig's triumphant tour of Britain in 1842. What is certain is that Daubeny had long been dissatisfied with his gloomy accommodation in the basement of the Ashmolean Museum and in 1848 he began to erect at his own expense a lecture room and laboratory close to the Physic Garden. This new laboratory was the main chemical laboratory in the University until Daubeny resigned his chemistry professorship in 1854 to devote himself more fully to botanical work. (109)

More important than Daubeny's multifarious scientific work was that he was one of the leaders of the movement for more

science teaching at Oxford. He was preceded in this however, by William Buckland who from 1813 to 1848 preached the cause of science. He was appointed Professor of Minerology in 1813, and his lively and interesting lectures helped to popularise science and prepare the way for the reforms of the mid-century. (110) Daubeny, and Robert Walker, the Reader in Experimental Philosophy, were the main agents of these reforms. From 1845 they were joined by Henry Acland, who had just been appointed Lee's Reader in Anatomy. (111) Subsequently the movement gained momentum. Daubeny believed that a complete system of education must include mechanical and experimental philosophy, chemistry and general physiology, and believed that attendance at professorial lectures should be compulsory. (112) Similarly he tried to reverse the tendency for science to be cultivated only in the large towns, and stressed the advantages of carrying out research in the more peaceful atmosphere of the University. At the same time he felt that science was an essential instrument of education. (113)

The result of the agitation was that a new examination statute of 1849 provided that two examinations must be passed by all candidates. These examinations were to be exclusively on classical subjects for candidates for Litterae Humaniores, and in classics and mathematics for those candidates for the School of Mathematics and Physics. A third examination was then to be taken in a number of subjects from which the candidate could select. These subjects included natural science. This was the beginning of the

School of Natural Science. The first examination was held on May 4th 1853, when two candidates satisfied the examiners. (114) At the same time schools of Law and Modern History had been set up.

In August 1850, the appointment of a Royal Commission, "to inquire into the state, discipline, studies and revenues of the University and Colleges of Oxford," showed that despite the opposition of much of the academic world, the government was aware of the need for change. At the same time a Royal Commission was appointed for Cambridge. (115) By the middle of the century we can see that the first breaches had been made in the struggle to include modern subjects at Oxford. Much of the credit as we have seen must go to the external reformers and it must also be remembered that despite the advances made, there was still, in the year of the Great Exhibition, nothing in the nature of a laboratory which a student could attend. Nevertheless Oxford was preparing herself for her greatest advances in chemical science since the days of the "Oxford chemists."

3. CHEMISTRY TEACHING AT CAMBRIDGE.

At Cambridge the religious and academic atmosphere was more favourable to reform. It was of course impossible for Dissenters, Roman Catholics or Jews to obtain degrees, but the University was not so prejudiced towards them as the University of Oxford. (116) The influence of Newton had created a strong mathematical tradition and the Mathematical Tripos had been recognised since 1747. (117)

In the teaching of chemistry, William Farish, who had become seventh professor in 1793, lectured on, "The Application of Chemistry to the Arts and Manufactures of Britain." His lectures dealt with mining, smelting, manufactures involving metals, linens, bleaching, dyeing and the processes by which sulphur, salt, alum, etc. were obtained. (118) In 1794 F.J.H. Wollaston became second Jacksonian Professor of Natural and Experimental Philosophy. He devoted his lectures exclusively to chemistry and this is probably the reason why Farish lectured on the industrial applications. Wollaston appears to have been progressive in his scientific views and in his syllabus we see the use of the modern terms oxygen air, hydrogen air and carbonic acid air replacing the older terms dephlogisticated air, inflammable air and fixed air. He also claimed to show over 300 experiments in his course. (119)

On Wollaston's resignation in 1813, Farish transferred to the Jacksonian chair and Smithson Tennant became the new Professor of Chemistry. He had taken the degree of Bachelor of Physic at Cambridge in 1788 and had begun scientific research while still at the University. He took up his professorship with a considerable scientific reputation having published several papers in the Philosophical Transactions, and having received the Copley medal. Tragically, this man who might have provided a great stimulus to the study of chemistry, died in a riding accident in 1815, after giving only one course of lectures. (120)

The ninth professor the Rev. James Cumming appears to have devoted almost exclusively to electrical studies. (121) He was later said not to have"enriched the literature of chemistry proper with a single contribution." (122) He gave 28 lectures annually until 1831. From then on 50 annual lectures were given but the original plan was resumed in 1845, because the attendance in the Easter Term was often as low as 4 or 5. The apparatus belonged to the professor, and there was no opportunity for any practical work by the students. As Cumming said: "Hitherto the study of Chemistry has not only been neglected but discouraged in the University, as diverting the attention of pupils from what have been considered their proper academical studies." (123)

However, despite this evidence that the teaching of chemistry in the middle of the century was almost non-existent, there had been reform of the examination system which had recognised the claims of science. From 1780 onwards the Senate House examination had been an effective test of knowledge. (124) All candidates took the "Previous" examination which included classics, religion and mathematics. Even for those candidates who did not aspire to mathematical honours the second examination was on a course which included a fairly large proportion of mathematics. (125) In 1822 the decision was made to institute a Classical Tripos and in 1824 the first examinations were held. However candidates had to have first secured mathematical honours. (126) This remained in force until 1850. In 1848 the Moral Science Tripos and the Natural Sciences Tripos were

instituted, the first examinations being held in 1851. (127)

Students were eligible for honours in the Natural Sciences Tripos if they had passed the examinations for the degree of Bachelor of Arts, Law or Medicine. The subjects which were examined were: anatomy, comparative anatomy, physiology, chemistry, botany, geology and minerology. (128)

As at Oxford examination reforms in science had just preceded the Royal Commission which had been appointed in August 1850. With regard to the teaching of chemistry in Cambridge at that time it is perhaps fitting conclusion to say that the Report of the Commission speaks of the "strong and unfavourable contrast" between "the provisions made for the manipulative instruction of Students," at University and King's Colleges London, The Royal College of Chemistry and the Royal Institution; and those at Cambridge. (129) As we shall see it was through these newer institutions that chemistry was to find a place in English education.

CHAPTER IV

CHEMISTRY TEACHING

IN LONDON.

1. LONDON UNIVERSITY.

As we have seen the teaching at the Universities of Oxford and Cambridge at the beginning of the nineteenth century was predominantly classical and mathematical. The expense of residence excluded many, and in addition Jews, Roman Catholics and Dissenters were unable to obtain degrees. What is more the claims of physical science were being largely ignored.

The early years of the nineteenth century, saw the growth of a new class which differed socially, economically, and often in religion, from the dominating English class of the eighteenth century.(130) The conditions were right therefore, for a new secular university in the metropolis;(131) and the educational climate of London had already been demonstrated by the enthusiastic support given to the London Mechanic's Institution. (132)

The first public move towards the founding of a London University was made by Thomas Campbell in a letter to The Times printed on 9th February 1925, although the idea had been widely discussed before that, and in fact had first been conceived by Campbell during a visit to the University of Bonn in 1820. (133) In this letter which he addressed to Henry Brougham, he described the education of the working class as already "a triumphant cause" and makes a plea for "a great London University" for the education of "the youth of our middling rich people." He estimated the cost "to Build and endow a London University" to be £100,000. (134) The Times described the idea as "crude in conception and meagre in

development" but did not condemn the idea out of hand. (135)

Campbell had already been given assistance by Isaac Lyon Goldsmid, the Jewish financier, (136) who had brought Brougham into the scheme. Brougham in turn gained the support of Birkbeck and the Dissenters. During the next few months, disagreement broke out as to whether or not theological chairs should be included in the new university, but finally Campbell secured agreement that it should be purely secular in nature. (137)

A public meeting was held at the Crown and Anchor Tavern on 4th June, 1825, and on 11th February, 1826 a Council was appointed. It included support from Whigs, Dissenters, Roman Catholics, Utilitarians, Evangelicals and Jews. (138) At the annual meeting of the Council on 28th February, 1827 it was reported that receipts amounted to £33,675. (139) The foundation stone was laid on 30th April, 1827, and thought was now given to the appointment of professors and the curriculum. (140) In the minds of the founders the university was to serve a dual purpose by: providing an education for those excluded from Oxford and Cambridge, and by teaching those subjects which were neglected by the ancient universities. (141) Teaching was to be the primary function of a professor and Campbell regarded authorship as a disqualification for some chairs. (142) Instruction was by means of lectures (143) and the founders recognised the importance of regular examinations as a stimulus to progress. (144) The University was divided into a General and Medical Department and the General Department included arts, laws and

sciences.(145) From the beginning medical and legal education were regarded as of great importance. (146) The dominance of medical studies is indicated by the fact that there were 347 medical students out of a total of 469 at Gower St. in 1834. (147) The early years of the University were difficult ones. After the 1829-30 session when the number of students was 630, the numbers declined. (148) The Council and the Warden, Leonard Horner, were tyrannical and interfering in their treatment of professors (149) and until the reform of the government of the University in 1832, and the establishment of a Senate, the professors had no say in the conduct of the affairs of the University. (150)

The next major problem was to obtain a Charter of Incorporation giving power to grant degrees. The promoters had striven for this from the beginning, but in this they were opposed. However, the rejection of a Bill by the Lords in 1834, which proposed to admit Dissenters to degrees at Oxford and Cambridge, provided new impetus. (151)

The first charter was sealed on 28th November 1836. It established a body known as the University of London empowered to grant degrees in Arts, Laws and Medicine to candidates who had completed a course of study at University College - as "London University" had become - King's College, or any other institution which might be authorised to grant certificates of attendance. (152)

The University of London issued its first detailed syllabus in

1838. In the Faculties of Arts and Laws the bachelor's degree was to be obtained by means of two examinations. The first, or matriculation examination was to consist of mathematics, chemistry and natural history, and classics. The final examination could be taken two years after matriculation. For the B.A. the subjects were mathematics and natural philosophy; chemistry, physiology and botany; classics; and logic and moral philosophy. All of these subjects had to be taken simultaneously in the examination. Those who obtained the pass degree could proceed to honours in mathematics or classics, and further examination in mathematics, classics or moral philosophy could lead to the degree of M.A. Similar regulations applied to the degrees of LL.B. and LL.D. In medicine students proceeded to the degree of M.B. or M.D., evidence of practical work being an essential preliminary. (153) Hence the University of London became an examining body, the main weakness being that the University had no means of effecting improvements in the affiliated bodies, some of which engaged in competition to lower the standards required for the granting of certificates.(154) By 1851 the total number of affiliated colleges was 89, including 60 medical colleges. (155)

From the beginning the scientific chairs attracted men of distinction. The chair of chemistry had been offered to Faraday, but feeling that he owed his loyalty to the Royal Institution during a period of difficulty, he declined. (156) In 1827 Edward Turner was appointed to the chair. (157) Turner had graduated in

medicine from the University of Edinburgh in 1819, and after practising for a time, entered the laboratory of von Stromeyer at Göttingen, where he remained for two years learning analysis and inorganic chemistry, returning to Britain in 1824 to take up an appointment as Lecturer in Chemistry at the University of Edinburgh. (158)

His syllabus for his course at London shows an interesting development of the subject, beginning with heat, light, electricity etc; proceeding to inorganic then organic chemistry, particular stress being laid on useful applications, relevance to medicine and chemical phenomena in the natural world. (159) There was no practical class during the first two sessions and in March 1829 Turner wrote to the Council with his proposals for a class for his own pupils. He outlined his method of instruction as follows:

> "Accordingly the students will stand close around the table and assist the operator in succession. The course will be 10 weeks in duration, 4 or 5 times a week."

The letter indicates that fears had been expressed that the class would lower attendance at lectures but Turner argued:

> "I am of the opinion...that instead of diminishing the number of students to the lectures it will tend materially to its increase, and it will besides hold out an additional attraction to the University because the superiority of apparatus will alone defy the competition of private teachers." (160)

By 1831 the classes had begun and in addition Turner had a few private pupils. (161) Turner was a popular and accomplished teacher. (162) His main scientific work was in improving methods of analysis,

and the determination of atomic weights, many of his results comparing favourably with modern values. These results disproved Prout's hypothesis that atomic weights were simple multiples of that of hydrogen. (163) Unhappily he died in 1837 at the age of 39.

Dr. Turner was succeeded as Professor of Chemistry by Thomas Graham. Graham was born in 1805 (164) and entered upon his university education at the age of 14 at the University of Glasgow where he acquired a taste for science at the classes of Thomas Thomson on chemistry, and Dr. Meikleham on natural philosophy. After spending two years in the laboratory of Hope in Edinburgh, he taught privately for a time, before becoming Lecturer in Chemistry at the Mechanic's Institution in Glasgow in 1829. (165)

He had already begun his work on gas diffusion which was to prove so fruitful, and in 1831 he read to the Royal Society of Edinburgh his paper entitled "On the law of the diffusion of gases" (166) in which he outlined the discovery of the law which bears his name. In 1830 he had succeeded Dr. Ure as Lecturer in Chemistry at Anderson's Institution (167) and in 1834 he was elected into the Royal Society. (168) Hence he came to London in 1837 with an enviable scientific reputation. Indeed he was singled out by Liebig in a letter to Berzelius dated November 20th, 1837, in which he recounted his impressions of a visit to England

> "Ich bin einige Monate in England gewesen, habe ungeheuer viel gesehen und wenig gelernt; England ist nicht das Land der Wissenschaft, es existirt dorten nur ein weitgetriebener Dilettantismus, die Chemiker schämen

"sich Chemiker zu heissen, weil die Apotheker, welche verachtet sind, diesen Namen an sich gezogen haben. Mit dem Volke war ich ausserordentlich zufrieden, Zuvorkommenheit, Gastfreiheit, kurz ich habe sonst an ihnen alle Tugenden gefunden Graham macht auch in wissenschaftlicher Hinsicht die schätzbarste Ausnahme, es ist ein vortrefflicher Mensch, auch Gregory, der an seine Stelle in Glasgow gekommen ist." (169)

Indeed at this time Graham was among the first rank of British chemists. By 1844 the year in which Dalton died, Graham had become the foremost chemist in the country. (Davy and Wollaston had by this time died and Faraday was devoting himself to electrical researches.) (170) In 1841 Graham became one of the founder members of the Chemical Society, (171) a step which was indicative of the growing importance of chemistry in the country, and also of Graham's interest in the dissemination of chemical knowledge.

Graham's work was concerned mainly with the diffusion of gases, and later liquids and solutions of solids in liquids; and his work pioneered the science of colloid chemistry. It has been said of him that his work provided one of the links between the chemistry of Davy, Berzelius, Dalton and modern chemistry. (172)

What was unique about Graham's position was that a chemist of such eminence was given such facilities and support in an English university. For the first time in the nineteenth century a chemist who was making discoveries which were to change the history of chemistry was lecturing to serious students of chemistry, many of whom were to achieve fame in chemistry or allied sciences. (173) At the same time he was in the process of creating a school of

chemistry which was to become famous throughout Europe. It has been said of Graham that, "no teacher of chemistry in England at the time exercised a greater influence." (174)

As a lecturer he seems to have been nervous and unsure in his manner, and with a limited power of oratory, but his lectures were learned and well-ordered. (175) Playfair described his lectures as being illustrated with excellent lecture experiments, but commented that the students were often inattentive. (176) It seems that he began to teach practical chemistry because his pupils expressed a desire for it. (177)

In 1845 the importance of practical chemistry was officially recognised by the founding of a chair of practical chemistry and the opening of a new laboratory known as the Birkbeck Laboratory. In further recognition of the work of Birkbeck, it was to be used for an evening course in chemistry, at a reduced fee, calculated to attract those engaged in manufactures; in addition to its normal daytime use. Prior to this, in 1838, a dissecting room had been given for practical chemistry. (178)

The first holder of the chair of practical chemistry was George Fownes, who had studied under Liebig at Giessen, and had been appointed as Professor of Chemistry to the Pharmaceutical Society in 1842. (179) His work in connection with this body will be dealt with later. Fownes did not live long enough to establish himself as a great chemist, but his Manual of Chemistry, Theoretical and Practical, first published in 1844 was for many

years one of the few popular chemistry books. (180) It is through this work, and his campaigns for new laboratories, which would prevent students having to go to France and Germany, that he exerted the most influence. As Secretary of the Chemical Society he was in a position of some importance. (181)

However, Fownes was plagued by ill-health during these years in London at the Birkbeck Laboratory and he died in 1849. (182) The era of practical chemistry really began with the accession of A.W. Williamson to the chair.

Williamson had become interested in chemistry through attending Gmelin's lectures on chemistry at the University of Heidelberg, where he had studied with a view to a career in medicine. Having resolved to become a chemist he went to Giessen in 1844 where he continued his studies under Liebig. There he remained for two years and during this time he seems to have been a most assiduous student. During this time at Giessen his English contemporaries included Crum, Brodie and Muspratt. (183) In the July of 1846 he went to Paris where he mainly occupied himself in the study of mathematics under the tuition of August Comte. Comte had been recommended to Williamson by John Stuart Mill. Williamson carried on with his chemical research in a laboratory which he set up in his house in Paris. It was during this period, which although not particularly fruitful from the point of chemistry, that Williamson made the acquaintanceship of Laurent, Gerhardt, Dumas and other French chemists, which continued during their lives. (184)

It was in Paris also that Williamson had a meeting in 1849 with Graham, which led to Williamson's appointment as Professor of Analytical and Practical Chemistry at University College London. He took up his appointment in October 1849 and it was in his first few years as professor that he accomplished his great work on etherification which did so much to clarify organic chemistry. (185) His first paper on etherification was published in the Philosophical Magazine. (186)

These must have been stimulating years at University College. Williamson's visitors included Kekulé, Odling and Brodie, and his pupils have testified to the success of his teaching. Professor Carey Foster has described him as being "always in the laboratory, going from one student to another, arousing and maintaining their interest in their work, and ready to discuss with them any point on which they sought his help." (187) After a few years however he left the teaching of practical chemistry to his assistants and at about the same time simplified his lectures. (188)

In 1855 Graham was appointed Master of the Mint, and from this time Williamson held both chairs until his resignation in 1887. By this time his major scientific work had been accomplished, but he continued to take an active part in science and education and was responsible for promoting many reforms within the College including the establishment of a Faculty of Science.

