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Newsletter

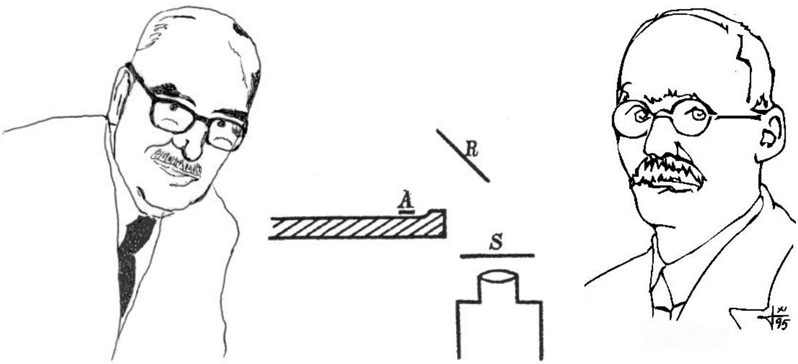

Fig. 3.

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Cover picture: Ernest Marsden and Hans Geiger with the diagram of their alpha particle scattering set up. (Drawing of Geiger by I Waloschek)

Taken from *Proceedings of the Royal Society*, A. **82**, 495-500 (1909)

Contents

Editorial

100 years ago this coming May 19th, a paper was received by the Royal Society from Professor E Rutherford FRS entitled *'On a diffuse Reflection of the alpha particles'*. It reported the results of experiments carried out by Hans Geiger and Ernest Marsden under the watchful eye of Ernest Rutherford, to see whether α - particles might exhibit diffuse reflection as did β particles.

The outcome of this work is, of course, very well known but at the beginning of this celebratory period I thought it worthwhile to revisit this historic moment.

At the turn of the 19th Century quantum theory was emerging to many as a hostile newcomer challenging the steady plod of classical physics and the structure of the atom was no exception to its all pervading influence. The uncovering of this structure proceeded at an enormous rate from the discovery of the electron in 1897 to Bohr's quantum model put forward in 1912, with the work of Geiger and Marsden providing a vital link.

They carried out their experiment in three parts:

The first used a 'reflector' of different metals. The second used reflectors of different thicknesses (to test whether the reflections were a surface effect or a volume one and this was done using gold leaf which was conveniently available in fairly consistent thicknesses). The third and possibly the most significant was to find the fraction of particles reflected.

The delightfully minimalist diagram showing the experimental set up is on the front cover – A is the radioactive source (radium C); R is a *platinum* plate and S is a zinc sulphide screen, which formed part of this human scintillation counter! It was the result of this part of the experiment – 1:8000 were reflected through an average angle of 90˚ which set Rutherford on the track of his planetary model of the atom.

So I think we really should refer to this seminal experiment not as the 'Gold leaf Experiment' but as the 'Platinum Plate Experiment'.

Malcolm Cooper

Brian Pippard 1920 - 2008

One of the doyens of British physics, Brian Pippard, died in September of last year aged eighty eight. He had a long and distinguished career culminating in becoming the Cavendish Professor of Physics at Cambridge between 1971and 1982. However to members of the History of Physics Group he is also fondly remembered as Chair of the Group between 1989 and 1997. Pippard was born in Leeds in 1920 and named Alfred Brian although he never used his first name. His father was a successful academic civil engineer holding professorial positions at the Universities of Cardiff and Bristol as well as at Imperial College, London. Pippard was educated at Clifton College in Bristol coincidentally the same place as Sir Nevill Mott his predecessor as Cavendish Professor. While at Clifton College he visited the chemistry department at Bristol University, which was headed by Maurice Travers who had carried out important researches with Sir William Ramsay on the first liquefaction of the rare gases. It was this which probably inspired his interest in low temperatures.

He graduated at Cambridge in 1941 and was immediately employed in war work in the development of radar at the Radar Research and Development Establishment in Great Malvern. It was here that he developed considerable expertise in microwaves and he realised that the use of microwaves could be a valuable technique for studying the properties of materials at low temperatures including superconductivity. In 1945 he returned to Cambridge and began academic research in the Royal Society Mond Laboratory under the supervision of Professor David Shoenberg, one of the pioneers of superconductivity in Britain. Pippard measured the penetration depth of currents in superconductors and this led to an important modification of the London theory of the electromagnetic properties of superconductors. He applied his microwave knowledge to study the anomalous skin effect in the normal state of metals. This effect had first been observed by Heinz London in 1940 in his pioneering investigations of the absorption by metals of very high frequency electromagnetic radiation. Pippard extended the work and he established without doubt that this was due to the mean free path of the conduction electrons being large compared with the skin depth of the penetration of high frequency currents.
Pippard obtained a detailed understanding of the anomalous skin effect in isotropic metals. He then went on to study theoretically the anomalous skin

depth effect in single crystals. His analysis suggested that by making measurements of this effect on a single crystal it might be possible to determine its Fermi surface. In 1957 he had a sabbatical leave at the University of Chicago and made these measurements to infer the Fermi surface of copper. However it was quickly appreciated that the relationship between the anomalous skin effect and the shape of the Fermi surface was so complicated that it was unlikely to be of great use in its determination. It was during a visit to the Cavendish Laboratory shortly afterwards by the distinguished Norwegian born physicist Lars Onsager that it was pointed out to Pippard and Shoenberg that the de Haas-van Alphen effect could provide a powerful technique for determining Fermi surfaces. At the time Shoenberg was one of the leading authorities in the world on the de Haas-van Alphen effect. Following Onsager's suggestion, this line of research was actively pursued at Cambridge and the resulting determination of the Fermi surface of copper confirmed Pippard's earlier work. The determination of the Fermi surface of other elements quickly followed. These researches led to Pippard being awarded the Hughes Medal of the Royal Society in 1959.

Throughout his research work he has demonstrated that important Cambridge trait of combining superb experimental technique and manual dexterity with a deep insight into the physics. Pippard seemed to move effortlessly through the Cambridge system becoming demonstrator in physics ((1946-50), lecturer in physics (1950-59), reader (1959-60), John Humphrey Plummer Professor of Physics (1960-71) and finally attaining the position of Cavendish Professor and Head of the Department of Physics (1971-82). From 1982 onwards he was an emeritus professor.

He became the Cavendish Professor at an important moment in the history of the physics department since the move from the Cavendish and Mond Laboratories in Free School Lane to a brand new site off the Madingley Road, was imminent. Pippard was closely involved with the design and planning of the new laboratories and throughout demonstrated considerable flair and innovation. He was anxious to ensure that the buildings were made as flexible as possible to adapt to the requirements of the different laboratories and that they conformed to the appropriate building regulations since they had to be low rise to blend in with the East Anglian countryside. Pippard gave a famous Inaugural Lecture as the Cavendish Professor in October 1971. This took place almost a hundred years to the day from the

Introductory Lecture by James Clerk Maxwell to mark the beginning of the Cavendish Laboratory. Pippard's flair for experimentation has already been remarked upon and it was amply shown during the lecture by his giving several memorable demonstrations. In one of these he took a cylinder of copper 4.5 cm in diameter and of the same length and asked the audience how long it would take to cool this down to the temperature of liquid nitrogen (-196C). The responses varied but the general consensus of opinion was that it would take between 30-60 seconds. In fact it took over six minutes to reach the temperature, a much longer time than that suggested, because people had not appreciated that immersing the copper block into the liquid nitrogen created a layer of nitrogen vapour which shielded the block thereby inhibiting the cooling.

This ability to provide striking experimental demonstrations is most widely seen today in his design in 1988 of a version of the famous Foucault pendulum in the Science Museum in London. For many years a traditional and somewhat ponderous Foucault pendulum had stood near to the main entrance of the Science Museum close to a statue of Galileo. This was replaced by Pippard's elegant new version of the pendulum which was re-sited to further within the museum. It has been seen and enjoyed for over twenty years by literally thousands of people for whom his name must mean little or nothing.

Throughout his time at Cambridge, Pippard was interested in teaching and education. He was prominent in the implementation of several major reorganisations of the natural sciences tripos. He was anxious to make the tripos more relevant to the needs of society as a whole rather than a small clique who were likely to pursue research. In this respect he was following in the ideals expressed by his predecessor James Clerk Maxwell. An academic venture which proved to be very successful was the foundation of Clare Hall, a graduate college in Herschel Road, Cambridge, which was an offshoot of Clare College to which Pippard was attached. He became its first Master, a post he held between 1966 and 1973. One of the aims of the college was to create an informal atmosphere while retaining academic excellence. This was in contrast to the rather staid environment existing in many colleges at that time.

Pippard, together with his wife Charlotte and three daughters, did a great deal to create the right atmosphere; they were the genial and friendly hosts at many College functions and set a tone for the College which exists to this day.

He was the author of several books, including the famous *Elements of Classical Thermodynamics* published in 1957, which must have been read by generations of students world-wide. He was also one of the three editors and a contributor to the massive and impressive three volume work *Twentieth Century Physics*, which appeared in 1995, published by the Institute of Physics.

Pippard was an outstanding pianist and might have made a career of it had he not become a physicist; playing the piano was a major relaxation for him. Throughout his life he retained a love of music and in his last years he and his wife were frequent attendees at concerts given in Cambridge by the choir *Collegium Laureatum* to which one of his daughters belonged.

During his life Pippard received many honours and awards. He was elected a Fellow of the Royal Society in 1956 and knighted in 1975. He became a Fellow of the Institute of Physics in 1970 and was its President between 1974 and 1976. In addition to receiving the Hughes Medal, he was awarded the Holweck Medal (1961) and the Guthrie Prize (1970) both from the Institute of Physics. He won the Dannie-Heineman Prize (1969) and the Lars Onsager Medal of the Norwegian University of Science and Technology, Trondheim (2005).

Brian Pippard is survived by his wife and three daughters.

Peter Ford

The Royal Society withdraws funding from National Cataloguing Unit for the Archives of Contemporary Scientists

In the last government Comprehensive Spending Review, the Royal Society's Parliamentary Grant-in-Aid for history of science projects was cut, for reasons which have not been satisfactorily explained. One consequence of this cut has been the withdrawal of core funding for the NCUACS at the University of Bath.

Readers may know that NCUACS has done invaluable work over many years in locating, cataloguing and finding repositories for the archives of hundreds of recent and contemporary British scientists. Among the many physicists whose personal and professional papers have been processed by NCUACS are E.V. Appleton, P.M.S. Blackett, B.H. Flowers, O.R. Frisch, N. Kurti, H. London, N. Mott, R. Peierls, C.F. Powell, A. Salam, G.P. Thomson and J.J. Thomson. Full details of NCUACS and its work can be found at: http://www.bath.ac.uk/ncuacs/

Without its core funding, the basis from which project-specific fund-raising is carried out, NCUACS and its important work are now under threat. The British Society for the History of Science has been coordinating action to secure a future for NCUACS and contemporary scientific archives. Under petition from more than 40 organisations (including learned societies, professional society history groups and major research libraries and archives) and prominent individuals (Fellows of the Royal Society and Fellows of the British Academy), the Royal Society has agreed to hold a small meeting to discuss the preservation of contemporary archives. Details of the outcome of this meeting will be circulated in due course.

If you would like to show your support to ensure that the unit can continue its valuable work, please write/email Malcolm Cooper – address on page 71.

Jeff Hughes

IoP History of Physics Group Committee Member
President, British Society for the History of Science

Website News

from Kate Crennell

Remember that the quickest way to visit our Group web pages is to use the URL: **hp.iop.org** then click on the words '***Latest news'*** in the column on the right of the page, which should show you this page and its updates.

