The RSC and SCI Joint Colloids Group's Three Awards: the Legacies of Graham, McBain and Rideal

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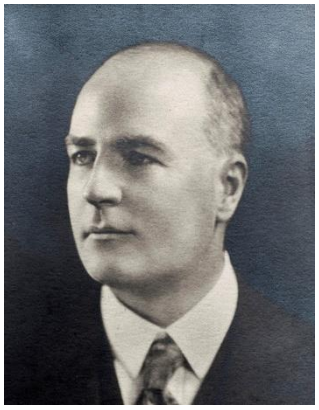
Introduction

Thomas Graham
(1805-1869)



William McBain
(1882-1953)

Sir Eric Rideal
(1890-1974)

The UK Joint Colloids Group (JCG) is a joint working group of the Royal Society of Chemistry's Colloid and Interface Science Group and the Society of Chemical Industry's Colloid and Surface Chemistry Group. The JCG committee administers three joint RSC/SCI awards. These awards recognise and honour current outstanding researchers in the subject, at varying stages of their careers: the Thomas Graham Lecture for persons in mid-career, the McBain Medal for early-stage researchers and the Sir Eric Rideal Award and Lecture for life-time achievement.

Thomas Graham, James William McBain and Sir Eric Rideal are three of the "big names" in the history of colloid and interface science in the UK. They were the leading lights in the establishment of three pioneering academic centres of research in this subject: University College London (UCL), Bristol University and Cambridge University, respectively.

The purpose of this article is to discuss the contributions to colloid and interface science made by Graham, McBain and Rideal, at their respective institutions, and to describe briefly how research in this field continued at each of these major centres in their wake.

Thomas Graham and University College London

Thomas Graham was born in Glasgow in 1805 and educated at Glasgow High School. He enrolled at the University of Glasgow in 1819, to study chemistry, receiving his MA in 1824. He subsequently studied medicine at the University of Edinburgh and then taught chemistry at different institutions in Scotland, before moving in 1837 to University College, London (UCL,

founded in 1826) as professor of chemistry [1]. He was a founder member of the Chemical Society of London in 1841 and indeed its first President. In 1855 he was appointed *Master of the Mint*, a prestigious position, founded in 1331 and held previously by other scientists such as Sir Isaac Newton and Sir John Herschel. When Graham died in 1869, the position was abolished and subsequently taken over by the Chancellor of the Exchequer. Graham was buried in Glasgow Cathedral. He did not marry and had no children.

Graham's most important contributions to science were made at UCL. He was the first person to study diffusion and effusion in the gas phase, as well as diffusion in solution. He invented the dialysis technique, based on the concept of diffusion of solutes through a porous membrane. He classified substances into two types: "crystalloids", substances (such as sugar) that pass through a porous membrane, and "colloids", substances (such as gelatin, glue and starch) that do not. Since it was Graham, in 1861, who coined the term "colloid", he is widely regarded as the principal "founding father" of colloid science.

A few years later, in 1864, Graham noted "the power possessed by salts of destroying colloidal solutions", i.e. the process we would now call "coagulation". In that regard, he was not the first person to make this observation. In 1847, Francesco Selmi, at the University of Modena in Italy had made the first systematic studies of inorganic and their coagulation by added salts. Also, in 1857, Michael Faraday (1791-1867), at the Royal Institution in London, had reported his classical investigation of the colour changes that gold sols undergo (red to blue) on adding salts to induce coagulation. Graham's work on coagulation was followed up at UCL, from about 1892 by Ernest Linder and Harold Picton. They were particularly interested in the role that surface charge of the particles played [2].

The next major developments in colloid and interface science at UCL came when Frederick George Donnan was the Professor of Physical Chemistry (1913-1937). He succeeded Sir William Ramsay at UCL. Donnan himself is best known for establishing the equilibrium potential (the "Donnan potential") which exists across a semi-permeable membrane separating two electrolyte solutions, one of which contains dispersed colloidal particles, which cannot pass through the membrane. In this respect, Donnan's work follows on directly from Graham's earlier ideas on diffusion across membranes. Donnan must also take credit for appointing at UCL a number of scientists who went on themselves to make major contributions to colloid and interface chemistry, in particular, E.K. Rideal (who went to Cambridge), W.E. Garner (who moved to Bristol), N.K. Adam (who moved to Southampton), G.S. Hartley (who was the first to postulate the spherical structure of surfactant micelles, following McBain's pioneering work) and Herbert Freundlich (at that time a refugee from Germany, who subsequently moved to Minnesota in the US). Joseph Kitchener, who was a research student at UCL in Donnan's time, was later appointed to the staff of Imperial College, London, where he established a world-famous school of research in surface chemistry, initially in the physical chemistry department and then in (what became) the Royal School of Mines.

The tradition of research in interfacial chemistry at UCL was continued during the second half of the twentieth century by such renowned men as Ken Ives and John Gregory, working more on the engineering aspects of processes such as filtration, flotation and flocculation. More latterly, it has been continued by others such as David Williams, who held the Thomas Graham Chair of Chemistry at UCL (1991 to 2002), and who worked on the surface chemistry of semi-conductors and sensors, and on interfacial electrochemistry.