2. KING'S COLLEGE.

The secular nature of the "London University", while being welcomed by those factions discussed earlier was viewed with alarm by the Established Church. The first indication that a second university was proposed was the comment of The Standard on 26th November, 1827, that it was rumoured that an application was to be made for the endowment of a second university under the control of the Established Church. (189) The moving spirit both in the first overt moves and in the early history of the new King's College was George D'Oyly. D'Oyly had been second wrangler at Cambridge in 1800, and by 1822 had risen to the position of Rector of Lambeth. (190) The first public step taken by D'Oyly was the publication of an open Letter to the Right Hon. Robert Peel, on the Subject of the London University written under the pseudonym of "Christianus". The letter while accepting the need for more universities, argues that "the principle on which the London University is founded" is contrary to all the other educational institutions in the land. The teaching of religion it is argued is necessary both morally and as a necessary adjunct to other university studies such as history and ethics. The letter concludes that a second university in the metropolis is called for: "in which it shall be made, of course, an essential part of the education imparted, to imbue the minds of youth with the principles of Christianity,... and in which the services of religion shall be performed as directed in the National Church." The suggestion is also made for the

founding of a new university in the north - thus anticipating Durham University. (191)

The result of D'Oyly's plea was that a scheme for a new Kings College was launched. A prospectus was issued in June 1828 and an inaugural meeting was held in the Freemason's Hall in Great Queen Street on Saturday 21st June, 1828. The Duke of Wellington occupied the platform accompanied by the Archbishops of Canterbury, York and Armagh, together with seven bishops and "the principle Nobility." (192) An array which shows that the support for the proposed college came from a very different source from that which was working towards the "London University".

The meeting was a great success, and in the words of John Bull (30th June, 1828), "the finishing blow has been given to the stye of infidelity building at the end of Gower Street." (193) Peel and Aberdeen promised large subscriptions at the meeting (194) and a provisional council of twenty seven members was elected. A sub-committee was appointed to draw up regulations for the College and on 1st July, 1828 the regulations concerning this matter were presented.

According to these, all members of the College were to attend the course of religious instruction and attend services, but persons who were not regular members were allowed to attend lectures, and were free of religious duties, but were not eligible for prizes etc. The result was merely to divide students into two classes: regular and occasional, but in fact to make entry almost

as unrestricted as at Gower Street. Religious tests were reserved solely for professors. At a subsequent meeting of the provisional committee on 30th December, 1828, it was decided that the College should be divided into a higher department for those over the age of 16, and a lower department for the younger boys. One other factor was important in the early history of the College, i.e. that the committee had no plans for the College to grant degrees. (195)

However the Council now ran into difficulties over finance. The action of Wellington and Peel in granting Catholic Emancipation led to withdrawal of financial support by the extreme anti-catholics who felt they had been betrayed, and hence the College began in the midst of heavy debt. (196) Nevertheless a site east of Somerset House was acquired and work on the main building began in September 1829.

The final great object of the provisional committee was that of obtaining a charter for the college. The attempts of "London University" had been unsuccessful, but King's College had the great advantage that it did not aspire to grant degrees, and therefore did not arouse the antagonism of Oxford and Cambridge. What was probably more important was the support which the College enjoyed from crown, government and church. The Charter was sealed on 14th August, 1829. (197)

The Council instituted by the Charter now set to work. (198) One of the first acts of the Council was the circulation of the

prospectus. In this it was explained that in the higher department:

> "The general course of education...will comprehend religion and morals, classical literature, mathematics, natural and experimental philosophy, chemistry, parts of natural history, logic, English literature and composition, the principles of commerce, and general history. To these will be added instruction in foreign languages, and in subjects connected with particular professions, as medicine and surgery, jurisprudence, etc." (199)

The lower department was to be a day school providing an education preparatory to the higher department. (200) It is clear from this that King's College, like "London University", recognised the claims of science, and accepted the idea of a university or college providing a professional training. Religion was not a disqualification to entry, and as the College was non-residential, great prosperity was not a prerequisite to entry. But as has been pointed out, the College in its early days was more akin to a school than a university, and with the exception of its medical school concerned itself mainly with preparing its students for Oxford and Cambridge. (201)

By 1st April, 1830, the Committee had decided what chairs were to be immediately established. The three main professors were to be those of classics, mathematics, and English literature and history. They were guaranteed a minimum of £300 each, while the less lucrative chairs of chemistry, natural and experimental philosophy, natural history and zoology, law and jurisprudence, etc. were to receive a portion of student fees but no guaranteed

minimum. (202)

Medical appointments were the first consideration of the Committee (203) but subsequent appointments included the scientific chairs. The Rev. Henry Mosely, a Cambridge mathematician, was made Professor of Natural and Experimental Philosophy on 30th January, 1831, and John Frederic Daniell was appointed Professor of Chemistry on 7th February of the same year. (204) Shortly afterwards Mr. (later Sir) Charles Lyell was appointed Professor of Geology at King's College. Geology was at this time a controversial subject and the Bishop of Llandaff opposed the appointment. However since Lyell was not considered to be hostile to the Church this objection was overcome. (205) He found however that the lectures distracted from his writing and travelling and as early as January 1832 he was considering giving up the professorship. (206) Subsequently the governors prevented ladies from attending his courses and this made the numbers so small that in 1833 Lyell resigned his position. (207)

On 8th October, 1831, the College was officially opened.(208) By the end of the first session there were 764 students distributed as follows:

higher department 66 regular - 149 occasional

medical department 48 regular - 339 occasional

junior department 162

The sciences and modern languages were non-compulsory subjects and were taught on weekday afternoons. (209) In 1834 a step was

taken which gave a greater degree of independence to the College. A three year course of study was laid down which would lead to a qualification known as Associate of King's College (A.K.C.). The basis of each years study was to be divinity, classics, mathematics and English, but in the second and third years other subjects could be added. (210)

At first King's College held aloof from the examination of the University of London, encouraging its best students to proceed to Oxford and Cambridge, rather than seek the "Godless diplomas" of the new body. Slowly, however, the barriers were broken down and King's College students took advantage of the London degrees. (211)

From the appointments mentioned earlier it is clear that King's College, like its rival institution, attached much importance to the teaching of science. The first Professor of Chemistry, John Frederic Daniell (1790-1845) was already well known at the time of his appointment, as a meterologist, and as the inventor of the hygrometer which bears his name. He had received a classical education and after a spell working in a sugar refinery, had concerned himself with meterology. Later he became an authority on the management of hot houses, and in 1830, just prior to his appointment to King's College, he further distinguished himself by inventing a new pyrometer, for which he received the Rumford Medal; and constructing a water barometer for the Royal Society. (212)

On taking up the chair of chemistry, he was awarded the sum of £300 for chemicals and apparatus. Much of his work from this

time onward, was directed to the study of electricity and electrochemistry. He was a close associate of Faraday, and after the publication of Faraday's Laws of Electrolysis in 1834, Daniell set about making a constant voltage cell which would provide a sufficiently large E.M.F. for electrochemical investigations. The invention of this cell, which bears his name, resulted in the award of the Copley Medal, and from this time until his death he was engaged in the classical work into the electrolysis of salt solutions.

His major publication was his Introduction to Chemical Philosophy in 1839, which Professor Hey describes as, "the most original book on the subject at that time and an authoritive work for many years after his death." (213) A study of the work is of interest for the insight it gives into the contemporary approach to chemistry. Almost the first half of the book is concerned with what we should now call physics, while much of the rest deals with electrolysis and allied studies. The Atomic Theory forms the final chapter of the book, for Daniell claims that atomic ideas when introduced at an early stage are "likely to turn the mind from that rigid method of induction from facts, by which alone the student can be safely guided..." (214)

Similarly we can learn something of chemistry teaching at King's College from the "Prospectus of the Course of Lectures and Demonstrations on the Theory and Practice of Chemistry" by J.F. Daniell and W.A. Miller. (215) The general scheme of lectures follows the arrangement of the book, which was in fact written to complement

his lecture course. It is stressed that the lectures refer to metallurgy, the pharmacopoeia, manufactures and domestic economy. We also learn that the lectures were given from 3 to 4 p.m. on Mondays, Tuesdays, Thursdays and Fridays, and that private instruction was available in "Operative Chemistry". A course in "Chemical Manipulation" was also given by Miller, under the supervision of Daniell, on three mornings per week at 10.15 a.m. These classes which lasted for two hours, continued for thirty weeks.

Daniell appears to have been active in the controversies following Babbage's criticisms of the state of English science, for it is said that he devoted his inaugural lecture to a rebuttal of the charges made against English chemistry. (216) He was also one of the original vice-presidents of the Chemical Society. (217)

Daniell died suddenly on 13th March, 1845 at a meeting of the Council of the Royal Society. (218) While the appointment of his successor was being mooted, Sir Benjamin Brodie, who had formerly been surgeon to George IV and who had entertained Liebig during a visit to England, led a movement to secure the services of the German chemist; but the Archbishops of Canterbury and the Bishop of London would not agree to the appointment of a Lutheran and the matter was dropped. Consequently William Allen Miller was appointed to the chair. Miller had had his scientific tastes aroused by chemical lectures and the use of the telescope while at the Friend's school at Ackworth in Yorkshire. He studied medicine at King's College, London, and for some months in 1840 he worked

with Liebig at Giessen. On his return he became demonstrator of chemistry at his former college and in 1842 he obtained the degree of M.D. from the University of London. In 1841 he had become an assistant lecturer, and from this time he worked in close collaboration with Daniell.

One of Miller's first acts after his appointment was the founding of a new department of analytical chemistry, to which the Council gave a grant of £250 towards the cost of equipment. Miller's first experiments in spectrum analysis had been made in a lumber room underneath the lecture room in the College. In 1851 a new chair was created and John Eddowes Bowman who had worked under Daniell and Miller became first Professor of Practical Chemistry. Bowman was apparently a splendid teacher but unfortunately suffered from poor health and died in 1857 at the age of thirty five. (219)

Clearly, at both the London colleges, chemistry had been considered a subject necessary of inclusion in an institution of higher learning. Similarly it is clear that both colleges were fortunate in their chemistry professors. Both attracted men who were among the foremost scientists of their time, and although there is little evidence of their views on science teaching, or much to suggest that they campaigned for the extension of facilities for studying science, they played their part in establishing chemistry as an integral part of an English university. By about the mid-century not only were laboratory facilities available at

both colleges, but the importance of practical chemistry, as a necessary part of a chemical education had been officially recognised. (37) But the chemistry taught was mainly inorganic. Organic chemistry was little taught, and we shall see in the next chapter that it was this branch of the subject which was to be the one which was to gain the approval of the English landowners and industrialists of the eighteen-forties. Although the London colleges had been based on the German universities, they were primarily teaching institutions and the idea of the university as a centre of research was to impinge only very slowly on the English universities. However throughout the first half of the nineteenth century the most spectacular developments in the teaching of chemistry were taking place elsewhere in London:at the Royal Institution.

3. THE ROYAL INSTITUTION.

The founding and early work of the Royal Institution have already been described. The period from 1802 to about 1806 was distinguished by two features: the subordination of Rumford's work for working class education, and the spectacular success of the young Cornishman, Humphry Davy. Davy had come to London from the Pneumatic Institution of Dr. Thomas Beddoes at Clifton, having already investigated the anaesthetic properties of the gas nitrous oxide. (220) One of his main reasons for leaving the Pneumatic Institution were the greater facilities afforded for research at the Royal

Institution. (221)

During the period 1801-1806 Davy's studies were mainly concerned with Galvanism, tanning, the analysis of minerals, and agricultural chemistry. (222) The invention of the Voltaic pile in 1800 (223) led to the new science of Galvanism and Davy read his first paper on the subject to the Royal Society on 18th June, 1801. (224) However it was 1806 before he made his next great step in this subject. In that year he gave The Bakerian Lecture to the Royal Society "On some Chemical agencies of Electricity." In this lecture Davy explained how he had extended the researches into the electrolysis of water, by effecting the decomposition of a number of substances in aqueous solution. From these experiments Davy deduced the relationship between chemical properties and electrical force and so became the founder of the science of electrochemistry. (225) The paper caused a sensation, so much so that the Institute of France was able to overcome national emnities to such an extent that Davy was awarded a prize founded by Napoleon "for the best experiment which shall be made in the course of each year, on the Galvanic fluid." (226) Davy quickly followed up this work with the electrolytic decomposition of soda and potash and the consequent discovery of the new elements sodium and potassium. He announced his discoveries in the Bakerian Lecture on 19th November, 1807. (227)

He was now established as one of the leading scientists of Europe and for the next 15 years the history of the Royal Institution was to be the history of Davy's life and work. However

Davy's powers as a teacher seem to have equalled his scientific talents. We learn that in his first course of lectures, "Men of the first rank and talent, - the literary and the scientific, the practical and the theoretical, blue-stockings and women of fashion, the old and the young, all crowded eagerly the lecture room."(228) The young Robert Peel attended the natural science lectures during the London season of 1805 (229) and we learn from a French visitor in 1810 that chemistry was most popular as a subject for lectures and that only Davy's lectures filled the lecture theatre. Furthermore over half the audience were ladies who assiduously took notes. (230)When Davy fell seriously ill in November 1807 bulletins had to be posted to satisfy the many enquirers as to his progress. (231) Not surprisingly we find that Davy used to write fresh lectures for each occasion so as to avoid repetition, practice the evening before, and devise his experiments carefully to illustrate his theme. (232)

However from the time of Davy's illness until well into the reign of Faraday, the Institution was in financial difficulties. (233) Davy was still making discoveries and publishing regularly and on 12th July, 1810, he read a brilliant paper to the Royal Society in which he showed that oxymuriatic acid (chlorine) must be considered as an element. (234) He was about to enter upon what was probably the most fruitful period of his career. At the same time he had achieved a high place in society. He was knighted on 8th April, 1812 and a few days later he married Mrs. Appreece, a widow

who possessed a considerable fortune. (235) On 11th March of the same year it was reported to the Managers that Davy would no longer promise to give courses of lectures but would be willing to carry on as "Professor of Chemistry and Director of the Laboratory and Mineralogical Collection without salary". Shortly afterwards in 1813, Davy became Honorary Professor of Chemistry although stressing that he would still communicate his results directly to the Institution and would still keep up his association with it. It was necessary to have someone to lecture regularly however, and W.T. Brande was elected as Professor of Chemistry. (236)

This year (1813) was to prove auspicious on two counts. Firstly, it was the year of the appointment, by Davy, of Michael Faraday, the former bookbinder's apprentice who was to exercise such a profound effect on science and education. Secondly, it saw the first attempts of the Royal Institution, since the days of the mechanic's school, at continuous teaching. Although Davy already had permission to take private pupils into the laboratory, (237) this aspect of the work of the Institution was really developed by Brande, who had been teaching medical students at a chemical school in Windmill Street and was allowed to transfer his class to the Royal Institution. These lectures were given by Brande and later Faraday in the laboratory at 8 a.m. In a report to the Managers in 1826, the opinion was expressed that "these lectures have been productive of great advantage to the Royal Institution and have greatly raised its character as a school of Chemistry..." (238) In 1852

Brande was to say that they were the first lectures in London to give such a wide view of chemistry and its various applications to geology, medicine etc. (239)

Meanwhile on 13th October, 1813, Davy, accompanied by Lady Davy and Faraday, left London on their European tour. (240) The absence of Davy put a great strain on the Institution. While Brande was an adequate lecturer, he must have been disappointing after the oratory of Davy. (241) During this period "the Institution did little for science", (242) and Faraday expressed his concern in a letter , from Geneva, to his friend Abbott. (243)

On their return to England, while Davy busied himself with the researches which were to lead to the invention of the miner's safety lamp, Faraday was happily throwing himself into his duties at the Institution. (244) During the next five years he was receiving his education as a scientist and as a teacher. He published his first research in 1816 (245) and from 1816-1818 gave a total of 17 lectures at the City Philosophical Society. By 1820 he was publishing regularly and was established as a professional chemist. (246)

Unfortunately the period was not such a successful one for the Royal Institution. In 1818 the bill for coals in 1816 was paid; in 1822 the treasurer had to advance £1,000 to pay bills, and in 1823 a loan of £4,000 was raised from the members. (247) It is obvious that in this period when Davy lectured less and less, the Institution was in serious financial difficulties. It was saved by Faraday's commercial analyses which brought income, and his

qualities as a lecturer which made him a worthy successor to Davy. (248) In 1821 he first lectured to Brande's class and in 1825, the year in which he became Director of the Laboratory of the Royal Institution, he helped to create the meetings which became known as the Friday Evening Discourses. During the course of his life Faraday gave over one hundred of these Discourses, many of which dealt with his own discoveries. (249)

In 1826 the Juvenile Lectures began. They were probably suggested by Faraday, and over the years he gave nineteen of these courses of lectures, and included in his audience such notables as the Prince of Wales who attended in 1858. Two lectures which have been preserved and are justly famous are, "The Chemical History of a Candle" and "Lectures on the Various Forces of Matter". (250)

On the further progress of the Royal Institution to the mid-century little need be said except that it continued successfully on the lines onto which Faraday had directed it. Faraday's development as a lecturer is however, of interest. As early as 1813 Faraday expressed his ideas on lecturing in four letters to Abbott which are so masterful in their analysis that they might well be made compulsory reading for all teachers today.(251) Space does not permit a full description but let it suffice to say that he stressed the importance of suiting the lecture to the audience, introducing apparatus, "at every convenient opportunity", diagrams and tables, clarity of expression and not least a well ventilated lecture room. Perhaps the children who attended his lectures were unaware of such

niceties, but certainly they would not forget the sight of Faraday "suddenly and without warning, hurl a scuttle of coals at the Royal Institution's great electromagnet, and then follow this with the fire tongs and poker - all reaching their target and sticking there!" (252)

As to the effect of the teaching of the Royal Institution during this period we can only speculate. It would be too much to suppose that the lectures contributed directly to the acceptance of chemistry as an instrument of education, but what they did do was to help the more influential members of society to understand the major advances in the science. It seems reasonable to suppose that the intellectual satisfaction of chemistry must have been conveyed to many, and this must have played its part in creating a climate of opinion, more favourable to chemistry. At the same time the techniques of lecturing in chemistry, which were developed to such a high degree at the Royal Institution, must have been both an inspiration and an example to later teachers. The success of the Juvenile Lectures also demonstrated for the first time that chemistry could be made interesting and intelligible to a youthful audience. It was to be many years before the majority of the nation's schoolchildren were to have the kind of experience that the Royal Institution provided.

