History of Physics Group Newsletter
No 23 January 2008

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Editorial

"Labour is not to be shirked in the study of a great question; but it may be lightened ...by calling forth an energy which shall diminish it relatively."

Thus says Prof. John Tyndall of the Royal Institution in the preface to his book 'Heat – a Mode of Motion' published in 1863. It takes the form of 18 lectures which must cover pretty well all aspects of the subject at that time and is the source of the cover illustration of this issue of the newsletter.

Prof. Tyndall's exhortation to knuckle down has an almost religious fervour to it but that would have been the last thing on his mind. As Prof. Andrew Whitaker says in his article on page 29 that Tyndall's address to the British Association in Belfast in August, 1874 was *'a call for any religious input to science to be eliminated'* – a very different attitude to that of William Thomson.

The Belfast Address was a speech of monumental scope covering enormous ground, starting with possible thoughts of prehistoric man on 'nature', journeying through the ancient Greeks on atomism (pausing on the way to demolish Aristotle) to the dark ages in Europe. He describes how, during this time, science continued in more enlightened lands, speaking of the work of Alhazen. Turning back to Europe he gives a penetrating setting to the world of Copernicus, Galileo and Gassendi and romps through the atomism of Bacon, Descartes, Hobbes, Locke and Newton. After a brief geological interlude he gets stuck into Darwin with all its consequent ramifications and concludes with a lengthy philosophical discourse.

Incidentally, my copy of the 'Belfast Address' appears in the 1875 issue of the 'Year Book of Facts in the Arts and Sciences' and I marvel at the range and detail it contains and wonder how such a publication would fare in this day and age. It was obviously aimed at a general readership with its advertisements for 'Goodalls Baking Powder and Yorkshire Relish, and it reports the latest developments in Mechanics, Natural history, Technology, Chemistry and Geology to name but a few. Articles on the American lobster trade and the longevity of 'Men of Science', contrast wildly with those on the possible evidence of radiation pressure from experiments by 'Mr Crookes', a communication from the 'Emperor of Brazil' expressing his satisfaction with the newly installed Brazil-France telegraph cable, and a report on the adoption of 'Sir William Thomson's Eclipsing Lighthouse Device.

Lord Kelvin also gets a mention in John Tyndall's book on heat as verifying James Thomson's prediction that the freezing point of water is lower when under pressure - which brings me very conveniently back to the delightful picture elegantly illustrating this now very familiar effect, the wire melting its way through the block of ice, the water refreezing as it descends.

Malcolm Cooper

Report of the Annual General Meeting held November 15th 2007

The 20th Annual General Meeting was held at 13.00 hrs on Thursday 15th November, at the University of Glasgow. It had two unusual features. First the meeting took place in the historic buildings of the University. Lord Kelvin used to lecture in the very room in which the meeting was held. Indeed in a recess in the wall was an ongoing experiment initiated by Kelvin to study the diffusion taking place between two different liquids. The second feature was that the AGM coincided with a visit to the University of Glasgow by the American Ambassador. This prompted a protest demonstration by a group of Glasgow students and necessitated many of those people attending the AGM to be escorted by men in black suits into the building via a side entrance.

Some twenty five members attended the AGM and in addition we welcomed as observers several members of the European Physical Society History Group, led by their Chairman Dr Peter Maria Schuster from Austria. The current Chair, Denis Weaire, decided to stand down from his position and the only nomination to replace him was Peter Ford, who had resigned his position as Secretary and Treasurer, and was duly elected. We are delighted that Denis will remain on the committee and would like to thank him for his sterling service as chair over several years. Peter Ford's election meant that there was a vacancy for the position of Secretary and Treasurer. Unfortunately there were no candidates or nominations for these roles, which are thus still vacant. As the new chair I would greatly appreciate it if anybody was willing to take up these posts and welcome anyone expressing interest. The remainder of the committee were elected nem con and in addition we welcomed Ted Davis, currently Distinguished Research Fellow at the Department of materials Science and Metallurgy at the University of Cambridge and also Emeritus Professor of Physics at the University of Leicester, who was elected to the committee.

After the AGM we had a lecture programme with the general title of "Kelvin in Context". This was to mark the centenary of the death of the great Victorian scientist William Thomson, Lord Kelvin, who spent some fifty three years as a Professor of Natural Philosophy at the University of Glasgow. The following lectures were given:

'Kelvin the Telegrapher' Professor Bruce Hunt, University of Texas, Austin

'Kelvin at Glasgow' Ken Sheldon, University of Glasgow

'Kelvin the Irishman' Professor Andrew Whittaker, Queens University, Belfast

'Kelvin and the River Clyde' Professor Crosbie Smith, University of Kent at

Canterbury

Crosbie Smith is the author, together with M Norton Wise, of a seminal book on Kelvin entitled 'Energy and Empire'

The date and venue of our AGM and lecture programme was determined by a series of lectures the day before entitled "Kelvin 2007", which was organised by the University of Glasgow and the Institute of Physics. It also gave delegates an opportunity to view a newly opened gallery devoted to Kelvin, which is located in the excellent University Museum. In organising our event I would like to thank Professor David Saxon and Professor Miles Padgett of the Physics Department of the University of Glasgow as well as other staff members of the University for their excellent help and assistance.

2007 was an active year for the group. On June 9th we had a successful half day meeting entitled "Physics at the Clarendon Laboratory". A report on this, as well as articles on two of the three lectures, appeared in the previous Newsletter, number 22, which appeared last August. On October 3rd another highly successful half day meeting was held at the University of Bristol marking the discovery of the pi-meson and other fundamental particles. The organisation and funding for this was a joint effort between the History Group and the High Energy Particle Physics Group as well as the South Western Branch of the IOP and the University of Bristol. Lectures were given by:

Professor Don Perkins, Emeritus Professor University of Oxford

Professor Robin Marshall, University of Manchester

Dr David Falla, University of Aberystwyth

Professor Emilio Picasso, CERN

During the year two excellent Newsletters appeared (Numbers 21 and 22 in January and August respectively). A vote of thanks and appreciation was given to our newsletter editor Malcolm Cooper.

At the AGM in Glasgow there was a brief discussion of possible future meetings. The following important anniversaries in 2008 were noted: the first liquefaction of helium in 1908 by Kamerlingh Onnes in Leiden, the four hundredth anniversary of the invention of the telescope which was so profoundly developed by Galileo in the following years - Professor Malcolm Longair of the University of Cambridge is organising a meeting in connection with this. 2008 is also the sixtieth anniversary of the invention of the transistor - a joint meeting with the history section of the IET might be appropriate.

There was a discussion as to celebrating the 25th anniversary of the founding of the History of Physics group of the IOP and in particular over the precise date. From early notes it seems that discussions about the formation of a group started in 1982, a preliminary meeting was held in 1984 after which a steering committee was set up. The Council of the Institute approved the formation of the Group in July 1984. The first meeting took place on 20th February 1985 and the first AGM was on 3rd July 1985.

Which date we celebrate as the will depend on what is deemed to be the key event in the process of founding the group. Apparently there is nothing on record for 1983, so it would seem that the event to celebrate is either the formal establishment of the group in 1984, or possibly the first meeting in 1985. This means a celebration meeting would be in 2009 at the earliest.

However, there was overwhelming agreement that the anniversary should be celebrated - probably at IOP headquarters and although there is plenty of time to arrange something I would be pleased to hear from any pioneering members of the group as soon as possible and their views as to the best way to mark the occasion.

Peter Ford

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Kelvin 2007

The Institute of Physics in cooperation with the University of Glasgow held a special day of lectures on the 14th November, 2007, to celebrate the achievements of Lord Kelvin who died one hundred years ago. It was held in the recently renovated Kelvin Gallery, adjacent to the Huntarian Gallery. The conference was opened by Sir Muir Russell, Principal of the University of Glasgow, noting that he was a graduate of physics, in his welcoming address and the meeting was chaired by Professor David Saxon.

Professor Michael Berry, Bristol University, gave an entertaining, but at times dense, lecture entitled *'Dark threads of nothing: vortices and light'* on the history of physics research on vortices in light, as well as their use in artistic work. The lecture included vivid visual displays of diffraction of light and elements of the history of the mathematical study of knots.

'The physics of cold atoms' was the title of the lecture given by Professor Edward Hinds of Imperial College, London. Very cold atoms could be held close to metal surfaces by magnetic fields and his research was concentrating on optimising the possibilities of maintaining this state for a maximum time interval. He posed the possibility of using this effect as a basis for a quantum computer.

The lecture given by Professor Wilson Sibbett of St Andrews University *'From technology to telecommunications'* which was more focussed on Lord Kelvin's life and achievements. He concentrated on his involvement with the technology of submarine long distance telegraph cables. In particular Lord Kelvin's work to overcome the failure of the 1858 attempt to lay an Atlantic cable through to the successful laying of a functioning cable in 1866. The second part of the lecture focussed on modern developments in fibre optics technology with the almost mind blowing acceleration of the technical capacity of the latest devices.

Professor Denis Weaire, Trinity College, started in his usual light hearted fashion introducing his talk – *'Foams and Kelvin's Legacy'* - as a play about three Irishmen and three Ethers. Reference to Irish identity is a familiar feature of Professor Weaire's many talks at history of physics events. The nature of the ether was a major preoccupation of 19th century physicists. Tait, a collaborator of Kevin, argued it was a soft and complex fluid but strong enough to resist powerful electrical and magnetic fields. Stokes suggested the ether was a jelly; Kelvin argued it must have a certain rigidity and could be similar to a foam. This was enough for Professor Weaire to launch into his favourite subject (and research for many years) the physics of foams.

The meeting closed with concluding comments and there were several who questioned the lack of discussion of Kelvin's other major areas of scientific interest - in particular, thermodynamics. Nevertheless, the day was a great success with an impressive series of lectures on Kelvin and aspects of modern physics

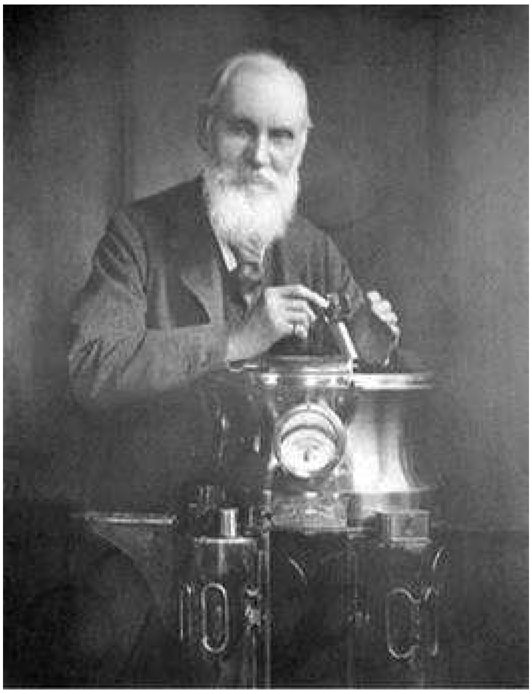
Stuart Richardson

It is with great pleasure that I can report the news that our Chairman, Peter Ford was awarded the MBE for services to Higher Education and Science, as announced in the New Year's Honours List. I am sure we all send him our warmest congratulations - *Editor*

Lecture series - 'Kelvin in Context'

Kelvin the Telegrapher

Prof. Bruce J. Hunt
History Department
University of Texas at Austin

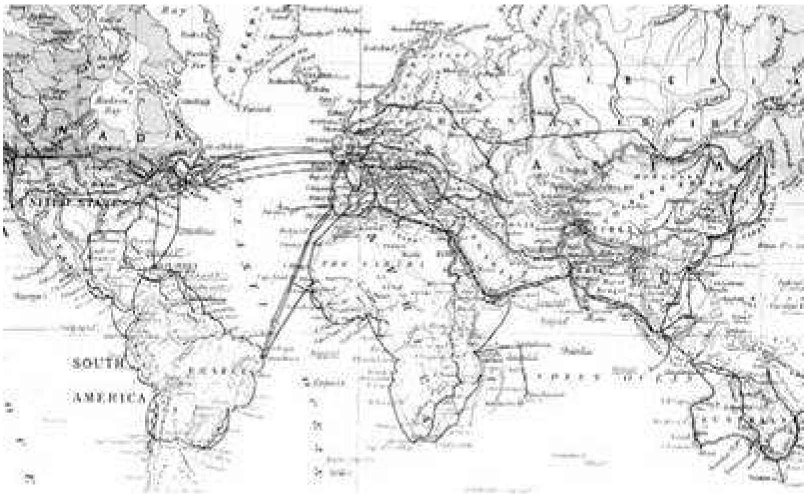


Lord Kelvin in 1902

On New Year's Day 1892, Sir William Thomson was granted a peerage. After 25 years as Sir William, he would now need to choose a new name, since "Lord Thomson" was already taken. Friends and relatives made various suggestions — "Lord Netherhall," perhaps, after his big seaside house at Largs? Another and particularly intriguing suggestion was that he call himself "Lord Cable."

He soon settled on "Lord Kelvin," after the small stream that flows near the University of Glasgow, where he had been Professor of Natural Philosophy for nearly 50 years. It might seem odd to think that, had Thomson made a different choice in 1892, we might now be talking of "degrees Cable" instead of "Kelvin," and that the American brand of refrigerator might be called the "Cablator" instead of the "Kelvinator." "Kelvin" was certainly a good choice in the emphasis it gave to his connections with Glasgow and its University, which were so important in Thomson's life. But "Lord Cable" would have better reflected the main source Thomson's wealth and fame, as well as the very close connection between science and technology, theory and practice, that permeated his work.

Submarine telegraphy was one of the characteristic technologies of the British Empire in the second half of the 19th century, and well into the 20th, and William Thomson — "Lord Cable" — sat right in the middle of it. The most famous cables were those across the North Atlantic, but there was an extensive network running throughout the rest of the globe, particularly linking the parts of the British Empire.



World Cable Map c1900

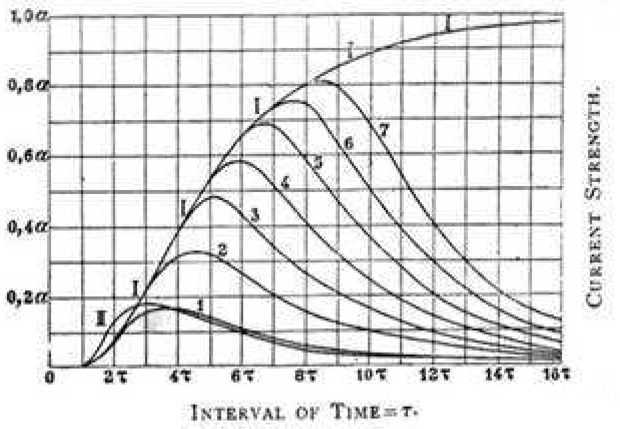
Almost all of these cables were built, laid, and operated by British companies, and between the 1870s and 1900 *all* of them used instruments designed and often manufactured by Thomson and his partners.

The first successful submarine cable was laid across the English Channel from Dover the Calais in 1851. Built, owned, and operated by a British company, it consisted of four copper wires insulated with gutta percha, a rubber-like tree gum from Malaya, and then wrapped with tarred hemp and protected by an outer layer of galvanized iron rope. It proved very profitable — especially carrying market information and other news between London and Paris — and was quickly followed by other cables to Belgium, Holland, and Ireland, as well as several cables in the Mediterranean. Many of these early cables broke during laying or failed in other ways; in the early days of cable telegraphy, enthusiasm often outran expertise and people learned mostly by making expensive mistakes.

An important phenomenon turned up on some of these early cables, and also on insulated underground lines that were laid at about the same time. Sharply defined signals sent in at one end of a cable emerged at the other slightly delayed and badly stretched out, so that they blurred together and often became unreadable. (Most signals in the 1850s were received on simple needle galvanometers, the telegrapher watching the swings of the needle and calling them out to be written down by an assistant.) This stretching and distortion came to be called “retardation,” and it put serious limits on how much traffic a cable could handle — if you tried to send too quickly, the message could not be read at the far end. And the problem seemed to be worse on longer cables.

Late in 1853 cable engineers demonstrated the phenomenon for Michael Faraday and asked his advice; in January 1854 he gave a lecture at the Royal Institution in which he said that retardation provided striking confirmation of the views he had developed years before about the relationship between electrical induction and conduction — views that had hitherto attracted little support from scientists. Induction, Faraday said, must precede conduction, and only after the insulating dielectric around the wire had been put into a state of inductive strain, with the storage of a certain amount of electric charge, could the wire begin to conduct a current. In ordinary overhead wires this happened so quickly that no one noticed and the current seemed to start flowing immediately, but submarine cables, consisting as they did of a copper wire separated by a thin layer of gutta percha from the surrounding iron armoring and seawater, were in effect very long capacitors or Leyden jars, able to store enormous static charges. The current thus did not appear immediately at the far end of the cable once the sending key was depressed, and it did not stop immediately once the contact was broken, retarding and blurring the signals.

William Thomson (then a thirty year old professor at Glasgow) took up the problem later in 1854 and worked out “arrival curves” based on Fourier’s equations for the diffusion of heat.



Thomson’s arrival curves for cable signals (1854)

The delay in the rise of the current was proportional, he said, to the product of the total resistance and capacitance of the cable; it was thus proportional to the square of the cable’s length. Double the length of a cable and its retardation quadrupled, while the maximum rate of signalling fell to one quarter that on the shorter cable. The only apparent way to hold down the retardation would be to reduce the resistance and capacitance of the cable by making its copper wire and gutta percha insulation much thicker — thus making the cable enormously more expensive. This was obviously bad news for promoters of really long cables, and battling retardation became one of the main preoccupations of British cable engineers and physicists - particularly William Thomson.
By the mid-1850s, various promoters were already laying out expansive plans for long cables, especially across the Atlantic from Ireland to Newfoundland, then on to the US. American businessman Cyrus Field began to promote such a project in 1854, and after failing to attract much capital in the US, he came to Britain and launched Atlantic Telegraph Company in September 1856, promising to lay the 2000 mile long cable the following summer. This was an enormously ambitious project, far beyond anything previously attempted, and Field pushed it ahead at breakneck speed.