1. **www.scienceplaces.org**

This has been set up as part of Liverpool's year as the 'European Capital of Culture' in 2008. You can download an mp3 'W*alking tour of Liverpool'* and discover the history of science and engineering in Liverpool during a 3 mile walk round the city. In addition there is a similar tour for *Manchester*.

If you do not have time to visit either city, you can read about the places visited on the website and listen on-line to key parts of the tour while browsing the interactive map.

2. **Websites for the IYA2009**

Physics World for January 2009 has a useful list of web pages for the International Year of Astronomy, IYA2009; some are for short term events and meetings, others for the whole year. Try looking at the Physics World site: **physics.world.com** for the current issue, January 2009, page 13.

Cosmic Diary: www.iya2009.org

Professional astronomers around the world will be blogging about what it is like to be an astronomer and what they do every day. Researchers from NASA, ESA and ESO are participating

Portal to the Universe: www.portaltotheuniverse.org

This site has been built for the year, it will contain links to other astronomical websites, observatories, facilities and astronomical societies as well as news, new images taken by telescopes and blogs by astronomers.

Eyes on the skies: www.eyesontheskies.org

This describes the IAU project to make a DVD, movie and Book about the last 400 years of telescopes and astronomy. It has links to many other supporting organisations.

3. Oxford Museum of the History of Science: www.mhs.ox.ac.uk

Exhibition: ***'The English Telescope from Newton to Herschel'***

15 October 2008 to 22 March 2009

They also have a series of lectures on Tuesday evenings at 7pm on the following telescopes, The William Herschel and Hubble telescopes; Jodrell Bank; the Lovell Telescope and e-Merlin, the Gemini telescopes, the Pierre Auger Observatory

Exhibition: **'The Double Horizontal Dial: Then and Now'**

13 January to 10 March 2009

The first 'double horizontal sundial' to be made since the 18th Century is on display prior to its installation in Oxford

All of these sites will be added to our 'links' page as soon as possible.

Other IYA Events

International Astronomy Day, 2 May 2009

Look out for local events in your area, astronomical societies, museums, planetariums and observatories will be giving workshops and presentations. Any I learn about I will add to our Group webpages, please send any you hear about to me to share with our members.

Great worldwide star-count: 9 - 23 October 2009

This event encourages everyone to go outside, look skywards after dark, count the stars they see in certain constellations, and then report their findings on-line.

Meeting Reports

Annual General Meeting, December 10th 2008

The 21st Annual General Meeting was held at 5.30pm on Wednesday 10th December in the Physics Department of the University of Liverpool. It was attended by about 20 people, which included all the members of the committee. It began with a summary of the activity of the group during the year (see below) by the Chairman. The existing committee were all willing to stand again for election and this was approved by those attending the meeting. In addition John Roche of Linacre College, Oxford University was also voted onto the committee. We are delighted that John has rejoined the committee. He was Secretary and founding member of the group until 1991 and also Chairman between 1996 and 2000, and he adds a great deal of knowledge and authority to the group. In addition the position Malcolm Cooper, who had been doing sterling work as the acting secretary of the group, was formalised.

Following these formalities a number of issues were discussed. Kate Crennell, the web pages editor, drew attention to some of the problems relating to the way in which the IOP headquarters operates its web site. In addition she pointed out that both the IOP headquarters in London and the IOPP in Bristol held valuable archive material going back many years, which she believes was not being properly catalogued and conserved.

After raising the matter in committee, Stuart Richardson drew the meeting's attention to the existence of some school curriculum authorities promoting courses on the history of science and he felt that our group could organize a similar week long course on the History of Physics aimed at teachers of physics. He was asked to draw up a document about this matter which could be sent to the Chief Executive of the IOP, Dr Robert Kirby-Harris.

In a short address the Chairman pointed to a successful year for the group. Two lecture meetings were held. The first was at the IOP headquarters on Thursday 17th July and was devoted to the life and work of the 3rd Baron Rayleigh. It began with an interesting lecture by the current Baron Rayleigh, the 6th in the dynasty, who lectured on "My Forebears".

This was followed by Professor Edward Davis who gave an excellent account of "The Laboratories and Work of the 3rd Baron Rayleigh".

The laboratories used by both the 3rd and the 4th Baron Rayleigh still exist at the family seat in the village of Terling in Essex. Professor Davis has been actively involved in cataloguing, photographing and archiving the many artefacts which have remained virtually undisturbed for some sixty years since the death of the 4th Baron Rayleigh in 1947.

The third lecture was by Sir John Meurig Thomas who had been the Director of the Royal Institution in London and dealt with the fascinating story involving the interaction between the 3rd Baron Rayleigh and Sir William Ramsay, which resulted in the discovery in 1895 of a new element called argon. At the time Ramsay was in the Chemistry Department of University College, London. The discovery led to Rayleigh being awarded the Nobel Prize for Physics in 1904 and Ramsay being awarded the prize for Chemistry in the same year.

Some seventy people attended this meeting. It is planned that the lectures will form the main part of a special issue of the newsletter which will be devoted to the 3rd Baron Rayleigh and this should appear during the first few months of 2009.

During the year two excellent newsletters were produced, in January and again in August. Thanks and appreciation was made to the editor, Malcolm Cooper.

The AGM and committee meeting had been preceded by a lecture day in Liverpool which celebrated the 127 year history of the Physics Department of the University of Liverpool. It was part of the City of Liverpool celebrations as the 2008 European Capital of Culture and was held in the magnificent and historic Leggate lecture theatre, which is part of the newly created Victoria Art Gallery and Museum (VGM) within the University. The following lectures were given by past and present members of the Physics Department:

Dominic Dickson: The early days: radio, X-rays and the ether.
Peter Rowlands: The cyclotron in war and peace.
Gerard Hyland: The theoretical dimension.
Mike Houlden: Nuclear and particle physics to the present.

The VGM had a small exhibition on the physicists associated with the Department at Liverpool. What came over clearly during the day was the seminal contribution made by the Department in a wide range of physics. Physicists associated with it included Oliver Lodge, Charles Barkla, James Chadwick, Otto Frisch, E.J. Williams, Joseph Rotblat and Herbert Frohlich. In addition to the lectures, delegates were presented with an excellent short book entitled '*125 years of excellence'*, which summarised much of what had been heard during the day. The event was attended by about 100 people and was highly successful. Our thanks should be given to all of those involved with its planning and organisation. These included our History of Physics Group committee member, Peter Rowlands.

The years 2009-2012 mark the centenary of an amazing series of experimental and theoretical investigations into the structure of the atom by Sir Ernest Rutherford and his colleagues at The Physical Laboratories of the University of Manchester. It was felt that at some time during this period a meeting should be held in Manchester to mark the event.

The date of the 25th anniversary for the founding of the History of Physics Group is slightly uncertain. However its formation was approved by the Institute of Physics headquarters in 1984 and so 2009 was deemed to be an appropriate time for holding a 25th anniversary meeting. This has been tentatively set for the end of November and will include our next AGM. It is planned that that the venue will be the Headquarters of the IOP in Portland Place, London. The theme will be a review of the first 25 years and it is hoped that as many of the past and present officers of the Group will be able to attend.

Dr P.J. Ford
Chair of the Group

Physics at Liverpool: A Capital of Culture Celebration

On 10 December 2008, as part of the Capital of Culture celebrations, the University of Liverpool's Physics Department celebrated its 127-year history, in collaboration with the IoP History of Physics group and the Merseyside branch of the IoP. The celebration was held in the historic Leggate theatre of the University's newly created Victoria Art Gallery and Museum. An audience of over a hundred heard the four speakers give an extensive account of the Department's fascinating and often exciting history. Dominic Dickson began with the founder, Oliver Lodge, one of the outstanding physicists of his time, and his work on radio, X-rays, and the ether. Lodge was followed by Lionel Wilberforce, a great public communicator, and the audience were entertained with a series of fascinating demonstrations, of the kind that Wilberforce used to inspire interest in physics – the Wilberforce spring, a diabolo, Euler's disc, a non-stop spinning top, a helicopter boomerang and a flying saucer (most of these are available from Hawkin's Bazaar, www.hawkin.com). Outstanding research was also done in the same period, Charles Barkla winning a Nobel Prize for his work on X-rays and the structure of matter.

The second speaker, Peter Rowlands, concentrated on Sir James Chadwick and his catapulting of the Department into the big league of nuclear and particle physics with the building of two large accelerators, the 37-inch cyclotron and the 156-inch synchrocyclotron. The first came on line in 1939, just as the Second World War started, and, though not built for war work, the cyclotron was quickly adapted for that purpose with the measurement of uranium fission cross-sections, vital both for weapons and the peaceful use of nuclear power. A dramatic series of developments ultimately led the Manhattan Project, with Chadwick overseeing the entire UK contribution. Chadwick also built up a great team at Liverpool including E. J. Williams, Otto Frisch, co-discoverer of fission, Joseph Rotblat, whose subsequent peace campaigning earned him a Nobel Peace Prize, and John Holt, whose post-war work on nuclear physics was particularly significant. It was Chadwick's successor, Herbert Skinner, however, who completed the synchrocyclotron, which, for a time, was the most important accelerator in the world, and which enabled Liverpool to make such significant discoveries as the violation of charge conjugation in 1957.

Lunch time gave the participants time to look at the extensive exhibition of artefacts, photographs, books, manuscripts, and video of Lodge, Chadwick and others, in the Victoria Building's spectacular interior (along with the Gallery's own extensive collections). The Tate Hall also gave a good view into the quadrangle with the Physics Department's original home, the George Holt Building on the right (home of the 37-inch cyclotron), and the Harrison Hughes building on the left, rebuilt after being struck by a parachute mine in March 1941. The first talk in the afternoon, by Gerard Hyland, gave an account of the theoretical contributions, beginning with James Rice, who was an expert on general relativity and who entertained Einstein on his 1921 visit. The big star, however, was Herbert Frőhlich, who, among many other things, made the first major breakthrough in the theory of superconductivity. The speaker also discussed Frőhlich's 'brilliantly daring introduction into biology during the late 1960s of the concepts of modern theoretical physics – in particular, that of *coherence*'. As well as being a brilliant individual thinker, Frőhlich built a very strong theoretical group at Liverpool, which made contributions in many other areas, especially nuclear and particle physics.

The final talk, by Mike Houlden, used an experience of more than forty years in the Department to bring nuclear and particle physics up to the present, enlivened with many illustrations and anecdotes. Bubble chambers, film analysis, the work of the scanning ladies (one of whom, Rita Legge, was present), the flying spot digitiser, Sweepnik, early computers, the OMEGA spectrometer at CERN, spark chambers, drift chambers, NINA at Daresbury, the Intersecting Storage Rings (ISR) at CERN, the European Muon Experiment (EMC), all flashed by with a wealth of anecdote and personal reminiscence. Liverpool's contribution to EMC was outstanding, and included the Q meters still in use and the cryostat for the polarised target. The big discovery was that the spin of the proton is *not* derived from the spin of the 3 valence quarks; the paper has been cited 1209 times. Then followed DELPHI, which showed (with other collaborations) that there were only 3 types of neutrino, the electron-proton collider at Hamburg and the H1 experiment, which showed that the proton contained point-like entities, CPLEAR, which for the first time showed the arrow of time, BABAR, with the first measurements of the elements of the unitary triangle, CDF, with the first precise measurement of the B_s oscillation frequency. In nuclear structure, the tandem Van der Graaff, the NSF at Daresbury – the discovery of the decay schemes of high spin nuclei was a major triumph – and the powerful new technique of Total Data Readout. Parallel to all this were developments in computing, leading up to MAP2, and in detector technology, leading to the new Semiconductor Centre clean room suite. The speaker identified the outstanding technical support given to the research staff at all times as a key element in the Department's success, as many of the photographs had already demonstrated.