CHAPTER V

CHEMISTRY TEACHING IN THE PROVINCES.

1. DURHAM UNIVERSITY AND THE TEACHING OF CHEMISTRY.

Throughout the period that chemistry teaching was being developed at the new University and King's Colleges in London by the distinguished men whose work we have discussed, an equally important chemist was teaching in the newly founded Durham University. The founding of this university need concern us less than the founding of the institutions of higher learning in London, as it did not arise as a result of any desire to teach science. It is not known with any certainty who first made the suggestion for a northern university (253) although the idea had been mentioned as early as 1829. (254) What does seem clear is that the reason for the founding of the University was the concern felt about the future of the Church in the period of unsettlement preceding the passing of the Reform Bill in 1832. The Church and in particular the wealthy clergy were subjected to much criticism, and the Chapter of Durham which was one of the richest of ecclesiastical bodies, resolved to use some of its money for educational purposes, in the hope that this would forestall appropriation for secular purposes. (255)

The matter had been discussed by two of the prebendaries, Dr. Durell and the Reverend Charles Thorpe, and Durell took the step of writing to Van Mildert, the Bishop of Durham, proposing that an educational institution be established. Van Mildert, who had himself already foreseen an attack on Durham, was sympathetic but advised that the matter be kept private until a more definite form

had been given to the suggestion. The first proposals included provision for professors of divinity, classics, mathematics, modern languages, history, natural science and philosophy. (256)

On 28th September, 1831 the Chapter agreed that an institution called "Durham College" be established. (257) On 9th December, 1831, Thorpe, who had provisionally been appointed as Warden brought out a scheme for the new body. This scheme (258) under the heading "The University of Durham" provided for professors of divinity and ecclesiastical history, Greek and classical literature, and mathematics and natural philosophy. There were also to be readers in law, medicine, history, ancient and modern, to which "may be added Readers in other branches of Literature or Science, as opportunities offer or circumstances require".

By 1832 Van Mildert realised that if the University was to gain support in the north, it would be necessary for it to have the power of granting degrees. Consequently a bill was prepared and Van Mildert moved the second reading on 22nd May, 1832. During the passage of the bill Dissenters tried to make provision for the admission of persons of all denominations, but when the bill received the royal assent on 4th July, 1832, it was little changed from its original form. The Act specifically referred to a "university", the government of which was to be vested in the Dean and Chapter. The latter was given power to sell lands, spend a portion of the sum obtained on building, and put the rest in trust. (259)

In a paper of Thorpe's dated 20th July, 1833 (260) the names of the staff who had by that time been appointed are given. These include Charles Whitley as Reader in Natural Philosophy and J.F.W. Johnston as Lecturer in Chemistry and Minerology. It is also announced that the University will begin in the Michaelmas term, 1833.

It seems clear that science played little part in the life of the University in the early days. No student could be admitted until he had passed an examination in the rudiments of the Christian religion, Greek and Latin, arithmetic and the elements of mathematics. For the B.A. degree the student had to pass examinations in the rudiments of religion and classics. For honours in mathematics and classics the requirements were much greater. The M.A. degree could be conferred after 9 terms had elapsed from the award of the B.A. No examination was required for the award of the M.A. (261)

However as we have seen chemistry teaching was available at the University from its inception. J.F.W. Johnston was born in Paisley in 1796. He studied at the University of Glasgow supporting himself at this period by undertaking private tuition. In 1825 he took charge of a school in Durham, in 1830 he made a rich marriage and subsequently studied for a time in Stockholm under Berzelius. (262)

Johnston was a man of remarkably wide accomplishments: he was at the same time chemist, agriculturalist, geologist, minerologist

and scientific missionary. He published some work on purely chemical subjects such as that on resins (263) but his best known work was on agricultural chemistry. His Lectures on Agricultural Chemistry and Geology (Edinburgh and London, 1844) is dedicated to Charles Thorpe and in it he tells us that the earlier lectures were delivered within the walls of the University to the Durham County Agricultural Society and the members of the Durham Farmers' Club.

The popularity of his work in this field must be unrivalled. His Elements of Agricultural Chemistry (Edinburgh and London) was brought out as a 17th edition as late as 1894. His Catechism of Agricultural Chemistry (Edinburgh and London, 1854) had passed through 57 editions by 1863 and was still being brought out in 1892. In this latter work, which Johnston dedicates to the "Schoolmasters and Teachers of Great Britain", he states that he wishes to secure not only their support but also their "cordial co-operation". The subject matter in the book is dealt with in question and answer form, with descriptions of experiments to be performed by the teacher.

Johnston was also active in working for the advancement of science. He was one of the original members of the Chemical Society and a leading figure in the formation of the British Association, of which more will be said in a later chapter. It was said of him that he had "done more than has ever yet been done to preach science to the masses, and to set its laws, discovered in the laboratory, a-working in our fields and factories". (264)

At the University also he attempted to promote the teaching of science. In 1833 he was to deliver a "Popular and Practical Course" during the Epiphany term.(265) In 1841 he proposed the formation of an agricultural school but this proposal was not adopted. He did however succeed in having chemistry made an optional subject in second year arts. Between 1848 and 1852 Johnston taught agricultural chemistry at what was later to be Bede College. This college which was completed in 1847 was for the training of schoolmasters. In 1838 an engineering class was begun at Durham and Johnston gave courses, including occasional practical courses, to the students of engineering. However these did not last for long as the school of engineering was short-lived. (266) We have evidence from the early Durham University Calendars that laboratory teaching was available at an extra charge but it is not possible to state whether use was made of this opportunity.

Johnston died at Durham on 15th September, 1855. After his appointment to the Agricultural Society of Scotland in 1843 he had lived in Durham only during term, but in his later years he had lived entirely at Durham. (267) With his death came the end of an era. In 1871 the College of Physical Science was founded in Newcastle. This college, which together with the Newcastle Medical School formed the nucleus of what is now the University of Newcastle, was the result of a growing realisation that Newcastle was a more suitable place for the teaching of science and engineering. (268)

2. THE DEVELOPMENT OF CHEMISTRY TEACHING IN MANCHESTER.

The founding of the Manchester Literary and Philosophical Society in 1781 has already been discussed. It was the first of a number of societies and institutions which arose in Manchester between the years 1780 - 1851, all of which in one way or another had educational functions. Such bodies were not peculiar to Manchester but it was in that city with its background of nonconformity and liberalism and its realisation of the utility of knowledge, that they particularly flourished. Among the institutions which arose in Manchester were The College of Arts and Science (1783), The Manchester Academy (1786), The Natural History Society (1821), The Manchester Royal Institution (1824), The Mechanics' Institution (1824), The Royal Medical College (1824) and The Manchester Statistical Society (1833). (269)

The Manchester Academy is particularly remembered for bringing John Dalton from Kendal to Manchester in 1793. He was employed as a tutor by the Academy in the department of mathematics and natural philosophy. He joined the Literary and Philosophical Society in 1794, becoming secretary in 1800, vice-president in 1808 and president in 1819; in which office he continued until his death in 1844. The Manchester Academy moved to York in 1803 and Dalton lost his connection with this body, but continued his work and teaching in Manchester in a room which had been provided for him in 1799 by the Literary and Philosophical Society at 36 George Street. Dalton published the first part of his <u>New System of Chemical</u>

Philosophy in 1808, in which he outlined his Atomic Theory. His immense prestige and his close association with the Literary and Philosophical Society caused the Society to benefit accordingly. (270) So great was the respect in which he was held in Manchester that on his death his coffin was visited by over forty thousand people. (271)

The Society dealt with a wide range of topics up to the eighteen-forties, after which with increasing specialisation in science, papers on literary and artistic subjects became uncommon. In 1842 J.P. Joule joined the Society.(272) He was at this time working on the experiments which led to the determination of the mechanical equivalent of heat, and Playfair has testified to the fact that he was only one of a number of scientists who were actively engaged in research in Manchester in the eighteen-forties. (273) Hence the Manchester Literary and Philosophical Society had the services of two of the most distinguished scientists of the nineteenth century.

This society was not the only Manchester institution sponsoring science teaching at this time. Between the years 1842-1845 Playfair was honorary professor at the Manchester Royal Institution. He fitted up a teaching laboratory in the cellars of the Institution which proved so popular that he was unable to accept all the pupils who came to him. Playfair also gave lectures at the Institution, his audience on some occasions including Joule and Dalton. (274)

In 1840 the Manchester Academy returned to Manchester as the Manchester New College. The New College was by this time sufficiently distinguished for its pupils to become candidates for the degrees of the University of London, two years of study in the New College enabling students to become candidates for the B.A. On its return to Manchester the educational work of the College was extended. (275) No students were admitted under the age of fifteen years and for those who wished to attend the regular course of a preliminary examination in classics, history, geography and mathematics had to be passed. The course of study normally lasted three years, the first year being spent in preparation for matriculation at the University of London, while the remaining two were spent in preparation for the B.A. examination. Special classes were available for students preparing for higher degrees. Fees for the course in physical science were:

Experimental Philosophy and Chemistry	£5 : 5 : o per session
Natural History	£3 : 3 : 0 per session

(276)

The lectures on physical science and natural history comprised chemistry, heat, electricity, natural history, mechanics, accoustics, hydrostatics, hydraulics and optics. The syllabus for the course of lectures in chemistry is given in appendix I. The senior students we are told would learn "methods of preparing, analyzing, and testing for Chemical Substances; and also Lectures upon Animal and Vegetable Chemistry." (277).

As to the value of chemistry, the professor, in his introductory lecture, stresses the advantages to agriculture, and the economies which would result in industry through the discovery of new uses for chemical substances: new uses which would become apparent through a study of the chemical properties of the substances. The professor did not consider that chemistry had yet reached the level of the more exact sciences but predicted that it soon would. He does however admit that chemistry is "so interesting and so beautiful, that the student will, when he has once fairly entered upon the study, quit it with reluctance". (278)

This excellent college which obviously set itself such high standards of education, was not destined to succeed in a Manchester not yet quite ready for its educational facilities. The first session had twenty eight students and this rose to thirty four in its second session, but after this the numbers declined and by 1852 had gone down to eleven. Consequently, in that year it was decided to move the College to London where it could be linked to University College. (279)

However, while one institution of higher learning was leaving Manchester another was taking its place. The idea that a university should be established in Manchester was not new. Even prior to the nineteenth century, suggestions had been made. These suggestions had often resulted in the founding of some of the societies which have been mentioned earlier.

In 1829 W.R. Whatton, a governor of the Manchester Royal Institution proposed that the Institution should form the nucleus of a university. The course of study he believed should fall into three main divisions: literature which would include modern languages and history, science, and the Arts. However the suggestion was never taken up and nothing came of the scheme. (280)

Further attempts to form a university were made during the eighteen-thirties (281) but no practical step was taken until the bequest of John Owens, a wealthy Manchester merchant, made such a step possible. Mancunians learnt of the bequest in an article in the Manchester Guardian of 6th August, 1846 entitled, "Collegiate Education in Manchester" which consisted of an account of the will. This provided for an education which was to be free of any religious tests, the only restriction to entry being that a preference be shown to local candidates. (282)

The sum which was finally received by the trustees was £96,942. 1s. 1d. (283) The first meeting held by the trustees, which was devoted to educational purposes was held on Tuesday, 13th June, 1848. They set about their task with considerable thoroughness and after obtaining advice from a wide range of men, they decided on a course of study which seems much more akin to present day school studies, including as it does English language, science and commercial subjects; than to the university subjects of the eighteen-forties. As Thompson says, it "needed no little boldness to suggest them, and great courage to persevere with them when, in

course of time, failure seemed imminent". (284)

By 17th December, 1849 the broad lines of the curriculum had been laid down and it was decided to appoint professors of language and literature of Greece and Rome, mathematics and natural philosophy, mental and moral philosophy and English language and literature. (285) Subsequently it was thought expedient to appoint a Professor of Chemistry in acknowledgement of the great local importance of the subject. (286)

Appointments began to be made during the later part of 1850 and Edward Frankland was appointed Professor of Chemistry on 2nd January, 1851. On 29th May permission was granted for the College to grant certificates qualifying students for examinations leading to degrees of the University of London, and on 12th March, 1851 the Owens College was opened. (287)

Twenty five students entered for the first term, the College being housed in the former residence of Richard Cobden, and for the first complete session the number of students had risen to sixty two. It soon became apparent however, that the standard of school education in Manchester was so low that the College was seriously hampered by the lack of preparation of the students. Consequently it was decided to progressively raise the standard of entry with a view to improving the quality of the elementary education in the city. Obviously this was a policy which had to be carried out with caution for a too drastic measure would have had the affect of closing the College. (288)

Like so many other institutions trying to provide a more advanced education such as have been described previously, the College's early years were ones of difficulty and uncertainty. Evening classes for schoolmasters were begun in 1852, but by 1857, the year in which Frankland resigned, the total number of students at the College had fallen to thirty four. (289)

It was from this date, under the inspired influence of the new principal A. Greenwood and Frankland's successor as Professor of Chemistry, H.E. Roscoe, that the College was to prosper and develop into the University of Manchester. (290)

Owens College was to have as its first Professor of Chemistry a scientist who was to achieve an exceptional reputation. Although Edward Frankland was at Manchester for only a few years a study of his education is interesting, throwing as it does, much light on the degree of determination required by anyone who at that time wished to become a practising chemist. He was born in 1825 and his interest in science was awakened by reading books at the local mechanics' institute. He studied no science at the Lancaster Free Grammar School which he attended between the ages of twelve and fifteen, but after leaving school was reintroduced to science, being apprenticed to a druggist in the hope that this would lead to a medical career. However, the six years he spent in this way, he later considered to have been totally wasted, except for the time that he was able to spend in scientific investigations. (291)

In October, 1845 Frankland went to London where he worked in the Duke Street laboratory of Lyon Playfair. Playfair at this time was entering upon his career of public service and was frequently absent on government business, but under the guidance of Playfair's assistant, Frankland made such good progress that Playfair offered him the post of Lecture Assistant at the Civil Engineering College, Putney. It was while working in Playfair's laboratory that he made the acquaintance of Hermann Kolbe, with whom he went to Marburg to work under Bunsen in 1847. Prior to this he had met a Mr. George Edmondson, who was proposing to open a new school at Queenwood in Hampshire. Frankland had accepted the post of science master at the school and consequently he remained only three months in Germany, continuing with Kolbe researches which they had begun in London on the preparation of organic acids from alkyl cyanides. (292)

At Queenwood (of which more will be said later) he taught chemistry including laboratory work, and also gave lectures on geology and botony. At the same time he became friendly with John Tyndall, who was later to be Professor of Physics at the Royal Institution. The two young schoolmasters entered upon a programme of mutual instruction: Tyndall teaching Frankland mathematics, and Frankland instructing Tyndall in the mysteries of chemical analysis. In addition to all this Frankland still found time to continue his researches. In June, 1848 Frankland and Tyndall set off for Paris where they attended the lectures of Dumas and Fremy, after which they

proceeded to Marburg where Frankland completed the work for his Ph.D. (293) Despite the short time which he spent at Queenwood he considered his time there well spent especially with regard to the teaching experience which he had gained, making the pereeptive comment that, "there is nothing like lecturing on a subject for getting to know it thoroughly". (294)

Wishing to widen his experience still further Frankland went from Marburg to Giessen in the autumn of 1849, remaining there until Christmas. Originally he had proposed to follow this with a visit to Heinrich Rose, the famous analyst, but on being offered the professorship of chemistry at the Putney College, in succession to Playfair, he returned to London in 1850. (295) However as we have seen the appointment was short-lived for he was soon to accept his post at Owens College.

Frankland's first task in Manchester was the planning and organisation of the laboratory. Since finances were inadequate for the building and equipping of a chemical laboratory, the sum of £9,550. 10s. had been raised for this purpose by public subscription. The first students had to make use of a temporary laboratory in St. John's Street. (296) Frankland received an annual salary of a mere £150 plus two-thirds of the student fees. This was at a time when he was about to publish his paper "On a New Series of Organic Bodies containing Metals", (297) which was to provide the basis of the theory of valency: the fundamental idea on which all theories of chemical combination have been built, and which was

to prove his most important contribution to chemistry. (298)

While at Owens College he published further papers on organo-metallic chemistry and also gave courses of lectures on technical chemistry. He resigned on 20th July, 1857 to take up an appointment as Lecturer in Chemistry at St. Bartholomew's Hospital. (299) Clearly the early years at Owens College were ones of extreme difficulty. Frankland himself referred to "the notoriously bad preparation of students entering the college". (300) Later he was to be a stern critic of governmental neglect of science, (301) and through his Lecture Notes for Chemical Students embracing Mineral and Organic Chemistry (London, 1866) a significant contributor to popular scientific education. (302)

CHAPTER VI

THE DEVELOPMENT OF LABORATORY INSTRUCTION IN CHEMISTRY

1. THE EARLY HISTORY OF LABORATORY INSTRUCTION

Training in practical chemistry seems to have been begun at the Mining Academy at Selmecbánya in Hungary. This Academy which was founded in 1735 became the centre of chemical research in Hungary and it soon had a European reputation. Later the methods used at Selmecbánya were to be copied by the Ecole Polytechnique. (303) Another very early attempt to teach practical chemistry was made by M.V. Lomonosov (1711-1765) between 1752-1756 at the Academy of Sciences at St. Petersburg. (304) There were other isolated attempts, and although there had been for some time prior to this, teaching of chemistry to students of military engineering in France, the modern teaching laboratory really began with the founding of the Ecole Polytechnique in 1794. The school was founded with the purpose of providing more engineers for the Republic. (305) Entrance was by means of competitive examination held simultaneously in twenty two cities, and most of the three hundred and eighty six men chosen for the first class were from the poorer ranks of society. (306) There were no tuition fees and students received a grant. (307) Hence, the recognition, that institutions of higher learning had a part to play in supplying professional training, and that such education should be available, irrespective of background, to all those able to benefit from it, was made much earlier in France than in any other European country.