The cable Field proposed to lay across the Atlantic would not be much thicker than those already used for much shorter lines. But if retardation increased with the square of the length, it might make signalling rates too slow to be profitable. This was a serious problem and threatened to scare away potential investors.

At this point E. O. Wildman Whitehouse entered the picture. He was a Brighton surgeon turned electrical experimenter, and a friend of J. W. Brett, the man behind the first Channel cable and later one of Field’s partners in the Atlantic Telegraph Company. In 1855 Whitehouse did experiments on lengths of cable being readied for shipment to Mediterranean; he said these showed that retardation would not be a problem even on cables long enough to reach across the Atlantic or to India and Australia. Whitehouse followed this up in 1856 with a frontal assault on Thomson’s “law of squares,” declaring that his experiments showed it to be nothing more than “a fiction of the schools.” This was just what Field wanted to hear; he soon brought Whitehouse into the Atlantic Telegraph Company as its “electrician,” in charge of all electrical arrangements.

Thomson answered Whitehouse and they had a fairly lively exchange, mostly in the pages of the *Athenaeum*. Neither was willing to back down, but Whitehouse was willing to concede that Thomson’s theory was true “as theory,” as long as Thomson would admit — as he soon did — that there might be practical ways to make a relatively thin cable work well enough to pay (mainly by using alternating positive and negative currents, which sped the discharge of the cable). Glasgow stockholders in the Atlantic Telegraph Company elected Thomson their representative on the company's board of directors, and from then on he played a very active role in the effort to lay the cable.

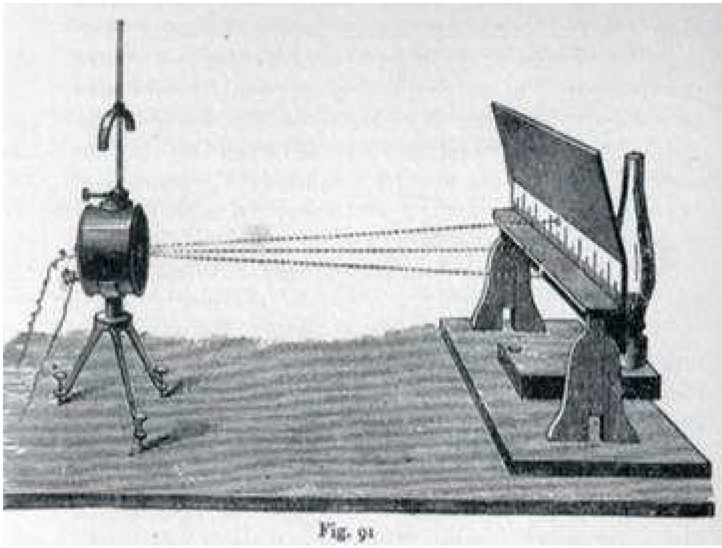
Through 1857, Whitehouse devised and patented various instruments, mainly large relays, induction coils, for use on the planned cable. The Atlantic Telegraphy Company reportedly spent as much as £13,000 on Whitehouse's instruments.

Thomson sailed with the first attempt to lay the cable, in summer 1857, but it proved abortive; the cable snapped and it became clear that the laying apparatus was inadequate. The effort was abandoned until the next summer, with the cable being stored — exposed to the air and weather — on the docks at Plymouth.

Meanwhile, Thomson, with no payment from the company, devised his own very light "mirror galvanometer" to respond to very weak currents.

He also began to make measurements of the conductivity of copper and showed that different samples of supposedly pure copper could vary widely in their electrical characteristics. He called on the company to require careful testing of materials and to insist on high specifications. All of this required the development of more sophisticated methods of electrical measurement.

Thomson had by then been drawing on students to help with some of his experimental work for several years; he now took over a basement room at the University and turned it into the first physics teaching laboratory in Britain.



Thomson's mirror galvanometer (1858)

Thomson set out with the cable-laying expedition again in the summer of 1858, and after several false starts, the first Atlantic cable was successfully completed from Ireland to Newfoundland on 5 August 1858. The ensuing celebrations were overwhelming, especially in America; the fireworks at the New York City Hall almost burned it down. The cable was hailed as the great triumph of the age, the annihilator of distance, the guarantor of universal peace and understanding.

But the 1858 cable never worked quite right. During laying, the operators had signalled through it quite well using Thomson's mirror galvanometer, but once the ends were landed and handed over to Whitehouse in Valentia, Ireland, and to his assistants in Newfoundland, they had great difficulty getting their heavy apparatus to work through it. Desperate, Whitehouse began using high voltages — including from a five foot induction coil — that further damaged the already fragile insulation. After a few weeks, the exasperated board removed Whitehouse and put Thomson in charge at Valentia. Thomson managed to get some additional messages through, but by then the cable had been fatally damaged; by late September, it had failed completely. The disappointment was profound; oceanic cable telegraphy looked like a great *failed* *technology*.

Thomson returned to Glasgow and continued working on problems of cable telegraphy. He began to collaborate closely with a young cable engineer, Fleeming Jenkin, who was then working on the Red Sea cable project, a great Imperial effort to lay a cable down the Red Sea and across to India to improve communications in the wake of the Indian Mutiny. The Red Sea project also proved a failure (in part because of contract provisions that guaranteed payment from the government whether the cable worked or not). By then the government Board of Trade and the Atlantic Telegraph Company had established a Joint Committee to investigate the whole question of the construction of submarine cables. Thomson's testimony before the committee played a big part in its conclusion that with proper procedures — including scientific measurement and careful quality control — oceanic cable telegraphy could be made a success rather than the dismal failure it had hitherto been.

Thomson's experience with cables convinced him that both telegraph engineers and scientists needed accurate and strictly comparable electrical units and standards, and he played a leading role in launching the British Association Committee on Electrical Standards in 1861, which went on to establish essentially the system of ohms, amps, and volts we still use today.

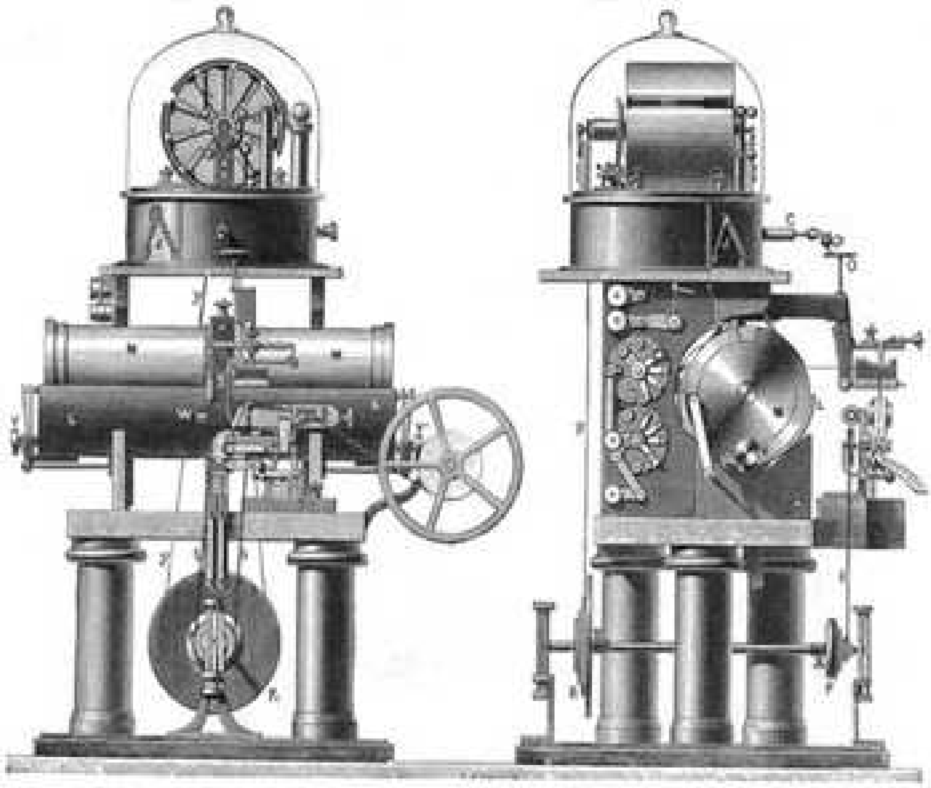
After a few years to regroup, Cyrus Field resurrected his Atlantic Telegraph Company, attracted financing for another attempt and chartered the Great Eastern, the only ship big enough to hold the entire length of cable. This time the company followed scientific advice (notably Thomson's) much more closely and saw that the cable was manufactured to much higher standards. By summer 1865 they were ready to set off again. Thomson again sailed on the expedition, which relied heavily on his instruments.

Unfortunately, the cable snapped about two-thirds of the way across. Many investors gave up, but Field tried yet again, and in 1866 a cable was successfully laid from Ireland to Newfoundland. What's more, the *Great Eastern* went back, grappled up the 1865 cable, spliced a new length to its end, and completed it Newfoundland as well.

Thomson's mirror galvanometers were used extensively for testing during the laying of the 1865 and 1866 cables, and then for virtually all signalling once they went into operation. Thomson was rewarded with a knighthood in November 1866.

A boom in cable-laying soon followed, and starting around 1869 cables were laid to India, Australia, Japan, and around the coasts of South America and Africa. Almost all of these cables were made, laid, and operated by British companies. The global cable network became a bulwark of British imperial power in the last third of the 19th century. It also had a big and continuing effect on British work in electrical science, both in stimulating work in precision measurement and in directing attention toward propagation and field effects.

The mirror galvanometer was very sensitive, but it produced no record of the received message and put a lot of strain on the operators, as one had to watch the spot very intently and another had to write down the signals as they were called out. Thomson responded by inventing his siphon recorder, patented in 1867 and brought into service in 1870.



Thomson's patented siphon recorder (1870)

This used a very delicate moving coil and a tiny glass tube that siphoned ink and squirted it electrostatically onto a moving paper tape; it was really an ink-jet device. Like many of Thomson's other patented devices, these were made by James White of Glasgow, with whom Thomson worked very closely — in fact becoming a partner in the business.

Thomson's siphon recorder became standard equipment on virtually all long cables after the early 1870s, and royalties brought him a very substantial income. In the 1860s he had formed a patent partnership with Fleeming Jenkin and another cable engineer, Cromwell Fleetwood Varley, and after some initial tough negotiations with the big cable companies, their patents brought in several thousand pounds a year for each of them through the 1870s and 1880s — this at a time when a few hundred pounds a year was a respectable academic income. Thomson also worked as a consultant to various cable firms, bringing in substantially more money.

By 1870 Thomson was flush enough to be able to buy himself a yacht, the *Lalla Rookh*, and he became an avid sailor. In 1873 he sailed the *Lalla Rookh* to Madeira, where he had met Frances Blandy on an earlier cable-laying trip; he proposed to her and they were married in 1874. The next year he used some of his rapidly accumulating cable profits to build "Netherhall," a large house at Largs on the seaside south of Glasgow. Clearly the cable business had been very good to Thomson.

By 1890 or so, the cable industry was mature and even getting rather stodgy. Once they had a reliable design and standard procedures, cable men were very reluctant to tinker with a successful formula; when even a small fault could ruin the value of such a huge investment, it was not worth taking much risk. There was a huge downside if anything went wrong, and little incentive to improve the carrying capacity by much, since the companies could make a good profit selling their available capacity at relatively high prices. There were some improvements in terminal apparatus, but fairly minor variants of Thomson's siphon recorder remained standard until well after 1900. The design and manufacture of the cables themselves scarcely changed between the 1860s and the 1920s — they were still copper wires covered with gutta percha and armored with iron wire — or in some important respects until the 1950s, when the first cables with electronic repeaters were introduced. By then the cable network was coming under serious competition from radiotelegraphy and a little later from satellite communications. Nowadays, of course, submarine cables are a bigger business than ever, but they are all fiber optic.

Thomson remained remarkably energetic in his later years, but he also became rather conservative; by the 1880s, though held in immensely high regard, he was widely seen as being a bit out of step with new scientific ideas. He stuck with the elastic solid theory of the ether long after most other physicists had given it up, and except for a fairly brief period in the late 1880s and early 1890s, when he was swept along by the excitement surrounding Hertz's discovery of radio waves, he never really took up Maxwell's theory of the electromagnetic field. He was also well known as an opponent of Darwin's theory of evolution, arguing based on cooling rates that the earth could not be nearly old enough for the slow process of natural selection to have done its work.

In the 1880s Thomson also became very active politically as a Liberal Unionist, opposing Gladstone's plans for Home Rule for Ireland. (Thomson had, of course, been born in Belfast.) It was partly as a reward for that political work, and as a way to leverage Thomson's scientific and technological fame for political purposes, that Salisbury granted him a peerage in 1892 — and confronted Thomson with the problem of choosing a name.

Just as the submarine cable was one of the characteristic technologies of the Victorian British Empire, William Thomson was the characteristic physicist of that same era and of that same empire. He really should have been called "Lord Cable."

Erratum for Hibbert Article in Issue 22

Page 43 Fig 4 should have had caption and attribution as shown below.

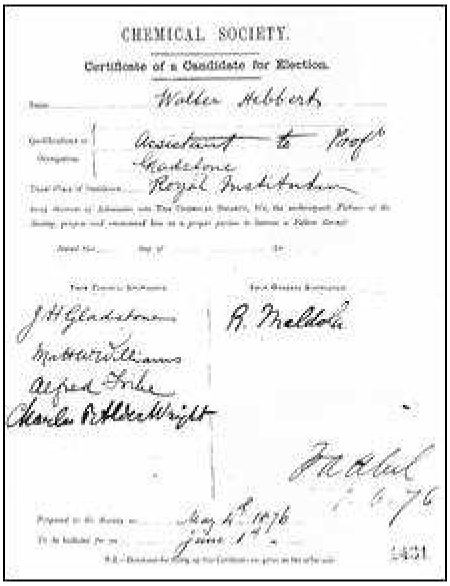

CHEMICAL SOCIETY.
Certificate of a Candidate for Election.
Walter Hibbert
Assistant to Prof. Gladstone
Royal Institution

Fig 4.
Certificate of proposal for Walter Hibbert's election to the Chemical Society, 4 May 1876
Reproduced with kind permission of the Library and Information Centre at the Royal Society of Chemistry

and

Page 48 Line 3: $1/d^2 \propto x$ i.e. $1/d^2$ is *proportional* to x

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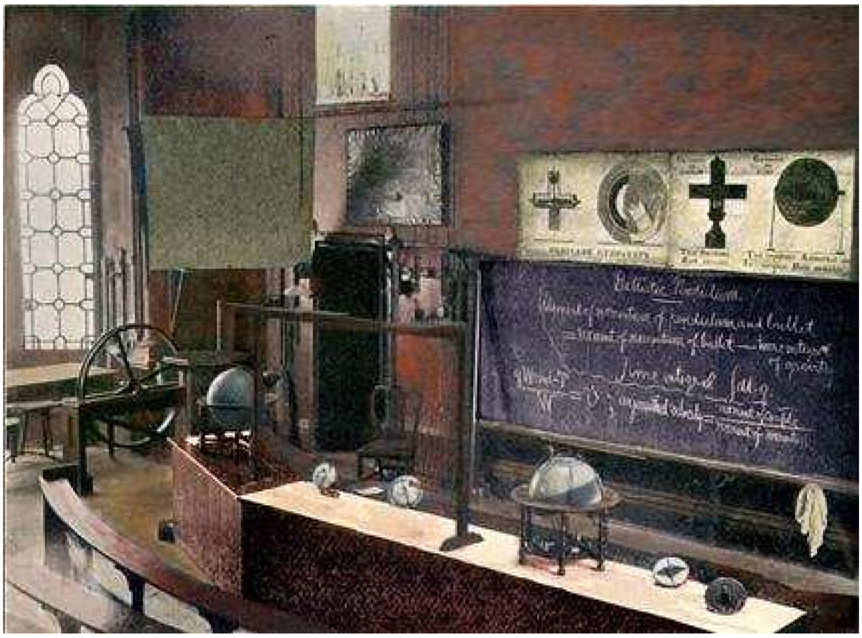
Kelvin at Glasgow

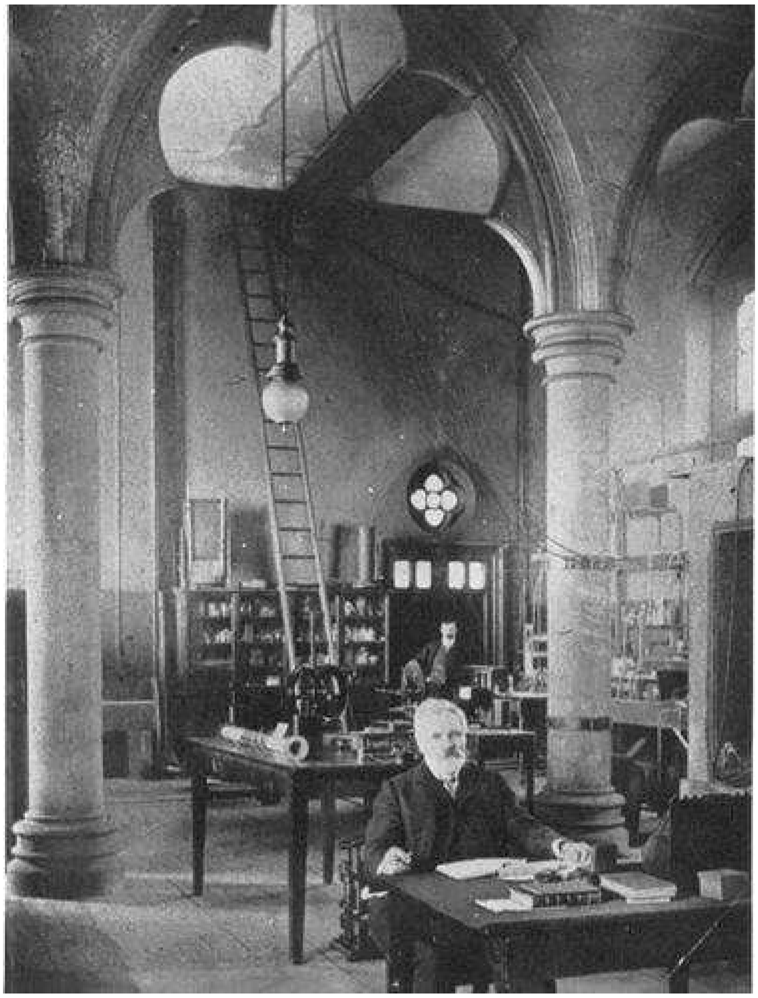
Ken Skeldon, University of Glasgow

Kelvin entered University of Glasgow aged 10, studied there and then at Cambridge, and was appointed Professor of Natural Philosophy at Glasgow at the age of just 24. He was a professor at Glasgow for 53 years, 24 of them at the old college site in the city's High Street and 29 of them at the present West-End site on Gilmorehill. Even when he retired in 1899, he promptly enrolled as a research student earning him the reputation of both the youngest AND oldest person ever to matriculate at Glasgow University.