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The following articles are taken from two of the talks at Liverpool – we hope to present the others at a later date - Editor
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Theoretical Physics in Liverpool

Dr. GJ Hyland
International Institute of Biophysics,
Neuss, Germany

60 years ago this year - in October 1948, to be precise - official provision was first made for Theoretical Physics at Liverpool with the appointment of Herbert Fröhlich - then Reader at Bristol - to the newly created Chair of Theoretical Physics. For the first 13 years of its history, Theoretical Physics was a sub-department of Physics from which it became independent in 1962 as part of Cassels' restructuring programme. This lasted until 1973, when, under Fröhlich's successor, Chris Michael, Theoretical Physics amalgamated with Applied Mathematics to form the Department of Applied Mathematics and Theoretical Physics (*DAMTP*), an arrangement that continued until 1996 when Theoretical Physics became a Division within the Department of Mathematical Sciences.

During Fröhlich's tenure, Theoretical Physics was a very small department with no more than 6 academic staff at any one time, representing research interests in solid-state physics, statistical mechanics, nuclear physics and field theory; it now has almost twice that number of staff all of whom work exclusively in theoretical particle physics. Another difference between then and now is the balance between research and teaching, which in former times was biased heavily in favour of research, Fröhlich himself, for example, giving undergraduate lectures only during the first few years of his 25 year tenure.

Although 1948 marked the start of Theoretical Physics as an academic subject in its own right, it would be wrong to assume that there had earlier been no activity in this field within the Physics Department. It should be remembered that at the time the Department was established (1881), the separation between experimental & theoretical physics was not as absolute as it now is; in England, for example, Chairs in Theoretical Physics were not established until the 1920s[1].

Right from the beginning, there is the example of **Oliver Lodge** who was highly fluent in both experiment *and* theory: indeed, his original title was *Lyon Jones Professor of Physics & Mathematics*[2].

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[1] In Germany, however, the first Chair of Theoretical Physics (held by Kirchhoff) was established in Berlin in 1875.

[2] This was changed to *Lyon Jones Professor of Experimental Physics* in 1882 and finally to *Lyon Jones Professor of Physics* in 1900, the year in which Lodge left for Birmingham.

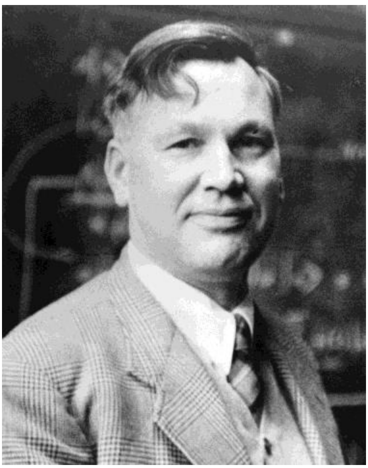
Examples of his theoretical work include contributions to the ether hypothesis out of which arose his prediction in 1893 of the *Sagnac* effect, 20 years before its experimental discovery. This effect is essentially the electromagnetic counterpart of the gyroscope, and is now used, for example, in Global Positioning Systems, wherein the rotation of the Earth has to be taken into account. In addition, already in 1891, Lodge was discussing the fourth dimension and world-lines, and in 1895 he was accredited by Lorentz with the *first* published description in 1893 of the length contraction hypothesis!

During the tenure of Lodge's successor, Lionel Wilberforce, theoretical activity in the Oliver Lodge mould continued in the person of Lodge's student, **Charles Barkla** (Liverpool, 1894-98, 1902-09), who was not only a brilliant experimentalist in the field of X-rays, but also was highly capable theoretically, making several contributions to X-ray scattering topics between 1903 and 1907, such as his attempt to improve Thomson's formula for the scattering of X-rays by atoms.

The first 'exclusively theoretical' theoretical physicist at Liverpool was probably **James Rice** (right) from Belfast (*b*. 1874, *d*. 1936; Liverpool 1914-36). He was appointed in 1914, and, together with Wilberforce, remained in Liverpool throughout the First World War. He became an associate professor in 1924, and from 1935 until his death the following year was Reader in Theoretical Physics. Already in 1917, he was lecturing on Einstein's General Relativity Theory published only the previous year, and in 1921 acted as host during Einstein's visit to the *George Holt Laboratory*. 1923 saw the publication of his book *Relativity, a systematic treatment of Einstein's theory*, which, for many years, was the most popular English language university text-book on relativity. He was certainly one of the most distinguished interpreters of relativity at the time, and could well have been the third person in the group of only three who were popularly considered to have understood relativity. When Eddington heard this he replied: '*I can't think who the third could be*' - the other two being Einstein and, of course, Eddington himself! In 1925, Rice derived a formula relating the fine-structure constant to the radius of the Einstein universe, foreshadowing Eddington's own ideas along similar lines four years later. His second book on relativity theory – this time, a more popular one entitled

Relativity: *an exposition without mathematics*, for which he received an appreciative letter from Edmund Whittaker - was published in 1926. In addition, Rice was one of the first to recognise the importance of quantum theory in chemistry, developing the idea of representing a chemical reaction in terms of the motion of a point in phase space, and in 1930 published his *Introduction to Statistical Mechanics*.

One of Rice's pupils was **William** (Bill) **Band**. After graduating in 1927, he was appointed lecturer, a post he held for two years during which he assisted with the design and building of a novel kind of X-ray tube (with detachable water-cooled ends and replaceable electrodes) that was later improved upon by Lipson and Beevers who went on to use it to great effect in the determination of crystal structures - one of which they published ahead of Wyckoff. Band left for China in 1929, eventually becoming Professor of Physics in Yenching, until the Japanese invasion in 1941, when, in the company of his wife, Mao Tse-tung and Chou En-lai, he just managed to escape, eventually returning to Liverpool where he obtained his *D.Sc.* in 1946. After this, he emigrated to the U.S.A. to embark on a brilliant academic career that culminated with his appointment as Professor of Theoretical Physics at Washington State University; he authored two text-books in physics: *Introduction to Mathematical Physics* and *An Introduction to Quantum Statistics*.



Wilberforce's successor, James Chadwick, was instrumental in the appointment, not only of Herbert Fröhlich in 1948, but also, 10 years earlier, of **Maurice Pryce**[3]**,** (left) to a Fellowship and then a Readership specifically in Theory, both of which were funded by the *Leverhulme Trust*. Already in his Liverpool lectures during the autumn of 1939, Pryce was discussing fission of uranium, and following the discovery of the more fissile element plutonium in Berkeley the following May, immediately considered the possibility of manufacturing it using the Liverpool 37" cyclotron; he calculated, however, that the yield would be too low to be useful. In 1945, he resigned his position in Liverpool to return to his Fellowship at Trinity College, Cambridge.

[3] For further biography of Pryce please see the article in Newsletter issue 22 - Ed.

Two years prior to Fröhlich's appointment, Schrödinger, who was then at the *Dublin Institute for Advanced Studies*, approached Liverpool with a view to procuring a Chair for himself. It has been suggested that this move might well have been an attempt to distance himself from the unfavourable climate that that final chapter of his book '*What is Life*?' had provoked in Catholic circles in Dublin. Personally, however, I do not think this would have bothered him too much; indeed, he would probably have relished it, but perhaps feared that his position at the Institute might have been placed in jeopardy. Given Schrödinger's research interests at the time - which included meson theory and unified field theory - Chadwick was at first enthusiastic about having him at Liverpool, but was eventually dissuaded from pursuing the matter on the advice of Rotblat.

The Chair to which **Herbert Fröhlich** was eventually appointed was first advertised by the University in May 1947, and applications were received from Benham, Jaeger, Jahn and Temperley. Although only Jahn and Temperley were invited for interview, Jaeger's application did receive serious consideration, partly on account of his work being known to the External Advisors (Mott & Peierls) and to certain members of the Selection Committee. Whilst it was agreed that these three had all merited careful consideration, it was finally concluded that none of them was likely to fully meet the needs of the subject in Liverpool. After discussion with the External Advisors as to whether an approach should be made to someone who had *not* applied for the Chair, they suggested that consideration be given to Dr Herbert Fröhlich of the University of Bristol, who was in fact already well-known to them; indeed, Mott, in his report to the Selection Committee, revealed that Fröhlich was likely soon[4] to be elected F.R.S. The Committee welcomed this proposal, and Fröhlich was duly invited to Liverpool for preliminary talks with the Vice Chancellor and Chadwick. On 20 February 1948, in the absence of the External Advisors, he met the Selection Committee, several of whose members already knew him, and they were all convinced that, in view of his high standing, he would bring a valuable and much needed contribution to the work of the university. Accordingly, the Committee unanimously recommended that Fröhlich, who was then 42, be appointed to the Chair of Theoretical Physics as from 1 October 1948; the appointment was reported in *Nature* on 8 May that year.

As part of his negotiations prior to his appointment, Fröhlich had managed to secure from the University the promise of a well-funded library under his own control. The library rapidly grew, and, over the years, proved to be the invaluable research aid that he had foreseen, and after his retirement in 1973 the University named the library (whose collection still exists) after him.

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[4] Fröhlich was first proposed in 1947, but was not elected until 1951.

Whilst Fröhlich was still in Bristol, Liverpool was not alone in approaching him with an offer of a position elsewhere, as exemplified by the invitation he received after the war from the *UKAEA* to become Head of the Theoretical Physics Division at Harwell. However, despite his earlier interest (with Heitler) in fission, he declined the offer, not wanting to have any part in the further development of atomic weapons, particularly once it had become clear to him that those involved in their development would have no say in their deployment; in his place, Klaus Fuchs was appointed!

A significant factor that recommended Fröhlich to the Liverpool Selection Committee was undoubtedly his pre-war work (in collaboration with Heitler and Kemmer) on a vector extension of Yukawa's meson theory of nuclear forces, which addressed issues such as the self-energies and magnetic moments of the neutron and proton, and the neutron-proton and proton-proton forces. In order that these latter two forces be of equal strength, it was found necessary to postulate the existence of a neutral meson - some 12 years before neutral pions were discovered experimentally. In addition, in Bristol, after the war, he had built up a working group on nuclear structure, whilst during the year immediately prior his interview, his work with Huang and Sneddon on the binding energy of very light nuclei had been published.

Fröhlich had arrived in Bristol in 1935 as a refugee from Stalin's purges in Leningrad (St. Petersburg) to where he had been invited by Frenkel after being dismissed by the Nazis from his post of *Privatsdozent* in Freiburg. Prior to leaving Germany, he had worked exclusively on metal physics, his *D.Phil* thesis being on the Photoelectric Effect in metals. Whilst in Russia, his interest broadened to include the then quite new (and barely reputable) field of semi-conductors, and he included a theoretical treatment of them in his first book *Elektronentheorie der Metalle,* which was published in 1935 (after his arrival in Bristol), and which for some years was the only text-book to discuss such materials.

Soon after arriving in Bristol, Fröhlich turned his attention to dielectrics, a field in which he became the undisputed master. Of particular concern to him at this time was the development of a theory of dielectric breakdown in order to understand how certain non-metallic materials cease to be insulators in high electric fields – an area in which he became a world authority. Essentially, breakdown occurs when a rapidly moving electron receives energy from the applied electric field faster than it can transfer it to lattice vibrations, thereby gaining more and more energy until, by ionisation, it is able to produce an abrupt increase in the number of conduction electrons. Dielectric breakdown was (and still is) a topic of great technological importance, and Fröhlich's work in this area – as well as that of some of his collaborators - was financially supported for many years by the Electrical Research Association (*E.R.A.*).