From the beginning, the founders were convinced of the importance of practical chemistry. For the purpose of practical work the

students were divided up into brigades of twenty with a chef de brigade to provide assistance. Three lecture courses were given, and the lecturers included Fourcroy, Vauquelin, Berthollet, Chaptal, Guyton and Pelletier. (308)

Originally, the school was planned to include twenty laboratories however insufficient chefs de brigade were prepared for the first session, and not all students began practical work. Initially, most of their work was concerned with making apparatus, and preparing distilled water, lime water, litmus paper, etc., but later, lecture experiments were repeated, and preparations of compounds from natural products were attempted. In addition, small research topics were given to the students, who were also taken on regular factory visits, and given experience working with the pottery furnace, lead chamber plant and glass works, with which the college was equipped. (309) By 1797, economies had caused the closure of some laboratories, and the loss of some staff, but by 1799 the position was such that the staff was increased by the additions of L.J.Thenard (1777-1857) and C.B.Desormes (1777-1862) as répétiteurs in chemistry. Although from this time, the amount of time devoted to chemistry was gradually reduced, practical chemistry was still regarded as of great importance. So much so that in 1806 a modified syllabus was introduced by Guyton. The course consisted of four parts. Non-metals and their compounds were included in the first part together with acids, bases and salts. The second part dealt with metals, including their

determination by analysis. The third and fourth parts dealt with organic chemistry, including the analysis of natural products and the extraction of pure substances from natural products. (310)

In 1809, Gay-Lussac, who had been a répétiteur since 1804, became Professor of Practical Chemistry, but on his transfer to the chair of general chemistry in the same year, Thenard became Professor of Practical Chemistry. These two continued to teach practical chemistry for many years, and as late as 1827 it was said that the teaching of practical chemistry was still considered to be of great importance. (311) One other place, apart from Paris, which attracted chemistry students in the early years of the century, was Berzelius's laboratory in Stockholm, where he received one private pupil in his laboratory each year. His most famous students included Heinrich Rose, Mitscherlich and Wöhler. (312)

The influence of the Ecole Polytechnique began to be felt in Europe in the early years of the century. In 1805 Friedrich Stromeyer, who had studied under Vauquelin at the Ecole became professor at Göttingen. In the following year he introduced laboratory work for his students. He was a fine analyst and his pupils included Mitscherlich and Bunsen. (313) In 1820 student laboratories were set up in Landshut by J.N.Fuchs, who gave a course in analysis which was open to a maximum of eight students who had shown sufficient merit; (314) and at Jena by Döbereiner. (315)

In Scotland, Thomas Thomson, who had studied under Joseph Black at Edinburgh, gave practical instruction in chemistry at the

University of Edinburgh, at least as early as 1807, and there is evidence that he taught practical chemistry after taking up his appointment as Lecturer in Chemistry at Glasgow, in 1818. The Edinburgh laboratory must have been the first university laboratory in Britain to provide facilities for practical work in chemistry.(316)

In England, the scientists were more sheltered from European influences, although as we have seen, Edward Turner who had begun the teaching of practical chemistry at University College, London, after 1829, had been a pupil of Stromeyer. But in general, the influence in the first quarter of the century came from Scotland rather than the Continent. We also know that Davy had permission to take private pupils at the Royal Institution, though there is little evidence to suggest that he ever did so. However, Friedrich Accum who was for a time "Assistant Chemical Operator" at the Royal Institution conducted an establishment in Old Compton Street, where he gave lectures, took private pupils, and sold chemicals and apparatus. (317) Clearly therefore, Liebig was mistaken when he wrote concerning the founding of his laboratory in Giessen in 1825, that:

> "Chemical laboratories in which instruction in chemical analysis was imparted, existed nowhere at that time. What passed by that name were more like kitchens filled with all sorts of furnaces and utensils for the carrying out of metallurgical or pharmaceutical processes. No one really understood how to teach it." (318)

Nevertheless, Liebig must be awarded most of the credit for the development of laboratory instruction in chemistry. Justus von

Liebig was born in Darmstadt, and after obtaining only a moderate success as a pupil at the Gymnasium, he became an assistant to an apothecary. At the age of 16 he went to the University of Bonn, where he studied under Kastner, whom he later followed to Erlangen. Realising that he could learn no more in Germany, and being fortunate enough to obtain the means to go abroad, he journeyed to Paris. (319) It was, as he was later to write, "a very wretched time for chemistry in Germany." (320) Mention has already been made of the best known of the German chemists who studied under Berzelius in Stockholm.

In Paris, Liebig found the lectures stimulating, but at first could not obtain access to a laboratory. Fortunately, through a meeting with Alexander von Humboldt, he made the acquaintanceship of Gay-Lussac, into whose laboratory he was accepted. (321) According to Hofmann, it was here, that "Liebig conceived the idea of founding in Germany a chemical school which he hoped to be to his younger fellow workers what Gay-Lussac had been to him." (322)

In 1824 Liebig was appointed Extraordinary Professor of Chemistry at the University of Giessen, and became Ordinary Professor in 1826. (323) Soon after taking up his appointment Liebig opened his laboratory to pupils. Analysis played a large part in the instruction, and so great was the popularity of the laboratory that an organised course of elementary and advanced chemistry had to be devised. (324) Soon students were flocking to the laboratory from Europe and the United States. His English students included as we

have seen Williamson, Playfair, Muspratt, Crum and Brodie.

The reason for the sudden flowering of practical chemistry teaching lies partly in the development which has been traced, but it seems that the main factor was the influence of Liebig himself. He had been dissatisfied with the facilities for study in Germany, and he brought to his work an enthusiasm which he succeeded in conveying to his students. Undoubtedly another factor was that Giessen was a small university. Later he was to say that in a larger university his energies might have been, "divided and dissipated.... but at Giessen everything was concentrated in work, and in this I took passionate pleasure." (325)

The elementary teaching was in the hands of Liebig's assistants, while Liebig himself took charge of the more advanced pupils. Little actual instruction was given but each pupil was assigned a task and he reported each morning on his progress. Criticisms or suggestions were made, but each student was allowed to follow his own inclinations. Twice a week, Liebig gave a review of his own work and that of his students. The hours were long, and the work difficult, but the only complaint was from Aubel, the laboratory man, that he was unable to get all of the students out of the laboratory, and was therefore unable to clean it. (326) Hence an atmosphere was created in which the aspiring chemist was in constant intercourse with his fellow students and his teacher, each contributing and cross-fertilising ideas, and the whole producing an esprit de corps.(327)

With the example of Liebig the teaching laboratory came into its own in Germany. Liebig's friend and research associate, Wöhler, was influenced by the Liebig method. In 1836, he succeeded Stromeyer at Göttingen, where a teaching laboratory was already in existence, but which under Wöhler's control operated in a similar fashion to that at Giessen. (328) Later in the century many students were attracted to the laboratories of von Bayer at Munich, Ostwald at Leipzig, Rischer at Berlin, and Meyer at Heidelberg. Hence during the century a new pattern of scientific education was developing in Germany. The universities were becoming the centres of "research schools" in which each student was engaged on work which was relevant to that of his fellow students and his teacher, and in which young men were undertaking creative research, at a period of their lives when they were often at their most successful.(329)

2. MEDICAL AND PHARMACEUTICAL EDUCATION.

We have seen that by the beginning of the nineteenth century chemistry was taught at the ancient universities as an adjunct to medical studies. Even so, before 1815, the teaching of medicine at these institutions was of an extremely low standard (330) Medicine was taught at the medical schools of St. Bartholomew's, the Borough Hospitals (St. Thomas's and Guy's) the London Hospital,

and at a number of private medical schools.(331) Even prior to 1800 there is evidence that lectures on chemistry were given at some of these institutions. For example in 1770 the governor's of Guy's Hospital set about building a lecture theatre in which lectures could be delivered on chemistry, materia medica, and the practice of medicine.(332) Although the Middlesex Hospital did not have a medical school as a separate unit until 1835, teaching in the wards began almost 100 years before this and in 1796 a laboratory was fitted up for lectures on chemistry.(333) Similarly the Newcastle Medical School had from its inception in 1834 a Lecturer in Chemistry.(334)

These examples provide evidence that chemistry did form a part of medical studies and we have seen that a number of notable chemists had their introduction to the subject through their study of medicine. Indeed chemistry has been described as the subject "which obsessed medical education" during the eighteen-thirties and forties. Even though, at this time, medicine was not sufficiently scientific for chemistry to make a real contribution.(335) However there appears to be little evidence as to the nature of the chemistry taught.

The study of pharmacy was conducted along entirely separate lines. It had no association with the great centres of learning and its professional standards of conduct and education were determined by its governing bodies. The first of these was the Society

of Apothecaries which was founded in 1617 and first held examinations in 1619.(336) It was, however, not until the beginning of the nineteenth century that the Society began to take a more active part as a teaching body and by 1823 lectures on pharmacy were being given. It was decided at this time that lectures in chemistry and materia medica should be given annually.(337) By 1841 the chemists and druggists had taken up their present position as dispensers of medicine while the apothecaries were becoming something akin to general practitioners.(338) With the apothecaries aspiring to medical practice it was realised that if pharmacy was to achieve any professional status it must be made more scientific and that an approved education must be provided. Consequently the Pharmaceutical Society of Great Britain was founded in 1841.(339) Inevitably as pharmacy progressed into an exact science then chemistry became a more important part of pharmaceutical education.

The first home of the Pharmaceutical Society was at 17, Bloomsbury Square, which was rented for a sum of £240 a year. Lectures were begun in 1842, Andrew Ure being the Lecturer in Chemistry and George Fownes the Lecturer in Organic Chemistry.(340) The lectures attracted attendances of between seventy and ninety and it was felt that this was sufficiently promising to justify providing accommodation for practical work. Consequently, in October, 1844 a laboratory was opened for ten students. This

proved so successful that a new laboratory with accommodation for twenty one students was fitted up in the basement of the premises in Bloomsbury Square. It was this laboratory which provided the model for the Birkbeck laboratory at University College, London. (341) Hence the laboratory of the Pharmaceutical Society was the first laboratory in England in which instruction in chemistry and pharmacy by means of practical work was carried out.

The laboratory attracted many distinguished visitors. These included Liebig, Rose and Mitscherlich, all of whom were conducted to the laboratory by a Mr. Morson who was also responsible for the appointment of Fownes. Liebig is particularly remembered for the modifications to certain procedures which he suggested. These modifications subsequently became standard practice.(342)

With the passing of the Pharmacy Act in 1852 pharmacy had the seal set upon its respectability, while the founding of the Chemical Discussion Association of the Pharmaceutical Society in 1858 is indicative of the growing link between chemistry and pharmacy. (343)

3. THE ROYAL COLLEGE OF CHEMISTRY.

The facilities for learning chemistry in England in the first quarter of the century have already been outlined. As we have seen there were few opportunities for an Englishman to obtain a knowledge of chemistry in this country except as a part of medical or pharmaceutical studies and consequently, after 1826, the aspiring English student usually went to one of the Continental laboratories for his training. Not only were there few opportunities for training, but there was a similar lack of employment. Sir Edward Thorpe has suggested that, in 1837 there were probably no more than two dozen people in the British Isles who were receiving instruction in practical chemistry, and that this number was probably equal to the demand. As Thorpe says: "Teacherships were few in number; analytical chemistry as a profession hardly existed, and chemical manufacturing was done by rule of thumb, and for the most part very badly done".(344) The young Lyon Playfair, after studying under Thomas Graham in London, left in 1839 to study at Giessen, where he gained both his Ph.D., and the admiration of Liebig. On his return to England, he must have been one of the best trained chemists in the country, yet he was not able to secure a better appointment than that of a chemical manager of a print works at a salary of £400 per year.(345) Because of the lack of prospects young men were advised against the study of chemistry, (346) and even in the eighteen-fifties, William Crookes, who had studied

under Hofmann at the Royal College of Chemistry, was unable to obtain very satisfactory positions teaching or working in chemistry.(347)

The idea of founding in England a school of practical chemistry to rival the Continental schools of Liebig and Wöhler can be traced back to Liebig's first visit to England in 1837. While in England at this time, the British Association requested him to produce a report on the present state of organic chemistry. Instead he produced his Organic Chemistry and its application to Agriculture and Physiology (1840).(348) In 1842 Liebig made a second highly successful visit to England. Liebig was accompanied by Playfair and William Buckland, the eminent geologist. Playfair acted as guide and interpreter for the party and took care that, the tour, which included visits to Sir Robert Peel, such well known agriculturalists as Pusey, as well as most of the important towns; received the maximum publicity.(349) Coming as it did at a time of great interest in agriculture, and at a time when there was a growing agitation for the repeal of the Corn Laws, the effect of Liebig's visit, together with his book, was to create a great wave of enthusiasm for chemistry as applied to agriculture; which in turn created a demand for the teaching of chemistry. Indeed the position of chemistry at that time has been compared with that of nuclear physics a century later.(350)

One consequence of the visit was the founding of the Royal

Agricultural College at Cirencester to which John Thomas Way was appointed Professor of Chemistry in 1846. He had studied under Graham in London and from 1843 had assisted Daubeny in the analysis of plant ashes. He made several important contributions to agricultural science. In 1849 he was succeeded by Augustus Voelcker who had studied under Wöhler at Göttingen, Liebig at Giessen and had worked for two years with Johnston at Edinburgh.(351) Another consequence was the founding of the Agricultural Station at Rothamsted by John Lawes. He had carried out experiments at Rothamsted since 1837, especially with regard to superphosphate manuring, and in 1842 had taken out a patent on a process which had first been suggested by Liebig. The process led to a superphosphate industry at Deptford. After 1843 the work of the Station became organised on a more systematic basis and Lawes, and his assistant Henry Gilbert, yet another of Liebig's pupils, continued their experiments both in the field and in the laboratory.(352)

At the same time the Government was becoming aware of the practical value of science. When Playfair was about to take up a teaching appointment in Toronto, Sir Robert Peel prevailed upon him to remain in this country, and promised him a government appointment. He was subsequently appointed to the Health of Towns Commission, and later when the Irish potato crop was threatened, Playfair and John Lindley, Professor of Botany at University College, London, were appointed to visit Ireland and prepare a

scientific report. On this report, which predicted famine on a colossal scale, the Prime Minister relied, when he faced his cabinet with his proposals for the repeal of the Corn Laws.(353) Playfair subsequently published two lectures on the results of his studies.(354)

It can be seen that it was not until the mid-forties that conditions were appropriate to the founding of a college of chemistry in this country. But even then nothing might have come of the original idea but for the personal role of the Prince Consort. So important is the part which he played, not only in the founding of the Royal College of Chemistry, but also in the development of scientific activity in other spheres, that it may be useful to briefly deal with his career. He had married Queen Victoria in 1840, and finding himself largely cut off from affairs of state at that time, he sought the company of artists, musicians and scientists. He found little pleasure in the affairs of the Royal Society, but being always more interested in the useful applications of science, he found a more congenial atmosphere at the Royal Society of Arts, of which body he became President in 1843.(355)

In view of all this it is not surprising that the Prince Consort should be associated with the founding of a college of chemistry. Indeed according to Playfair, it was the Prince Consort and Sir James Clark, the Queen's physician, who deserve the most credit for the founding of the college. The main reason for the

promotion of the scheme was their desire to provide a professional training for chemists, and not merely as was the case at that time, an education in chemistry which was subordinated to other professional needs, such as was the case in the education of physicians, engineers etc. The raison d'être of the college was therefore, to enable chemistry to be studied for its own sake, and with the hope that its students might subsequently either engage in research, or follow chemistry as a career.(356)

As early as 1843 a number of people, including Dr. John Gardner, the translator of Liebig's Familiar Letters on Chemistry, and J. Lloyd Bullock, who had been one of Liebig's pupils and who was at that time running a thriving pharmaceutical business in Conduit Street, had enlisted support for a proposed National Practical School of Chemistry. They had emphasised the agricultural effects of Liebig's work and the benefits which industry would be likely to derive. In the autumn of 1843, proposals, which had been worked out in some detail, were presented before the Managers of the Royal Institution. The scheme proposed that the college be accommodated in the premises of the Royal Institution, where it was thought that thirty to forty pupils could be accommodated. Student fees were expected to be low, and it was believed that a professor from one of the German schools could be obtained for a salary of £250 per year plus a share of student fees.

The authors of the scheme considered that the space available

at Albemarle Street would be sufficient to provide a laboratory which would enable each student to have his own bench, the professor a private laboratory, and that there would still be adequate space for storage etc. In addition to all this it was hoped to provide a laboratory for studies in applied chemistry. This laboratory was to be under the supervision of Mr. Lloyd Bullock who was prepared to undertake this task without payment. The Managers of the Royal Institution passed on the plans for the consideration of Brande and Faraday in November 1843. Their first reaction appeared to be favourable but in a second report which was presented to the Managers on 19th December they were less enthusiastic, it being stated that, "place could be made for the School in the Royal Institution, but at a loss of many conveniences to itself and its Professors". (357) Although the report strongly supported the establishment of such a school, and despite the objectivity with which Brande and Faraday approached the matter, it became clear that space was insufficient and the Managers regretfully informed Messrs. Gardner and Lloyd accordingly.(358)

However the breakdown of negotiations did not lead to the abandonment of the project. On 29th July 1845 a public meeting was held in St. Martin's Place at the temporary offices of the College. A council and officers for the new College, of which Prince Albert agreed to be president, were elected, their first consideration being the appointment of a professor.(359) It was suggested by Sir

James Clark that Liebig be asked to recommend a suitable man who had received training at Giessen, and hence would be able to teach analysis and research. It was for these qualities that one of Liebig's pupils was sought, for as Hofmann points out, "There was no lack of most excellent chemical lecturers in England; indeed the style of experimental illustrations, then quite general in England, was infinitely superior to that which at that period prevailed in Germany and on the Continent in general". (360) Liebig was approached and he recommended, in order, Will, Assistant Professor at Giessen, Fresenius, Professor at Wiesbaden, and Hofmann, "Privat Docent" at Bonn. Offers were made to Will and Fresenius, both of whom declined, no doubt being unwilling to give up secure chairs in Germany for such a speculative English venture. Hofmann, however was sufficiently interested to have an interview with Dr. Gardner, who travelled to Bonn for the purpose, and who had by this time become secretary to the college.(361) Hofmann was understandably reluctant to leave a good position for one which was only assured for two years and was only persuaded to accept through the intervention of Prince Albert who, a fortnight after the meeting of the Council happened to be visiting Germany. Accompanied by Queen Victoria, and with a retinue which included Sir James Clark, the party stayed as guests of the King of Prussia at Brühl while on their way to the Prince's old university town of Bonn.