He was an accomplished mathematician, an ingenious applied scientist and an innovative inventor. It was this mix of skills that made him such a prominent contributor in so many aspects of 19th century scientific discovery and progress. He carried out research in energy, light, electricity, magnetism and many topical issues of the time including how heat and work were inter-related, how light travelled, calculations on the age of the earth and what constituted matter.

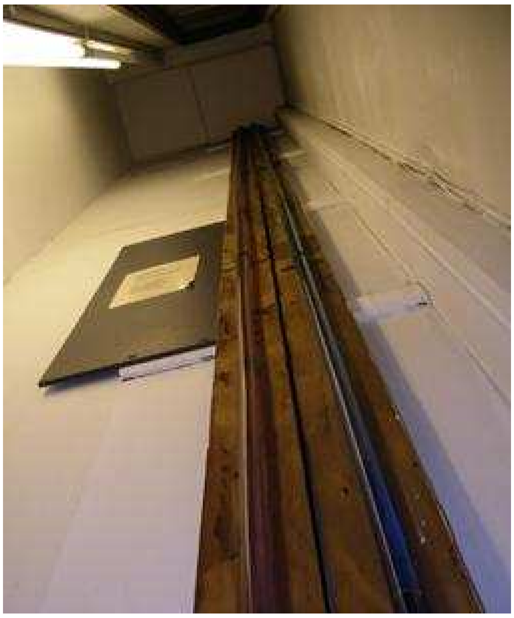


Kelvin's classroom set up for a dynamics lecture



Kelvin's laboratory -photographed shortly after Kelvin's retirement as a professor.

However it was not only Kelvin's contributions to scientific discovery that made him famous. He was, above all else perhaps, an inspirational teacher. His methods of teaching by demonstration and encouraging students to become involved in his laboratory research, in many ways anticipated the higher research degree structure that would eventually unfold. One famous classroom demonstration is still in place to this day.



The diffusion experiment (seen on the left, and still present in the University's Senate room (previouslyKelvin's classroom)) which he set going in 1872 is the only remaining artefact from his classroom and lab suite and is now widely considered the longest running experiment in the world. It comprises two glass tubes each 17 ½ feet long filled with alcohol and copper sulphate then topped up with water. The gradually shifting boundary layer demonstrates the migration of molecules from one liquid into the other. Kelvin estimated that it would take 10,000 years for the mixing to be complete.

No.11, Professors' Square

There was an order of seniority expressed by the occupancy of the houses in the University's Professors' Square, not just in terms of the professors in post, but the subject they taught. The principal residence was at No 12 – and is the only building in the square still used as a residence today, by current Principal. Kelvin's residence was No 11 and was the first house in the world to be lit entirely by electric lighting back in 1881. Kelvin personally oversaw the changing of all 112 gas lamps. His house, as it might have appeared following his pioneering upgrade, is shown above!

The meeting room in No.11 was most likely Kelvin's reception room with open views beyond – now the view is onto the present Physics block, opened in 1907 – the same year as Kelvin died. The print on the wall of the reception room is a 1902 photo of Kelvin, aged 78. This painting shows Kelvin with his compass, one of the many patented instruments his city-centre firm would sell to marine organisations including the UK's own admiralty. Notice also his distinctive diamond finger ring, which also prominently features in the X-ray taken of his hand, and held in a collection at the Royal Society in London. picture

(N.B. - This can be seen on page 7 the first page of Bruce Hunt's article 'Kelvin the Telegrapher')

Another interesting feature in the reception hall of No.11 is the free pendulum clock of 1867, (seen here on the left), originally designed to drive a telescope mechanism. Its large face was added in the late 1870s after Kelvin's wife requested it be more functional, if it was going to occupy such a large space in the house.

Other points of interest around Glasgow University's campus include the Memorial Gates at the brow of the hill on University Avenue and upon which Kelvin has a prominent mention, alongside many other famous people associated with the University. Close by, you can also see the statue of Kelvin by Archibald Macfarlane Shannan in Kelvingrove Park (check out the often-overlooked sculpting at the rear depicting Kelvin's instruments).

Within the West Quadrangle of the University main building there still exists the easily overlooked fast-running clock in the south wall (used by Kelvin during various experiments on gravity).

Of interest to some might be the most recent addition to Kelvin memorabilia, specially conceived for the 2007 centenary year. This takes the shape of a new commemorative stone and accompanying gyrostat sculpture and was unveiled on December 17th, the precise day of the centenary of Kelvin's passing. The memorial was commissioned by the Royal Philosophical Society of Glasgow, which Kelvin twice presided over, and can be seen adjacent to the Thomson Family stone in Glasgow's Necropolis cemetery.

Finally, visitors to Glasgow, and the University, with an interest in Kelvin should also make a trip to the University's Hunterian Museum, where they will find a permanent exhibition devoted to Kelvin's life and work. Many of Kelvin's original scientific instruments are on display as well as a host of interactive demonstrations helping to bring alive all aspects of his achievement. Admission to the museum and exhibition is free and is currently open every day except Sunday.

Kelvin and Ireland

Prof. Andrew Whitaker
Queen's University Belfast

The unveiling of the statue of Lord Kelvin in Belfast's Botanic Gardens by Sir Joseph Larmor in 1913. ©The Ulster Museum:Hogg Collection

Introduction

William Thomson, or Lord Kelvin as he will nearly always be called here, was born in Belfast in 1824, and there is a magnificent statue to him in the Botanic Gardens in that city. However he left Belfast in 1832, when his father, James Thomson, at that time teacher and Professor of Mathematics in the Belfast Academical Institution (always called Inst), was appointed to the Chair of Mathematics in the University of Glasgow. With the exception of his period of study in Cambridge from 1841-5, Kelvin was to live in Glasgow for the rest of his life, and was Professor of Natural Philosophy at the University from 1846 to 1899. It might seem that his birth in Ireland was of little relevance to his life and work.

Quite on the contrary, though, in their famous book, *Energy and Empire*, Crosbie Smith and Norton Wise contend that: 'For an understanding of William Thomson, Lord Kelvin, his Irish context is essential.' For a start, his father, an Ulsterman to the core, had an enormous influence on his upbringing and education, and the formation of his character, beliefs and approach to life, and in particular he was largely responsible for Kelvin obtaining his own Glasgow Chair. Other family members returned to Belfast, and in particular his elder brother, also James, played an important role in Kelvin's best-known work.

Also important for the whole family was a rather special set of religious and political circumstances in Belfast at the end of the eighteenth century and for around the first third of the nineteenth. These circumstances mirrored James Thomson (Snr)'s beliefs and helped to form those of Kelvin. It may be addded that for much of his life, with family and friends in Ireland, Kelvin maintained an intense interest in Irish affairs and Irish politics, and, particularly after he had bought his yacht, the *Lalla Rookh*, in 1870, there would have been frequent visits to Belfast. Lastly it may be noted that his intense interest in Irish politics was to lead, towards the end of the century, to his peerage.

James Thomson, Kelvin's father

James Thomson, the father of Lord Kelvin, 1847. A drawing by Agnes Gardner King, a grand-daughter of James, based on one by Elizabeth, her mother. © National Portrait Gallery, London.

Let us first consider his father, James Thomson, in his own way as remarkable a man as Kelvin himself. He rose from working on the family farm near Ballynahinch in County Down, first via local study to become a teacher in the nearby school. At the same time he was learning Latin and Greek to obtain admission to the University of Glasgow. During his years of study, he did his academic work in the winter, supporting himself by teaching and farm work in Ireland during the summer. His qualifications from Glasgow enabled him to become a teacher of mathematics at the new and highly-regarded Inst, and eventually took him to the Chair at Glasgow.

Not only did he obtain these positions of steadily rising importance, but it seemed that he always and inevitably the leader or dominant personality wherever he taught. At both Inst and Glasgow he was noted as a curriculum reformer, being particularly keen to bring up the level of teaching by the recognition of continental contributions to mathematical research. At Glasgow, he campaigned over many years to remove nepotism and patronage,and to create a University fit to match and assist the rising commercial and technological prosperity of Britain's second city. He combined the vision to see what was required to improve the institution, with the political acumen to appreciate how this might be achieved.

We will discuss James Thomson's beliefs in some detail, because it will be obvious to what a large extent Kelvin's were similar. Indeed, the only major difference seems to have been that, while James was prepared to endorse comfort but certainly not frivolity – even his holidays were designed for instruction as well as enjoyment, his son, who had not been subject to the same early struggles, could be tempted by, for example, a small boat while a student at Cambridge, and a considerably larger one when he had made his fortune.

James Thomson was a devout Presbyterian, but he was strongly non-sectarian. It must be remembered that there were effectively three classes of person in Ireland at this time. Definitely at the top were members of the Church of Ireland – Anglicans, episcopalians. In more political terms, they might be called the Ascendancy or Anglo-Irish, and they possessed full rights to own land. Just as definitely at the bottom were the Catholics who had practically with no rights. Rather awkwardly placed in the middle were the Presbyterians, who were allowed to possess land as a privilege. While the first two groups were found in all parts of Ireland, Presbyterians were mainly in Ulster in the north.

James Thomson was adamantly opposed to this state of affairs, and was proud of the fact that, at Inst, the authorities prided themselves on not even knowing the denomination of a particular pupil. He believed that people should be considered on their own merits rather than on the basis of their religious beliefs. It must be admitted, though, that neither he not his son would have had any time for the Catholic church, which both would have thought of as clerically dominated and backward, anti-commerce, anti-science, anti-technology, against, in fact, virtually everything that the Thomsons valued.

In Scotland, of course, things were different and Prebyterianism held sway. When James Thomson took up his position at Glasgow, religious tests meant that, on taking up their Chairs, Professors had to swear to uphold the Presbyterian faith. Rather than being pleased that this, in a sense, improved their standing, James, and later Kelvin, were adamantly opposed to the tests, and much of James' politicking over many years was aimed at their removal. Indeed it was to emphasise his opposition to this form of sectarian discrimination, as much as to the Irish form, that Kelvin, while retaining his fundamental Presbyterian views, made a point of attending Anglican and free church services on a regular basis as well as Presbyterian ones.

As often with the family, there may seem to be a certain ambivalence about the reason for their opposition to the tests. On the one hand, they clearly thought that it was wrong to discriminate against different classes of people. On the other hand there was the more pragmatic point that one could hardly hope to achieve a professoriate of distinction if Anglicans and free church members were excluded, however high their merits.

Just as he was liberal in religious beliefs, James Thomson, and following him Kelvin also, was liberal politically, against unearned privilege and patronage, an advocate of commerce and free trade. Kelvin himself was a keen supporter of the Whig and then liberal parties, until there was a dramatic parting of the ways towards the end of the century, with important personal consequences as we shall see at the end of this account.

It might be said that James Thomson showed himself to be a good Ulster Protestant with his strong work ethic. We have alrady seen his work rate as he rose in life. Even when he was in a comfortable position at Inst, he still rose early in the morning to spend four or five hours each day writing a series of best-selling mathematical textbooks. Again we may note a little ambivalence about his motives. On the one hand he certainly believed that his books, which expressed a modern and practical approach to mathematics, deserved to replace competing texts and were a service to education, On the other he felt no apology was necesary for the fact that the books made him a great deal of money; the labourer, he certainly felt, was worth of his hire!

Again and quite obviously Kelvin was to follow his father. Enthusiastic about pure research as he was, he also felt it an worthwhile use of his time, not only to design, build and make operational novel and useful devices, but to promote their adoption where required in government committee, and to fight for due rights in court. Yet again we may notice some ambivalence. On the one hand he made far more money from these activities than his professorial salary. On the other, his marine inventions – compass, depth-finder and so on, had the specific aim of making seamanship safer, and did indeed save many lives, and Kelvin regarded telegraph cables as an undoubted benefit to mankind, bringing nations together.

To return to the father, we could go further than calling him an extremely capable academic politican. Glasgow University was, at the time or Thomson's arrival, a hotbead of nepotism. If your father had a chair there, you stood every possibility of following him. But of course that was exactly the type of practice that Thomson was trying to stamp out. In that context, his three-year campaign which successfully installed his own son at the age of 22 into the Chair of Physics, despite his youth, his lack of experience in physics as distinct from mathematics, and the slightness of his experience in teaching, must enable him to be reckoned as the academic wheeler-dealer of all time. Of course the resulting appointment was triumphantly successful.

Liberal Belfast c. 1790-1830

In the eighteenth century, Presbyterians in Ireland had at least moderate reason to be dissatisfied with their lot, and a number had elected for comparative religious liberty in America. It will be remembered that a number of Ulster Prebyterians were among the signatories of the Declaration of Independence. (Today 'Irish-Americans' are thought of as almost exclusively Catholic, but that wave of immigration relates to the later famine period. The early Presbyterians had become founding Americans.)

It is scarcely surprising that, in the 1790s, the period of the French and American Revolutions, Presbyterians were broadly supportive of what was seen as a similar movement in Ireland – the United Irishmen under Wolfe Tone. This movement differed greatly from later nationalistic organisations in Ireland in that it avowedly linked 'Catholics and dissenters', and was in fact anti-clerical, aiming at religious tolerance. The 1798 rebellion was strongly supported by many Presbyterians including James Thomson, but it was put down in violent fashion.

However the spirit of liberalism implicit in the United Irishmen remained strong in Belfast in the first third of the nineteenth century. Indeed it is quite amusing to realise that several people who must have been quite close to being hanged around 1798 soon became pillars of the establishment. Several institutions, such as the Ulster Reform Club and the Linenhall Library, which were founded in this period, retain a general spirit of liberalism to this day. Foremost was the Belfast Academical Institution, Inst, founded in 1810 specifically to promote liberalism and non-sectarianism. In its early years this doubled as a school and a small college, and James Thomson had positions teaching mathematics in both; he soon became the dominant personality. By 1832 he was married with seven children; with his textbook earnings he was reasonably well-off, and was able to but a substantial house opposite Inst.

However in 1830 tragedy struck the family when Thomson's wife died. Within two years he had moved with his children to become Professor of Mathematics at the University of Glasgow. It is not clear which of several possible reasons was the spur for this move. Of course the widower may have liked the idea of a fresh start in a new location. Also while he had the title of Professor in the Collegiate Department at Inst, the move to a full University would probably be seen as a step up.

Lastly by the 1830s, the political mood in Belfast was changing for the worse. The popular Presbyterian preacher Henry Cooke was successfully persuading members of his flock to form a united front with Anglicans in opposition to Catholics, and the crude sectarian divisions were forming which have largely characterised politics in the city to this day. While Glasgow itself, of course, was to be far from free from sectarian strife, Thomson may still have felt the move may have been benficial on these grounds as well.

Over the next decade, Thomson established himself as the leading personality in the University of Glasgow, and had considerable success in achieving a variety of reforms. Thus when the Queen's Colleges were founded in Belfast, Cork and Galway in 1845, it seemed natural that Thomson should become President of Queen's College Belfast (QCB).

Cooke, however, would not countenance a non-sectarian liberal in such a position, which he coveted himself. He threatened that, if apppointments were made of which the Presbyterian church disapproved, no trainee from the ministry would be allowed to attend Queen's. The result was that neither Thomson nor Cooke was appointed and the position went to Dr Pooley Henry, an inoffensive minister, and an adminstrator rather than an academic or even an educationalist. Thomson was offered the position of Vice-Principal, at a salary exactly half that of the Principal, a post he naturally turned down. This position went to a student of Thomson's, Thomas Andrews, who was to become well-known as the instigator of the famous Andrews'experiment, which demonstrated the difference between a vapour, whcih may be liquefied by pressure alone, and a gas which may not.

James Thomson, Kelvin's brother, and thermodynamics

Kelvin's brother, James, two years older than Kelvin himself, was also an exceptional character. His obsession was engineering, but he was, in some ways, a more rigorous thinker than his brother; Larmor desribed him as 'the philosopher who plagued his pragmatical brother'.

Until he was in his thirties, his life was something of a struggle; he seemed to feel he was under the shadow of his younger brother, and ill-health disrupted his engineering apprenticeships. However his sister Anna, who had married a Presbyterian minister and returned to Belfast, encouraged James to return to Belfast also. He became Professor of Engineering at Queen's from 1854 to 1873, and during this period, as well as performing his academic duties, he played a larger part in the various schemes to improve the sanitation and standard of life in the rapidly growing industrial city. He moved to take the chair at Glasgow in 1873, retiring in 1889 and dying in 1892.

He had made a major contribution to Kelvin's own thoughts leading to thermodynamics; indeed he may be regarded as one of the founders of thermodynamics in his own right. Indeed even before the first full understanding of thermodynamics in 1850-1, the brothers made what may be seen in retrospect as the first application of the theory. As early as 1824, Sadi Carnot had put forward and analysed his Carnot cycle, which, in modern thermodynamic terms says that high temperature heat obtained from fuel cannot be wholly used for work; some heat must be deposited at a lower temperature. James pointed out that if a Carnot cycle is used to repeatedly freeze and melt ice/water, and work is performed when the freezing takes place, the Carnot cycle must be between different temperatures, In other words there must be a depression of the freezing point under pressure. This important result was soon confirmed experimentally by William.