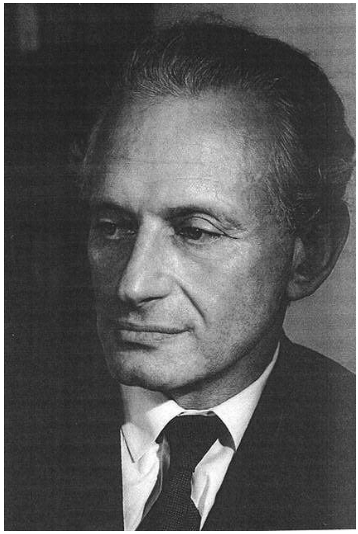
Upon his arrival in Liverpool, he brought from Bristol and the *E.R.A.* a substantial number of co-workers, including H. Pelzer (a member of the Senior Research Staff of the *E.R.A.*, and already well-known as the co-author with Wigner of a seminal paper on the rates of chemical reactions), B. Szigeti (Research Fellow supported by the *E.R.A.)* who was highly experienced in dielectrics and crystal dynamics, Kun Huang (*I.C.I.* Fellow), and A.B. Bhatia (*1851 Exhibition Scholar*); in addition there was S. Zienau, a research student working on electrons in polar crystals. The only staff member besides Fröhlich was his assistant lecturer, R. Huby. The first research students were Miss S. N. Ruddlesden and Mr. A. C. Clarke who had both recently graduated from Liverpool. During the university vacations, Huang went to Edinburgh to work with Max Born on what was to become the well-known treatise *Dynamical Theory of Crystal Lattices*, which was first published in 1954.

Although the new department of theoretical physics had been assigned an elegant Georgian House in Abercromby Square, it was not ready for occupation when Fröhlich and his group arrived in Liverpool, and for a short time they effectively had to ‘squat’ in the *George Holt Laboratory*.

Once established in 6 Abercromby Square (below left), where the department remained until 1959, there was a constant stream of eminent visitors from abroad, such as Bardeen, Bethe, Heisenberg, Heitler, Onsager and Prigogine, which soon made it a truly international centre of excellence in theoretical physics.

To some in Liverpool, however, this was a source of some disquiet in the immediate post-war years when the visitors included both German and Japanese physicists, such as Haken and Nakajima. To Fröhlich, however, racial, political and religious differences were no impediment to sincere scientific discourse.

Among the most significant events of the day at 6 Abercromby Square were undoubtedly morning coffee and afternoon tea at which important ideas often emerged from extended and animated discussions, to which the congenial atmosphere of the house was so conducive.



Herbert Frohlich *circa* 1950

One day in 1950 - 26 June, to be precise - Fröhlich did not appear at coffee, which was unusual since it was known that he was not away on a trip; neither did he appear at afternoon tea, by which time he *was* known to be in the Institute. In response to queries, Szigeti (who had also been absent at morning coffee) explained that Fröhlich had got married that morning, and was now making up for lost time! His wife was Fanchon Aungst, whom he had met whilst she was passing through Liverpool from Chicago on her way to read Philosophy at Oxford.

One year after his arrival in Liverpool, Fröhlich's second book *Theory of Dielectrics* was published, and it is of interest in this connection to record the disappointment expressed by some in the Liverpool Physics Department that, having been appointed on the strength of his work on meson theory and in nuclear structure, Fröhlich should now be preoccupying himself with something as non-relativistic and seemingly mundane as dielectric theory. The research activities of *other* members of the department were, however, more closely related to experimental programmes in the Physics Department. Huby, for example, was involved, along with Bhatia, Huang and Newns, in developing (in 1952) a theory of low energy deuteron stripping that had been discovered by J.R. Holt and C.T. Young in 1949 using the 37" cyclotron. Their theory showed how stripping could provide valuable spectroscopic information on the states of excited nuclei, including the determination of nuclear spin and parity, and this motivated further experimental studies on a wide variety of other nuclei. Subsequently, other members of the group maintained close collaboration with experimenters involved with the tandem van de Graaff accelerator.

In an attempt to strengthen further the collaboration between theory and experiment, Skinner had Newns appointed Lecturer in the Physics Department in 1955, and during the early 1960s he worked closely with John Holt on the basic design of the Daresbury 4GeV electron synchrotron *NINA*, which was commissioned in 1967. This arrangement continued until 1962 when Cassels persuaded Fröhlich to have Newns back in Theoretical Physics.

Earlier, in 1949, K.J. Le Couteur, an expert in relativistic field theory, had been appointed Senior Lecturer, and he soon applied himself to the theory of the design of the beam extractor from the 156", 400MeV synchrocyclotron that was being built by the Physics Department during the early 1950s, and in 1955, successful extraction was reported, the beam being several times stronger than that from any comparable machine. Le Couteur's solution to the extraction problem was later adopted by Chicago and *CERN*. When he left for Australia in 1956 to take up a Chair in Canberra, Le Couteur was replaced by his research student G.R. Allcock who maintained an ongoing activity in field theory, both in the relativistic and non-relativistic domains, applying it, for example, in the solid state context of the *polaron*.

A *polaron* is the quasi-particle formed when account is taken of the reaction back on an electron moving slowly through a polar crystal of the electric polarisation it induces in its vicinity. In an important paper published in collaboration with Pelzer and Zienau in 1949, Fröhlich brought to bear the experience he had earlier gained in meson field theory, in the language of which this reaction expresses itself in terms of the emission and re-absorption of virtual optical phonons. These processes endow the electron with a (finite) self-energy and an increased effective mass, both of which can be expressed in terms of a coupling constant that now bears Fröhlich's name. Most importantly, it was found that, as a polaron, the electron remains *free* to move through the lattice, rather than becoming self-trapped, as had earlier been predicted by Landau. Allcock later extended Fröhlich's original weak coupling treatment of the problem to the case of strong coupling[5]. A very elegant review of polaron theory written by Fröhlich in 1954 prompted Feynman to apply his path-integral method to the problem, and this yielded a generally valid treatment for *all* coupling strengths.

Powerful as Feynman's approach was, its utility was, however, *physically* undermined by the progressive breakdown, as the strength of the coupling increases, of the validity of the underlying treatment of the ionic lattice as a dielectric continuum: a new approach was called for. In the West, this was again initiated by Fröhlich whose ideas were subsequently developed into what is now known as 'small' polaron theory by G.L. Sewell, then of the Department of Applied Mathematics. Sewell (1957-62) was only one of a number of members of that department who, over the years, had research interests close to those pursued in Theoretical Physics, another being D.J. Hooton (1956-59) who worked with Allcock on field theory.

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[5] A number of years later in 1969, Allcock, in an attempt to show that von Neumann's measurement theory does not cover all scenarii, published 3 important papers dealing with the measurement of the time of arrival in non-relativistic quantum mechanics.

Later appointments included J.R. Mines (1967) and M.W. Kermode (1969), both of whom collaborated over many years with Huby in nuclear theory research.

Polaron theory was immediately followed in 1950 by Fröhlich's fundamental contribution to the theory of superconductivity - which proved crucial to the eventual solution of the problem - namely, that the basic underlying interaction was a hitherto unrecognized aspect of the *same* interaction as is responsible for the converse phenomenon of electrical resistivity, namely, the *electron-phonon* interaction. It must be remembered that, at this time, superconductivity was *the* central problem in solid-state physics. Extending the same field-theoretical concepts as he had used in the case of the single electron involved in the polaron to the *many* electrons in a metal, he realised that the emission of a virtual *acoustic* phonon by one electron followed by its re-absorption by *another* here entails – in direct analogy with the meson case – an (attractive) interaction between electrons near the Fermi surface - one electron being attracted to the lattice distortion created by another, and *vice versa*.

Consistent with the involvement of the ions of the crystal lattice in the phenomenon of superconductivity was the contemporaneous discovery of the *isotope effect* for which his theory perfectly accounted, although in other respects it was less successful. The following year (1951), Fröhlich was elected F.R.S.

Interaction of electrons with lattice vibrations

By H. Fröhlich, F.R.S.
Department of Theoretical Physics, University of Liverpool

(*Received* 30 *July* 1952)

Using methods of modern field theories a canonical transformation of the Hamiltonian of free electrons in the field of the lattice vibrations is performed. This transformation takes account of the bulk of the interaction of the electrons with the vibrational field and leads to a renormalization of the velocity of sound and of the interaction parameter F. An objection of Wentzel's against the use of large F is removed in this way. Even in the case of weak interaction the transformed Hamiltonian contains already in zero order terms which require a modification of the usual procedure in the theory of metals, and which at low temperatures lead to an increase of the effective mass of the electrons. Treatment of strong interaction requires the development of a new method.

Abstract from Proceedings of the Royal Society Vol. 215 p291

1952 marked the start of a new era in solid-state physics, with Fröhlich's introduction of creation and annihilation operators for both electrons and phonons, in terms of which what is now known as the *Fröhlich Hamiltonian* was first formulated. This permitted, for the first time, systematic investigation, using techniques developed in *Q.E.D.*, not only of superconductivity, but also of the electron-phonon interaction in general. In addition, this prompted a gradual flow of concepts from condensed matter physics into nuclear and particle physics, such as collective motion in nuclei and quark/gluon condensates.

Of particular significance was his own exact solution of his Hamiltonian for the energy spectrum of a one-dimensional model of a metal, which was found to be characterised by gap and by an *essential singularity* in the electron-lattice coupling constant. This feature was shared by the 3-dimensional solution of Bardeen, Cooper & Schrieffer 3 years later, and accounted for the failure of earlier perturbative attempts to obtain superconductive solutions. Given this progress, together with the fact that electron pairing had been qualitatively considered by Schafroth during his stay in Liverpool 3 years before Cooper's work was published, and also that the structure of Schrieffer's many-electron extension of Cooper's pair wave-function was actually motivated by the form of the variational wave-function used by Fröhlich and Gurari to treat the intermediate-coupling regime of the polaron in 1953, it remains a scandalous mystery why Fröhlich was not included in the Nobel citation shared by Bardeen, Cooper & Schrieffer in 1972. In that year, Fröhlich was, however, awarded the *Max Planck Medal* of the German Physical Society.

In 1959, Rickayzen (whose research interest was superconductivity, and who later, in 1965, authored *Theory of Superconductivity*) was appointed Lecturer in Theoretical Physics, and the Department moved from its original home in 6 Abercromby Square to occupy the top 3 floors of the 8-storey Chadwick Tower, the stairs of which Fröhlich daily athletically climbed, two-at-a-time, until he broke a thigh bone in the 1970s!

Following the move, Fröhlich returned to particle physics, motivated by the then quite recent discoveries of parity violation and *CP*-invariance. Between 1960 and 1963, he developed a novel continuous approach to *space reflection* as a kind of generalised rotation in 4-dimensions. This yielded a wave-equation having solutions for bosons of *differing* spin with the correct isobaric spin properties to describe all bosons then known, namely, light quanta, π & K mesons. *In addition*, however, it predicted a further 4 particles with properties identical to those postulated by Yang & Lee from empirical considerations of the weak interaction, and to those of the subsequently discovered (K^*) vector mesons.