During the celebrations for the visit Sir James Clark met

Hofmann for the first time and arranged for him to meet the Prince. It was agreed that the Prussian Government be approached and asked to grant Hofmann two years leave of absence, so that if he failed to establish the school in England he would be able to return to his former position. Furthermore Sir James felt that, as Hofmann might reasonably be expected to have gained promotion in this time if he had remained at Bonn, he should be allowed to rejoin the University of Bonn with such promotion as he might have earned. Hofmann considered that in the space of two years he might have become Extraordinary Professor, and so Sir James Clark resolved that he must persuade the Prussian government to give him such a position on his return. Since it was felt that such an assurance would be given only if the Prince Consort made a personal request to the King of Prussia, the Prince was again called on. The Prince succeeded in his request and after certain other procedural difficulties had been overcome Hofmann was granted two years leave of absence and so the matter was settled.(362)

In October 1845 the analytical course at the College of Chemistry began in temporary accommodation in Great George Street, Hanover Square. Twenty six students, including several such as Warren de la Rue, F.A. Abel, E.C. Nicholson, Thomas Rowney, C.L. Bloxam and Robert Galloway who were later to achieve fame, entered for the first session. Encouraged by promises of support, the Council took premises in Hanover Square with a piece of ground which had a frontage in Oxford Street and plans for new laboratories

in Oxford Street were prepared under Hofmann's guidance. On 16th June 1846 the foundation stone of the new building was laid by Prince Albert, and in the following October the buildings were sufficiently completed for work to commence in the new premises. The Prince Consort played a further part in the success of the new foundation by obtaining the Queen's assent to it being named the Royal College of Chemistry.

Unfortunately the debt which was due on the building, even after the payment of all subscriptions to the building fund, stood at £2,000 and this sum had to be paid off by members of the Council. (363) The College enjoyed an early success. The subscribers included Palmerston, Gladstone and Faraday.(364) So great was the interest of the Prince Consort that he paid regular visits to the laboratories and had Hofmann delivering lectures at Windsor Castle. (365) In 1847 when Hofmann's leave of absence had expired the Prince Consort was able to write in terms of glowing praise about Hofmann and his part in, "raising the new Institution to a high pitch of usefulness and popularity, and there is every prospect that it will continue in the same course". (366) Although the College proved popular its continued success depended on subscriptions. It was later estimated that £5,000 had been spent in the building and equipping of the College. Hofmann received a salary of £400 per annum plus £2 per pupil who attended for a year. In addition to this the professor was provided with a furnished house. There were two

sessions in the year and the scale of fees was:

4 days attendance per week £10 a session,

3 days attendance per week £8 a session,

2 days attendance per week £6 a session,

1 days attendance per week £4 a session. (367)

Undoubtedly Hofmann did play a large part in the early success of the college. He arrived with only one assistant, Herman Bleibtreu, and spent his first two years in the College working in conditions which were far from conducive to successful scientific research.(368) In a paper published in 1849 Charles Mansfield who carried out his work at the College referred to the problems of working, "in a laboratory imperfectly furnished with gas and other conveniences",(369) In addition to these difficulties Hofmann had to cope with the strain of improving his English and the work involved in planning and equipping new laboratories. His success has been ascribed to a combination of exceptional abilities as a teacher, his outstanding flair for research, his capacity for hard work, and his resolution in face of difficulties. Hofmann's method of instruction is clearly derived from Liebig. He visited each student twice during the day's work but unlike Liebig devoted as much time and effort to the beginners as to the advanced students. Not until the College was established in the Oxford Street laboratories did Hofmann deliver courses of lectures, but he would often, on his tours of the laboratory give an extempore address on some point

which had caught his attention.(370)

Hofmann was not only an accomplished laboratory teacher, he was also a conscientious and stimulating lecturer.(371) Although he was not a skilled manipulator of apparatus, and as Abel says, "he used to tell us that, in his student's days, all his fingers were thumbs, and that he could hardly handle a test tube without 'scrunching' it", (372) his lectures were well illustrated with experiments performed by his assistants. His course of lectures at the Royal College of Chemistry was later published (373) and in the preface he speaks of the uncertainty and controversy which had characterised chemistry in the last quarter of a century. His method of teaching he explains is to present only a limited number of facts, but to present these experimentally, and from them to draw the widest possible theoretical conclusions. This he says is the determining factor in the lectures and consequently he has had, "to break with the classical traditions of chemical teaching". For example the elements are studied in a new order. He goes on to discuss the art of lecturing and suggests that the lecture is the most suitable vehicle for his approach. As he says, "The mere limits of time to which he is bound, preclude in any case, his attempting the exhaustive treatment of his themes. At the lecture-table he is only expected to display a few salient facts, in a striking and attractive form, and to deduce therefrom a few guiding principles, so as to assist his auditors in acquiring for

themselves the details of the science. Any attempt on the lecturer's part to make his brief discourses encyclopaedic must, of necessity, fail;".(374) It is interesting to note that Hofmann in his dedication of the book, which was prepared on the eve of his departure from this country to Germany, expresses gratitude to Sir James Clark and refers to him as one who has, "constantly sustained me in endeavouring to promote, in the country of my adoption the great cause of chemical education", and it is also interesting to speculate how much his decision to leave this country was dictated by the failure to sustain the chemical education which he had done so much to promote.

For many of his lecture experiments he developed new or modified apparatus, in particular those which dealt with the volume composition of gases such as hydrogen chloride, ammonia, and methane.(375)

W.H. Perkin who entered the College in about 1853 at the age of fourteen has described his teaching at the College and this gives us further insight into Hofmann's approach. Perkin was set to work firstly on the reactions of the metals and then went on to a course of qualitative and quantitative analysis which Perkin in his desire to begin research soon completed.(376) Perhaps the greatest testament to Hofmann's success as a teacher was the success of his pupils. Normally his most able pupils remained at the College for a few years as assistants. Their work included

assisting Hofmann at lectures, in the general instruction and in working on his researches. Among those who held such positions and later distinguished themselves in industry or science were Abel, Nicholson, Bloxam, Rowney, Brazier, Medlock, Crookes, Spiller, Tookey, Ansell, Church, McCleod and Groves. In addition a succession of Germans were attracted to the College, among whom are still remembered were Griess, Martius and Fischer. Besides these men the College employed a number of chemists who were given the rank of assistant professor or honorary assistant. These posts were usually occupied by men who had come from Giessen.(377)

The research work at the Royal College of Chemistry was almost exclusively in the fields or organic and analytical chemistry. One hundred and forty researches were carried out in the laboratories of the College between its founding and its incorporation in the Royal School of Mines in 1853.(378) An indication of how prolific was Hofmann's contribution to chemistry while in England is the list of 170 papers published in the Royal Society's Catalogue of Scientific Papers.(379) And so highly was he regarded by his English colleagues that on his death the Chemical Society's memorial lecture was given by four men and occupies a striking one hundred and fifty seven pages in the published memorial lectures.

Hofmann's research work at the Royal College of Chemistry was essentially a continuation of the work which he had begun in Germany. His initial efforts in chemistry were devoted to a study

of the aromatic amines and in particular aniline, which he later always referred to as his "first love". Himself a poor experimenter, his great success seemed to lie in his power of selecting fruitful investigations. For example the young William Perkin was given as his first investigation the preparation of a nitro compound of anthracene, with a view to converting this by reduction to an amine. Although this result was not accomplished results were obtained which later proved of great value. Although little was known of the structure of organic substances at that time, Hofmann was interested in the laboratory synthesis of naturally occurring substances, and it was while attempting a synthesis of quinine that Perkin discovered aniline purple, the first synthetic dye and the first of a series of discoveries which led to the founding of a coal tar dye industry.(380).

Despite the impetus which Hofmann gave to the new College the enthusiasm which had greeted the founding of the College declined. There was a withdrawal of financial support and after a while the College found itself in difficulties. The reason for the decline seems to have been that the popularity of chemistry which preceded the founding of the College was founded on a false premise that chemistry would provide a lightning cure for all agricultural ills. As Playfair says: "Every landowner then thought that agricultural chemistry was to be his salvation. Liebig's book was not a muck manual and did not produce the expected results;".(381) Government

support was not forthcoming and various suggestions were made as to how the College might be saved. One suggestion was that private investigations and analyses should be undertaken, while another was that exhibitions, evening lectures and conversaziones should be arranged. Such developments would have changed the whole character of the College and converted it from a school of research into a body more along the lines of the Royal Institution. Hofmann, not surprisingly disapproved of such changes, describes the members who supported the proposals as, "well meaning but ill advised," and gives the chief credit for the rejection of such ideas to Sir James Clark and other influential members who, "succeeded in convincing the Council that the only way of saving the College would be by confining themselves to the principal object contemplated in the foundation, viz., the advancement of science by means of practical instruction in the laboratories and by researches". (382) Fortunately, this view prevailed and it was decided that every effort would be made to retain the College in its original form. All unnecessary expenditure was cut, Hofmann gave up half his emoluments, property to the rear of the laboratories which had been intended for the future development of the College was sold, and together with a grant from the Council these measures enabled the College to embark upon a series of more prosperous years.(383)

However Sir James Clark was still anxious to establish the

College on such a basis that it would be unaffected by financial considerations. A still indifferent government gave no support until in 1852 an opportunity occurred with Playfair's resignation from the post of Professor of Chemistry at the School of Mines, which was connected with the Museum of Practical Geology in Jermyn Street. An amalgamation of the Royal College of Chemistry and the School of Mines was subsequently brought about, largely through the efforts of Sir James Clark and Lord Ashburton. Hence Hofmann became "Director of the Laboratory and Chemist to the Museum".(384)

While the move ensured the continuation of the work of the College it meant that it was now part of a geological institution and hence it lost a measure of its independence. Its work now became subordinated to the institution of which it was now part.

The transfer to the Government occurred on 7th July 1853. By this time a total of three hundred and sixty students had received a training at the laboratories of the Royal College of Chemistry, an average of forty five per year. When this is compared to the number of chemists which Thorpe suggested existed in 1837, one obtains some idea of how great was the achievement of the College. After 1853 the number of chemistry students at the College declined, the average number between the years 1853 and 1870 being thirty eight. The support of chemical education by the Government which might have been expected did not materialise and the work which Hofmann initiated in founding an English school of chemistry was

never fully exploited. Hofmann himself was probably aware of this for he resigned his chair on 30th June 1865 and returned to Germany.(385) The Prussian Government was prepared to support the study of chemistry and built extensive and palatial new chemical laboratories at the Universities of Bonn and Berlin. No expense was spared. The professor's apartments at the University of Berlin included a ball-room and the thoroughness with which the buildings were planned has been described in a report which Hofmann sent to the Department of Science and Art on 20th March 1866.(386)

At the same time the coal tar dye industry was passing into German hands. In 1863 the Badische Anilin Company erected a works at Ludwigshafen and by 1865 was employing sixty workers.(387) This time also saw the beginning of the return to Germany of the Germans who had first been attracted to this country by Hofmann, and who had been working in the coal tar dye industry. Caro returned in 1867, Martius about 1870, and Witt in 1879. This coincided with the retirement from business of the English founders: Nicholson in 1868, Perkin in 1874 and Greville Williams in 1877.(388) A discussion of the reasons for the decline of the coal tar dye industry lies outside the scope of this work.(389) Probably the death of the Prince Consort in 1861 played a part. Nevertheless, even though the country did not reap its full economic harvest from Hofmann's work, the Royal College of Chemistry continued to produce students who later made outstanding contributions to science, industry and

education.(390) Perhaps it is not too much to agree with Sir F.A. Abel in his comments about Hofmann's chemical work at the Royal College that,

> "the cultivation of that science became a branch of national education in this country through the invaluable combination of circumstances which placed England under a lasting debt of gratitude to August Wilhelm von Hofmann".(391)

CHAPTER VII

STATE AID FOR SCIENCE

1. THE FACTORS LEADING TO THE GOVERNMENT SCHOOL OF MINES AND OF SCIENCE APPLIED TO THE ARTS.

The Government School of Mines and of Science applied to the Arts, of which the Royal College of Chemistry became part in 1853, itself played an integral part in the development of English scientific education. Not only because it was a school which taught chemistry and other sciences, but because it was a result of both individual endeavour and government finance; and because it was the first institution in England devoted to the teaching of science which was to be wholly supported by government.

The roots of the school can be traced back to the pioneering work of a few geologists. The first geological survey was carried out by William Smith who published his "Map of the Strata of England and Wales" on the 1st August 1815. For this achievement, the embodiment of twenty years work, he was awarded £50 by the Society of Arts. (392) Subsequently in 1820 Greenhough's Memoir of a Geological Map of England was published. It had been produced on the recommendation of the Geological Society. (393)

Soon after the publication of Smith's map, Henry De la Beche, a young man imbued with a love of geology, became a Fellow of the Geological Society and after a visit to Jamaica in 1824, returned to begin a second geological survey of Great Britain. Working on a subject which was little known there was scant hope of government aid. However in 1832 De la Beche obtained permission to affix geological colours to maps recently published by the Ordnance

Survey. (394) Having once been brought to the attention of the Board of Ordnance he continued his work in connection with it, and so successful was he that in 1835 the Board of Ordnance consulted Buckland (Professor of Geology at Oxford), Sedgwick (Professor of Geology at Cambridge), and Lyell (President of the Geological Society), as to the advisability of combining a geological survey with the geographical one then being carried out. On their recommendation, which stressed the material benefits which might accrue, the Geological Survey of Great Britain was placed on a permanent footing under the direction of De la Beche. (395) Although the grant of £300 was inadequate and had to be supplemented by De la Beche, it was nevertheless a great step forward. His staff became the Ordnance Geological Survey of which he became director. It was at this time that De la Beche realised that his operations might be the nucleus of a national school of mining. However as Geikie says, "He was too sagacious a man to go before a British Minister of State with so ambitious a scheme." He did however communicate with the Government with a view to obtaining premises to house his geological specimens. (396)

At the same time there was a growing realisation that a mining record office was long overdue. De la Beche persuaded Thomas Sopwith, a well known mining expert, to put the case at the 1838 meeting of the British Association for the Advancement of Science, in Newcastle. (397) In a paper entitled "Suggestions on the Importance of preserving National Mining Records" Sopwith pressed home the

point that Britain's future prosperity was closely linked with her mining industry. (398) The British Association took action and a committee was appointed to communicate with the Government. The committee stressed the disasters which might have been avoided if records had been kept, and the result of the negotiations was that two houses, numbers 5 and 6 Craig's Court, were provided to house the national mining records and the geological collection. Two years later in 1841 the Museum was opened to the public. (399)

In 1839 a small chemical laboratory was opened and Richard Phillips, who had been a founder member of the Geological Society, a friend of Davy and Wollaston, and who was later to become President of the Chemical Society; was appointed analytical chemist. The laboratory became popular and government assistance was often provided. Sir Robert Peel who had been a sympathetic figure during the negotiations sent specimens of iron ore from Drayton Manor. (400) The chemist's duty was, "to conduct the analysis of metallic ores, and other minerals and soils...", and it is clear that he took pupils for in 1840 we learn that, "The pupils in this laboratory are already actively employed in learning the arts of mineral analysis, and the various metallurgical processes." (401)

Meanwhile the work of the Geological Survey was progressing and in 1845 it was transferred by Peel from the Ordnance Survey to the Department of Woods and Forests. Hence it came under the same control as the Museum and the Mining Record Office in Craig's Court.(402)

The organisation was now suitable for the school which De la Beche envisaged and he was already in the process of recruiting a staff of teachers. One such teacher in whom he took a particular interest was the chemist Lyon Playfair. De la Beche was anxious to secure the services of Playfair, and as early as 1842 when Playfair had been offered the appointment in Toronto, he had proposed that Phillips be offered an alternative appointment so that Playfair might join the staff of the Museum. Peel agreed to Playfair's appointment at a salary of £400 per annum provided that Phillips was prepared to resign voluntarily. Phillips however was not inclined to resign, and despite vigorous efforts on the part of De la Beche, the proposals fell through. (403) Subsequently Playfair was appointed Chemist to the Geological Survey with a laboratory in Duke Street, Westminster. Here he continued his work with Joule, which had been begun in Manchester, on the atomic volume of salts. (404)

Andrew Crombie Ramsay had joined the Survey in 1841 as assistant geologist (405), Edward Forbes, who had been Professor of Botany at King's College, London, was appointed paloeontologist in 1844, Warington Smyth was appointed mining geologist in the same year, and Robert Hunt was appointed as Keeper of the Mining Records in 1845. (406)

By this time the quantity of material which had been acquired by the Geological Survey had become embarrassingly large. De la Beche took advantage of the wave of interest in science, which had begun

with Liebig's visits and which reached its culmination in the Great Exhibition of 1851, to press his claims for new premises for his collections. In 1848 the Government agreed to a site being provided between Jermyn Street and Piccadilly, and on 12th May 1851 the new Museum was opened by the Prince Consort. (407)

De la Beche was now poised for the fulfilment of his great ambition: the founding of a national technical school whose main function would be to teach mining and metallurgy and their associate science geology, but which would also provide teaching in chemistry, physics, biology and other subjects. The teaching of these subjects had been authorised as early as 1839 but with neither finance nor facilities nothing had been done. (408) However by the time the new Museum was opened the need for a more scientific approach to coal mining was becoming more widely recognised.

The loss of life in mine accidents had been diminished by the introduction of the Davy and Stephenson lamps but ignorance still led to many fatalities. Lord Ashley's Coal Mines Act of 1842 eradicated some of the evils associated with the employment of women and children in the mines and focused attention on the evils of the mines. (409) In 1844 Lyell and Faraday reported on the cause of the explosion at the Haswell Colliery, in County Durham, and in their suggestions as to how such accidents might be prevented in the future, commented on the dangers which were the result of the ignorance of the colliers with regard to simple scientific matters. They suggested that, "They might be taught, for example, such simple

parts of chemistry and pneumatics as relate to the nature of gases and air; the first principles of hydrostatics and of geology,...."

They further commented that,

> "In countries such as France and Germany, where a far less amount of capital is embarked in mining enterprises, there are large schools of mines and scientific establishments, in which professional men of different grades are carefully instructed in those branches of Knowledge which are closely connected with the arts of mining."(410)

Between 1845 and 1850 De la Beche and other members of the staff of the Museum were often called upon to investigate explosions in mines and in 1849 the Report of the Committee of the House of Lords commented on the need which was being felt for a mining school.(411) In 1850 the need became still more pressing because the passing of the Coal Mines Inspection Act in that year introduced the inspection of mines with a view to preventing accidents. (412) For the implementation of the Act inspectors were needed and consequently an institution in which they could be trained.