The two brothers had thought deeply for many years about a dilemma at the heart of the physics of heat and work. Heat or human effort could be used to perform mechanical tasks; however in other circumstances it may appear to have no product. The brothers also saw the same dilemma between the arguments of James Joule, who claimed that heat was a form of energy and energy was conserved, and Carnot, who had shown that it was impossible to make complete use of any quantity of heat.

This dilemma was actually part of an important question about the ultimate fate of the universe. Until the early 1830s, it had been generally assumed that the motion of the solar system, and presumably by extension that of the universe, was stable and unchanging. However the discovery at that time of a slowing down of Encke's comet, indicating the presence of a resisting medium in space, seemed to indicate an eventual end to the universe. For the brothers, this was related to a major theological conundrum in their set of Presbyterian beliefs. On the one hand, they believed in the principle of conservation; only God could create or destroy. However, on the other hand they felt the significance of texts such as 'The world shall wax old like a garment' and 'The things that are seen are temporal', which indicated dissipation, change and decay, a direction or arrow of time, and the eventual end of the universe,

Rather amazingly the dilemma became resolved clearly in the first and second laws of thermodynamics. The first law, attributed by Kelvin to James Joule, expresses the conservation of energy. The second, attributed to Carnot, however, says that, though energy is conserved, it may be rendered 'unavailable'; thus we obtain dissipation of energy, an arrow of time and irreversibility.

The laws of thermodynamics are usually attributed to Rudolf Clausius and William Macquorn Rankine as well as to Kelvin, Rankine being at the time Professor of Engineeering at the University of Glasgow. Indeed technically Clausius was the first to publish his work. However the interests of Clausius were mainly limited to the steam engine, and Rankine thought in terms of molecular models rather than large scale systems. It was Kelvin who had the vision to see thermodynamics as central to the whole history of the Universe, and it is not fanciful to say that this enhanced understanding was stimulated by the two strands of his Presbyterian beliefs.

Kelvin and Irish mathematicians and scientists

Anyone who studies Kelvin's life and work will realise that he had many interactions of different types with mathematicians and scientists who were Irish or had Irish connections, and in general had a high opinion of Irish science and mathematics. For the latter point, it may be mentioned that, when he became Editor of the *Cambridge Mathematical Journal* in 1845, he replaced *Cambridge* by *Cambridge and Dublin*, in order to encourage contributions, in fact, from all parts of Ireland.

It is interesting to present a brief list of Kelvin's contacts who had Irish connections. We may start with James MacCullagh (1809-47), a theoretical physicist from Trinity College Dublin (TCD), who studied the passage of light through solids; we may speak of this as an early contribution to study of the ether, a material through which it was supposed that light should travel. Many Irish scientists including Kelvin spent much of their careers studying the properties of the ether, and Kelvin was heavily influenced by MacCullagh..

Today everybody who uses statistics or the computer has heard of the work of George Boole (1815-64). Much of his early work was performed when he was an amateur mathematician, and Kelvin played a considerable part on obtaining for him his first position as a mathematician when, on the foundation of the Queen's Colleges in Ireland, he became first Professor of Mathematics in Queen's College Cork in 1849.

William Rowan Hamilton (1805-65) of TCD was, of course, one of the most famous mathematicians of the nineteenth century. Kelvin fully appreciated his early work on optics and dynamics, but though most of Hamilton's work on his own discovery of quaternions, of which Hamilton himself was most proud, was published under Kelvin's editorship, Kelvin came to consider quaternions 'an unmixed evil to those who have touched them in any way'.

In this opinion, he disagreed with P.G. Tait (1831-1901), in most other ways his greatest supporter. Tait was a Scotsman, but was Professor of Mathematics at QCB from 1854 to 1860, before becoming Professor of Natural Philosophy [Physics] at Edinburgh. Kelvin and Tait collaborated on the famous *Treatise on Natural Philosophy* always known as *T and T'*, which was the first book on physics to be centred around the new paradigm of energy rather than Newtonian force. Tait was a devotee of quaternions and wished them to appear in the book, but Kelvin overruled this suggestion. Another relevant scientist with QCB connections was Thomas Andrews (1813-85), who we have already met.

George Stokes (1819-1903) from County Sligo, famous today for several Stokes' Laws and Theorems, was Lucasian Professor at Cambridge from 1849. He was the scientist closest to Kelvin, and they communicated mainly via innumerable letters on the ether and many other branches of physics.

John Tyndall (1820-93) from Carlow, on the other hand, was Kelvin's greatest scientific opponent. He was a self-made man who rose to be Professor of Natural Philosophy at the Royal Institution, and, as a follower of Thomas Huxley and a fellow agnostic, his approach to life was completely opposed to that of Kelvin. Tyndall's famous 'Belfast address' to the Britsh Association of Science in 1874 was a celebration of materialism, and a call for any religious input to science to be eliminated.

Samuel Haughton (1821-97) became Professor of Geology in TCD as early as 1851, later gaining a medical qualification and becoming Registrar of the School of Medicine. As a geologist, he was a strong supporter of Kelvin in his battle over the ages of the Earth and the Sun. Kelvin argued that these ages must be very limited, indeed far too small to allow the processes demanded by the evolutionists and most geologists. The discovery of radioactivity was to render Kelvin's age limit completely wrong, and the reputations of both Kelvin and Haughton were to suffer from their (actually quite mild) opposition to the theory of evolution over the question of the enormous periods it would take.

John Everett (1831-1904) was acknowledged by Kelvin as his most able student in the whole of his 53 years in Glasgow. Subsequently he became Professor of Natural Philosophy at QCB from 1867-97, where his main interest was one of Kelvin's, the establishment of a practical set of electrical units.

George Francis Fitzgerald (1851-1901), another great figure from TCD, is best known today for his proposed explanation of the Michelson-Morley result – the so-called Fitzgerald(-Lorentz) contraction. He was an ardent follower of Clerk Maxwell's electromagnetism, and thus, though he admired Kelvin and his work in general immensely, he became a strong critic of Kelvin's failure to agree with Maxwell as a result of his failure to obtain a physical understanding of the displacement current.

John Perry (1850-1920) was a graduate of QCB; he worked with Kelvin in Glasgow in the 1870s, and then, together with William Ayrton, took Kelvin's methods to Japan. Back in England in the 1890s, he became the most prominent critic from the physics point of view of Kelvin's arguments on the ages of the Sun and the Earth. Perry considered these arguments correct in principle, but suggested that the specific answers obtained depended on detailed assumptions which were rather arbitrary.

Joseph Larmor (1857-1942) was a native of County Antrim. After study at QCB, he moved to Cambridge, where he became Senior Wrangler in 1880. He was Professor of Natural Philosophy in Queen's College Galway from 1880 to 1885, when he returned to Cambridge as a lecturer, succeeding Stokes as Lucasian Professor in 1903. In turn he was succeeded by Dirac in 1932. His main interests were in electromagnetism and the ether, and he interacted frequently with Kelvin in connection with these areas of science. He was to edit the collected works of both Stokes and Kelvin.

Lastly we mention John Townsend (1868-1957). A native of Galway, he studied at TCD before worked with J.J. Thomson in Cambridge, and in 1900 he became the first Wykeham Professor of Physics at Oxford. It is interesting that Kelvin, then in his 70s, wrote references for Townsend, and, when he had accepted the Oxford position, assisted him to obtain a Royal Society grant for equipment.

It is interesting to speculate on and generalise Kelvin's interactions, positive and negative, with scientists from Ireland. Some have suggested the existence of an Irish tradition, or possibly an Irish-Scottish tradition, including, for example, Maxwell, and clearly one could construct an argument along these lines centred around studies of the ether . Some have even suggested a mutually supporting 'Irish mafia', and pointed to, for example, the large number of Irish names among those giving testimonials for Kelvin when he obtained his Glasgow chair.

While these suggestions are worthy of further study, it should be noted that Irish and Scottish science was strong in the nineteenth century. England and Wales had only two Universities between them until well into the century, Universities obviously of the highest achievement at their best, but certainly not continuously at their best. Even when the 'redbrick' Universities were founded, initial achievement in science was low, and it was practically the end of the century by the time that, for example, Oliver Lodge and John Poynting made their substantial contributions.

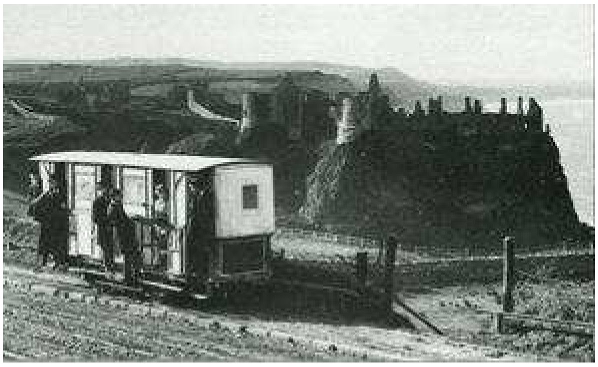
In contrast, TCD and the Scottish Universities were well-established and, at least from the eighteenth century, of respectable achievement, while the Queen's Colleges, particularly QCB, made a quite auspicious start. Irish and Scottish mathematicians and physicists may have interacted closely merely because there were a substantial number of successful ones.

Kelvin and industry in Ireland

As is well-known, as well as his science, Kelvin made enormous contributions to technology, playing the largest part in the establishment of the Atlantic cable, and designing and constructing many important devices, several of great use for the safety of ships – the mariner's compass and the depth sounder, for example. From the point of view of this article, the main significance was that Kelvin's contributions, as he saw them, to the power and properity of the British Empire convinced him of the importance for Ireland of remaining within the fold. This belief shaped his political stance in the latter decades of his life. Here we mention two of the examples of his technical prowess in Ireland.

The first is the famous Giant's Causeway tramway of 1883, the first in the UK, and the first to use hydroelectric power in the world. Kelvin had long been a proponent of the use of electrical power and became a Director of, and Technical Consultant to the project.

Kelvin also had the excellent idea that the light from lighthouses should be modulated by Morse code to indicate which lighthouse was its source, an idea of great use to lost seafarers. The lighthouse at Holywood near Belfast was the first to utilise this scheme.



A tram on the Giant's Causway tramway at Dunluce Castle c. 1890 © The Ulster Museum Welch Collection

Kelvin and Liberal Unionism

Through his life Kelvin was liberally minded, non-sectarian and against all forms of patronage. As late as 1884 he had actually been asked to stand as the Liberal candidate for the University seat of Glasgow and Aberdeen.Yet from the following year, events took place within the Liberal party that led to his campaigning strongly against it over the issue of Home Rule for Ireland.

As has been said, Kelvin had become a strong supporter of the British Empire and he saw every benefit, cultural, technical and commercial, for Ireland to remain an equal partner. In contrast he saw the Home Rule movement on the second half of the nineteenth century as against commerce and technology and clerically dominated. He considered the Catholic church irredeemably backward-looking.

In the 1885 General Election, the Irish party under Charles Stewart Parnell gained the balance of power between the Liberals under William Gladstone, and the Conservatives under Lord Salisbury, and in the following year, Gladstone, with the support of the Irish party, put forward a Home Rule Bill. However this split the Liberal party. Many Liberals, especially in the West of Scotland, were unable to stomach Home Rule, more than 90 Liberal MPs voted against the Bill, and it was defeated.

In the forthcoming election campaign, a large section of the Liberals split from Gladstone, forming the Liberal Unionists. Among them was (as he then was) William Thomson, who campaigned vigorously against Gladstone. In the election, 78 Liberal Unionists were elected, and the Conservatives defeated the Liberals heavily. The Liberal Unionist MPs broadly supported the Conservative government under Salisbury, though for tactial reasons they sat on the Opposition benches with Gladstone's Liberals. By 1900 those left in the Liberal Unionists were essentially united with the Consevatives, and the merger into the Conservative and Unionist Party was completed in 1912.

Thomson remained an enthusiastic Liberal Unionist, attending rallies and giving speeches, and in 1891 became President of the West of Scotand Liberal Unionist Association, the Honorary President being the Duke of Devonshire. It was the Duke who suggested to Salisbury that Thomson would make an excellent Liberal Unionist peer, and in 1892 he was indeed ennobled as Baron Kelvin of Largs. This would not have happened had it not been for his science and technology; equally it would not have happened but for his political activities.

At the next General Election in 1892, Gladstone was back in power with the support of the Irish party, and in the following year his Second Home Rule Bill passed through the House of Commons but was easily defeated in the Lords. This was to spell the end of Gladstone's political career. The Conservatives were in power from 1895 for over ten years, and Kelvin's worries over Home Rule must gradually have subsided. This general complacency led to the Liberal Unionists themselves splitting over fiscal reform, and in 1906 the Liberals were returned to power. Over the next fifteen years, immense changes were to take place in Ireland, but of course Kelvin died in 1907 so they lie outside our story.

Conclusions

Kelvin was born in Ireland but spent nearly all of his life based in Scotland, It may be best to think of him and the Thomson family as Ulster-Scots. Their descendents had moved from Scotland to Ulster in the mid-seventeenth century. It was natural for James Thomson (Snr) to study in Glasgow, and for both James and William to seek Chairs in Glasgow. It was equally natural for William's sister, Anna, and his brother James (Jr) to return to Belfast. It is quite clear that Kelvin retained an intense interest in every aspect of Irish life – political, cultural,commercial and technogical. Certainly once he was in possession of his ocean-going yacht, one would have found him sailing regularly to Belfast for a political talk, a scientific or technical discussion, a family get-together, equally interested in, and concerned and involved with the affairs of Ireland as those of Scotland.

References

The two standard works on the life of Kelvin are T*he Life of Wiliam Thomson, Baron Kelvin of Largs* by Silvanus P. Thompson (MacMillan, London, 1910; Chelsea, New York, 1976 (2 vols.)) and *Energy and Empire: A Biographical Study of Lord Kelvin* by Crosbie Smith and Norton Wise (Cambridge University Press, 1989). Both have been of great use in the writing of this paper.

In order to save space, further references are not given here, but may be found in those books or in my article 'Kelvin : The Legacy' in Kelvin: Life, Labours and Legacy edited by Raymond Flood, Mark McCartney and Andrew Whitaker (Oxford University Press, 2008), or in other chapters in that book.

Kelvin and the Clyde

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On the occasion of his installation as Chancellor of the University of Glasgow on 29 November 1904, Lord Kelvin recalled how, some 90 years earlier, his father and a party of fellow-students from Ulster landed at Greenock and set out on foot to complete their journey to the University:

> On their way they saw a prodigy – a black chimney moving rapidly beyond a field on the left side of the road. They jumped the fence, ran across the field, and saw to their astonishment Henry Bell's Comet – then not a year old – travelling on the river Clyde between Glasgow and Greenock. Their [student] successors, five years later, found in David Napier's steamer Rob Roy (which in 1818 commenced plying regularly between Belfast and Glasgow) an easier, if a less picturesque and adventurous, way between the College of Glasgow and their homes in Ireland.[1]

It is certainly no exaggeration to claim that not only was William Thomson born into an era of steam navigation but that his whole life, from beginning to end, was interwoven with that maritime context.

Back in the 1810s of course things were very different. On occasions even the 40-foot Comet had scarcely enough depth to navigate the Clyde. William's father had had to endure three-day passages between Belfast and Glasgow – on one of which the sailing smack, laden with lime for Glasgow's iron works, had been carried by the tidal streams three times around Ailsa Craig, the 1000-foot high haystack-like island in the entrance to the Firth of Clyde known to seafarers as 'Paddy's Milestone'.[2]

William's mother had also made her first visit from Glasgow to Belfast on board a sailing packet. The then Margaret Gardner set out in May 1816 to visit a cousin, William Cairns, Professor of Logic and Belle Lettres at the newly established Belfast Academical Institution. The sailing packet, departing from Bowling, had taken at least twelve hours to reach Greenock, a few miles down river, where the wind had failed completely.[3]

Margaret recorded the experience in her correspondence. *'Much as I had heard of the badness of the accommodation of these Packets', she wrote, 'the scene presented upon first stepping down to the Cabin far surpassed anything I had imagined'. In a space no more than nine feet square were stowed 'four children nursing', four more able to stand on their feet, eight women, and one 'very big man', in addition to herself and her two companions. Later, the 'very big man' insisted 'upon lighting a candle to amuse the children' while amusing 'himself by smoking'. And in reply to objections raised against the smoking, he told his critics 'that he did not come here to pay and not be allowed to do as he pleased'.*[4]

Transferring to another packet possessed of what she regarded as superior accommodation, Margaret reached Belfast in a 20-hour passage from Greenock. It was during this, her first visit to Ireland that she became acquainted with James Thomson whom she married the following year (1817).[5]

Eight years later, with four children including one-year-old William, the Thomsons paid their first visit as a family to Glasgow. This time the spiritual, moral and material 'improvers' of steam navigation had displaced the old sailing packets on the North Channel.[6] Belfast to Glasgow's Broomielaw in summer now took just under 24 hours. One of the most energetic promoters of such cross-channel steamship services was George Burns, youngest son of the minister of Glasgow's Barony Church and brother of Glasgow University's regius professor of surgery, Dr John Burns. Both families were mainstream Presbyterians, the Thomsons belonging to one of Belfast's newest Presbyterian congregations (Fisherwick) and the Burnses to one of Glasgow's oldest. Both were strong admirers, as well as close friends, of the Reverend Thomas Chalmers, Scotland's leading Presbyterian preacher of the day.[7]

Not everyone in Scotland shared the Burnses' and Thomsons' unbridled enthusiasm for steam navigation. A deeply pessimistic Calvinism, which emphasized the inevitable consequences of human depravity, commanded a popular following, especially outside Glasgow and Edinburgh. These popular forebodings were recalled by the celebrated naval architect John Scott Russell (builder of the *Great Eastern*). The early steamer Glasgow had departed around 1816 on a short sea passage, the venture being described by so-called friends of the ship's crew as 'a tempting of Providence'.[8]

Although the Comet only foundered after eight years service and then without loss of life, the second Comet fulfilled the gloomy prognostications of Scotland's Calvinists with a melancholy disaster – involving heavy loss of life – following collision with another steamer on Trafalgar Day, 21 October, 1825, not far from Greenock and only a few weeks after the Thomsons had returned by steamer to Belfast. The sinking of this second Comet occasioned much moralising. One anonymous pamphleteer quickly highlighted 'the fate of the Comet as a signal instance of the uncertainty of life, and the constant peril which besets those who "go down to the sea in ships"'. And while the *Edinburgh Observer* concluded as a result of the disaster that it would 'require a considerable length of time to restore public confidence in steam navigation', the *Edinburgh Weekly Journal* lamented in strong evangelical tones the tragedy of 'so many immortal creatures … in a few brief seconds, hurried to their eternal audit'.[9] Needless to say, none of these grim warnings deterred the Thomsons from their love of steam navigation.