McBain and Bristol University

University College Bristol (UCB) was founded in 1876, with E.A. Letts, an organic chemist, appointed as the first professor of chemistry. He was succeeded in 1880 by William Ramsay. Ramsay was not really a surface chemist, *per se*, but one of his research projects was concerned with the adsorption of dyes onto wool; this arose through his association with several of the wool processing companies in the south west of England. In 1887 Ramsay moved to UCL, where he began the research which led to the award of the Nobel Prize for his discovery of the inert gases.

UCB became the University of Bristol, in 1909, upon receiving its royal charter. Since 1906, until the present day, there has been ongoing research activity in colloid and surface science. It commenced with the appointment that year of James William McBain as lecturer in physical chemistry. McBain was born in New Brunswick in 1882, and went to the University of Toronto, gaining an MA in chemistry and mineralogy in 1904. He then went to Germany to extend his research experience. He went first to work with Professor Luther at the University of Leipzig. At that time the university had on its staff two men who became "giants" of surface and colloid science in Germany: Wolfgang Ostwald and Herbert Freundlich (mentioned earlier). McBain then moved to Heidelberg University to work with Georg Bredig. There, significantly, he met Friedrich Krafft who had been the first person to report the anomalous colligative properties of dilute soap solutions in water, although he did not offer any satisfactory explanation at that time.

When McBain first came to Bristol he worked on a variety of topics, including silver-tin alloys, the effects of adding dye molecules to a silver iodide sol (clearly of significance in the wet photographic process), and the effects of adding small amounts of albumin to a ferric hydroxide sol. However, he soon turned his attention to the study of soap solutions. He undoubtedly drew on his first-hand knowledge of the earlier work of Krafft in Heidelberg, and on the experience of an organic chemist at Bristol, Professor Francis Francis, who had shown how to purify fatty acids. In 1919 McBain was appointed to the Leverhulme Chair of Physical Chemistry, which was created for him, largely to fend-off an approach by his old *alma mater*, the University of Toronto, to recruit him. McBain's work on soap systems was well known to the Lever Bros. company. The Leverhulme chair was destined to become the established physical chemistry chair in the area of colloid and surface chemistry at Bristol.

McBain first described his experimental work on the association of soap molecules (such as sodium oleate and sodium palmatate) in solution at a meeting of the Faraday Society in London in 1913. He showed that a discontinuity occurred in plots of the electrical conductance as a function of concentration, leading to the idea that such molecules associated in solution at concentrations greater than a critical concentration (which we would now recognise as the critical micelle concentration) [3].

In 1926 McBain was finally tempted back to North America, to Stanford University. He published more than 450 scientific papers and two major textbooks: *The Sorption of Gases and Vapours by Solids* (1932) and *Colloid Science* (1950).

In 1927 William Ernest Garner, from UCL, was appointed to the Leverhulme Chair in Bristol. He was responsible for major advances in the surface chemistry of solids and in heterogeneous catalysis. Two of his research students in Bristol went on to found schools of surface and colloid science in other universities: Dan Eley at Nottingham (in 1954) and Frank Stone at Bath

(in 1972). When Garner retired in 1954, Douglas Everett became the third Leverhulme Professor in Bristol. He made major contributions in applying thermodynamic concepts to the adsorption onto (porous) solids from the gas phase and from solution. Everett was also responsible for establishing, in 1964, the first postgraduate (MSc) course, by advanced study and research, in colloid and surface chemistry. To this end he brought Ron Ottewill from Cambridge to set up the course. Although, his research work was multi-facetted, Ottewill's principle research interest was in applying scattering methods (light and neutron) to studying interparticle interactions in, and the structure and properties of, concentrated, monodisperse colloidal dispersions. In 1982, Ottewill became the fourth holder of the Leverhulme chair. He was succeeded by Brian Vincent (in 1992) and then Terry Cosgrove (in 2008), as the fifth and sixth holders of this chair.

Rideal and Cambridge University

Although the strong reputation of the Cambridge school in colloid and interface science largely stems from the enormous contributions made by Sir Eric Rideal and his group, the origins *per se* of research in colloid science in Cambridge can be traced back to another, earlier great Cambridge scientist, Sir William Bate Hardy (1864-1934). Hardy was essentially a physiologist, whose primary interests were concerned with the properties of biological cells, particularly cell division; he thought that colloid science might help in understanding this process. However, he also made a major contribution to the study of the coagulation of colloidal dispersions.

Eric Rideal, born in Dulwich, was the son of a consulting chemist [4]. He was educated at Oundle School and from there he won a scholarship to Trinity Hall, Cambridge, from where he graduated in 1910. He then went to Bonn, Germany for his PhD. In 1913, he returned to England to work with his father. He joined the Royal Engineers in the First World War and was injured in the Battle of the Somme in 1916. He returned home and after the war joined Donnan's lab at UCL, where his lifelong interest in catalysis began. In 1918 he moved to the University of Illinois, where he met Irving Langmuir. He also met Hugh Taylor at Princeton, then the world's leading authority on catalysis. With Taylor, he wrote his first book: *Catalysis in Theory and Practice*.