The result of these various pressures was the founding of the Government School of Mines and of Science applied to the Arts which was opened on 6th November 1851. De la Beche had succeeded in adding the School to the Museum of Practical Geology, the Mining Record Office and the Geological Survey. The School occupied the same Jermyn Street premises as the Museum. The staff consisted of De la Beche, Lyon Playfair (chemistry), Edward Forbes (natural history), Robert Hunt (mechanical science), John Percy (metallurgy), Andrew Crombie Ramsay (geology) and Warington W. Smyth (mining and

minerology). (413) It has been said that this was the most able teaching staff which had ever been brought together in England at that time. (414)

Despite the quality of the teaching which was made available, the early years of the school were not auspicious ones. Few students presented themselves and in the first year there were only seven matriculated students entered for two years and about twenty occasional students. The number of occasional students was often quite high, but many of these students were ladies who attended the School because it became the fashionable thing to do. The average number of matriculated students in the first eight years of the School's existence was a meagre fourteen. (415)

2. THE INFLUENCE OF THE GREAT EXHIBITION OF 1851.

The year 1851 brings us to an event which was to prove so important in the history of scientific and technical education, and which was to affect the future of the Government School of Mines, the Royal College of Chemistry, and indeed all existing bodies which were concerned with science teaching, that it is necessary to discuss it before proceeding further. The Great Exhibition which has been described as, "the starting point of scientific education in this country" (416) grew out of the exhibitions of the Society of Arts. This society had been founded in 1754 in order to encourage

the progress of the industrial arts by the award of prizes. (417) It had enjoyed a successful history, but by 1843, the year in which the Prince Consort became President, the Society was in a state of financial distress. At this time Francis Whishaw was secretary to the Society and in 1844 he visited national exhibitions in Paris and Berlin. He was so impressed by these that he determined to organise a similar if less ambitious exhibition in London. His first exhibition which he organised and financed himself was held on 6th December 1844. This effort was sufficiently successful to inspire the Society to finance a similar exhibition in the following month, at which eight hundred people attended.

Whishaw's next step was to outline his proposals on the occasion of the Prince Consort's annual visit to the Society. The reaction of the Prince was to request that the plan should be presented to him when it had been developed in a practical form. This was deemed to be sufficient approval and a "National Exhibition Sub-Committee" was appointed, whose function was to raise finance and determine the degree of support among the manufacturers. However the results of these enquiries were disappointing and the scheme was for the time being abandoned. (418)

Instead it was proposed to extend the prize competitions of the Society with the hope that they would provide exhibits for future exhibitions which might prove to be forerunners of a national exhibition. The first of these exhibitions was held in May 1847. It proved to be a great success attracting over two thousand visitors;

but perhaps the greatest success of the prize competitions lay in bringing Henry Cole into the Society. (419)

Cole (1808-1882) was a versatile man with exceptional qualities of zeal and initiative. At the time that he became associated with the Society of Arts he had already figured in postal reform, had published books, was a talented water colourist and was much in demand as a publicist.(Cobden had offered him the post of secretary in the anti-Corn Law League in 1839). (420)

Following the success of the 1847 exhibition, further highly popular exhibitions were held in 1848 and 1849; and as a result of this the Society of Arts announced that its first national exhibition would be held in 1851. (421) However what was to make the 1851 exhibition unique was that it was the first international exhibition ever held and according to Playfair the credit for this development is shared equally between Cole and the Prince Consort; although the idea of an international exhibition was first proposed by M. Buffet, the French Minister of Agriculture and Commerce. (422) Sir Robert Peel gave his approval to the proposals but warned that the Prince should not be publicly associated with the project until the support of the manufacturers had been assured. (423)

From the minutes of a meeting held at Buckingham Palace on the 30th June, 1849, we learn that the Prince suggested a classification for the exhibition and pointed out the suitability of a site in Hyde Park. He further proposed that a Royal Commission be appointed under the leadership of himself, which would be responsible for the

execution of the work. This commission was to include members of the Society of Arts who had been active in the original preparations for the exhibition. The Society of Arts was to remain responsible for the raising of money. (424)

Subsequently events progressed rapidly and the names of the Commissioners were published on 3rd. January 1850. They included Sir Robert Peel, Lord John Russell, William Ewart Gladstone, Sir Charles Lyell, Richard Cobden, William Cubitt the engineer, and Philip Pusey the agriculturalist. (425) All was not well however with the preparations for the exhibition. It was being found difficult to raise funds, but the difficulties were somewhat alleviated by a brilliant speech made by Prince Albert at a Mansion House Banquet on 21st March 1850. He saw the exhibition as, "a true test and a living picture of the point of development at which the whole of mankind has arrived in this great task, and a new starting point from which all nations will be able to direct their further exertions" (426)

In spite of this subscriptions remained a source of concern, the Government being particularly anxious in view of the fact that the Prince was now publicly associated with the exhibition. One reason for the lack of support was that the rigid classification for the exhibition which had been decided on by the Prince Consort was unwieldy. According to this system the exhibits were to be classified into three sections:

(1) The Raw Materials of Industry

(2) The Manufactures made from them

(3) The Art employed to adorn them.

The general concern which was being felt led the Government to ask Playfair, who had shown an interest in the exhibition, to accept the post of "Special Commissioner". Playfair was reluctant to accept, fearing that his appointment would lead to jealousies, and also because he realised that his scientific work was now in danger of being permanently eclipsed by his public duties. At the same time De la Beche was anxious to retain one of his most distinguished members of staff and he supported Playfair's objections. Playfair however, was unable to refuse the request when Peel made a personal intervention and reminded him of the patronage which he had shown him in the past. As Playfair says of Peel: "I owed everything to his kindness." Consequently he accepted on condition that he could consult Peel about any difficulties which arose. The qualities of tact and charm which Playfair possessed were soon tested, for on the second day after his appointment he met Cole, who was on his way to resign, walked him up and down Whitehall, and finally persuaded him to destroy his letter of resignation.

The first task which Playfair took in hand was to draw up a new classification of twenty nine sections. The Prince Consort clung rather tenaciously to the original classification, but after his objections and those of the foreign Commissioners had been overcome, there occurred, among the manufacturers at least, "a marked change in favour of the Exhibition." (427)

Nevertheless many difficulties remained and there was still political opposition. The proposed site in Hyde Park caused much wrath, and in particular the fate of ten elm trees which were growing on the site. The elderly Lord Brougham, Punch, and the protectionists, were all united in their criticism of this demonstration of peace and free trade. The result of the objections, some of which were understandable, but some of which Playfair describes as "puerile and absurd", brought the Prince into disfavour and threatened to bring an end to the scheme. (428)

In the midst of these difficulties the death of Peel on 2nd July 1850 caused the Queen and the Prince great distress. The accident from which he died occurred only a few hours after he had attended a meeting of the Commissioners. (429) Ironically the effect of the tragedy seems to have been to nullify much of the criticism of the exhibition. Motions attacking the exhibition were defeated in the Commons on 4th July and a change of heart seems to have occurred almost spontaneously. Shortly afterwards the Prince was able to record in his diary, "The feeling respecting Hyde Park is quite changed." (430)

The last great difficulty to be overcome was the building.(431) Once Joseph Paxton's design had been approved, the erection of the Crystal Palace was accomplished at a speed which at that time was unrivalled. It was revolutionary in its construction, and according to C.R. Fay the structure was, "in advance.... of much of the practice of the building industry in 1950." (432) The opening of

the Great Exhibition on 1st May 1851 was a brilliant success. Congratulations flowed in and the Queen was able to record: "Albert's name is immortalised, and the wicked and absurd reports of dangers of every kind.... are silenced." (433)

If the Prince Consort deserves the major share of the credit for the planning of the Exhibition, then the Queen must surely receive the credit for helping to make it fashionable. She made a total of forty three visits which is more than one third of the days for which the Exhibition was open. The royal children were usually conducted by Playfair. (434)

The Exhibition closed on 15th October 1851. It had been an enormous success and it was estimated that the profit from it would be in excess of £150,000 (435) The disposal of this sum was the problem which now faced the Prince and the Commissioners. The Prince first suggested his views in a memorandum dated 10th August 1851. He proposed that the surplus should be invested in land and that twenty to thirty acres of ground lying almost opposite to the Crystal Palace should be purchased. On this site he suggested that four institutions should be built each of which should be devoted to one of the following: Raw Materials, Machinery, Manufactures, and Plastic Art. The institutions were to include libraries, lecture rooms, exhibitions, and rooms for study, meetings, discussions etc. He further suggested that accommodation might be offered to the learned societies so that they might be brought

together on one site. (436)

Just how clearly the Prince saw the role which scientific education was to play in the future prosperity of nations is shown by a similar memorandum which is quoted by T. Wemyss Reid.

> "The improvement in locomotion, the increased means offered by science for the extraction, preparation, or culture of the raw material, have lessened the peculiar local advantages of certain nations, and thus have depressed the relative value of the raw material as an element in manufacture; while they have immensely increased the value of skill and intelligence as the other great element of production."

And again after commenting on the systems of technical instruction which had by that time been developed in France and Germany.

> "But in England the progress of science is daily equalising more the distribution of raw materials, and depriving us of those local advantages.... it is an obviously growing necessity that it should afford to its manufacturers the means of acquiring that knowledge without which they cannot long keep foremost in the struggle with nations." (437)

The proposals met with a mixed reception. The learned societies disliked the idea of becoming part of a much larger scheme. (438) Playfair, who from the time of his appointment as a Special Commissioner had been active in the progress of the Exhibition, particularly with regard to the organisation of the juries, was generally in support of the Prince's plan. The views of Sir Henry De la Beche were solicited in a letter dated 20th August 1851, in which Playfair outlined his own view of the proposals. He recommended that the School of Mines should become a central college empowered to grant degrees and that a second central

institution should be linked to the existing schools of design.(439)

The final surplus from the Exhibition was £186,436. (440) The Second Report of the Commissioners deals with the disposal of this sum. After discussing the various suggestions which have been made it concludes that the best way of disposing of the surplus is by founding an instution which would "serve to increase the means of Industrial Education, and extend the influence of Science and Art upon Productive Industry." It comments on the lack of space at many existing institutions and mentions along with others the difficulties of the School of Mines and the Royal College of Chemistry. As a result of this lack of space and organisation and also due to a realisation that British industrial supremacy was being challenged, the Commissioners purchased, with the aid of a grant of £150,000 from the Government, seventy acres of land comprising the "Gore House Estate" and the "Villars Estate". (441) Subsequently seventeen acres of the "Harrington Estate" were purchased. (442)

The Prince wished to see all the great institutions of London including the National Gallery and the Royal Academy brought to "South Kensington". In addition to this he anticipated a Museum of Art and a Museum of Science. (443) The degree to which these proposals have been accomplished lies outside the scope of this work (444) except to mention that during the next fifty years such institutions as the Royal Albert Hall, the Imperial Institute, the Science Museum, the Royal College of Art, and the Victoria and

Albert Museum, gravitated to, or originated at South Kensington. Today the Imperial College which incorporates the Royal College of Science, the Royal School of Mines and the City and Guilds of London Institute, occupies the site.(445) Another valuable proposal which has since come into being was Playfair's suggestion that scholarships should be set up. It was on such a scholarship that Rutherford came to England.(446)

This was one important effect of the Great Exhibition: one other was the founding of the Department of Science and Art. The origin of the Department can be traced back to the founding of a school of design in Somerset House in 1837. By 1851-1852 the parliamentary vote for this school and the associated provincial schools which subsequently developed was £15,000. This sum was administered by the Department of Practical Art under the Board of Trade. (447)

The Department of Science and Art was set up in 1853. Playfair was appointed secretary of the Science Department and Cole secretary of the Art Department. In 1857 the Department became part of the new Education Department. (448) Playfair remained in office administering the science division until 1858 when he made an attempt to once again take up his scientific pursuits as Professor of Chemistry at Edinburgh. It was during this period that following the Exhibition Playfair began his crusade for increased provision for technical and scientific education: a crusade which

he was to keep up for forty years: a difficult task, which he described as "weary and dreary work". (449)

The third important effect of the Exhibition was the series of lectures which was delivered under the auspices of the Society of Arts. These Lectures on the Results of the Exhibition of 1851. had been organised at the suggestion of the Prince Consort and the first lecture was delivered on 26th November 1851 by the Rev. W. Whewell on "The General Bearing of the Exhibition on the Progress of Art and Science." Playfair lectured on "The Chemical Principles involved in the Manufactures shown at the Exhibition, as a proof of the necessity of an Industrial Education". Other speakers included Del la Beche, Jacob Bell and Henry Cole. A recurrent theme in the lectures was the necessity for more scientific education if Britain was to retain her leading position as an industrial nation. (450)

The Great Exhibition therefore led to an increased consciousness of the importance of scientific study and to a period of increased activity in scientific education.

How did the Exhibition affect the Government School of Mines? According to Forbes the uncertainty regarding the disposal of the Exhibition surplus prevented students from coming forward. With the founding of the Science and Art Department in March 1853, the School along with the Museum of Practical Geology, the Geological Survey, The Museum of Irish Industry, the Royal Dublin Society, and the Department of Practical Art, all came under its control. At about the same time the Royal College of Chemistry became the

chemistry department of the School of Mines. It was envisaged that the School would teach a wider range of scientific studies but the School was destined to continue for several years in uncertain fashion before all the hopes of its founders were fully realised.(451)

CHAPTER VIII

THE REFORM OF SCIENCE AND SCIENTIFIC INSTITUTIONS

At the beginning of the nineteenth century the institutions in England which provided for teaching or investigations in science were very few. The ancient universities, the medical schools, the newly-founded Royal Institution, the dissenting academies and the provincial scientific societies have already been mentioned. The Royal Society was the sole large organisation which was devoted wholly to the advancement of science. It depended for its existence however entirely on the entrance payments and contributions of its members, plus any donations which might be made to it.(452)

A comparison with French science is illuminating. Even before the Revolution France had many great scientific schools. In addition to these there existed a large number of provincial academies of science, some dating from the seventeenth century. A number of these were affiliated to the Academy of Sciences in Paris, which from as early as 1671 had received government funds, and had been responsible for carrying out research and publishing the results of its inquiries.(453)

The effect of the Revolution was to make science in France no longer merely "a fashionable pursuit, a luxury of the great," but a subject of educational and practical importance. Science was held in such high regard that it was felt that the greatness of the nation depended upon the state of science and its place in national education.(The Ecole Polytechnique was one sign of this). (454) France was therefore the first nation to encourage scientific

research, provide an organisation in which it could flourish, and realise that the dissemination of its findings was a factor in national prosperity. Merz considered that the French scientific schools remained supreme during the first three decades of the nineteenth century.(455)

In Germany the scientific spirit found conditions which were ideal for its growth, since the German universities by the early nineteenth century had reached a position of great eminence and were imbued with a philosophy of learning extremely sympathetic to the methods of scientists. The University of Göttingen was inaugurated in 1737 and in this university the faculty of philosophy became equally as important as the traditional German faculties of theology, law and medicine. It became the function of the faculty of philosophy to seek after truth for its own sake. Hence the university teacher combined the profession of teacher with the practice of research. In addition the close relations with the high schools and technical schools meant that teachers in these schools looked upon private research as a necessary qualification for a schoolteacher.(456)

In this way the German universities laid the foundations of Wissenschaft, (457) and although it was the work of humanists it is clear that the German universities evolving in an atmosphere of Wissenschaft provided a climate of opinion which was sympathetic to the scientific spirit. It was not until the second quarter of

the nineteenth century that science began to enter the universities there being some opposition due to the influence of Naturphilosophie: a movement which opposed the empirical approach to nature and the collection of data. Its influence was marked between 1797 and 1831. Meanwhile scientific studies in Germany were carried on at many small centres outside the universities, the result of this being that scientific periodicals became well established as a consequence of the scientists not being concentrated at a few great centres.(458) It was against this background of Wissenschaft that Liebig's laboratory at Giessen flourished only a short time after the weakness of scientific instruction in Germany had compelled him to seek his scientific education in France. Hence German scientists arose who were characterised by their thoroughness and power to communicate ideas to others, and their ability to recognise and nurture talent. Surrounded by others of like mind, whose work touched upon his own, in a university which was sympathetic to his aims, the German scientist felt his function to be the further exploration of the field of science.(459).

How did English science compare at a time when French Academicians and German professors were enjoying institutionalised support? Certainly such lack of support did not prevent English scientists from making major contributions. Davy, Faraday, Young, Dalton, Wollaston and Graham were all scientists of the first rank. With such an array of brilliance it might seem strange that the eighteen

twenties and thirties were to see an increasing criticism of English science. If the progress of science had been measured solely in terms of the work of these gifted men then there would have been little to criticise in English scientific institutions, but as has been pointed out, "such original work with little training is possible only for a few and probably only at certain stages in the development of a science." (460) The result of the situation was that England produced a few brilliant original workers but failed to produce a large body of trained scientists.

To a large extent scientists worked in isolation. Consequently little notice was taken of other worker's results, papers were often not brought before a wide audience, and discoveries were often delayed because of lack of assistance.(461) It is however interesting to recall that it was similar conditions in Germany which led to a flourishing scientific literature. Despite these comparisons between Britain and other European countries the opinion has been expressed that, "the British government patronised science perhaps more in the first half of the nineteenth century than in either half century on either side." (462)

It was during the first half of the nineteenth century also that attempts were made to reform the Royal Society. Since 1778 it had been under the autocratic control of its President Sir Joseph Banks. He remained to control the Society's affairs until his death in 1820.(463) The presidency of Sir Joseph Banks coincided

with that period of popular interest in science which characterised the end of the eighteenth century, and which has been discussed in Chapter I. This interest led to the founding of a number of societies which were devoted exclusively to a particular branch of science. The first of these was the Linnean Society founded in 1778. This was founded with the approval of Banks and, as we have seen, he actively co-operated in the founding of the Royal Institution. Similarly the founding of the Society of Animal Chemistry which included among its members Davy, Brodie and Brande, and for a short time Cavendish, received the approbation of Banks. This was because the Society was to be subservient to the Royal Society, to which body all its communications would be presented. Such a situation suited Banks since it served, "to strengthen the foundations of the ancient edifice," rather than to weaken it in any way.(464)

Subsequently however, he opposed the formation of new societies seeing their independence as a challenge to the Royal Society. In particular the founding of the Geological Society (1807) and the Astronomical Society (1819) met with his disapproval. As he commented: "I see plainly that all these new fangled associations will finally dismantle the Royal Society, and not leave the old lady a rag to cover her." Although Sir Joseph's fears have proved to be unfounded one effect of the specialised societies was that the Philosophical Transactions was no longer the sole vehicle for the publication of scientific papers. Indeed between the years

1800-1830 the Philosophical Transactions is said to have not published a single paper on botany.(465).