Clyde-built and Clyde-owned

The River Clyde and its wide Firth, the numerous sheltered lochs to the north and the cross-channel voyages to Ireland acted as the testing ground for several generations of early passenger steamers. Very soon, however, certain families and social networks earned a reputation for trustworthiness and reliability.

The Napiers and Dennys of Dumbarton had long been skilled in iron as blacksmiths and iron founders. David Napier made the boiler and castings for the Comet and set up a foundry in Glasgow to produce small engines for river steamers. He voyaged to and from Ireland to observe the behaviour of sailing ships in rough weather and then constructed models for testing hulls on a 'burn' near his works (using a falling weight connected over a pulley to the model as the means of propulsion). On the basis of these experiments he constructed the first cross-channel steamer (1818), the Rob Roy. With this fulfilment of promises, orders flowed in. His engineer/managers included David Tod and John MacGregor, famous in their own right from the 1840s as builders of large ocean-going iron steamers in Glasgow.[10]

Robert Napier, originally intended for the Kirk, took over part of cousin David's works and constructed his first 'side lever' engine for a river steamer in 1823. His engineer/manager David Elder designed the engine which combined ease of access at sea with exceptional strength and reliability. It was also compact compared to Boulton & Watt beam engines. Very soon Napier (and Elder) had a reputation for the best marine engines in Scotland (and later the world).[11]

George Burns entered coastal shipping in the 1820s, first in sail and then in steam. Deeply religious, he worked closely with the Rev. Chalmers to 'improve' the condition of Glasgow's growing mass of poor (mostly displaced from the Highlands) through moral education, teaching self-restraint and self-reliance. Burns (and his associates) believed that God (Providence) did not act arbitrarily to punish individuals and societies. Rather, God acted through laws of nature and society. But individuals (and societies) could bring disaster upon themselves by 'tempting Providence': by over-population, wasteful use of resources, or putting to sea in less-than-seaworthy ships. As a result, the Burnses became known for the very high practical and moral standards of their ships and masters. George (and brother James) established a large network of coastal and cross channel steamers and joined forces with rival David MacIver in the 1830s.[12]

George Burns, David MacIver, Robert Napier and David Elder were instrumental in the launch of the British & North American Royal Mail Steam Packet Company in 1840 – subsequently known as the Cunard Steamship Company. George Burns's elder son John (later First Baron Inverclyde) assumed the chairmanship of the Cunard Line of Steamers from the late 1870s and remained a close friend of Sir William Thomson. Indeed, the Burnses and the Thomsons were near-neighbours, with their respective country seats at Castle Wemyss and Netherhall overlooking the upper Firth where Clyde-built ships ran their speed trials at that time.[13]

Marine engine economy

Two years after Margaret's death in 1830, James Thomson took up the chair of mathematics in Glasgow College. Throughout the 1830s, the family spent most summer vacations on the coasts of the Firth of Clyde – with Arran a particular favourite. Steamers and the sea were an integral part of their education. While at Kirn near Dunoon in 1836, for example, William's older brother James (aged 14) observed the passing steamers and noticed the way in which each paddle blade struck the surface awkwardly before lifting an immense weight of water – with consequent waste of power. He therefore set about inventing an arrangement whereby the paddles would dip perpendicularly into the sea, strike back, and rise without raising unnecessary water. The arrangement was embodied in a working model. His father then took him to Glasgow to show the arrangement to unnamed experts there – who informed him that a patent for a similar purpose had been taken out only a few weeks before.[14]

In the summer of 1839 the Thomson family travelled for the first time to London and the Continent. There was then no railway between Glasgow and Carlisle. So they embarked on the Burns and MacIver steamer *City of Glasgow*, built by John Wood (builder of the first *Comet*) and engined by Robert Napier four years earlier as one of the quality show-pieces of Clydeside shipbuilding and engineering. This state–of-the-art paddle steamer had reduced the passage time between Greenock and Liverpool to under 20 hours (typically the passage time by steamer was over 30 hours). Scaled-up versions of these kinds of steamer provided the design for the first four – and subsequent – Cunard mail steamers for the Liverpool, Halifax and Boston service.[15]

In the autumn of 1843, with William an undergraduate in Cambridge, his brother James began an engineering apprenticeship at William Fairbairn's shipbuilding yard at Millwall, Isle of Dogs, on the River Thames. The yard had strong Scottish engineering connections: Fairbairn himself and James's master (Robert Murray). It was later incorporated into John Scott Russell's yard for the construction of the Great Eastern. But most significantly for William and his brother it was to provide the context of marine engineering economy for the reworking of the theory of the motive power of heat.[16]

In letters to William in the summer of 1844, James articulated Sadi Carnot's theory of the heat engines in which the work done by a steam engine depended on the temperature difference between boiler and condenser, analogous to the difference of water levels accounting for the motive power of water wheels. James's reading gave particular attention to questions of waste – in the context of enhancing the economy of marine steam engines for ocean steamers – and several times referred to 'the sea' as the base level (of gravitation or of temperature) below which neither waterwheels nor heat engines would deliver useful work or mechanical effect. Correspondingly, the engineer's quest was to minimise loss of mechanical effect 'higher up' – through spillage, conduction and so on during the passage of water (or heat) from source to sea.[17]

Over the following decade, these early considerations lay behind much of the brothers' scientific and engineering agendas: James's patents for efficient vortex turbines (horizontal waterwheels); William's formulation of an absolute scale of temperature from Carnot's theory; their understanding of the depression of freezing point of ice under pressure; William's debates with James Joule on the mechanical value of heat; and the construction of the new science of heat and energy.[18]

Thermodynamics and energy brought William – professor of natural philosophy in Glasgow from 1846 – into close association with Glasgow engineers: the successive University professors of engineering Lewis Gordon and Macquorn Rankine (as Ben Marsden has shown), as well as practical shipbuilders and engineers including John Elder (a son of David Elder and former pupil of Gordon), John Scott (who attended the natural philosophy class in the late 1840s), William Denny, and (most closely) James Robert Napier (son of Robert Napier).[19]

Close friendships coincided with shared academic and business concerns. 'The Gaiter Club' in Glasgow unified its members by virtue of their common interest in walking tours in Scotland wearing gaiters. The President was John Burns (Cunard chairman), the Secretary was his brother James Cleland Burns (also a Cunard partner of the second generation), and the Chaplain was the Reverend Norman Macleod (minister of the Barony and editor of the best selling periodical Good Words). Members included Sir William Thomson and novelist Anthony Trollope.[20] Not surprisingly, Macleod elicited a good many contributions from these friends for *Good Words*, including articles on 'Energy' and the 'Mariner's Compass' from Thomson. With Sir William devoting much time to navigational instruments (notably his compass and sounding machine), it is equally unsurprising that the coastal steamers of Burns were among the first to adopt the new technologies.[21]

Dreadnought

From the early 1880s Captain 'Jacky' Fisher (later the Admiralty's First Sea Lord) found in Sir William Thomson a major scientific ally in the causes of naval reform. His 'reading' of Sir William was one of economy of time and energy: of efficiency and effectiveness. They first became acquainted when Fisher vigorously pursued the cause of Sir William's patent magnetic compass (and sounding machine) with the Admiralty. Sir William already had strong Admiralty connections. He had been a member (along with Rankine and William Froude) of the Committee upon the Design of Ships of War which recommended major hull design changes to an earlier *Dreadnought* in the wake of the capsize in 1870 of HMS *Captain*. He was a close friend of James Robert, son of Admiralty contractor and Clyde shipbuilder Robert Napier. He was also a very old friend of Cambridge wrangler Archibald Smith (brought up near Glasgow) whose work on compass error culminated in an Admiralty manual on the subject. But his own compass design had been scorned by the Astronomer Royal, G.B. Airy, and contested by the Hydrographer, F.J. Evans. Foreign navies – but especially the British merchant service – had meanwhile shown considerably greater enthusiasm.[22]

By 1882 Fisher was in command of HMS *Inflexible* (1876), at 11,900 tons displacement the largest fighting ship in the Royal Navy and a participant in the bombardment of Alexandria. He later reported that 'the firing of the eighty ton guns of the *Inflexible* … blew my cap off my head and nearly deafened me, [but] had no effect on … [Sir William's] compasses, and enabled us with supreme advantage to keep the ship steaming about rapidly and so get less often hit whilst at the same time steering the ship with accuracy amongst the shoals'.[23]

A successful outcome of the compass battle became imminent in 1889 when the subject was brought formally before the Board of Admiralty and Hydrographer. Fisher's advice to Sir William was to 'stand entirely aloof from the whole business and let your disciples do the fighting'. Sir William travelled by overnight train from Glasgow to London, 'drove at once to Admiral Fisher's, where he had his bath before 8.30 breakfast' prior to attending the formal hearings. The rhetorical strategy involved ridicule of the old compass. When asked by the Judge at the inquiry whether the Admiralty compass was sensitive, Fisher, as Sir William's witness, replied: 'No, you had to kick it to get a move on'. By that time, the decision was a foregone conclusion. The Thomson compass became the standard one between c.1889 and c.1904 until displaced by a new Admiralty liquid compass.[24]

Given Fisher's long enthusiasm for electricity, it is not surprising that he also found common cause with Sir William on the subject of electric lighting aboard ships of war. Among many technical innovations, HMS *Inflexible* had been fitted two devices for electricity supply in which Sir William had a deep practical and scientific interest: a.c. generators and Faure accumulators (large-capacity storage batteries). Fisher, however, called his attention to a report that a crew member had received a nasty shock through touching an arc lamp powered by generators at some 600 volts. Diagnosing the problem as 'a nasty little leak, but not likely to be dangerous to life', he accidentally touched the bare wire of the offending cable and simultaneously leapt into the air. His revised verdict was 'Dangerous, very dangerous to life. I will mention this to the British Association'. The subsequent death of a stoker due to a similar leak resulted in 80 volts being adopted as standard aboard Royal Naval ships.[25]

Fisher's close friendship Kelvin had extended over more than two decades. In February 1894, for example, just two years after Sir William Thomson's elevation to the peerage as Baron Kelvin of Largs, Admiral Gerard Noel recorded dining at the Fishers where he met Lord and Lady Kelvin and Joseph Chamberlain. Kelvin's ennoblement as the first British scientist to be made a peer owed much to his active involvement in West of Scotland Liberal Unionism.[26]

Splitting from Gladstone's Liberals over the issue of Irish Home Rule in 1885-86, Liberal Unionists represented a powerful alliance of aristocrats (including their leader Marquis of Hartington and the Earl of Selborne), civic and imperial interests (including Chamberlain), and men of science (including Kelvin). Theirs was a vision of a quintessentially rational, scientific, industrial and Protestant Britain and her Empire defined in opposition to what they saw as reactionary, mystical and rural nationalist movements exemplified by Irish nationalism. Their Unionist vision was one of an Empire united (and defended) by the science and engineering prowess of Britain, exemplified by the heavy industries of the Clyde, the Tyne and Belfast. Many of the leading figures shared in crusades for economy and efficiency against any ideology – whether materialist, agnostic or Roman Catholic – that threatened an avowedly Protestant and British faith.[27]

Maximum efficiency and economy were the hall-marks of the science of energy, whether in physical science, engineering or political economy and industrial economy. From his earliest meetings with Kelvin aboard HMS *Inflexible*, Fisher admired above all Kelvin's facility for 'redeeming the time'. He later cited as telling examples the cases of sounding machine and compass, both supposedly worked out when Sir William was rendered otherwise inactive by a broken leg and both designed not only to minimise waste of ships and lives but to economise on human and physical energy.

Fisher thus suggested later that Kelvin's sounding machine, instead of the 'laborious' and 'inaccurate' practice of stopping the ship, enabled depths to be gauged 'no matter how fast the ship was going'. And Sir William had told Fisher in 1892 that 'A ship with us is never detained on account of weather for the adjustment of her compasses'.[28]

Appointed as First Sea Lord in succession to the aristocratic Lord Walter Kerr in 1904, Fisher won the right to establish a Committee on Designs with Fisher as President, ostensibly 'to devise new types of fighting ships'. But he privately admitted that the designs had already taken shape and that 'it was a politic thing to have a committee of good names' for the critics to fire at. To get his way with the politicians, Fisher would again invoke the authority and expertise of esteemed scientific men who would appear aloof from all political dealings and controversies – while of course owing their positions to Fisher. And of all the scientific men, it was the 80-year-old Lord Kelvin who could be represented in an iconic role, adding credibility, lustre, and trustworthiness to the Committee's deliberations and advice.[29]

In practice, ill-health restricted Kelvin's attendance, but in correspondence he typically posed questions about the fuel capacity and consumption of the new leviathans:

> We shall want information about coal supply both for voyages and for fighting times

> and places. I suppose the constructors will be able to tell us how much coal per hour will be needed for 21 kn[ot] new battleship, 25½ kn armoured cruiser, and destroyers 36 kn; and how much coal each can carry in going into action.

A week later he informed Fisher that he was 'in correspondence with Froude about submerged shape of ram-less battleships' while in March he urged the First Sea Lord to take a day off in April in order that he, as Chancellor of the University of Glasgow, might confer on him an honorary doctor of laws: 'I think your name ought to be on the Honours' Roll of the most naval University in the world'.[30]

Conclusion

In this resume of Lord Kelvin in the context of the Clyde, I have stressed how, from start to finish, those maritime contexts of marine steam engineering and iron/steel shipbuilding were inseparable from his life and work. Indeed, I argue that it is impossible to understand – let alone do justice to – the natural philosophy of William Thomson without locating his theories and practices and inventions in those maritime contexts. Moreover, it is scarcely accidental that his choice of name for the peerage in 1892 fell on the River Kelvin – which both embraced the new University site on Gilmorehill *and*, laden with symbolism, was a significant tributary of the larger commercial and shipbuilding River, the Clyde. University knowledge, laboratory science in particular, Lord Kelvin's *forte*, fed the larger maritime enterprises of Glasgow's engineers and industrialists just as their wealth, power and philanthropy fed the construction of that great cathedral of knowledge, the University of Glasgow.

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[2] Ibid., p.4.

[3] Elizabeth King, *Lord Kelvin's Early Home* (London, 1909), pp. 14-16.

[4] Ibid., pp. 15-16 (quoting Margaret Gardner's letter to her sister dated 26 May 1816).

[5] Ibid., pp. 18-19.

[6] Ibid., pp. 33-34.

[7] Crosbie Smith and M. Norton Wise, *Energy and Empire. A Biographical Study of Lord Kelvin* (Cambridge, 1989), pp. 13-14 (Chalmers and the Thomsons); Crosbie Smith and Anne Scott, '"Trust in Providence": Building Confidence into the Cunard Line of Steamers', *Technology and Culture* 48 (2007): 471-96 (Chalmers and the Burnses).

[8] Ibid., p. 475.

[9] Ibid., p. 478.

[10] See for example James Napier, *Life of Robert Napier of West Shandon* (Edinburgh and London, 1904)pp. 18-28

[11] Ibid., pp. 29-68.

[12] Smith and Scott, 'Trust in Providence', pp. 475-80.

[13] Ibid., pp. 471-96; Smith and Wise, *Energy and Empire*, pp. 705 (Netherhall), 776 (John Burns).

[14] King, Early Home, pp.118-32, esp. p.129.

[15] Ibid., p.146; Smith and Scott, 'Trust in Providence', pp. 480, 488-94.

[16] Smith and Wise, *Energy and Empire*, pp. 288-89.

[17] Ibid., pp.289-91

[18] Crosbie Smith, *The Science of Energy. A Cultural History of Energy Physics in Victorian Britain* (Chicago and London, 1998), pp. 30-99.

[19] Ibid., esp. pp. 150-66.

[20] Edwin Hodder, *Sir George Burns, Bart. His Times and his Friends* (London, 1890), pp. 333-38.

[21] For example, Smith and Wise, *Energy and Empire*, p. 776.

[22] This section draws directly on the 'Kelvin' parts of my recent article '*Dreadnought* science: the cultural construction of efficiency and effectiveness', *Transactions of the Newcomen Society* 77 (2007): 191-215, esp. pp.202-05.

[23] Ibid., p. 204.

[24] Ibid.

[25] Ibid., pp.204-05.

[26] Ibid., p.206; Smith and Wise, *Energy and Empire*, pp. 799-814 (fuller development).

[27] Smith, '*Dreadnought* science', p. 206.

[28] Ibid., p.207.

[29] Ibid.

[30] Ibid.