New Heavy Bosons

In recent publications (Fröhlich 1960 a, b) a new approach to space–time reflections† was used to postulate a wave equation which comprises all known bosons, i.e. π- and K-mesons, and light quanta; from the symmetries involved it followed that four further bosons (denoted as ν-particles) should exist. These ν-particles have spin 1, a mass larger than that of K-mesons, and consist of a positive, a negative and two neutrals. In isospace the properties of the bosons are described in terms of two vector operators with components $\underset{\sim}{Q}_K$ and T_K ($K=1, 2, 3$). Here $\underset{\sim}{Q}_3$ is the electric charge operator and, on the usual assignments, T_K is the isospin operator. For both K- and ν-particles T_K consists of two doublets ($T=\frac{1}{2}$) and $\underset{\sim}{Q}_K$ of a triplet and a singlet ($\underset{\sim}{Q}=1, 0$).

The above results follow simply from the symmetries of the wave equation; interactions have not been considered as yet. It seems of considerable interest, therefore, to note that from a discussion of the empirical properties of weak interaction, Lee and Yang (1960) came to the conclusion that four new bosons should exist with exactly the same properties as have been predicted from my wave equation. Lee and Yang's 'schizoid'‡ isospin behaviour as doublets, or as triplet and singlet, in particular is described in exactly this manner in terms of eigenvectors diagonalizing the operators T_3 and T^2, or $\underset{\sim}{Q}_3$ and $\underset{\sim}{Q}^2$, respectively.

Department of Theoretical Physics, University of Liverpool. H. FRÖHLICH.

27th March 1961.

‡ As an alternative to schizon I propose to name the particles $\phi\alpha\nu\chi\omega\nu$ (from $\phi\alpha\nu o\sigma$ and $\chi\omega\gamma$).

Proceedings of The Physical Society Vol LXXVII p 1223

In 1963, Szigeti left to take up a Chair at Reading, and was replaced by A.W.B. Taylor, a former research student of Fröhlich, with whom he collaborated on deriving a Boltzmann equation for electron-phonon systems. In 1965, Rickayzen departed for the newly established University of Kent, and was replaced by Ch Terreaux who had been a pupil of Pauli in Zurich. Terreaux collaborated with Fröhlich on many topics in both solid-state physics and relativistic field theory. In 1969, Newns left the Department to become Sub-Dean in the Faculty of Science.

During the late 1960s and early 70s, Fröhlich was active in many other areas, such as statistical mechanics, where he did much to promote the appropriate way to study the connection between microphysics and the physics of macroscopic systems near thermal equilibrium, including not only 'classical' systems, but also those exhibiting quantum effects on a macroscopic scale, such as superfluids and superconductors. The peculiar flow properties that characterise these systems, he expressed in terms of long-range correlations between the phases of appropriate macroscopic wave-functions.

In 1973, the year of his retirement, he succeeded in deriving from the relevant macroscopic wave-equation, *without* detailed solution of the many-body problem, the main results of the *B.C.S.* theory of superconductivity, one of which had earlier been obtained along similar lines by A.W.B. Taylor.

Nowhere was Fröhlich's characteristic broad outlook better illustrated than by his brilliantly daring introduction into biology during the late 1960s of the concepts of modern theoretical physics - in particular, that of *coherence*.

He stressed that from the point of view of physics, *living* systems are highly non-linear, open, dissipative systems with remarkable dielectric properties, which are held *far* from thermal equilibrium by their metabolic activity. From this perspective, he predicted that, given a sufficient rate of energy supply, the lowest frequency longitudinal electric polarisation mode becomes so strongly excited that it attains *macroscopic significance*. Stabilisation of this 'coherent excitation' is achieved by virtue of the system's ability to elastically deform, whereby it can lower its polarization energy, since this energy depends on the *shape* of the system. He first presented these results in 1967 at a meeting held at Versailles under the auspices of *l' Institut de la Vie.* (See page30 – Ed.)

Fröhlich retired in 1973 after 25 years, during which time there was a total of only 9 academic staff, with no more than six at any one time. After his retirement, which was marked by the publication of a Festschrift entitled *Cooperative Phenomena*, Fröhlich became *Professor Emeritus*, and occupied an office of the 3rd floor of the Oliver Lodge Laboratory, continuing to work right up to his death in 1991. His 80th birthday saw the publication of a second *Festschrift*, and the 100th anniversary in 2005 of his birth was celebrated by international symposia in Prague, in Germany (at the International Institute of Biophysics in Neuss) and in Liverpool, the proceedings of the latter being published under the title: *Herbert Fröhlich – a physicist ahead of his time*, the 2nd edition of which has just been published.

The majority of his so-called 'retirement' was taken up with biophysics, both with developing further his novel ideas theoretically and with persuading various experimental groups to perform appropriate experiments to check his predictions, and in some of these programmes he actively participated. The situation as of 1988 was summarised in the book *Biological Coherence & Response to External Stimuli* (Springer, 1988), which he edited at the age of 82.

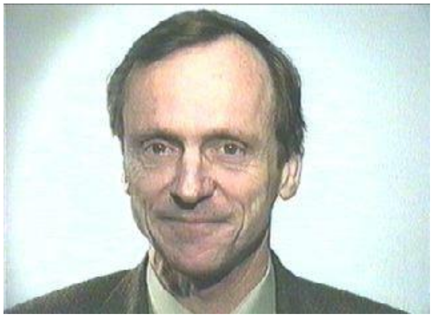
His bold conjecture of coherent excitations in living systems near room temperature - for which there is now accumulating experimental support - stimulated much work by others, both theoretical and experimental, and led to many international conferences, such as those that were held for many years at *l' Institut de la Vie* in Paris, and those that are still held at Charles University in Prague.

The importance of his pioneering work on coherent excitations in living systems is that it directed attention from (static) biological structure to dynamic biological *functionality*. It continues to generate considerable interest because of the variety of possibilities it offers for understanding the ultra-sensitivity of living systems to very weak electromagnetic fields of specific frequencies, in which deterministic chaos was later found to be implicated. Quite unexpected, was the role that *macroscopic quantum effects* apparently play in living systems - a role that has been subsequently invoked in consciousness studies.

In parallel with these biological activities, he returned again, during the last 20 years of his life, to particle physics, where eschewing contemporary approaches based on interactions, he focused instead on attempting to understand the separation of Dirac particles into leptons and quarks in terms of a novel *bilocal* extension based on the Dirac bilinear covariants. In the course of this, he unexpectedly made contact with his work of 1963 in which he had shown that the continuous reflections he had introduced in 1960 could be represented by non-linear transformations of a triad of 3-dimensional vectors – transformations that were equivalent to rotations in a 4-dimensional space of an associated *tetrad* with certain geometrical properties; at the time, however, this tetrad had to be introduced in an *ad hoc* way. It now became apparent that the Dirac bilinear covariants *themselves define* a tetrad having exactly the *same* relativistically invariant geometrical properties, and which could now be expressed in terms of the generators of SU_4. In non-local extension, the tetrad satisfies a *pair* of Dirac-like equations that contain a closed set of equations of motion for the 5 fields constituted by the bilinear covariants, one of which entails, in the 'internal' space associated with the admitted bilocal extension, the conservation of the pseudo-vector spin of a Dirac particle. It was from consideration of the extended group of transformations under which this pair of Dirac-like equations remain invariant when space & time reflections are admitted in the new internal space that he hoped that the separation of Dirac particles into leptons and quarks might follow as a kind of symmetry breaking - a programme that sadly remained incomplete at the time of his death.

With Fröhlich's retirement in 1973, the Chair of Theoretical Physics passed to 31 year old Chris Michael from *CERN*, and Theoretical Physics, which had by then existed for 25 years, ceased to be an independent department and amalgamated with Applied Mathematics to form the Department of Applied Mathematics & Theoretical Physics (*DAMTP*).

Six members[6] of the former Applied Maths Department moved into the Chadwick Tower to join Chris Michael and the 4 other staff[7] remaining from Fröhlich's time. This arrangement lasted until 1996, when *DAMTP* merged with Pure Mathematics and Statistics to form the *Department of Mathematical Sciences* in which Theoretical Physics has the status of a Division with its own divisional leader, currently Professor Ian Jack; his predecessors were Dr Irving and Prof Jones. With the gradual retirement of the staff from the *DAMTP* days, academic staff[8] with research interests exclusively in particle physics have been appointed, and now number 11 - almost twice as many as the maximum number in Fröhlich's time. Since 2003, Theoretical Physics has occupied part of the first floor of the former Oceanography building.



With the arrival of C. Michael, (right) the study of strongly interacting particles (hadrons) using *lattice gauge theory* started and still continues (Michael, Irving & Rakow), of particular current interest being computer simulations of *QCD* (which exhibits significant non-perturbative behaviour) in an attempt to understand quark masses. Another area that was subsequently established (Faraggi, Gracey, Jack, Jones, Teubner & Vogt) was *gauge field theories and phenomenology*, current interests here being the calculation of the particle mass spectrum (*via* supersymmetry) and the cross section for the production of the Higgs boson. The remaining research area is *string theory* (Faraggi, Mohaupt & Tatar), one programme within which is establishment of the connection with experimental data *via* the development of models that resemble the supersymmetric Standard Model. Work in all these three areas have generated a large number of significant publications that are frequently cited.

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[6] M. Ball, R. Bowers, B. Doman, M. Kermode, A. McKerrell and. R. Mines.

[7] G.R. Allcock, R. Huby, A.W.B. Taylor and Ch. Terreaux.

[8] As of November 2008, the other tenured Academic Staff members are Profs. A. Farragi, J. Gracey, A. Irving, T. Jones (part retired), C. Michael (part retired) & A. Vogt, together with Drs. P. Rakow, T. Teubner, T. Mohaupt and R. Tatar.

Thus, during the 127 years that there has been Physics at Liverpool, there has always been some activity in Theoretical Physics –often in the forefront of contemporary developments - although for the first 67 years (1881-1948) it was carried on by members of the Physics Department, some of whom were primarily experimentalists. With the creation of the First Chair in 1948, however, Theoretical Physics became recognised in its own right, and for the next 25 years flourished under the inspiring leadership of Herbert Fröhlich until his retirement 1973. Under Fröhlich's successor, Chris Michael, Theoretical Physics has, over the past 35 years, gradually become exclusively focussed on particle physics, a field in which it has acquired a world-wide reputation in the quest to misunderstand matter at an ever deeper level: ***long may this continue*!**

Acknowledgments:

The help of the following is gratefully acknowledged: A. Allan, P. Harper, R. Huby, R. Lumb, C. Michael, H.C. Newns and P. Rowlands.

Sources:

125 years of excellence - P. Rowlands, 2006.

Report of the Selection committee on the Chair of Theoretical Physics - University of Liverpool Special Collections, 1948.

Selective historical notes on Theoretical Physics at Liverpool during Fröhlich'*s tenure of the Chair, 1948-73* – R. Huby, 1988.

Annual Reports/ Reports to the Court – University of Liverpool Special Collections, 1948-98.

The making of physicists - R. Williamson, Adam Hilger, Bristol, 1987.

Herbert Fröhlich: a physicist ahead of his time **–** G.J. Hyland & P Rowlands (Editors), University of Liverpool Press, 2006; 2008.

Catalogue of the papers & correspondence of Herbert Fröhlich, F.R.S. – P. Harper & T. Powell, National Cataloguing Unit for the Archives of Contemporary Scientists, NCUACS No.159/2/08.

Supplementary Catalogue of the papers & correspondence of Herbert Fröhlich, F.R.S. – P. Harper & S Coleman, National Cataloguing Unit for the Archives of Contemporary Scientists, NCUACS No. 168/11/08.