Although Sir Joseph's administration of the Royal Society was marked by dissension, each successive attack on his leadership served only to tighten his control over the affairs of the Society (466) At the beginning of his long reign Sir Joseph had expressed the intention of examining more closely the qualifications of those who entered the Society, but such promises were not fulfilled, and that part of his presidency which carried on into the nineteenth century was characterised by stagnation and inefficiency.(467) Banks envisaged two kinds of members: those who were contributing directly to science, and those who by virtue of position or wealth contributed indirectly by promoting science. Since approval by Banks was a necessary qualification to entry; not surprisingly Sir Joseph created a certain degree of animosity especially among rejected candidates.(468)

Sir Joseph's long tenure of office came to an end with his death on 19th June, 1820. He was succeeded as President by Dr. W.H. Wollaston, who had studied medicine at Cambridge and had subsequently turned to the study of science; with great success being the discoverer of the elements palladium and rhodium. However Wollaston was unwilling to continue in office and was succeeded by Davy.(469)

With the election of Davy the Royal Society took its first

step towards reform. For the first time a majority of the Council were scientists, and this acknowledgement of the superior claims of the scientists led to an increase in the attendance at Council meetings.(470) Unlike Banks Davy welcomed new scientific societies, realising that science had outgrown one central body, and he expressed a desire for amicable relations with the new societies.(471) Davy's presidency was marked by a number of investigations carried out by the Society for the Government. The most famous of these was Davy's research on the corrosion of the copper sheathing on naval vessels.(472)

During the eighteen-twenties the admission to membership of the Royal Society remained a vexed question. It appears that at this time admission was almost a formality for anyone proposed. A committee, appointed by the Council, which reported in 1827 recommended that until the membership be reduced to four hundred, only four new members should be elected annually. The committee consisted of Wollaston, Young, Davies Gilbert, South, Herschel, Babbage, Beaufort and Kater, several of whom as we shall see were to play an important part in subsequent events. The Council referred the matter to the following year, at which time the Council, under the presidency of Davies Gilbert, rejected the reforms.(473) The failure to effect this reform which would have served to strengthen the scientific representation, together with other irritations which have been discussed earlier combined to create

even more dissatisfaction with the organisation of English science.

Isolated criticism had been made before this time; in particular from the eminent astronomer John Herschel. In his "Treatise on Sound" in the Encyclopaedia Metropolitana he compares unfavourably, "the crude and undigested Scientific matter which suffices (we are ashamed to say it) for the monthly and quarterly amusement of our own countrymen," with the Annales de Chimie and the journals of Poggendorff and Schweigger. The article goes on:

> "It is vain to conceal the melancholy truth. We are fast dropping behind. In mathematics we have long since drawn the rein, and given over a hopeless race. In chemistry the case is not much better. Who can tell us anything of the Sulfosalts? Who will explain to us the laws of Isomorphism? Nay, who among us has even verified Thenard's experiments on the oxygenated acids, Oersted's and Berzelius's on the radicals of the earths, -Balard's and Serrulas's on the combinations of Brome,- and a hundred other splendid trains of research in that fascinating science?" (474)

Even Davy, by the end of his life, was ready to say of science that, "it is followed more as connected with objects of profit than those of fame, and these are fifty persons who take out patents for supposed inventions for one who makes a real discovery."(475)

However, such criticism, even from these distinguished men, produced no effect.(476) But in 1830 Charles Babbage's Reflections on the Decline of Science in England, and on Some of its Causes, was published. Babbage was Lucasian Professor of Mathematics at Cambridge and the book was written in such a spirit that it could not fail to command attention. The largest part of the book is

devoted to an attack on "the party" which controlled the affairs of the Royal Society. There are few aspects which escape attention: irregularities and alterations to the minutes, extravagance in the preparation of the Philosophical Transactions, an award of the Royal Medals which contravened the regulations, and criticism of an award of a medal to Wollaston for his discovery of a method of making platinum malleable, (a discovery which Wollaston had patented and had hence not made immediately available to science); and the revelation that an award had been made to Colonel Sabine for what Babbage shows to be inaccurate work. In particular he criticises the method of becoming an F.R.S. of which he comments:

> "if A. B. has the good fortune to be perfectly unknown by any literary or scientific achievement, however small, he is quite sure of being elected as a matter of course. If, on the other hand, he has unfortunately written on any subject connected with science, or is supposed to be acquainted with any branch of it, the members begin to inquire what he has done to deserve the honour; and, unless he has powerful friends, he has a fair chance of being blackballed."(477)

The quotation serves to illustrate the vein of sarcasm which runs through the book and the polemical spirit in which it is written. Despite this, much of the criticism of the Royal Society was justified, and some of the suggestions, such as publishing abstracts of the Philosophical Transactions, were constructive.

With his criticism of English science he speaks less convincingly. Obviously he feels strongly about the failure to honour scientists, comparing this country unfavourably with France, and

protests about the way in which science has not been an important part of the studies at the ancient universities. It is also apparent that he clearly discerns the English preoccupation with the material benefits of science, for he criticises the lack of honours given to those scientists who discover the principles on which future inventions may be based.

But perhaps his most telling evidence is an appendix which consists of a "List of the members of the Royal Society, who have contributed to the Philosophical Transactions, or have been on the Council." This shows that of one hundred and fourteen members who had been on the Council seventy six had never published a paper in the Philosophical Transactions. On the other hand there were eleven members who had published five or more papers who had not been on the Council. Clearly the Royal Society had become an association of amateurs over which the professionals had little control.

The effect of Babbage's work was to produce a great public debate. A specific charge of altering the minutes, which had been made by Babbage (478) was defended in a letter to the Philosophical Magazine, by the Secretary P.M. Roget.(479) Babbage replied to the letter and effectively exposed the fallacies in Roget's arguments. (480) Further attention was called to the matter by a review of the Reflections on the Decline of Science in England, which concurred with its arguments, particularly decrying the failure to honour

scientists, and pointing out the superior treatment of scientific men in France, Germany, Russia, Sweden and Norway.(481) While in England, it is stated, "There is not a single philosopher who enjoys a pension, or an allowance, or a sinecure, capable of supporting him and his family in the humblest circumstances!"(482) The writer makes the suggestion that the wretched condition of science might be ameliorated by allowing professorships at universities to be filled by two men, one of whom would teach leaving his more eminent colleague free to pursue research. Furthermore, he urges the learned societies, and in particular the Royal Society, to make greater efforts to induce the Government to reward scientists.(483)

There were those however who felt that Babbage had gone too far. One of these was Faraday, who while professing not to take sides in the argument published a pamphlet by G. Moll of Utrecht "On the Alleged Decline of Science in England, by a Foreigner" which praised the breadth of study of English scientific men and criticised the preoccupation of the "Declinarians" with honours and wealth (484). Brewster replied with a critical review in the Edinburgh Journal of Science (485).

Faraday's objections were not to the attack on the Royal Society, but only to the overall condemnation of English science, and he was later to be on the side of the reformers when it came to the election of the next President.(486)

The success with which Babbage had pressed home the charge of

falsifying the minutes had by this time made the position of Davies Gilbert untenable, and while he had privately decided to resign, he determined that there should be no surrender to the professionals and that he should retain a position on the Council. Consequently, without informing the Council, and confident of their acquiescence, he made overtures to H.R.H. the Duke of Sussex proposing that the Duke stand for election for the presidency of the Royal Society. Rumours of Gilbert's actions reached the ears of a number of Fellows, who requested that any negotiations be made public. The result was that the President and Council called a meeting at which the reformers passed a resolution to the effect that only practising scientists be eligible for election to the Council, or to serve as Officers. What is more it was proposed by Herschel and seconded by Faraday that a list of fifty Fellows should be drawn up. This list would include the present members of the Council and would be circulated to all Fellows so that they might be able to make a free choice for membership of the Council, instead of merely approving the Council's nominees. The resolution was duly passed, and the list from which the ten vacancies on the Council were to be filled was drawn up, and found not to include the Duke of Sussex. The cause of reform seemed to have triumphed.(487)

However, the jubilation of the reformers was premature. Davies Gilbert, and his followers, as has been pointed out, "were

amateurs only in science, and not in the art of politics." (488) Davies Gilbert calmly pointed out that the actions of the reformers had no validity as they had not been approved by the Council, and proceeded to renew his campaign for the Duke of Sussex. The perplexed reformers quickly drew up a "Declaration of support for John Herschel" and Babbage set about canvassing support for his candidate.

Ironically it was Babbage who was to cause the campaign to be lost. Having ascertained the degree of support he was so confident of victory that he informed a number of Fellows living outside London, that they need not trouble themselves to vote. Sadly he had erred in his estimate. The result of the vote was one hundred and ninetten votes to H.R.H. the Duke of Sussex and one hundred and eleven votes to John Herschel.(489)

The reformers had for the time being been well and truly defeated. The reforms for which they had fought were to be accomplished in the eighteen-forties, but meanwhile they were to devote themselves to an organisation to cater for the needs of professional scientists. The defeat of the reformers had left them frustrated and disappointed and although some, such as Faraday, continued their association with the Royal Society, others like Babbage and Herschel withdrew their support. The new organisation was the British Association for the Advancement of Science. It has been claimed that the founding of the British Association

resulted directly from this failure to effect the reform of the Royal Society.(490) On the other hand it has been stated that this is not so. In connection with this it is interesting to note that Herschel did not at first give his support to the British Association.(491) Certainly as we shall see the vigour of provincial scientific societies played an important part in its success.

From what we have already seen it is clear that the critics of English science viewed the situation on the Continent with a mixture of admiration and envy. It is not surprising therefore that an existing German scientific organisation, the Deutscher Naturforscher Versammlung, should catch their imagination. This was founded by Lorenz Oken (1779-1851) who in 1817, while Professor of Natural History at Jena, began a monthly literary and scientific magazine called the Isis. It was in the Isis that he first made the suggestion that an annual meeting of German scientists be held. Unfortunately Oken had made himself unpopular through the political views expressed in the Isis, and consequently the first meeting held at Leipzig in 1822 attracted little more than thirty people. At subsequent meetings held in different German towns the numbers grew, suspicion diminished, and after the Berlin meeting of 1828 the movement became accepted and established.(492)

Charles Babbage was the sole British representative at the 1828 meeting and on account of the proceedings there is appended to his Reflections on the Decline of Science in England. (493)

The admiration of Germany is apparent and according to Babbage, "there is no country in Europe in which talents and genius so surely open for their possessors the road to wealth and distinction." (494) On the first evening he tells us, twelve thousand people including the King of Prussia, Frederick William III, attended a soirée given by Alexander von Humboldt. For the remaining six days papers were presented and discussed at various sections and each scientist was able to attend the section in which he was most interested.(495)

At the Hamburg meeting in 1830 J.F.W. Johnston was a visitor, Berzelius, Liebig and Oersted were among the distinguished arrivals. The proceedings consisted of a series of meetings of sections: each section devoted to a particular branch of science. Papers were read, the quality of which, according to Johnston, varied considerably, and there also general meetings and excursions. The primary object of the Deutscher Naturforscher Versammlung was to stimulate the progress of science by bringing scientific men together. After reviewing the benefits which it is hoped to derive, Johnston concludes: "Such and similar benefits have already resulted from the meetings in Germany. Might not similar results in our own country be looked for from a similar institution?" (496).

This then provided the model for the British Association for the Advancement of Science. On the 21st February 1831 Brewster wrote to Babbage with the news that he had been reading a "very interesting account of the different meetings of the German natur-

alists" and enquiring whether Babbage favoured the founding of a similar body in England. The suggestion met with an enthusiastic response.(497) Brewster then took the step of proposing to John Phillips, the secretary of the Yorkshire Philosophical Society, that the first meeting should be held at York, and that the Philosophical Society should co-operate in the organisation. Fortunately Brewster had chosen wisely, for the proposals were well received by John Phillips and the Reverend Vernon Harcourt, the principal officers of the Society. They succeeded in securing the support of the Corporation of the City of York and the first meeting was held on Monday 26th September 1831.(498)

On the following day a general meeting was held. Various speeches and statements were made and a letter from the Duke of Sussex, who had been invited to attend, was read. This was couched in warm terms and while unable to attend the Duke assured the meeting of his future co-operation.(499) Vernon Harcourt formally proposed the formation of a British Association for the Advancement of Science and laid down a series of resolutions which formed a statement of the aims and rules of the new Association. The address is interesting for it denies the decline of science in England, but on the contrary Vernon Harcourt insists that the proliferation of scientific institutions makes such a body as the British Association a necessity. As far as he was concerned it was only relative to Continental countries that science had declined.(500) The British

Association was also made necessary by the Royal Society since it "no longer performs the part of promoting natural knowledge by any such exertions as those which we know propose to revive. As a body it scarcely labours itself and does not attempt to guide the labours of others"(501) Yet the progress of science and the formation of specialised societies was resulting in the insulation of one group of scientists from another. The British Association would help to overcome this problem.(502) Another great advantage would be the contact with fellow scientists for, according to Vernon Harcourt, "no solitary industry or talent can ever hope to equal the power of combined wisdom and concerted labour." An even greater incentive would be requests by the Association to conduct an investigation and present the results at the next meeting.(503)

Murchison attended the first meeting and in his account he reveals that while he strongly supported the formation of the British Association, and canvassed support among his friends, his efforts were for the most part without success. As to the meeting itself, he confesses that, "the feebleness of the body scientific was too apparent". (504) Nevertheless the founders were enthusiastic about the venture and the brilliance of supporters such as Brewster and Dalton was sufficient to convince Murchison that the venture must not be allowed to falter.(505)

The organisation of the British Association was clearly derived from the Deutscher Naturforscher Versammlung. In 1831 there

were "sub-committees" for mathematics and physical science, chemistry, minerology, geology and geography, zoology and botany, and mechanical arts. These groupings were to vary over the next few years. By 1835 some degree of stability had been achieved and the sections, as they were by this time called, were for mathematics and physics, chemistry and minerology, geology and geography, zoology and botany, anatomy and medicine, and statistics. Later changes were to occur as the growth of science made subdivision, and sometimes addition, of sections necessary. One of the most valuable functions of the sections was to call for reports on the state of science. The value of such reports cannot be overstressed for they provided guidance to workers as to the most profitable lines of research, and brought to their notice, in a form which was easy to assimilate, any new discoveries.(506)

It was originally envisaged that membership of the British Association should be restricted to members of Philosophical Societies: a restriction which in fact was not maintained. In addition to the annual meetings and reports, the British Association performed a valuable service in its awards of grants for research. The first of these grants was awarded in 1834. (507) Grants for chemistry included £10 : 10 : 6 in 1839 for a study of animal secretions and £5 : 0 : 0 in 1848 for a study of colouring matters used in the arts: both reflect important chemical interests of the time. (508)

During our period of study the British Association for the Advancement of Science was largely concerned with promoting science and it was only at a later date, when science had consolidated its position, that the British Association turned its attention to the associated problem of scientific education. Thus public lectures were not instituted until 1867 although informal attempts at working class scientific education were not unknown before that time. (509) For example at the Newcastle meeting in 1838, Sedgwick tells us: "On the Friday of the Association week I went to the mouth of the Tyne with a geological class of several hundreds, and nearly all the population of Tynemouth turned out to join us". (510) Murchison described a similar incident during the Glasgow meeting of 1840. (511)

It would be a mistake to conclude from the foregoing that the British Association was founded without opposition. Even before the first meeting Murchison recounts, "the scheme was for the most part pooh-poohed". (512) The second meeting at Oxford helped to establish the Association on a firm foundation, and after this many scientific men in London and the universities, who had been suspicious of the new venture, gave their support. (513) At this Oxford meeting honorary degrees of D.C.L. were awarded to Brewster, Faraday, Brown and Dalton, a fact which caused Keble to complain that the university had "truckled sadly to the spirit of the times" in receiving "the hodge podge of philosophers." (514) Another

persistent critic was The Times (515), but among the scientists the British Association flourished, and by the 1838 meeting Sedgwick was commenting on the great increase in the attendance and was of the opinion that in the near future no centre would be sufficiently large to take the annual meeting. (516)

By the eighteen-forties when the long awaited reform of the Royal Society was accomplished, the British Association was so well established that the reforms did nothing to weaken the Association's work. On the contrary, although the bodies maintained a quite separate existence and performed different functions, they served to complement the work of each other: that each has carried on to the present day is sufficient evidence of the success with which they have performed their work.

Ten years after the founding of the British Association the Chemical Society was founded. The existence by this time of a number of local scientific societies provided the necessary conditions for the founding of a chemical society. The British Association already had a chemical section but this, after all, met only annually, and at different venues. Robert Warington was the moving spirit behind the founding of the Chemical Society of London. He, like a number of other founder members, was a member of the Spitalfields Mathematical Society. Twenty five interested parties met on the 23rd February, 1841 at the Society of Arts. A committee of fourteen was appointed and a month later a general meeting was

held at which Thomas Graham was elected president, and W.T. Brande, J.T. Cooper, J.F. Daniell, and R. Phillips were elected vice-presidents. The number of members was seventy seven at this stage and they included W.R. Grove who was soon to play an important part in the further reform of the Royal Society.(517)

It has been pointed out that the introduction of the penny postage in 1840 greatly facilitated the correspondence involved with the organisation of the Chemical Society. This, together with a period of unusual inactivity in the life of Warington, led to the Chemical Society being founded at this particular time. Warington described his reasons for founding the Society as being, "not only to break down the party spirit and petty jealousies which existed, but to bring Science and practice into closer communication, and to bring the experience of many to bear in discussing the same subject".(518)

The year 1841 marked the beginning of a great interest in English chemistry, the immediate cause of which was Liebig's influence through his visits and publications. The Chemical Society was therefore, founded at an opportune time and it immediately served to provide a journal for the publication of results and a meeting place for discussion.(519)

Shortly after the founding of the Chemical Society one of the founder members was to play an important role in securing the final major reform of the Royal Society. This was W.R. Grove who was

born in 1811. After studying at Brasenose College, Oxford, and graduating B.A. in 1832 he studied law and was called to the bar in 1835. However early in his career he practised little and instead devoted himself to scientific pursuits.(520) His most important claim to scientific fame is as the inventor of the fuel cell. He described an improved form of the Voltaic Cell to the British Association meeting in 1839, (521) and in 1845 he published his famous paper, "On the Gas Voltaic Battery".(522)

He had been elected a Fellow of the Royal Society in 1840 and soon associated himself with the reforming group. He became a member of the Council in 1846 and shortly after this a committee was formed to consider the possibility of amending the Charter. Grove was co-opted onto this committee and with his knowledge of the law was able to assist the committee through a number of legal difficulties which arose.(523) It was Grove who went to the crux of the matter by proposing changes in the method of electing Fellows. The Council accepted the recommendations and found a means of accomplishing them within the confines of the original Charter. The new statutes provided for the election of new Fellows on only one day each year and stated that it should be the duty of the Council to suggest up to fifteen candidates for election as Fellows.