Otto Baumbach - Rutherford's Glassblower

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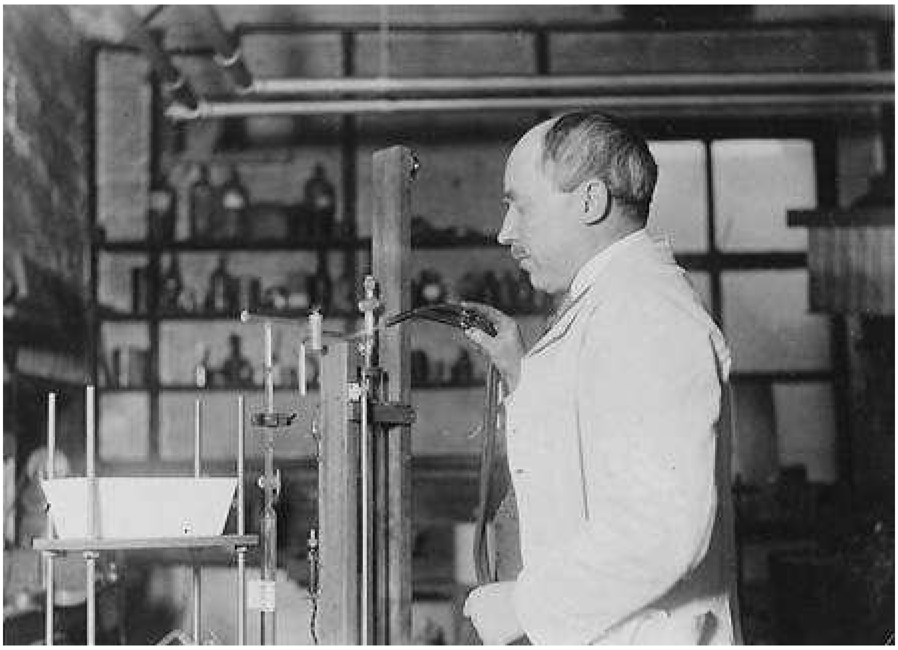
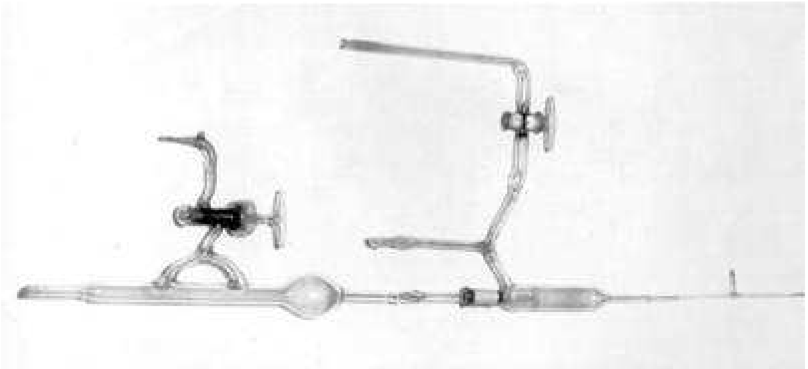


Otto Baumbach in 1928

During the period 2001 - 2004 I had several enjoyable conversations with Geoffrey, son of the German glassblower Otto Baumbach. Otto was a very skilled craftsman, notable for the construction of the delicate apparatus that Ernest Rutherford used in 1908 to confirm the identity of alpha particles as ionized helium, and also for the heated argument with Edward Andrade that seemingly resulted in Otto's internment for most of the First World War. The following account of Otto's life is based on a taped interview and correspondence with Geoffrey, supplemented with details from various documents in the possession of the Baumbach family, plus some further research.

Ernest Rutherford had already earned a considerable scientific reputation when, in 1907, he gave up his post at McGill University in Canada to become professor of physics at the University of Manchester. He had been invited to accept the chair by the retiring incumbent, Arthur Schuster, who was able to facilitate the transition by persuading the university authorities to offer Rutherford a generous pay deal. In a letter dated 7th October 1906, Schuster wrote in glowing terms about a new instrument maker and added: ‘We also have a tinsmith next door and a very excellent glassblower within easy reach.’[1] At that time it was not unusual for researchers to construct much of their own equipment. However, Schuster had taken note of the advantages of having at least a few skilled technicians at hand (or rather the disadvantages of being without). His method of accomplishing this at Manchester was to establish agreements with various individuals whereby they would supply the university as a priority when required to do so, but make up their earnings by taking on work for outside customers. This type of cost-effective arrangement provided the services of a tinsmith (William Stelfox), an instrument maker (Charles William Cook) and glassblower Otto Baumbach. These, businesses in their own right, were housed in university property and subject to relocation as the campus developed. Ties with the university were eventually broken and, with the exception of Stelfox, they continued to trade successfully for many years afterwards.

Rutherford had a pretty good idea of the nature of alpha particles when he arrived at Manchester but set out to prove conclusively that they were charged helium. Using the radioactive ‘emanation’ from radium as a source, the alpha particles were allowed to pass through an extremely thin glass tube whilst being prevented from further travel by a second, thicker, glass wall. After allowing the particles time to combine with electrons, spectroscopic analysis confirmed the presence of helium in the space between the two tubes that had been thoroughly evacuated beforehand. A further experiment demonstrated that helium under pressure could not penetrate the thin-walled glass tube.



Apparatus for Rutherford's 1908 alpha particle experiments

In a joint paper with Thomas Royds dated 1909, Rutherford reported

This fine tube… was sufficiently thin to allow alpha particles from the emanation and its products to escape, but sufficiently strong to withstand atmospheric pressure. After some trials, Mr. Baumbach succeeded in blowing such fine tubes very uniform in thickness.' [2]

Another scientist of the first rank to be found in Manchester's physics department before World War One was Harry Moseley. H.J.G.Moseley, who was not noted for his praise of others, recorded in 1913: *'Mr. Baumbach, the University glass blower, successfully undertook the difficult task of assembling the apparatus.'* [3] Of course, he may have taken his cue from Rutherford, an enthusiastic experimentalist with a firm belief in giving credit to others when it was due. Moseley's brilliant and productive career, sometimes working with Kazimierz Fajan, was brutally cut short by his tragic death in the battle for Gallipoli in 1915. His great achievement was in using X-ray spectra to place the members of the periodic table in order of their atomic number. In doing so he cleared up several anomalies and predicted the existence of missing elements.

Apart from purely scientific work, Otto also turned his hand to the occasional household item.

'Dear Mr. Baumbach, I have just returned from a holiday and find here the very beautiful menu holders that you have so kindly made for me. It was very good indeed of you to take so much trouble for me and I admire them greatly. With renewed thanks I am yours sincerely,
Mary Rutherford.' [4]

The trio of Stelfox, Baumbach and Cook formed a close community, united by their common bond of service to the university. Into the mix came William Alexander Kay, the go-between, laboratory steward in the physics department and trusty assistant to Rutherford. When Charles Cook moved away to Ashby de la Zouch, Otto Baumbach visited him there. Otto also helped Stelfox with financial problems and William Kay kept up his friendships, with Otto at least, for many years after the departure of Rutherford to Cambridge in 1919.

During 1912 the University of Manchester had an extension built at the rear of the physics department. The annex included a room for a glassblower's workshop and another for the tinsmith. At the official opening in March, Otto demonstrated mercury distillation apparatus made from silica, Bone & Wheeler gas analysis apparatus, an automatic Sprengle pump and Haldane gas analysis apparatus. Charles Cook also provided a display but the tinsmiths, Stelfox, were absent. What part Stelfox actually played in the chain of supply is less well documented than the other two providers. Their Articles of Association stated that they were manufacturers of scientific apparatus and in a taped interview with William Kay, the transcribed record states: ‘And Telefox used to make all the electroscopes, and everything like that, and he [Rutherford] used to think it was a godsend.’ Kay was aged 77 at the time of the interview and, although his memory failed to recall the precise name (or was misheard), he was clearly referring to Stelfox. What is unclear is whether or not he confused Stelfox with Charles Cook who manufactured a range of electroscopes. Stelfox was the least successful of the three. Otto would later tell Geoffrey that the son of the founder was hopeless at business and just let the company fold.

Turning to earlier days, Gottlob Otto Baumbach was born on 10th September 1882 in Niederwilligen, a village surrounded by the pine forests of Thuringia. His father, Frederick, had no known connections with glassblowing and it is believed that he earned a living in Germany by hunting and selling game meat, such as roebuck. Otto studied at the Thüringische Landesfachschule für Glasinstrumententechnik in Ilmenau (Thuringia School for Glass Instrument Technology) then worked briefly for Professor Heike Kamerlingh Onnes (1853-1926) at Leiden University in the Netherlands. Kamerlingh Onnes became the first person to liquefy helium (in 1908), which resulted in the saying that the coldest spot on earth was at Leiden! His laboratory developed into an internationally known centre for studying low temperature physics, as well as a training school for instrument makers and glassblowers.

The date of Otto’s arrival at Manchester has been given variously as 1902[5], and ‘around 1905 after spending a short time in London’[6]. Certainly, it is unlikely to be later than 1904 as a paper presented in May of 1905 gives the credit: ‘We are indebted to the skill of the University glassblower OTTO BAUMBACH for the accurate grinding of these taps, and for the joints by which he succeeded in fusing hard Jena to soft glass.’[7] Initially, Otto was provided with bench space in the chemistry department by Professor Harold Bailey Dixon but after a short time moved to a university building (previously a house) at 10 Lime Grove, one street away. An advertisement of 1911 lists all the firms in the UK supplying the Jena brand of German-made laboratory glassware. Otto’s business was one of four stockists in Manchester (the others being: Baird & Tatlock, Frederick Jackson & Co Ltd and James Woolley, Sons & Co Ltd).[8] It was from Lime Grove that Otto supplied Captain Robert Falcon Scott with sample tubes for the ill-fated Antarctic Expedition of 1910-1912. Why would Scott, based in London, select a supplier in Manchester? It may possibly have been through a recommendation by Arthur Schuster who is known to have advised Scott and others about measurements of the earth’s magnetic field[9].

In 1906 Otto married Hannah Lilian Cowlishaw, the daughter of a commercial traveller. It was his father-in-law, John Charles Cowlishaw, who would help Otto to circumvent the restrictions imposed by the Custodian of Enemy Property on ‘enemy aliens’ trying to resume business activities after the First World War. Hannah and Otto’s first child, Rudolph, died after surviving for only a month, in 1907. Carl (later Charles) Otto Baumbach was born in 1910 and his sister Olga in 1912. The final addition to the family came in 1921 with the birth of John Geoffrey Baumbach, the first names deliberately chosen as typically English.

The argument between Otto and Edward Neville da Costa Andrade has been recounted in a number of Rutherford biographies. Since the accounts are taken from Andrade’s version of events there is more than a possibility of bias. The scenario was that Andrade called in to see Otto only to be greeted with a stream of ultra-patriotic German invective about the superiority of the Kaiser's army. Andrade, who had studied at Heidelberg and understood the language well, told him to keep his mouth shut or he would find himself in trouble. Geoffrey Baumbach wrote to the New Scientist about this incident, following the publication of an article on Rutherford that had repeated the story.[10]

‘The patriotic outbursts are likely to be quite true. He was only 32 at the time and perhaps somewhat hot headed, as indeed I was at that age. The outbreaks were not spontaneous however. He was not the sort of man to make rude or ill conceived provocative remarks. What has to be remembered however is that part of the strategy of conducting any war is to inflame

public opinion against the enemy. My father was an enemy alien surrounded by now with a somewhat hostile population. It is not surprising that he stood his corner now and again, even if a little indiscreetly.' [11]

World War One turned Otto's life upside down. Fritz Hartwig, a glassblower who had arrived from Germany to assist Otto before the war, now found himself heir to the business. Perhaps merely by keeping a low profile, Fritz had escaped the unwelcome attentions of the authorities whereas Otto Baumbach and his nephews, the Nauber boys Rudolf and Otto, were incarcerated.[12] Hartwig's new enterprise, formed in partnership with Alfred Frederick Edwards, and based for a few years at the Baumbach workshop on Bridge Street, was called the Scientific Glassblowing Company.[13]

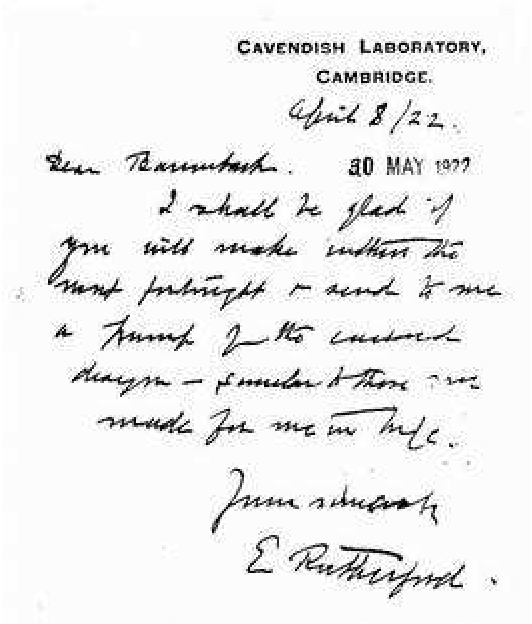
In anticipation of resuming his profession at the end of the war, and aware that the Scientific Glassblowing Company had replaced him at the university, Otto made an appeal to Rutherford. It was clear that a fresh start had to be made but first he needed to collect whatever debts were outstanding. Rutherford replied:

'I have received your letter asking whether permission could be granted to you to settle up your business affairs in Manchester and have been making enquiries to see whether anything can be done in the matter. It seems to me desirable that the university matters should be settled before long for as you may have heard I am leaving for Cambridge in July. I have nothing definite to tell you at the moment but will let you know if the prospect improves.' [14]

A financial settlement, although of a very minor nature, came in 1920 when Chaim Weizmann[15] paid a bill for £4 9s 3d with the comment: 'I shall be glad to hear from you whether you are continuing your former work.'[16]

Otto now thought it prudent to run his business under a non-German name so began trading as J.C.Cowlishaw, making mainly thermometers, from premises at 403 Chester Road, Old Trafford. Apart from providing the trading name, John Charles Cowlishaw assisted Otto by looking after the books. The business was incorporated on 15th July 1925 and the following year moved to 44 Bridge Street. Meanwhile, the university had been negotiating with both Stelfox Ltd and the Scientific Glassblowing Company because the Electrotechnics department needed extra room.[17] As a result, the glassblowers found premises on nearby Wright Street and Stelfox moved further down Bridge Street, to number 42, next to J.C.Cowlishaw's works. These two adjacent buildings may have both been owned by Otto as Geoffrey Baumbach spoke of his father showing considerable generosity to Stelfox by providing them with space. However, within three years of moving, the shareholders of Stelfox had voted to put the firm into liquidation.[18]

Rutherford continued to use Otto's services after taking up the appointment at the Cavendish Laboratory, presumably until the lab appointed its own glassblower in the person of Felix Niedergessas. A letter from Rutherford, written in 1922 survives, although the specification for the requested pump has vanished along with most of the other items from Otto's early records.


CAVENDISH LABORATORY,
CAMBRIDGE.
April 8/22.
Dear Baumbach. 30 MAY 1922
I shall be glad if
you will make within the
next fortnight & send to me
a pump of the enclosed
design – similar to those you
made for me in M/c.
Yours sincerely
E Rutherford.

Dear Baumbach,
I shall be glad if
you will make within the
next fortnight and send to me
a pump of the enclosed
design – similar to those you
made for me in m/c

[Manchester]

It is interesting to note that Geoffrey Baumbach had no recollection of his father ever mentioning Felix Nidergesass despite the fact that Otto & Felix ran their own glassblowing businesses in Manchester during the 1920s.[19] In addition, both were German immigrants who had arrived in this country to live in the same district, and of course worked for Ernest Rutherford. Seemingly, James Chadwick was familiar with Felix and his work before going to Cambridge, since it was Chadwick who recommended the glassblower to Rutherford.[20] Felix moved from his home in Manchester to take up his appointment at the Cavendish in approximately 1926.

Sometime in the 1930s, Otto set off with his family to visit Charles Cook. Chas (as he liked to be called) had left the heavily industrialised city of Manchester in about 1922, to live at Ashby de la Zouch where he had bought the Royal Hotel as a rather unusual location for his engineering works, basing the workshops in the disused Spa Baths at the rear of the main hotel building.[21] The young Geoffrey Baumbach remembered the trip because of the anxiety of being late for tea and, on arrival, for the brightly coloured parrots that were kept at the hotel. Another visitor representing the old university days was the engineer William Eccles who wrote to Ludwig Wittgenstein on 28th July 1926, about the trip.[22]

Bernard Lovell arrived at the University of Manchester to join W.L.Bragg's staff in 1936 and has written of the experience:

'I tried, but failed absolutely, to interest myself in Bragg's research and made the bad mistake of trying to restart my thin film work in a place with no facilities and only a poor quality commercial glassblower several streets away' [23]

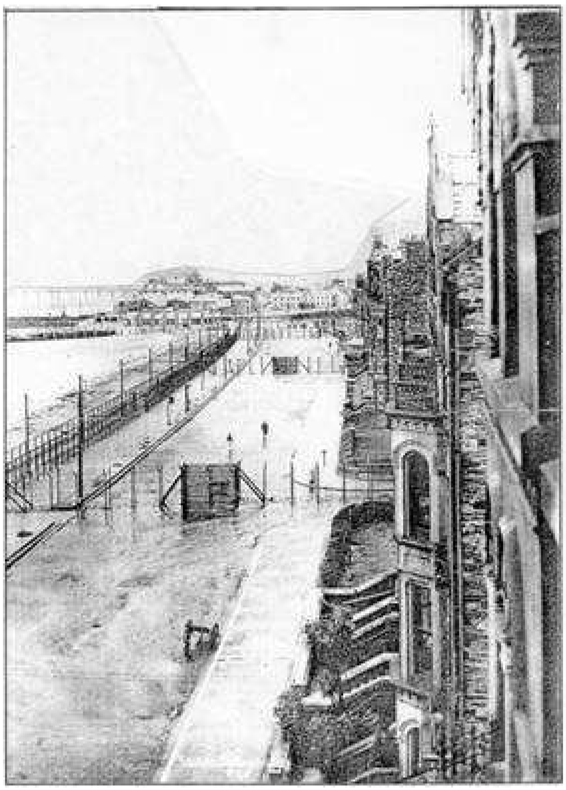
This appraisal of Otto is certainly not in keeping with the opinion of others, even the abrasive Edward Andrade.[24] Recently, Sir Bernard Lovell has clarified the situation:

'As regards Otto Baumbach, he is undoubtedly the glassblower referred to in my article. I fear that my unenthusiastic reference to him is most unfair. I had just come from Bristol where Burrows[25] had succeeded in making a most complex pyrex high vacuum equipment for my research on the deposition of thin films of the alkali metals and this type of apparatus was beyond Baumbach's experience.' [26]

Edmund Bowen, in a paper on the Balliol-Trinity Laboratories, Oxford, discussing the problems faced during the 1930s, recalled: 'There was no workshop, glass-blower, or technical assistance; special glass apparatus was sometimes ordered from Otto Baumbach of Manchester…'[27] Joseph Alexander Gray, in a letter to W.L.Bragg of 19th November 1931, wrote that he was working on the scattering of X-rays at small angles and intended to obtain a special Dewar flask from Baumbach.[28]

At the end of 1929, J.C.Cowlishaw died. Hannah replaced him as a director, until 1931 when she stepped down in favour of Charles Baumbach.[29] Charles became personally involved with some new work for the University of Manchester. When Rutherford resigned as Langworthy Professor at Manchester his successor was William Lawrence Bragg, followed in turn by Patrick Blackett. Blackett arrived in 1937, bringing his team from Birkbeck College: L.Janossy, J.G.Wilson and H.J.J.Braddick. With Bragg at the helm, the research emphasis had been on X-ray crystallography but now this changed to cosmic ray studies. Radiation was now back on the agenda and Charles made many Geiger Counters for Blackett's team. In particular, Geoffrey Baumbach remembered his brother's association with Janossy.