In 1920 Rideal returned from the USA to a fellowship at his old college in Cambridge and the Humphrey Owen Jones lectureship in physical chemistry. Co-workers of Rideal during that period included R.G.W. Norrish, J.K Roberts, V.K La Mer and C.P. Snow (the author). Rideal was appointed Professor of Colloid Physics in Cambridge in 1930 and in 1931 founded the famous "Colloid Science Laboratory" in Free School Lane [5]. Many well-known surface scientists worked with Rideal in that laboratory over the next 15 years. To pick out a few: Frank Bowden (who pioneered work on friction and lubrication), Jack Schulman (who discovered transparent microemulsions; Harry Melville (who moved to Birmingham University); Geoffrey Gee (who, after a period in industry, moved to Manchester University, where he developed its polymer group); A.S.C. ("Soapy") Lawrence (who moved to Sheffield University); Frederick Eirich (who moved to Brooklyn Polytechnic, New York, and became an authority on rheology); A.E Alexander (who returned to Sydney University, to launch the famous colloid school there); Sam Levine (a theoretician, who moved to Manchester University); Dan Eley (who moved to Bristol University – see earlier); and Charles Kemball (who moved to Queens, Belfast and then to Edinburgh University).

In 1946 Rideal left Cambridge for the Royal Institution in London. He was succeeded as the Humphrey Plummer Professor of Colloid Science in Cambridge, by Francis Roughton. Like Hardy earlier, Roughton was primarily a physiologist with interests in physical chemistry.

However, Jack Schulman continued the mainstream surface chemistry research and in 1959 his group moved to a new, second location, the Ernest Oppenheimer Laboratories on Madingley Road. One of his assistants there was Brian Pethica (who went on to head-up the Unilever research laboratories at Port Sunlight). Schulman departed for Columbia University, New York, in 1957.

Another key member of staff in the Free School Lane laboratory, during Roughton's time, was Paley Johnson, who completed his PhD under Rideal during the Second World War. He developed a strong interest in applying physical techniques, such as ultracentrifugation and light scattering, to studying biological systems. Ronald Ottewill worked with him, as a Nuffield Fellow, from 1952 on antibody-antigen interactions, before Ottewill turned his interests to mainstream colloid science following six months in Theo Overbeek's lab in Utrecht. Ottewill moved to Bristol in 1964, the year that Roughton retired. Paley Johnson continued at Cambridge and it seemed natural that he would be the next head of the colloid science group. However, university politics intervened, and the Department of Colloid Science was closed. Johnson's group moved to the Department of Biochemistry until his retirement in 1984. However, colloid and interface science research continued in the newly established Department of Biophysics, led by Dennis Haydon, who in 1980 was appointed Professor of Membrane Physics, the post he held until his premature death in 1988. One of Haydon's co-workers was Bob Aveyard. In 1972, Bob moved to the University of Hull, where he founded its famous, ongoing school of surface and colloid science.

David Tabor (like Hardy earlier, a fellow of Gonville and Caius College) was appointed reader in physics in 1964 at the Cavendish Laboratory in Cambridge, and then professor in 1973, until his retirement in 1981. He strongly developed the earlier work of Bowden in Cambridge on the friction between solid surfaces, and really was the person who should be credited with the invention of the modern "surface forces apparatus", now widely used for measuring both the normal and the lateral (frictional) forces between two surfaces close to contact.

In 1972 research at Cambridge (especially theoretical work) in soft matter physics (which incorporates many aspects of colloid science) received an enormous boost when Sam Edwards (also a fellow of Gonville and Caius College) was appointed John Humphrey Plummer Professor of Physics (and then Cavendish Professor of Physics in 1984, until his retirement in 1995). He led a powerful, world-renowned research group, which continues to this day with former protegeés such as Athene Donald and Mark Warner. Other current, world-renowned scientists in soft matter, who have passed through the Edwards group in Cambridge, are Michael Cates (who moved to Edinburgh, but is now back in Cambridge), Tom McLeish (who went to Sheffield, then Leeds and now at York), Richard Jones (who went to Sheffield), Colin Bain (who moved to Oxford, then to Durham), Robin Ball (now at Warwick) and Joe Keddie (now at Surrey).

Conclusions

Colloid and interface science research in the UK is alive and well and spread over many universities, although to some extent these days, perhaps somewhat "hidden" within more

fanciful, “modern” research topics, such as “nanoscience” or “soft matter”. As I have tried to demonstrate in this article, many of the current UK research centres within the family-tree of colloid and interface science, can trace their roots back to three, long-standing research centres: University College London, Bristol University and Cambridge University, whose own foundations will always be associated with the names of three men: Thomas Graham, James William McBain and Sir Eric Rideal, respectively.

Finally, I should state that, in a short, historical article of this nature, I have not been able to mention many of the excellent current UK research leaders in the field. If anyone should feel “aggrieved”, then I apologise.

Acknowledgements

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