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Long-Range Coherence and Energy Storage in Biological Systems

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Abstracts

Biological systems are expected to have a branch of longitudinal electric modes in a frequency region between 10^{11} and 10^{12} sec^{-1}. They are based on the dipolar properties of cell membranes; of certain bonds recurring in giant molecules (such as H bonds) and possibly on pockets of non-localized electrons. In Section 2 it is shown quite generally that if energy is supplied above a certain mean rate to such a branch, then a steady state will be reached in which a single mode of this branch is very strongly excited. The supplied energy is thus not completely thermalized but stored in a highly ordered fashion. This order expresses itself in long-range phase correlations; the phenomenon has considerable similarity with the low-temperature condensation of a Bose gas. General consequences and proposals of experiments are discussed in Section 3.

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The Liverpool Cyclotrons

Dr. Peter Rowlands
University of Liverpool

Left to right – James Chadwick, Lionel Wilberforce and Oliver Lodge
1935

Liverpool University's Physics Department probably would not now exist if James Chadwick, second-in-command to Rutherford at the Cavendish Laboratory, Cambridge, had not married Aileen Stewart-Brown, daughter of a Liverpool stockbroker, at St. Anne's Church, Aigburth, on 11 August 1925 (Peter Kapitza being best man). It was the family connections which helped to entice Chadwick to come to Liverpool after Professor Lionel Wilberforce retired in 1935, and set up a world-class department.

Immediately prior to Chadwick's arrival there had been several significant developments. In February 1932, at the Cavendish, Chadwick himself had discovered the neutron, the missing neutral component in the nucleus. The neutron, because it was uncharged, was a potentially much more powerful tool for probing the nucleus than any charged particle. Only two months later, in April, Cockcroft and Walton, again at the Cavendish, reported the first disintegration of a nucleus using artificially accelerated particles. The Cockcroft and Walton machine was soon superseded by the cyclotron, developed at Berkeley by Ernest Lawrence, which had its main public announcement in September 1933. The cyclotron accelerated charged particles many times in a spiral path before releasing them as a beam. This meant that it could be made more compact and so produce much more acceleration in the same space as the linear accelerators previously used.

When Wilberforce announced his impending retirement from the Liverpool chair in 1934, the University saw its opportunity to make a world-class appointment to replace him. Chadwick, at Cambridge, was unhappy with Rutherford's determination to stick to bench-top physics. He foresaw that the future required big accelerators and he wanted to build a cyclotron. He also wanted to lead his own team. Liverpool saw the opportunity, and offered virtually unlimited resources to make this possible. Chadwick accepted, and his wife was no doubt delighted to return to the home of her family.

Chadwick retained the existing lecturers appointed by Wilberforce – Roberts, Ablett, Edwards and Rice – as teaching staff, but brought in new people to enhance the research effort. The first of these was Norman Feather (later an FRS), who came with him from Cambridge. There were also significant changes in the way the Department was run. Mr Welch, the chief technician under Wilberforce, had been something of a 'gentleman's gentleman', but Chadwick wanted none of that. Welch put it into humorous perspective:

'*I am most grateful to him [Chadwick] for his tolerance of my earliest efforts – sweating drops of blood in the first few years, then waking up to the fact that the Victorian era was over ... So I pulled up my socks and tried to do better.'*[1]

He also instituted a series of seminars on the most up-to-date physics. Stanley Rowlands, a student at the time, wrote that:

‘The weekly departmental colloquium was usually high-brow, new-fangled stuff like quantum mechanics. However, one week they announced that next week’s would be given by a visitor who would talk on surface tension. Near me were two older pre-Chadwick lecturers. One said, ‘Now perhaps we will get some honest-to-God Physics.’’[2]

The new status that the Department had acquired was aptly symbolised by the award of the Nobel Prize to Chadwick, which was announced in October 1935, just in time for Liverpool to take the credit! Chadwick, unlike Wilberforce, disliked lecturing, but he felt he had to set an example, and took on a lecture course (optics), far from his main interests in nuclear physics. John Holt, then an undergraduate, recalled Chadwick’s first lecture: *‘‘I remember his entrance, a tall bird-like figure, followed by the chief technician Welch whose job it was to assist with the slide lanterns and demonstrations. After glaring at us for a few moments he looked down in thought and then began a concise presentation of the wave optics of lenses, using diagrams which he drew on the blackboard using board compasses. It was a beautifully prepared course which progressed through physical optics to electro-magnetic waves ...*’[3]

Chadwick organized the main research activity into two distinct groups, which still exist today – the physics of elementary particles, initially using cosmic rays, and the physics of the nucleus. Nowadays, we associate particle physics with large accelerators, but, at that time, no man-made apparatus could match nature’s own accelerator. The more complex arrangements involved in nuclear structure were recognised as a fundamentally different problem, with energies in reach of the cyclotron under construction. In addition to these, some work was done by H. O. W. Richardson in the □-ray spectroscopy of naturally occurring radioactive sources. Other changes happened fairly quickly. The theorist, James Rice, whose main work was in general relativity, died in April 1936, ending this line of activity, while the X-ray crystallographers, who were the main pre-Chadwick experimentalists, left for Manchester where facilities were better. In 1938 Chadwick managed to secure some money from the Leverhulme Trust to found a Fellowship and a Readership specifically in Theory. The first holder, Maurice Pryce, was an eminent applied mathematician (later also FRS).

The main thrust in the Department’s activity for the first four years was the construction of the cyclotron. Here Chadwick had the generous cooperation of Lawrence in Berkeley and Cockcroft in Cambridge. He also had industrial support from Metropolitan Vickers, in Manchester, and B.I.C.C. He quickly hired new staff, who were expert in this area, including Bernard Kinsey and Harold Walke, who had both been working with Lawrence in Berkeley, and Mike Moore who came from Metro-Vick. In addition, he saw the value of taking on the brightest graduates to do research, in particular, Gerry Pickavance and John Holt, and later Stanley Rowlands. With his own northern working-class background, Chadwick was oblivious to class distinctions. While Kinsey was, it has been said, 'in voice and manner ... a character straight from Wodehouse',[4] Mike Moore was a man of very different character. He had been a craft apprentice at Metro-Vick, who impressed Chadwick when he visited the firm in autumn 1936. Chadwick persuaded the firm to part with him when he came to Liverpool to fit the cyclotron magnet. Though he was not a graduate, Chadwick ultimately made him a lecturer.

Particle physics involved work on the mass of the neutron. Feather analysed cloud chamber photographs of the γ-ray photodisintegration of the deuteron. His analysis showed that the binding energy for deuterium was 2.25 ± 0.05 MeV, which meant a mass of 1.0090 for the neutron (by comparison with the proton). This was a significant result in both nuclear and astrophysics. Dissatisfied by the lack of immediate research opportunities, however, Feather was enticed back to Cambridge in autumn 1936, and was replaced by the brilliant, but sadly short-lived, physicist E. J. Williams, from Manchester. Williams was an outstanding researcher, equally at home in theory and experiment, and an expert on cloud chambers. Williams's expertise gave Liverpool a lead in cloud chamber design, and put the Department at the forefront of particle physics research, a position that continues to the present day. One of his most significant results at Liverpool was the first photographic evidence of the muon.

At that time there was evidence of a particle intermediate in mass between the electron and proton, which was thought to be the 'meson', predicted by the Japanese physicist Yukawa, to mediate the exchange of strong forces between protons and neutrons in the atomic nucleus. During the summer of 1937, Williams and his student, Eric Pickup, managed to photograph a heavily ionising cosmic ray particle using a cloud chamber at Liverpool. This was the first direct photographic evidence of the existence of a particle with a mass about two hundred times that of electron. Further work produced not only a value for the mass of the particle, but also indicated a possible spontaneous disintegration and origin.

Williams resigned in 1938 to succeed Gwilym Owen as Professor at Aberystwyth, but Pickavance continued the work by assembling and making operational a high-pressure cloud chamber brought from Cambridge by Feather. Results showed both positive and negative 'mesons' with a range of mass values, but they also created doubts that the 'meson' detected in cloud chamber experiments was Yukawa's carrier of the strong nuclear force. The particle passed through lead too easily, and so seemed to be only weakly, rather than strongly interacting. It was eventually established that it was not Yukawa's meson, but rather a kind of heavy electron, which later acquired the name ‘muon’. Another research line was the investigation of K-electron capture, discovered recently at Berkeley. The Liverpool group observed the first example of the process without accompanying nuclear radiation, and identified the K40 / Ar40 process, later important in geological dating.

When the parts for the cyclotron finally arrived, they were assembled in the George Holt basement during 1938. John Holt recalls that: ‘Chadwick used to come down to the basement as often as he could to discuss progress, but he was inevitably busy with other matters as well, including the uranium question, he was also much involved with cancer therapy problems and was very interested in other applications of physics to medicine.’[5] The ‘uranium question’ soon to dominate Chadwick’s thoughts, as well as those of a number of other European physicists.

In spring 1939, Joseph Rotblat arrived from Warsaw. He was interested in the new process of nuclear fission in uranium, discovered by Hahn and Strassmann, and explained by Frisch and Meitner in January of that year. His measurements showed that approximately six neutrons were liberated for every fission. The significance was immediately apparent: ‘From this discovery it was a fairly simple intellectual exercise to envisage a divergent chain reaction with a vast release of energy. The logical sequel was that if this energy were released in a very short time it would result in an explosion of unprecedented power.’[6]

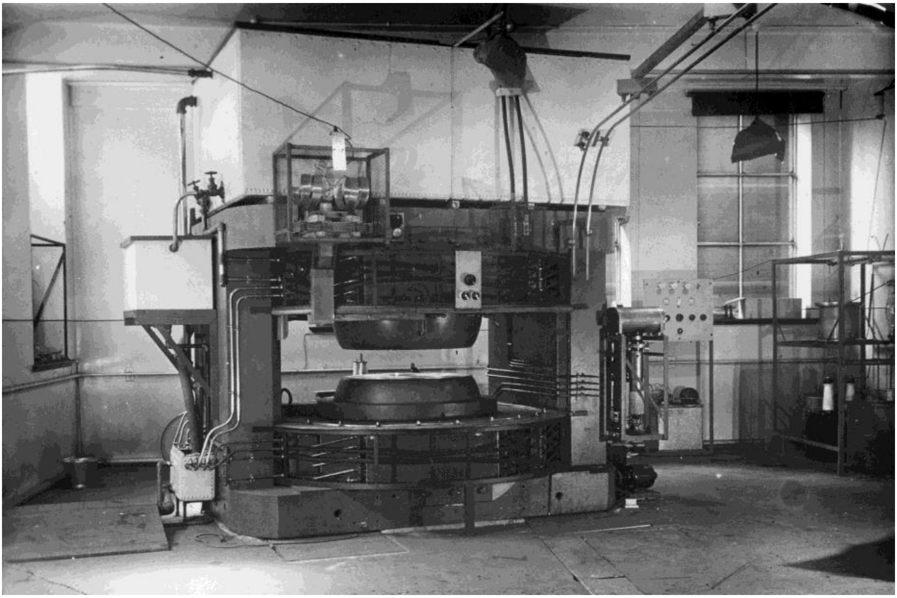
On 30 April 1939 the *Sunday Express* carried an article by Major C. A. Lyon, writing from ‘somewhere in England – Saturday’. The headline screamed:

> ***‘Scientists Make An Amazing Discovery / Stumble On A Power ‘Too Great to Trust Humanity With’ / A Whole Country Might Be Wiped Out In One Second’.***

With amazing accuracy or foresight, the article proclaimed:

> ***‘Their Secret / The professors of Liverpool, Birmingham, Cambridge, America and / France have kept their amazing experiments secret.’***

As an outsider, Rotblat was amazed to see that the ‘Physics Department was two departments, cohabiting in the same building, but with very little contact between the two. One was the teaching side, the other was the research side. The teaching side was mostly lecturers who were left over from the days of Wilberforce ... not concerned in research and ... quite happy to go on slowly, teaching the old fashioned type of teaching. Then quite separate, almost physically too because most of the other research was in the basement with the cyclotron – the most up to date equipment there. And the two parts hardly mixed. ... I was shocked when I went to the teaching lab and discovered they had no a.c.’[7]



A general view of the first Cyclotron – switched on in 1939

The cyclotron became operational in July 1939. Chadwick was ready to start his planned research but the situation on the Continent had become ominous. Rotblat, who had gone back to Poland for his wife, waited until the last minute to leave Warsaw, but his wife had appendicitis and was unable to travel, and he had to leave her behind hoping that she could travel later.