The first of the Second World War internment camps on the Isle of Man was set up at Mooragh Promenade, Ramsey after the inhabitants of several boarding houses were served with official notices to vacate on Monday 13th May 1940. It was here that Otto became an internee for the second time.



Mooragh internment camp, Isle of Man

A peculiarity of the camp was that it held a number of Finnish prisoners without due regard to their affiliations. Several violent confrontations resulted between pro and anti-Nazi Finns, culmin-ating in the murder of Nestor Huppunen in 1943. By the time of Otto's release on 19th September 1944, he had spent a total of nine years in captivity during both world wars. According to Geoffrey, the experience did not leave him embittered and he soon resumed his old work. One of his first acts on returning home was to sit down and construct a complex glass manifold. Otto became a naturalised British subject in November 1946.

A Compulsory Purchase Order was placed on the Bridgeford Street property (previously named Bridge Street), prompting some drastic action. The sale of 'Four Gables', Otto's house at Mobberley, raised some of the capital for the next venture; relocation to a purpose built factory on a plot of land at Peary Street in Manchester. This was completed in 1963, a year after the death of Otto's wife Hannah. Otto went to live with his son Geoffrey at Alkrington, near Middleton, Manchester where he died at age 83 in 1966.

Thermometers had been the bread and butter of J.C.Cowlishaw's activities but a dwindling market for these products demanded a rethink. Then came the lifeline, an opportunity to supply Mather & Platt Ltd with the glass bulbs used in automatic fire-fighting sprinklers. About sixty people were eventually employed hand-making bulbs until it became uneconomical to continue production.

J.C.Cowlishaw moved into electronic circuit assembly work as the requirement for bulbs started to fall. In 1979, after the difficult task of serving redundancy notices on employees of long standing, it became obvious that a voluntary liquidation was the only sensible answer and the company was officially wound-up in 1982.

Per F.Dahl, in *Flash of the Cathode Rays*, has gone so far as to say that Rutherford's identification of alpha particles in 1908 is sometimes referred to as the Rutherford-Royds-Baumbach experiment.[30] Others have commented, along with Dahl, that Otto's internment more or less brought to an end the small number of experiments still possible at Manchester during the Great War.[31] Niels Bohr and Walter Makower, for example, abandoned their investigation when an intricate quartz device constructed by Otto was destroyed by fire.[32] Without doubt, during the period 1907-1914 the glassblowing skill of Otto Baumbach was a timely resource that enabled Rutherford and his co-workers to employ considerably more complicated equipment in their endeavours than might otherwise have been the case. Otto continued after 1919 but with the emphasis on work of a commercial nature, although he was sufficiently well known in the academic world to attract further patronage from university departments. Otto's second spell of internment came as a bitter blow for a man who had already paid for his youthful indiscretions and given no further offence to his adopted country. Yet despite the deep hurt that this caused, he remained an Anglophile. Friends, family and employees alike remember him for what he was - an intelligent, hardworking man who was modest enough to look back on his life without thinking that he had done anything special.

Acknowledgements

This article would not have been possible without the help of the late Geoffrey Baumbach, and his son Philip. For personal reminiscences I am grateful to Professor Sir Bernard Lovell. Thanks are due to Brian Hosie and Stanley Taylor for discussions about their working life at J.C.Cowlishaw Ltd and to Malcolm Cooper for helpful suggestions with the preparation of this article.'. Details of Internment and the picture of Mooragh Camp came from Yvonne Creswell, Curator of Social History at Manx National Heritage. The photograph of the alpha particle apparatus is courtesy of Keith Papworth at the Cavendish Laboratory, University of Cambridge. Thanks also to Jeff Hughes of the Centre for the History of Science, Technology & Medicine, University of Manchester, under whose guidance much of the research work was undertaken.

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[5] Letter from Thaddeus Trenn to Geoffrey Baumbach 6th October 1971 (Source: Baumbach family).

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[7] Dixon, H.B. and Edgar, E.C. (1906) The Atomic Weight of Chlorine, *Philosophical*

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[8] Advertisement in Nature, November 16, 1911 p.xxiii

[9] Davies, P.J. (1983) Sir Arthur Schuster 1851-1934, PhD Thesis, UMIST.

[10] Jones, G. The Phantom of the Atom, *New Scientist*, 28th January 1988.

[11] Undated letter written by Geoffrey Baumbach in early 1988 to the editor of the New Scientist (Source: Baumbach family).

[12] A beautifully constructed wooden box in the possession of Philip Baumbach is carved with the words: 'AUS DER KRIEGSGEFANGENSCHAFT, OLDCASTLE, IRLAND 1916' (From the prisoner of war camp, Oldcastle, Ireland 1916).

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[25] J.H. (Johnny) Burrow, glassblower at the University of Bristol.

[26] Letter from Sir Bernard Lovell to the author, dated 27th March 2003.

[27] Bowen, E.J. (1970) The Balliol-Trinity Laboratories, Oxford 1853-1940, *Notes and records of the Royal Society of London* 25 (2), p.235

[28] Royal Institution of Great Britain, ref. W.L.BRAGG/77E/95.

[29] She became a director again in 1938. Companies House, Archive Microfiche.

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[31] The laboratory steward, William Alexander Kay, was still available to construct apparatus. Although he could also turn his hand to glassblowing, his skills were not of the same order as Otto's.

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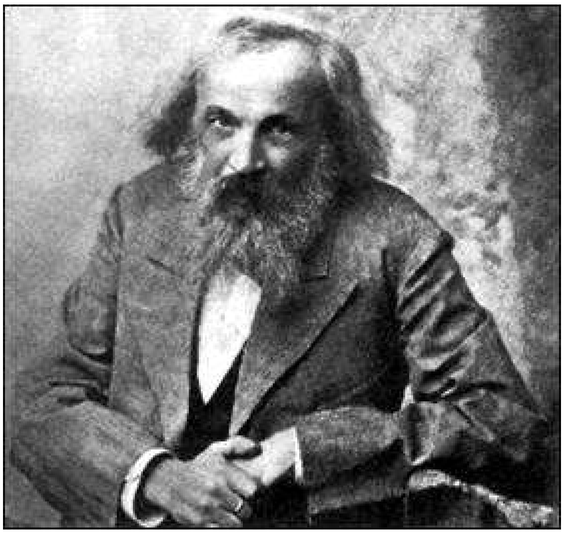
Dmitry Ivanovich Mendeleev

Dr. Peter Ford
University of Bath



Last year, 2007, saw events marking the centenary of the death of William Thomson, Lord Kelvin. Articles based on the lectures which took place after our own AGM in Glasgow appear in this issue of our Newsletter. 2007 also marked the centenary of the death of another very famous and influential scientist, which as far as I can tell went completely unnoticed in this country. I am referring to Mendeleev the inventor of the Periodic Table. Charts of the Periodic Table appear in almost every school science laboratory and university chemistry department that I have ever visited. It is probably the most ubiquitous chart in science. I even have in my possession a rather up-market coffee mug on which it is displayed! The purpose of this short article is to summarise his life and to recount how the Periodic Table originated.

Dmitry Ivanovich Mendeleev was born in the Siberian town of Tobolosk on the 8th February 1834. He was the fourteenth and last child of Ivan Mendeleev who was a teacher of Russian Literature. His mother, Maria Kornileva, had a great influence on Mendeleev's formative years. In 1850, shortly before her death, she took him to St. Petersburg where he was enrolled in the faculty of physics and chemistry at the Main Pedalogical University. He graduated from there in 1855, having obtained an outstanding academic record, and then began to embark on research.

From very early on in his research career Mendeleev was interested in the chemical and physical properties of the elements. He spent the year 1859-60 at the University of Heidelberg working in the research group of Bunsen. This must have been an exciting and influential time for Mendeleev, since Bunsen and his colleague Kirchhoff were actively involved in establishing and developing the principles of spectral analysis, which has become such a powerful investigative technique in science and astronomy. In the course of their work Bunsen and Kirchhoff discovered the elements caesium and rubidium. In 1860 Mendeleev attended the first International Chemical Congress in Karlsruhe. One of the main aims of the congress was to standardise and reach a consensus about some of the basic concepts of chemistry such as atomic, molecular and equivalent weights. The meeting also provided an excellent opportunity for him to meet and discuss with some of the leading chemists of the day.

As the decade of the 1860s progressed, Mendeleev became a rising star in the Russian chemical fraternity. In 1867 he was appointed to the highly prestigious chair of chemistry at the University of St. Petersburg. By this time he had acquired a really detailed knowledge of the existing elements and their compounds.

It was at the start of the nineteenth century that John Dalton, while working in Manchester, had first put forward the idea that each element had a characteristic atomic weight. Mendeleev wrote down the atomic weight and major chemical and physical properties of each element on separate cards. He then placed the cards in vertical columns according to their increasing atomic weight, in a similar manner to playing the card game Patience, which Mendeleev was very fond of doing as a relaxation. Hydrogen, the lightest element, did not seem to fit into any scheme and so he assigned it to a first column all on its' own. He was perhaps fortunate that helium, the second lightest element, had yet to be discovered, since that too would have given problems within his scheme. From then on things began to make some sense. The next elements in ascending atomic weight are lithium, beryllium, carbon, nitrogen, oxygen and fluorine and Mendeleev placed them in a second vertical column. After fluorine comes sodium and Mendeleev realised that this had similarities to lithium and hence he placed this at the top of a new, third vertical column. Continuing in this manner the next six elements are magnesium, aluminium, silicon, phosphorous, sulphur and chlorine. A pattern was beginning to emerge since, just as lithium and sodium had some similarities at the top of the vertical columns, so did fluorine and chlorine at the bottom. The next element after fluorine in ascending atomic weight is potassium and Mendeleev placed this at the top of a fourth vertical column to be followed by calcium.

It was at this juncture that the first real problem began to appear. The next element in ascending atomic weight known to Mendeleev was titanium and this did not appear to have similarities to either boron or aluminium, which were sitting in the third row of his two previous columns. It is here that Mendeleev's great insight into the properties of the elements came into play. Around 1869, when he had become seriously involved in this study of the elements, only sixty three of them had been identified while today we know that there are ninety two naturally occurring elements. Hence Mendeleev left a gap in this column, predicting that this was due to an element, which had yet to be discovered. He then placed titanium in the same horizontal row as carbon and silicon where its' properties seemed to be more in tune. Likewise in his next vertical column Mendeleev predicted that there were again missing elements in the third and fourth rows and, if allowance was made for these, the column would end with bromine with properties which are similar to both fluorine and chlorine. It is difficult to overestimate the intuition that was required by Mendeleev to place gaps in his table, which he believed corresponded to undiscovered elements. Its significance lay in the fact that not only was he able to predict the existence of undiscovered elements, he was also able to suggest their likely atomic weights and some of their properties.

It was some years before Mendeleev's predictions were verified. In 1875, the French scientist, Professor Wurtz, reported to the French Academy in Paris the discovery in his laboratory of a new element, which had similar properties to aluminium. With understandable Gallic pride the new element was named gallium and had been discovered spectroscopically by Lecoq de Boisbaudran. It was some time before news of this discovery reached Mendeleev in St Petersburg. However, he was then able to point out to the members of the French Academy that the newly discovered element had similar properties to those that he had predicted for the missing element in the fourth vertical column and third row as discussed earlier. In addition he was surprised by the low value obtained by Lecoq de Boisbaudran for the specific gravity of the new element and suggested that he re-determine it using a purer sample. The latter reluctantly agreed to do so and the new value that he obtained was much closer to the value which Mendeleev would have expected. It did much to enhance his prestige in that he seemed to have a much better insight into the properties of the new element than the person who had actually discovered it.

Later in 1879 the Scandinavian chemist Nilson discovered another element, which was called scandium while in 1886 the German chemist Winkler discovered a further element, which not surprisingly was named germanium. These two elements corresponded to the two missing elements predicted by Mendeleev and discussed earlier. By this time Mendeleev had acquired considerable fame and prestige and was feted throughout much of Europe although this did not extend to all of Russia where he had managed to offend the Tsar with some of his liberal political ideas.

Mendeleev had succeeded quite clearly in establishing that there was some underlying pattern or periodicity in the behaviour of the elements as the atomic weight increased. This strongly suggested that there must be some internal structure within atoms, which gives rise to this structure. Here one is entering the domain of the physicist.

In 1897, J.J. Thomson, the Cavendish Professor of Physics at the University of Cambridge, discovered the electron and showed that it had a negative charge and a mass which was some two thousand times smaller than that for the hydrogen atom. Further work quickly established that it was a fundamental constituent of all atoms. Thus hydrogen had one electron, helium, which by 1897 had been discovered, had two, lithium three and so on. Thomson attempted to explain the Periodic Table using his "plum pudding" model of the atom in which the negatively charged electrons moved in concentric rings within a positively charged matrix such that the atom was electrically neutral. Thomson found that after the addition of a certain number of electrons, their mutual repulsion gave rise to instabilities requiring the formation of a new ring. Thus, very qualitatively, he could begin to explain the periodic nature of the atoms.

Thomson's ideas floundered as a result of some brilliant experiments of Geiger and Marsden carried out in 1909 in the Physical Laboratories of the University of Manchester, which was headed by Rutherford. They bombarded a platinum plate with alpha particles and very occasionally observed large angle scattering of the alpha particles taking place. Rutherford realised that this could only be explained by the atom having a heavy positive nucleus surrounded by planetary electrons analogous to the solar system. Rutherford's theory of the atom in 1911 was able to account for the observations of Geiger and Marsden. Thomson had also considered a nuclear model for the atom but was forced to reject it on the basis of his sound knowledge of classical physics. Any electron circulating in an orbit around the nucleus would radiate energy and spiral around before crashing into the nucleus. Hence atoms would be unstable in contradiction with the well established fact, going back to the ancient Greeks, of the stability of atoms. Thomson was born in 1856 and was steeply immersed in the ideas of classical physics.

No such inhibitions were felt by the Danish physicist Niels Bohr who was born nearly thirty years after Thomson and was only a teenager at the time that Max Planck first put forward his revolutionary quantum ideas. During his doctoral studies at the University of Copenhagen, Bohr had worked on the electron theory of metals and had found several occasions when classical physics appeared to break down. Bohr believed firmly in the validity of the concept of the nuclear atom. He spent much of 1912 in Rutherford's laboratory at Manchester and it was here that he began working on his series of seminal papers "On the Constitution of Atoms and Molecules", which were published in the Philosophical Magazine. Originally the aim of his work was to understand the Periodic Table. However, these papers are best remembered today for containing an explanation of the Balmer series for the spectral lines of the hydrogen atom. This was achieved by using a clever combination of quantum and classical ideas. However Bohr's work also did much to throw light on the Periodic Table especially the positions in the Table of the rare earth elements. His insight had an important consequence in that colleagues working within his by now famous Institute in Copenhagen were able to isolate without ambiguity a new element. This was called hafnium, which is the Latin name for Copenhagen. Bohr had the considerable coup of being able to announce the discovery of this new element at the end of his Nobel Prize lecture given in Stockholm in 1922.

The Periodic Table that we see today in numerous books and posters is a far cry from the early tentative steps first put forward by Mendeleev beginning around 1867. Nowadays we know of the existence of the noble or rare gases (helium, neon, argon etc.) as well as the artificially created transuranic elements. Mendeleev had to wait until 1955 before element number 101, mendelevium, was named after him. For the rest of his life Mendeleev was constantly trying to refine and develop his ideas. It is right that the Periodic Table is indelibly associated with his name and before 2007 finally disappears over the horizon it is appropriate to mark the centenary of his death and record his enormous contributions in science.

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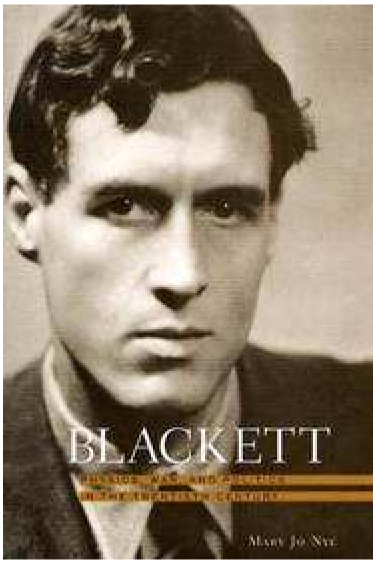
Book Reviews

Patrick Blackett



Blackett: Physics, War and Politics in the Twentieth Century

Mary Jo Nye

Harvard University Press *2004*
ISBN *0-674-01548-7*
255pp *Hardback £29*

Reviewed by:
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Patrick Blackett (1897-1974) was a distinguished experimental physicist in particle physics, cosmic rays, geophysics, magnetism of rocks and the earth, as well as in wartime operational research (O.R.). He was a senior science adviser, during peace and war, to UK governments and during his presidency of the Royal Society 1965-70, his service to science was recognised successively by awards of Companion of Honour, Order of Merit, and a Life Peerage. Although he had never taken a doctorate, he was awarded the Nobel Prize in Physics in 1948. Some indication of the spread of Blackett's achievements is that each of two biographical volumes carries triple subtitles, between them embracing physics, the Royal Navy, war and politics.