This reform was to give the Royal Society its present character. Under the new statutes with their restriction on membership,

the amateurs who had been elected under the old system, no longer became Fellows. As the non-scientific Fellows died they were replaced by scientists, and so gradually the whole character of the Society changed.(524)

These changes were not brought about without opposition and in order to safeguard the gains which had been made, Grove and his supporters formed a dining club known as the "Philosophical Club". It was limited to forty seven members in memory of the reform and for over fifty years it served to discuss and watch over the affairs of the Royal Society.(525)

CHAPTER IX

THE TEACHING OF CHEMISTRY IN SECONDARY SCHOOLS

At the beginning of the nineteenth century the English Grammar Schools were still largely concerned with the teaching of Latin and Greek. The introduction of more modern subjects into the schools was hampered by two main factors. Firstly the Grammar Schools had often been founded in the sixteenth and seventeenth centuries with the purpose of preparing scholars for the universities. Consequently the curricula of the schools was to a considerable degree governed by the requirements of the universities; and so lack of progress in the universities was reflected in the schools.(526) Secondly the founders had often laid down details of the curriculum to be followed.

However during the eighteenth century there had been an increasing dissatisfaction with the education provided by the Grammar Schools and a growing realisation that it was unfitted to the needs of the time. This coincided with a fall in the numbers attending Grammar Schools. The public, or non-local Grammar Schools of old foundation, such as Eton, Winchester, Westminster, Harrow, Rugby and Shrewsbury, had by the end of the eighteenth century become the preserve of the rich. (527)

The general dissatisfaction, and possibly the influence of dissenting academies with their teaching of natural science, led to attempts to enrich the curriculum. Such attempts were however severely curtailed by Lord Eldon's judgement in the Leeds Grammar School case of 1805. The Grammar School had been undergoing a

period of decline during the latter part of the eighteenth century, and the governing body laid the major share of the blame on the curriculum which was limited to Latin, Greek and divinity. It was decided therefore to appoint a teacher of writing, and a teacher of French and other modern languages. The move met with opposition from the headmaster and staff, and so, after an inquiry in 1797 by a Master in Chancery, the case went before Lord Eldon, the Lord Chancellor. He decided that he was unable to sanction the introduction of subjects other than those laid down by the founders. This judgement was upheld by subsequent decisions and the restrictions were not really removed until the Grammar Schools Act of 1840 which allowed governors to introduce new subjects into the curriculum. (528)

Under the influence of such reformers as Dr. Samuel Butler, headmaster of Shrewsbury from 1798-1836, and Dr. Thomas Arnold, headmaster of Rugby from 1828-1842, the curriculum of the public schools underwent reform and reorganisation in the first half of the nineteenth century, but classics remained the central subject of study.(529) As late as 1864 the Clarendon Commission stated that with the exception of some ancient history, and geography, classics was the exclusive subject of study at the public schools.(530)

The failure of the public and grammar schools to meet the needs of an emerging middle class led to the founding of a number of proprietary schools of the public school type.(531). These schools

unhampered by foundation statutes were able to develop more liberal courses of study, sometimes vocational in character, as for example, in the case of Cheltenham College which prepared a number of boys for entry into Woolwich and Sandhurst. In addition to these a number of private schools arose which catered for the children of middle class parents who could not afford to send their children to public, grammar or proprietary schools. Standards in these schools were variable and parental pressure tended to impose a curriculum designed solely to fit the pupil for his future occupation.(532) However the Schools Inquiry Commission commented on the more modern approach of these schools.(533)

There was throughout the period under review little chemistry teaching in any kind of school and its history is largely the history of individual efforts.

Rugby appears to have been the first of the public schools to teach science. It was introduced by Dr. Tait, a local physician and F.R.S. in 1849, and took the form of lectures on physics and chemistry delivered in the Town Hall to voluntary audiences. Later two of the classics teachers who had shown an interest in science carried on the teaching. By 1859 a laboratory and lecture room had been provided.(534)

At Eton science lectures by visiting speakers were begun in 1849. The charge was two shillings and the lectures were well attended.(535) It was not until 1869 in which year a chemistry laboratory was built that science became a part of the fifth year

curriculum.(536) Even as late as 1870 no science was taught at St. Pauls, Merchant Taylors' and Shrewsbury and it appears from the Devonshire Commission Report that science teaching was the exception before about 1860.(537) It is said that in the Grammar Schools a similar if not worse situation existed.(538)

However the newer proprietary schools presented a rather brighter picture. Mill Hill was providing some teaching of physical science by 1821.(539) Similarly the City of London School had at its founding in 1836 a curriculum which has been described as "as progressive as any in England at that date." It included "Lectures on Chemistry and other branches of Experimental Philosophy".(540) Science teaching was begun in 1838 with the appointment of the Rev. William Cook in January of that year. He obtained an air pump, glass tubes, a condensing syringe, mercury and a lathe for the purpose of teaching natural philosophy. Cook however left in November of the same year but because he was convinced of the value of the lectures he continued to deliver them from time to time.(541)

In 1845 the headmaster made an attempt to reintroduce a regular course of scientific lectures into the curriculum. As his comments show he regarded the lectures as an important part of the school studies.

> "I do not look to these Lectures as a mere source of amusement, but as affording the means of a thorough education in the principles of Chemistry and Experimental Philosophy to all who leave the higher classes of the School."

The teaching of chemistry really got under way with the promotion of Thomas Hall from form master to Lecturer in Chemistry in 1847.(542) Hall had received all his chemical education under Hofmann at the Royal College of Chemistry. He gave his lectures during the lunch break so as not to interfere with ordinary lessons, and those boys (W.H. Perkin was one) who showed aptitude and were appointed as lecture assistants were able to assist in the preparation of lecture experiments. A yearly examination was held at which the examiner was F.A. Abel who had also been a pupil of Hofmann at the Royal College of Chemistry. According to Perkin over thirty of Hall's pupils later studied at the College .(543) Certainly by 1870 the record of successes at the school in chemistry is nothing short of astounding.(544) Because of the limited accommodation which he had available for practical work, Hall was in the habit of encouraging his pupils to carry out experiments at home and bring their preparations to school for examination. The fee for the chemistry classes was seven shillings and since his bill for chemicals and apparatus in his first year was £118 it appears that his pupils received good value.(545)

Another school which stands out through the quality of its chemistry teaching is University College School. This was a remarkable school in several respects. There were no compulsory subjects in the school but most of the pupils learnt Latin and many also learnt French and German. There was no religious teaching or

flogging.(546) Some form of science teaching seems to have been available from the time that the school became part of University College in 1832. A class in chemistry was first formed in the 1839-1840 session and the pupils were able to carry out experiments with the aid of apparatus provided by the College. A text book by Fownes was used by the pupils who by 1851 were distinguishing themselves in Graham's class. It was not until 1859 that a laboratory became available and practical chemistry began to be taught by G. Carey-Foster. (547)

Hull Grammar School was another school which provided lectures on chemistry at an early date. This was due to the appointment as headmaster of J.D. Sollit who had taken an active part in the adult school movement and was a popular lecturer on chemistry and physics. He was appointed in 1838 and the science teaching began shortly after.(548)

Sir Henry Roscoe has left an interesting account of his studies at the High School of the Liverpool Institute. This he describes as one of the first of the "modern" schools. Roscoe entered the upper department of the school in 1842 and he comments: "Even in those days we had a chemical laboratory in which the boys worked.." Other subjects in the curriculum were English, mathematics, classics, French, drawing and natural philosophy. The chemistry teacher was Balmain who Roscoe tells was the discoverer of boron nitride and Balmain's luminous paint; and it was through this

teacher that Roscoe developed his interest in chemistry. This is perhaps not surprising in view of Balmain's somewhat drastic teaching methods. Roscoe recounts that when Balmain was teaching the preparation of hydrogen sulphide each boy was given a glass containing dilute sulphuric acid and a second glass containing iron sulphide. The pupils were then instructed to add the acid to the sulphide and retire as quickly as possible. "The result was such a fearful stench that each boy will carry down the recollection of that moment to his grave..."(549)

Of the private schools the most outstanding with regard to the teaching of chemistry was Queenwood College. Initially the building had been constructed as Harmony Hall in 1842 and represented an attempt by the followers of Robert Owen to form a socialist community. The community included a school and by 1844, 94 children were pursuing a course of study which included geography, astronomy, history, chemistry, anatomy and physiology. However the community failed and the buildings were let to George Edmondson, a Quaker, and former agricultural adviser to the Tsar. Under Emondson, Queenwood College as the institution was now called, included the teaching of classics, modern languages, natural philosophy, painting, music and surveying. In addition to this the school had a farm attached at which the pupils were able to make a scientific study of agriculture at first hand.(550)

Edward Frankland was introduced to the school through a meeting

with Edmondson in 1846. Edmondson was at that time proprietor of Tulketh Hall School near Preston. Frankland found that he was called upon to work very hard at Queenwood since in addition to teaching chemistry he gave lectures on botany and geology and was in charge of the laboratory.(551)

The school was equipped with a chemistry laboratory, the boys carried out practical work, and the science teaching was pervaded by an atmosphere of research.(552) Indeed the standard of chemistry teaching seems to have been exceptional for Robert Galloway (553) commented that although only four hours a week were devoted to science the standard of analytical skill reached by the boys was so great that "on attending the London Medical Schools, three or four years afterwards,"...."the chemical instruction they had received in Hampshire was much more perfect and extensive than that given in those Schools." (554)

While Frankland was at Queenwood, John Tyndall was teaching mathematics and surveying at the school. Both teachers left to study under Bunsen at Marburg in June 1848, but Tyndall returned to the school in 1851 to find a marked deterioration. Fortunately under his influence there was an improvement (555).

One feature of the school which distinguishes it, apart from the quality of its teaching, is the number of its staff who subsequently became professors. No doubt at a time when there were few posts for scientists the school was one of the few institutions in

which a young man who had learnt some science could put his knowledge to use. Later in the century as more teaching posts in universities and colleges became available the men who had by this time made some kind of reputation for themselves as scientists, were able to acquire professorial chairs. Apart from Frankland and Tyndall the school had the services of William F. Barrett, (556) Thomas Archer Hirst, (557) Heinrich Debus, (558) and Robert Galloway all of whom later achieved eminent positions.(559).

Queenwood did not represent the only school providing science teaching in Hampshire at this time. A unique educational experiment was being carried out in King's Somborne at the village school which had been opened by the Rev. Richard Dawes in October 1842. The school was open to all sections of the community and through the excellence of its instruction remained self-supporting, its fees being adjusted according to income. After the school had been open two years Dawes gave lectures on elementary physics to the staff and the more advanced pupils, and in 1847 Frankland was invited to give a course of six lectures on agricultural chemistry. His audience consisted of older pupils, schoolmasters and local farmers, and the lectures were subsequently used as the basis of a course on agricultural chemistry.(560)

The apparatus which Dawes acquired later proved to be important. A revised list of the apparatus was drawn up in 1868 and the Committee of Council granted financial assistance to elementary schools

which wanted to purchase this apparatus with a view to teaching practical science.(561) Hence these humble beginnings played their part in the introduction of practical science into elementary schools.

CONCLUSION

It is hoped that the main developments which occurred in the first half of the nineteenth century and some of the reasons for them have been made clear in the body of the thesis. However some conclusions seem to be worthy of emphasis, and a brief consideration of the position in the years after 1853 may be of interest.

By 1853 it is clear that the foundations of a system of English technical and scientific education had been laid and that chemistry was likely to play an important part within this system. At the same time chemistry was just beginning to be established as a profession. As we have seen much of the credit for this must go to Hofmann and the Prince Consort whose unique services to education seem to have been insufficiently appreciated.

The period which has been studied was one of growing interest in science, and concern with the problems of education. This concern was shared by both government and individuals alike. The interest of individuals is reflected in the growth of such bodies as the Royal Institution and in the founding of mechanics' institutes. Government support developed much more slowly but by 1853 the existence of such bodies as the Government School of Mines and the Department of Science and Art is evidence of a considerable change in attitude since 1799.

At Oxford and Cambridge the development of chemistry teaching was hampered through the preoccupation with the traditional

curriculum, and the conception of the nature of a university. Again the mid-century proved a landmark for it was at this time that the part which science had to play in education was officially recognised. The newer universities and colleges were always more sympathetic in their attitude to science and by the eighteen-fifties London, Durham and Manchester were providing some kind of laboratory facilities for students of chemistry. However the main impetus for the practical teaching of chemistry came from another direction: through the efforts of Playfair, the Prince Consort and others, who had been inspired by German experience. Their efforts to promote chemistry teaching were made in an England which had produced a number of eminent chemists but had failed to produce research schools and hence an ever increasing number of trained workers. The period is also significant in that it includes the turmoil over the organisation of science and in particular the government of the Royal Society. By the eighteen-fifties science was being served by a vigorous British Association and a reformed Royal Society.

An important aspect of the problem of teaching chemistry was that during the first half of the nineteenth century medicine and industry had not become so scientific as to demand trained workers. The tradition of learning manufacturing processes by serving an apprenticeship was difficult to break down and the Victorians seem to have been obsessed by the immediately practicable. Liebig

summed up the English attitude perfectly in a letter to Faraday dated 19th December, 1844, in which he commented:

> "What struck me most in England was the perception that only those works which have a practical tendency awake attention and command respect; while the purely scientific, which possess far greater merit, are almost unknown. And yet the latter are the proper and true source from which the others flow. Practice alone can never lead to the discovery of a truth or a principle. In Germany it is quite the contrary!"(562)

It was the continuing failure to perceive this truth which made the development of chemistry teaching so slow. In the light of this the success of the Royal College of Chemistry is all the more striking. Even so, as we have seen, the desire for quick results served to weaken this body also. Many of those who were interested in the development of scientific education were concerned with mounting the Great Exhibition of 1851, the success of which, blinded all but the most perceptive to the extent to which the prosperity of a country depended on the skill and education of her population. The Paris Exhibition of 1867 revealed to even the most near-sighted the degree to which England had declined as an industrial nation since 1851. In an article written in 1877, W.W. Thornton tells us that out of ninety classes of exhibits England was first in only one dozen. Since 1851, the Continental countries, being unable to rival Britain in her natural reserves of coal and iron, and abundance of capital, had set out to produce more cheaply through more efficient industry, the foundation of which was a thorough system of scientific and technical education.

At the time of writing Thornton considered England to be the worst educated of the foremost European powers.(563)

Another observer who perceived the extent to which national prosperity depended on education was Matthew Arnold. Following an extensive inspection of European schools and universities he made strong criticism of English attitudes.

> "In nothing do England and the Continent at the present more strikingly differ than in the prominence which is now given to the idea of science there, and the neglect in which this idea still lies here;"(564)

By the eighteen-sixties Davy would no longer have been able to boast of the fact that money for the voltaic apparatus at the Royal Institution had been raised by public subscription and not, as it would have been in other countries, provided by the Government.(565)

Even in those areas where the Government was taking an active part the results were not always entirely satisfactory. The Department of Science and Art was tackling the problem of providing scientific instruction in schools and in 1859 it instituted examinations. They payment of teachers was linked to the success of pupils in these examinations. At the same time an examination was instituted for science teachers although subsequently a pass in the advanced school examinations constituted a qualification to teach science. These measures increased the supply of science teachers and the number of people under instruction rose from 500 in 1860 to 34,283 in 1870. Unfortunately the character of the teaching left much to be desired. It is clear that much of the teaching

consisted of mere book learning, that apparatus or field studies were uncommon, and that instruction was usually confined to the methods by which the teachers themselves had received "their own imperfect knowledge".(566)

It was left to Huxley to point out the necessity of having well qualified people teaching elementary science.(567) In public and grammar schools the inclusion of chemistry in the curriculum was hampered by the expense of building laboratories even when the traditional antipathy to science had been overcome.

To sum up one can say that the foundations of a system of scientific education had been laid by the nineteenth century, but that these foundations were not built upon with a sufficient sense of urgency. Other European powers placed greater emphasis on science teaching and basic research and this was an important factor in the relative decline of Britain in the second half of the nineteenth century.

APPENDIX I

Syllabus of the Lectures in Physical Science and Natural History.

(From: Introductory Discourses delivered in Manchester New College, at the opening of the session of 1840, London, 1841)

CHEMISTRY

Lectures for Junior Students.

First Series.

The General Principles of Chemistry - Chemical Nomenclature - Crystallization.

Second Series.

Chemical History of Inorganic Bodies. - Non-Metallic Bodies. - Electro-Negative Bodies; viz. Oxygen - Chlorine - Bromine - Iodine and Fluorine. - Electro-Positive Bodies; viz. Hydrogen - Nitrogen - Carbon - Sulphur - Phosphorus - Boron - Selenium - Silicon; and their Combinations.

Third Series.

The METALS. Kaligenous Metals or those whose Oxides are Alkalies; and Ammonia. - Their combinations and uses.

Series the Fourth.

Terrigenous Metals, Common Metals, whose Oxides cannot be reduced by heat alone. - Their combinations and uses.

Series the Sixth.

Common Metals, whose Oxides are reduced by heat. - Their combinations and uses.

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