On 1 September 1939, the very day Rotblat arrived in Liverpool, Poland was invaded by German forces, trapping him in England. Britain declared war on Germany two days later. Rotblat never saw his wife again.

Chadwick, who was abroad, fishing on an isolated lake in northern Sweden, would have recalled that he had spent the whole of the First World War interned in Germany, after he was trapped in Berlin at the outbreak. This time, he managed to get back to England, via Holland, but only just. The party in the Dutch transit hotel, which included H. G. Wells (the ultimate inspirer of the chain reaction and the nuclear bomb through his novel *The World Set Free*), made the North Sea crossing in a 'stinking, rusty, tramp steamer'.[8]

Fission was discussed that autumn in Pryce's lectures, though there was already speculation that a uranium fission bomb might be Hitler's 'secret weapon'. Both Chadwick and Rotblat suspected that the critical mass of uranium needed, using fast neutrons, would be much less than the many tons supposed on current measurements. After eventually confiding in each other, they decided to embark on a new determination of the fission cross-section and the speeds of the neutrons emitted. At the same time, Cecil Frank Powell was invited to come from Bristol to use a camera and photographic emulsions designed for cosmic ray work, to detect and measure the particles emitted from a target in the cyclotron.

Chadwick realised that he had to convert the Liverpool cyclotron to 'get a beam of neutrons of definite velocity, and make measurements of the fission cross section' and that Powell's photographic technique could be used to measure the energy of the neutron beam'.[9]

A major disaster occurred when Harold Walke was electrocuted while making adjustments on the cyclotron on 21 December 1939, but the machine was fully operational by the time that the Bristol group arrived in January 1940. One of their members was Alan Nunn May, who was later (1946) exposed as a spy, operating under the codename 'Alek'. (Chadwick was so perturbed by this treachery that he deleted all reference in his CV to joint publications with Nunn May.) According to Stanley Rowlands: 'Nunn May was a swarthy, gloomy lump of a fellow who ... was very much the assistant to extroverted Powell.' Another member 'was a super-technician whose name I forget. But he was a superb glass blower and, like most of his trade, a superb beer drinker. He was very good company in contrast to Nunn May.'[10]

At this time only Chadwick and Rotblat believed that a uranium bomb was feasible. However, a famous memorandum, written by Otto Frisch and Rudolf Peierls at Birmingham in March 1940, included a new calculation from which it became evident that a bomb might be possible if one could obtain a few kilograms of the pure isotope uranium-235, which formed only 0.7 % of natural uranium. Chadwick learned of this on April 24 at the first meeting of a new Committee for the Scientific Survey of Air Warfare created under the chairmanship of Sir George Thomson. This quickly developed into the famous Maud Committee, which met mostly at the Royal Society. Chadwick was made responsible for all the pure physics work.

When a new element plutonium was discovered at Berkeley in May 1940, Rotblat thought it would be more fissile than uranium but Pryce's calculations showed that the yield of the new element from the Liverpool machine would be too low. Arthur L. Hughes, a Liverpool graduate, made the first sizeable sample of plutonium at Washington University, St Louis, in 1943.

The important thing now was to measure the cross-sections for the two natural uranium isotopes, U-235 and U-238, as accurately as possible, and Chadwick recruited Otto Frisch to complement Rotblat, Pickavance, Holt, Pryce, Rowlands and Moore. Frisch was still, theoretically, an enemy alien, and there are many amusing stories about his breaking the rules by straying outside the city limits, by venturing out during the dark, and by riding a bicycle, with or without headlights, sometimes all on the same occasion. Frisch proved to be a particularly inventive member of the team, and in rapid succession he produced the gridded ion chamber, improvements to scale-of-two counter circuits, and the first automatic pulse height analyser.

Secrecy was kept by apparent openness. A student of the time, John Curry, recalls: ‘it didn’t cross my mind that having had lectures from Dr. Roberts and Evan Edwards and Dickie Ablett that there were new faces appearing on the scene. And, of course, these faces were none other than Otto Frisch, Joe Rotblat, et al. It didn’t occur to me that there was anything really special about this at all. I thought Liverpool was doing very well and Chadwick was pulling a lot of big people in here and that’s how it went ...’[11] Rotblat even talked about the possibility of a chain reaction in his lectures. Less sensitive work (such as the results of the inelastic scattering of protons off gas molecules, done with Powell’s team) appeared in published papers to give the impression that the Department was operating on a normal basis.

Of course, amid all the deadly seriousness of wartime work, there were some lighter moments. When the beam current was quadrupled to over 50 µA, on 11 November 1942, Chadwick produced a bottle of champagne, which was drunk out of laboratory beakers to celebrate the achievement. The serious work was also punctuated by horse-play. At the instigation of Mike Moore, Gerry Pickavance was on one occasion nailed by his labcoat to the laboratory floor. Chadwick on coming into the laboratory, carried on a normal conversation with the embarrassed student for a short while before going out, and telling his secretary, Miss Lloyd-Jones, that ‘the boys have been up to their tricks again’.[2] All this time, the city, including the University area, was under constant bombardment. On the evening of 18 March 1941, while Rowlands and Pryce were on fire-watching duty on the balcony of the Victoria Tower, a parachute carrying a land mine descended into the University courtyard, carrying a ton or so of high explosive, and reduced the Engineering Building (Harrison Hughes) to rubble. Chadwick asked John Holt to discreetly take a Geiger counter to the site to see if there were detectable radiations, caused by a nuclear explosion! The George Holt Building survived, though its windows were blown out.

The work on uranium, completed in Liverpool by the late spring of 1941, was the 'basis for the reports of the Maud Committee which ultimately triggered' the Manhattan Engineering District Project to build a nuclear bomb in the USA. By April 1941, Chadwick was able to inform the Maud Technical Committee that a critical mass for U-235 would be 8 kg or less. From the beginning, Chadwick and Rotblat had realised that fast neutrons would be necessary for an explosive device, while slow neutrons would produce heat for controlled power. In May 1941 Chadwick reported also on work done in the Cavendish Laboratory, 'showing their claim that the fission chain reaction was potentially divergent, with slow neutrons, with their set-up of ordinary uranium, moderated by heavy water, was justified'.

Work on the uranium fission neutron spectrum was completed by the summer. The Maud report, written in July, mainly by Chadwick, summarised all the work done under his overall direction into the use of uranium in a bomb and as a source of power. The results obtained turned out to be accurate to about 1 %, though work on obtaining even more accurate results on purer samples continued. Copies of the report were sent to the United States; one went to Vannevar Bush, who sent his own investigators to England, and reported on their findings to President Roosevelt. The subsequent Japanese attack on Pearl Harbor persuaded the Americans to begin work on a serious bomb programme. It was also on the basis of Chadwick's report that the Americans went ahead with their heavy water manufacturing plant, while the slow-neutron measurements contributed to Fermi's achievement of controlled nuclear power in December 1942.

In the meantime, huge numbers of service personnel came to Liverpool for crash courses on electronics and radio by Roberts and Rotblat. The necessarily unreliable state of the equipment (and the consequent effect on Joe Rotblat's temper) is suggested by an anonymous poem, of which the last verse reads:

In the Radio Laboratory, when the sun sinks down to rest,

You'll find wreckage lying round both high and low,

For an H.O.4 had burst, and Joe fallen to the curse,

Of the Blue Spot of the Bl.... C.R.O.[12]

Chadwick also sought to obtain the services of Niels Bohr in occupied Denmark, and microdot messages were sent between them smuggled by the courier in a hollow tooth and covered with a filling. Bohr finally escaped to Britain in October 1943, with his son Aage, and, during long conversations with Chadwick in London and in Liverpool, learned for the first time about the Allied Project and probably also gave vital information about the German efforts under Heisenberg, and no doubt about the confrontation between himself and Heisenberg so brilliantly portrayed by Michael Frayn in his play *Copenhagen*.

Relations between Britain and the USA had not been good for over a year, and the Manhattan Project was started under J. Robert Oppenheimer without any British knowledge of it. However, an agreement on cooperation with the USA was signed in 1943, and Chadwick was made head of a British Mission to the Manhattan Project, which made a very significant contribution to its success. Four other Liverpool-based physicists, Frisch, Rotblat, Don Marshall and Jim Hughes joined the Project at Los Alamos, whose acting Assistant Director at the time was Arthur Hughes. Moore went to Berkeley to do work with Lawrence on isotope separation. The British Mission's integration was greatly eased by the successful personal relationship between Chadwick and General Groves, military leader of the Project. Groves liked Chadwick's straightforward and no-nonsense approach, stemming from his relatively humble origins in Northern England.

In 1944-45, Frisch conducted the extremely dangerous experiment of 'tickling the dragon's tail', in which a critical assembly of uranium was momentarily created. Frisch recalls how on one occasion he made a subcritical assembly go critical by leaning over it and reflecting some of the neutrons back with his body! Rotblat, however, left the Project early, in December 1944, when it appeared that the bomb might be an offensive rather than a defensive weapon.

Chadwick and Frisch were among those who observed the test of the first nuclear bomb at the Trinity site at 5.30 a.m. on 16 July 1945, and both wrote spectacular descriptions of this momentous event. On 6 August, a uranium bomb ('Little Boy') devastated the Japanese city of Hiroshima. Press releases, published in the *Liverpool Daily Post*, gave the local population information about the key involvement of the Liverpool University Physics Department and staff, its cyclotron and the important role played by Chadwick. On 9 August, a plutonium bomb ('Fat Man') was exploded over Nagasaki, and, on 14 August, the Japanese surrendered, and the War finally ended. Liverpool's Physics Department had played a vital role in making this possible.