P*atrick Blackett: sailor, scientist, socialist* (ed. Peter Hore; London, Frank Cass, 2003), a multi-authored collection of biographical articles stressing the nature and influence of a strict naval education, was reviewed in I*.O.P History of Physics N/L* No 22, 61-66 (Aug. 2007). Mary Jo Nye, a science historian, has published a more unified and reflective monograph, Blackett: physics, war and politics in the twentieth century.

In the past, Nye has researched and compared the careers of Blackett and his contemporary at Manchester in the 1930s and 1940s, Michael Polanyi, Professor of Physical Chemistry (a biography of Polanyi was reviewed in HoP Newsletter Issue No 20, pp 30-34 (July 2006)). Nye's interest in the interaction between the scientific practice and achievements of these men and their politics (and, in Polanyi's case, his philosophy of science) has led her to emphasise Blackett's scientific leadership and his science-based political controversies in this book.

In six theme-based main chapters in roughly chronological sequence, Nye presents Blackett's life and career in the context of education, science, and political attitudes of the day. These are preceded by a 12-page introduction, appropriately sub-titled a life of controversy, which ends with brief summaries of the aims of each chapter. There is a glimpse of Blackett's happy family life and attention is drawn to his courage in championing causes, notably the inefficiency of aerial indiscriminate bombing in World War II, and the independent development by the UK of atomic weapons, unpopular with his political masters. More generally, Nye records the views of friends, colleagues and opponents, not all as favourable as those of Sir Edward Bullard (who, after being supervised by Blackett at Cambridge, became an Admiralty operational research colleague and later a critic of Blackett's theory of the earth's magnetism): 'the most versatile and the best loved physicist of his generation'.

Blackett's early life and naval education and experience, the subjects of the first few articles in Hore's book, are covered in Nye's first chapter 'From the Royal Navy to the British left', which also recounts Blackett's Fabianism and association with the A.Sc.W. and anti-war groups in Cambridge (contrasting with the traditional separation of science from politics) and London. Despite differences over science policy and the supremacy of freedom rather than direction in research, Nye notes that Polanyi and Blackett and their wives remained close friends. With Blackett serving both as president of the A.Sc.W. and as a member of a Royal Society committee on post-war University planning, moderate consensus views about science organisation in the 1950s appeared to prevail.

In a chapter exploring Blackett's leadership style and recognition, there is an interesting aside describing the international correspondence, discussion and process leading to his nomination as early as 1935 for the Nobel prize, ultimately awarded in 1948 in recognition of his inventions and discoveries in nuclear physics and cosmic radiation. The award preceded, of course, his researches on the earth's magnetism and continental drift. Nye recognises that, in his later career, Blackett was content to conduct his experimental science in Manchester and London, at Imperial College, rather than Cambridge. At Manchester he was a successor to Ernest Rutherford and WL Bragg and would have been a prime candidate to replace Bragg at the Cavendish (not that geophysics there was seen to be a major branch of physics) and/or might have been a choice for Provost of Kings College, Cambridge. Instead, he deliberately chose to move to London in 1953; he was a Londoner by birth and was glad to enjoy the cosmopolitan life and be close to the power centres of science and government.

The bulk of Blackett's physics is covered in four chapters. One has the title 'Corridors of power' and is a considerably amplified version of Nye's article in Hore. The title is that of a 1964 C.P. Snow novel in which Snow has admitted that the politics of the physicist character Francis Getliffe are taken from Blackett, who had known Snow in Cambridge from the late 1920s. The two were agreed on the need to expand science and technology education at home and to utilise the scientific revolution in reducing the increasing disparity in wealth between the industrialised and underdeveloped countries. In this chapter, Nye describes Blackett's support for radar defence from 1936, his development of O.R. (covered by several authors in Hore) in all three services during the war, and his unpopular post-war campaigning about nuclear weapons. She recounts some of the arguments with politicians and fellow scientists about carpet bombing of Germany (dealt with at greater length by Paul Crook in Hore) and defence policy during the Cold War. Perhaps Blackett's most explicit participation in the corridors was as scientific adviser to Harold Wilson's Ministry of Technology, 1964-69 (Blackett declined the post of Minister, while Snow, as a life peer, became Parliamentary Secretary), and as President of the Royal Society, 1965-70, culminating in his life peerage. Chapter 2 focuses on the experimental mastery achieved by Blackett with cloud chambers, Geiger counters and magnetic fields at the Cavendish until 1933 and then successively at Birkbeck and, pre- and post-war, at Manchester. His studies involved nuclear transformations, showers of cosmic-ray particles, and the emergence of strange V-tracks attributed to the decay of heavy neutral particles. Under the title 'Temptations of theory', chapter 4 narrates in some detail the 1947-52 period at Manchester when Blackett's attention turns to the link between rotating bodies, such as the earth, and magnetic fields. Historically this was in the steps of a predecessor, Henry Schuster, who had, as early as 1912, questioned the origins of terrestrial magnetism. Blackett had noticed a parallel between the equations relating angular momentum to magnetic moment for the earth and sun which led him to an equation implying that a mass element in motion develops an intrinsic magnetic moment. Blackett had a long-standing interest in fundamental constants, and in cosmology and astronomy, but Nye quotes Clifford Butler as deducing that Blackett sought a research topic that, in contrast to cosmic rays, he could fit in by himself between (or during) his frequent trips to London. Nye outlines Blackett's four strategies for testing his law and theory of the earth's magnetism but, ultimately, it appeared that any magnetic field from the rotating mass was undetectably small.

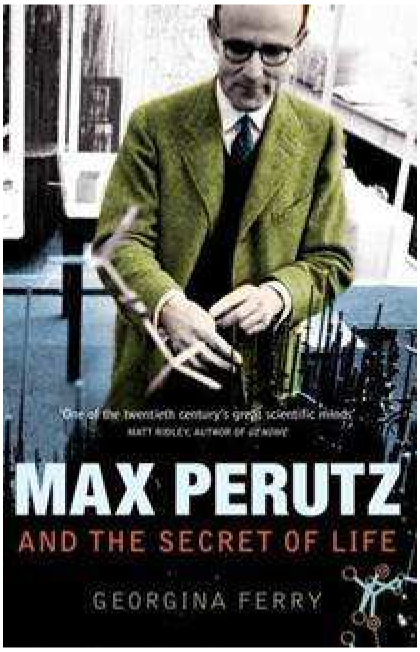
Blackett's development of a very sensitive astatic magnetometer led to studies of geomagnetism and palaeomagnetism and continental drift, initiated at Manchester and pursued further at Imperial College, as described in chapter 5. Some of the research on the earth's field was in collaboration with Indian colleagues; a group set up in Bombay made the first palaeomagnetic survey of the sub-continent. Blackett made a dozen serious visits to India from 1947 onwards and formed close friendships with several Indians (often with a Cambridge background) influential in politics and science and technology. Jawahalal Nehru was sympathetic to Blackett's attitude to state planning of research, the peaceful development of atomic energy, and the need for India to invest in modern technology. In his 1967 Nehru Memorial lecture, Blackett somewhat unpopularly advocated stronger links between laboratory science and its industrial application.

Blackett described the physicist Horu Bhaha, head of both the Tata Institute and the Indian Atomic Energy Commission, as 'my best personal friend'. Nye deals adequately with Blackett's affection for India and Indians and his science advisory role in her leadership chapters. However, in Hore, the science historian Robert Anderson goes into more detail about advice on industrial research and, especially, about Blackett as a military consultant in India.

Nye's concluding chapter on style and character in scientific life emphasises the extent to which Blackett courageously put his reputation, whether in physics or in politics and scientific policy, at risk. She quotes Leon Rosenfeld, his theoretical physics colleague at Manchester, remarking that Blackett was undeterred by apparent failure, while he had overcome lamentable laboratory conditions encountered on arrival at Birkbeck. Scientists he greatly admired were Henry Tizard, a fighter pilot in World War I, and Frederic Joliot-Curie, courageous in World War 11. Tizard, with whom Blackett had worked on secret government advisory committees before and during World War II, shared scepticism about the effectiveness and morality both of wartime carpet bombing and of post war UK nuclear weapons policy. Joliot-Curie, an antifascist organiser in Paris from the 1920s, was respected as a friend, although a scientific competitor in nuclear and Cosmic-ray physics. Nye sums Blackett’s physics up as that of a gifted experimentalist: a master craftsman in instrumentation with theoretical acumen. 'Exploration, discovery, discipline and courage were central to this controversial scientist's life'.

Nye includes only a dozen photographs, although they illustrate most significant aspects of Blackett’s life; but nearly 900 notes, tidily correlated with text pages, are a testimony to thoroughness. One of the merits of a book of only moderate length is that, as each facet of Blackett’s career emerges and is highlighted, the background is sketched and brief pen portraits are given of the relevant scientists and politicians, whether historical or of the time. This self-contained, thoughtful and enjoyable biography is recommended.

Max Perutz



Max Perutz and the Secret of Life

Georgina Ferry

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Max Perutz (1914-2002) began his scientific life as a chemistry student in Vienna and was a founder and head of the outstandingly successful Laboratory of Molecular Biology (LMB) in Cambridge. But for the first two decades of his X-ray crystallographic research on the structure of haemoglobin under J. Desmond Bernal (the Sage) and W. Lawrence Bragg, he was in or associated with a physics laboratory, the Cavendish (headed by Rutherford when Perutz arrived in 1936). Moreover, outside the protein field in which he shared the Nobel Prize for Chemistry with the physicist John Kendrew in 1962, Perutz made significant contributions in the late 1930s and the 1940s to the physics of ice crystals and glacial flow. However, his lack of a strong mathematical background may account for his initial scepticism in the early 1950s about the potential of direct methods for structure solution (for which Herbert Hauptman and Jerome Karle received the Nobel Prize in 1985).

Georgina Ferry is not a scientist but is the biographer of another crystallographic Nobel Prize winner, Dorothy Hodgkin [Granta, 1999], who was also apprenticed to Bernal for a time. Further, she is co-author of *The Common Thread* (Corgi, 2003) which is written in the form of an autobiographical account by Nobel Prize winner, John Sulston (a member of the LMB until the Sanger Centre was established) about science and politics in the project for sequencing the human genome. Ferry's reputation and her grounding in the vocabularies of X-ray crystallography and molecular biology were such that Perutz asked her, almost on his deathbed, to be his biographer. Perutz's fears about the availability of enough material proved unfounded and Ferry managed to trace much of his correspondence (retained by recipients, including his devoted wife Gisela) as well as calling on the recollections of an array of relatives, friends and scientists. The result is not only an intelligible account of Perutz's skill, insight and determination in investigating the structure of haemoglobin and in negotiating for, establishing and leading the LMB but also provides a discerning examination of the life of a cultured, humorous and gentle person. Included are pictures of the principle characters, unostentatious page-by-page notes (instead of footnotes) and a good index.

Ferry's book is broadly chronological with the first chapter devoted to Perutz's upbringing in Austria. His affluent parents, with town and country homes, wanted him to read law rather than science at Vienna in 1932 as a preparation for running the family textile business in the present-day Czech Republic. Subsequently, they escaped to England as refugees with no financial resources so that their support was for long a concern to Perutz. They only reluctantly agreed, but then provided support, for him to transfer from Vienna in 1936 with an Absolutorum (i.e. not a degree) to Cambridge for research instead of staying for his Doctorandum.

Summarizing his knowledgeable and affectionate memoir [*Biog. Mem. Fell. Roy. Soc.*, **50,** 227-256 (2004)], David Blow said that it was largely written by Perutz himself. This was because, in his later life, Perutz was an accomplished and stylish expositor of science. His more popular books often had idiosyncratic titles such as *'I wish I'd made you angry earlier'* (Oxford University Press, 1998), this one prompted by a remark of WL Bragg, Perutz's stalwart champion at the Cavendish, about the discovery of the _-helix. Perutz's summary of his 60 years work on haemoglobin, *'Science is not a quiet life'* (ICP World Scientific, Singapore, 1977) opens with a chapter entitled 'Diffraction without tears' but is a compendium of papers 1938-1995, together with commentaries on progress and the people involved. The many stages of the haemoglobin story, both before and after the Nobel Prize, take up about half of Ferry's book.

Perutz's earlier collection of more general thoughts about scientists and their impact on society, *'Is science necessary?'* (Barrie and Jenkins, London, 1989), consisted chiefly of essay book reviews. But the most poignant article in it was an autobiographical account of what happened to Perutz when, having been a research student for four years at Cambridge, he was declared an enemy alien in 1940. Ferry covers the World War II period in two chapters, one titled 'The most dangerous characters of all', Perutz's ironic description of his fellow internees (including Hermann Bondi), who were mostly refugees from Nazi oppression. Perutz's privations, in the Isle of Man and Canada, doubtless engendered the lifelong passionate concern for human rights. Eventually, he was able to return to England and participate, 1942-1943, in the Allied war effort through the Habbakuk project. This was the bizarre-sounding and ultimately rejected scheme for constructing a vast ice ship to act as a floating aerodrome in the ocean, a project which involved considerable high-level research and engineering. Participation in the Allied enterprise (sanctioned by Lord Louis Mountbatten who had Bernal as Scientific Advisor to Combined Operations) involved visits to Canada and the USA and so required Perutz's rapid naturalisation to British citizenship in 1943.

Despite ill health in early life, Perutz became an enthusiastic and skilful mountaineer and skier (he kept a mountaineering diary), making a walking tour in the Arctic as a student in 1933. As late as the 1960s he contrived to hold protein structure workshops in an Austrian ski resort! At Cambridge in 1937 and 1938, the combination of experience in snow mountaineering and crystallography enabled him to join the glaciologist Gerald Seligman on the Jungfrau in a study of glacier formation and the physics of skiing.

Having chaired a Glacier Physics Committee, Perutz collected further inclinometer experimental data on glacier flow mechanisms under blizzard conditions in Switzerland and in a 1948 expedition. Ferry recounts in some detail the wartime consequence of the ice crystal background; a summons to Perutz, around the time of his marriage in 1942, by Bernal and the eccentric Geoffrey Pike to discuss first signalling in glaciers and then the practicalities of the above unsinkable iceberg floating airfield: Habbakuk. Perutz wrote up both the research on the glacier flow mechanism (*Proc. Roy. Soc.* (A) **172,** 335-60, 1939 and *Proc Phys Soc.* **52,** 132, 1940 and that on the properties of frozen wood pulp for construction of the refrigerated Habbakuk bergship (*J.Glaciology* **1,** 95-104, 1947). Such was his standing that in 1947 he was invited to join an international Antarctic expedition as senior glaciologist, but declined.

Perutz's dominant scientific achievements were in molecular biology in pursuit of which he had overcome many financial and scientific obstacles. Perhaps as significant as his persistent long-term hands-on research into the structure and, later, mechanism of haemoglobin was his relaxed chairing of the inter-disciplinary LMB. This institution in Cambridge had been born out of the MRC Research Unit on Molecular Structure of Biological Systems in the Cavendish under Bragg and yielded a clutch of Nobel prize-winners. One of them, the brilliant Francis Crick

(Nobel prize also 1962) respected Perutz's work and was a friend but somewhat unkindly described Perutz as a very persistent plodder.

James Watson's depiction of the principal characters involved in *'The Double Helix'* (Athenaem, 1968) led to considerable controversy about the use of Rosalind Franklin's and Ray Gosling's X-ray data. Although Maurice Wilkins (who shared the 1962 Nobel prize with Crick and Watson) showed Watson the data in January 1953 (and some may have been included in an earlier King's College seminar attended by Watson), the subsequent debate was about the propriety of Perutz passing to Crick in February 1953 the content of an MRC report of which Perutz was the reviewer. John Randall, director of the King's biophysics lab, regarded the report as confidential, whereas Perutz felt that it was for information of other MRC workers. Recent attempts to amend some of Watson' s inferences and set out the interactions between the model builders at Cambridge and the more experimental workers at King's between November 1951 and February 1953 include Brenda Maddox's biography, *'Rosalind Franklin; the dark lady'* (Harper Collins, 2003) and Watson Fuller's article in Nature, 424, 876 (2003). Ferry suggests that Perutz's long letter of justification to Science 164, 1537) in 1969 smacked of protesting too much about his behaviour. Thus, in this and other ways, she recognises that Perutz exhibited some of the weaknesses of other scientists; he would be aware, for example, that there was greater public recognition of Watson and Crick than of himself. Ferry also notes that, for a warm and generous person, Perutz had some surprisingly acrimonious scientific conflicts in the 1980s. Suffering from coeliac disease (intolerance to gluten in wheat flour) from 1954, he was exceedingly diet-conscious and something of a hypochondriac.

Perutz loved art, music and literature while knowledge of languages helped his appreciation of European culture. However his behaviour was in some ways that of an archetype charming, relaxed Englishman, complete with eccentricity, understatement and admiration for the Queen. His awards included a CBE (he politely turned down the knighthood as a potential barrier within the laboratory) and received the greater distinctions of Companion of Honour in 1975 and Order of Merit in 1988. In her final chapter called, after his last public talk, *Truth always wins*, Ferry notes Perutz's ultimate elevation to British national treasure by being a guest on the BBC's Desert Island Discs.

This is a well-written and enjoyable biography of a dextrous, persistent and perceptive researcher, an influential scientist, and a compassionate, engaging and thoughtful man.

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Peter Ford, our new chairman of the History Group of the Institute of Physics, has recently retired from the Physics Department of the University of Bath. His email will remain as given above for the time being. -Ed