Chadwick himself spent most of the next two years in the United States as a kind of nuclear ambassador. Students referred to this in their PME (Physicists' Merry Evening) rhymes:

They seek him here.
They seek him there.
They seek Prof. Chadwick everywhere.
Is he in New York or Chungking,
That damned elusive neutron king.[13]

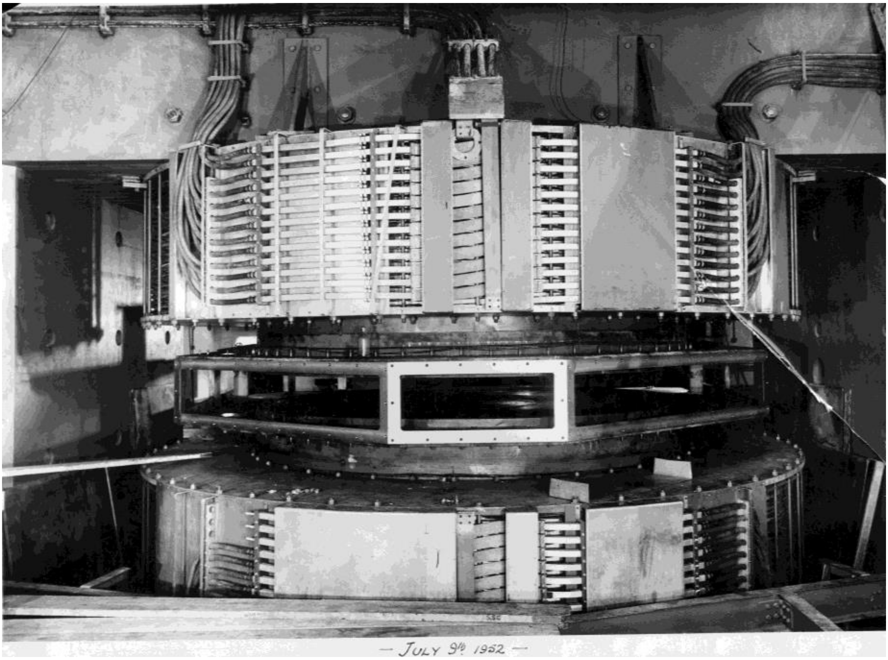
While Chadwick was in Washington, in 1946, he received a telegram asking if he would be willing to consider an application from Erwin Schrödinger for a Chair in

Theoretical Physics. Schrödinger was then at the Institute for Advanced Studies in Dublin, but had become unpopular in certain circles due to his book on *The Physics of Life* (1943), and, no doubt, certain well-known aspects of his 'extracurricular activities'! Inquiries by Rotblat revealed that he had a reputation for being difficult and a less than ideal team member, so Chadwick reluctantly turned him down. Schrödinger was certainly the 'greatest physicist Liverpool never had'.

The years of preparation using photographic emulsions at Liverpool during the wartime finally bore fruit when Powell, and a team including Lattes, Muirhead and Occhialini, finally discovered the pion at Bristol in 1947. This, not the muon, was Yukawa's meson, the true mediator of the strong interaction. Powell received the Nobel Prize for this discovery in 1949. One of the team members, Hugh Muirhead, subsequently came to work at Liverpool on particle physics, becoming the only physicist from Liverpool involved with the discovery of the *W* and *Z* mesons (the mediators of the weak force) at CERN in 1983.

When Chadwick finally returned in 1947, the Vice-Chancellor, Sir James Mountford, said he had never seen a man 'so physically, mentally and spiritually tired'. He sensed that Chadwick 'had plumbed such depths of moral decision as more fortunate men are never called upon to peer into', and had suffered 'almost insupportable agonies of responsibility from his scientific work'.[14] He still had many responsibilities in the post-war reconstruction, and played a major part in national programmes which encompassed both pure research and commercial exploitation, including Aldermaston and Amersham. He was also instrumental in the establishment of the Atomic Energy Research Establishment at Harwell.

At Liverpool, while the cyclotron was refurbished, plans were drawn up for a much larger 156-inch synchrocyclotron, on land obtained on lease near the Roman Catholic Cathedral, then under construction on Mount Pleasant. In a synchrocyclotron, an RF field compensates for the relativistically increased mass which limits the maximum energy of the basic machine, providing energies within the realm of particle, as well as nuclear, physics. Land was leased on part of the proposed site for the cathedral, and a new Nuclear Physics Research Laboratory (NPRL) established. Rotblat claimed that he got the idea of building underground from a visit to the catacombs in Rome. The new machine, offered to Liverpool for its vital wartime contribution, enabled the Department to remain in the top rank of British universities, a position it has held ever since.



The synchrocyclotron, 9 July 1952

Rotblat himself turned away from nuclear research into Medical Physics, taking the first major step within the UK in the field of nuclear medicine. An early success was the first use of the radioactive isotope of iodine in the location of a thoracic goitre (1948). Rotblat left to become Professor of Medical Physics at St Bartholomew's Hospital, London, in 1950. Even more significant was his work as a campaigner for World Peace, leading to the Einstein-Russell manifesto of 1955, the Pugwash conferences, the Partial Test Ban Treaty of 1963, and the Nobel Peace Prize for 1995. While still at Liverpool, he was involved in public education campaigns on nuclear matters, most notably on the Atom Train project, which many people still remember.

The refurbished cyclotron immediately showed its potential for peace-time physics as well as war work. One of the first experiments, by John Curry in 1947, showed a nitrogen nucleus bombarded with a deuteron disintegrating into four alpha particles (a kind of double fission). The most significant result, however, was the discovery of low energy deuteron stripping by Holt and C. T. Young in 1949. Stripping provided spectroscopic information on the states of the excited nucleus, nuclear spin and parity.

Chadwick left to become Master of Caius College, Cambridge in 1948, leaving his successor to complete the synchrocyclotron. After some delay Herbert Skinner arrived from Harwell, in 1949, to succeed him. Skinner was not a nuclear physicist but had done outstanding war work in radar, and the Liverpool job seems to have been his reward. The NPRL on Mount Pleasant and adjacent teaching building now became the Department's centre of gravity. In 1950, another Harwell physicist, Bruno Pontecorvo, was lined up for a new chair in experimental physics, but he became instead the second Liverpool appointment who didn't show up on Monday morning. (The first was Reginald James, who went on Shackleton's expedition in 1914, and helped to save the main party by finding a place to land.) On 21 October, news broke out that Pontecorvo had disappeared, presumably behind the Iron Curtain. He was not heard of again for many years, and the full reason for his defection has never been established. Many false stories were told about the event. Bruno's physicist son, Gilberto, for example, told me that he had encountered a man who told him that he was the son of the captain of the *submarine* on which the family had defected to Russia, but Gilberto assured me that he had never been on a submarine in his life.

There are many stories about Skinner, whose bumbling professor image hid a powerful intellect. At that time, staff and research students met for tea and coffee round a long coffee-table. On one occasion it was mentioned that it was a scandal that Watson-Watt had been rewarded with £50,000 for his work on radar, which ought to have been done purely for the good of his country in wartime, 'lesser' inventors having received nothing for their work. Skinner, puffing at his pipe, said, 'I only got £20,000.' This was in the days when £20,000 was an enormous amount of money, equivalent to more than £1 million today. Another story involved the well-known book on Laboratory Techniques by Searle, in which, without consultation he quoted the results of his students' experiments. One day in the George Holt library, which doubled as the department tea-room, Skinner was berating the experiments he had just seen in the Optics Laboratory. 'We didn't do that sort of thing in Cambridge,' he said, to which Roberts leaned forward, extracted a copy of Searle's book from the library shelf and said, 'Excuse me, Professor, you did and here are your results.'

The Departmental work was not entirely concentrated on nuclear and particle physics. Skinner's own research was in soft X-ray spectroscopy applied to the band structure of solids, in particular metals. Skinner's work, which was summarised in a report of 1954, though long regarded as invalidated by later work, was eventually vindicated, and shown to be a very significant contribution to the subject. Another group worked on applied acoustics, including design work for the Royal Festival Hall.

At the NPRL, the 1.2 million volt HT Set, installed in 1950-51, was used for γ-ray spectroscopy using resonance capture reactions, to measure the spins and parities of excited nuclear states and the transition rates between them predicted by the shell model of the nucleus. This was supplemented by work using Chadwick's original cyclotron, which was moved from the basement of the George Holt Building to an annexe of the new laboratory in April 1952. In particle physics, Albert Crewe and Wynn Evans built Liverpool's first diffusion cloud chamber in 1952, while a second one followed in 1953. The 156-inch synchrocyclotron, produced its first circulating beam in April 1954, ensuring that the Department maintained its status as a world player in both nuclear and particle physics. Unlike the 37-inch cyclotron, the synchrocyclotron, the most powerful machine in Europe, produced enough energy to be used for particle physics, though it would soon be superseded by the big international accelerators, including the one switched on at CERN, in Geneva, in 1960. Liverpool was represented by Mike Moore on the design group for the CERN synchrocyclotron after CERN was formally established in August 1954, but, even after 1960, the Liverpool machine continued to be important for quite a number of years, both in research and in training for the CERN accelerator.

Liverpool scored a notable first with a method for the extraction of a beam of protons from a synchrocylcotron, in December 1954. Theory by Ken Le Couteur (using one of the first electronic computers in England, at Rothamsted), which was put into practice by Albert Crewe and John Gregory, meant that up to 10 % of the proton beam could be extracted, immediately nullifying one of advantages of the alternative linear accelerator system. For a short time, Liverpool led the world in particle accelerators, and the Liverpool method was followed by other laboratories including CERN. Crewe, however, was quickly poached by Liverpool's competitors at Argonne Laboratory in Chicago. He went on, there, to be build a microscope which for the first time made atoms visible.

In 1955 rival Liverpool teams, led by Jim Cassels and Alec Merrison, measured the Panofsky ratio, a crucial number at the time in particle physics. This was the ratio of the probabilities between the emission of a neutral pion plus neutron emission, or of a gamma ray plus neutron, following the capture of a slow negative pion by a proton. Theory said it should be close to 2, but early results suggested it was nearer 1. The Liverpool measurements converged on values in the region 1.5 to 1.6. The explanation of the discrepancy was ultimately found in the violation of parity conservation, put forward by Lee and Yang in 1956. Nonconservation of parity, which was confirmed at Washington early in 1957, created an ideal opportunity for exploiting the power of the Liverpool synchocyclotron. Subjects investigated included the longitudinal polarization of electrons from β-decay, and the forward-backward asymmetry of electrons from a polarized radioactive nucleus, in addition to asymmetries and polarization in the decay of pions and muons. One of the major results was the discovery of the violation of charge conjugation symmetry, reported on 12 October 1957. In a classic experiment, John Holt's group used the direction of the spin of positive muons to determine the spin of the neutrinos emitted in □-decay, from which they established that the □-decay couplings were V (vector) and A (axial vector) rather than S (scalar) and T (tensor), as had been previously supposed.

A story about this crucial experiment gives some indication of the way real experiments are sometimes conducted, as opposed to the highly depersonalized versions created for scientific publication. The experiment was done in a hurry over a three-day period of virtually non-stop work, as there was serious competition for a result, the researchers catching whatever sleep they could manage while they were in the Department. It required a huge electromagnet to determine the direction of the spins, and this direction would decide whether the result was V – A or V + A. When a result was finally obtained, the researchers suddenly found that they didn't know which way round the magnet was wired! At 3.00 a.m. there were arguments about whether north magnetic poles were north poles or north-seeking poles, and whether Fleming's left-hand rule should be applied or Fleming's right-hand rule. Eventually one of the team went for a small magnetic compass, and held it in one pole of the magnet, proclaiming that it was north. This suggested V + A, the less likely result, and arguments followed immediately. 'I'll show you,' he said, taking the compass outside. 'There's the pole star.' But the compass was pointing due south! The magnet had changed its orientation. So, the V – A result, of immense significance for the fundamental nature of the weak force, and obtained using the most sophisticated scientific equipment then available, was finally established by recourse to the techniques of ancient navigation!

A rapid increase in staff and student numbers at the end of the 1950s meant that the George Holt Building was no longer adequate for the department's needs, and departmental activity was moved to the new Chadwick Physics Laboratory in August 1959. A tandem Van de Graaff generator, ordered to replace the H.T. set, was delivered August 1960, and installed in a new building close to the Chadwick Laboratory. In the midst of these developments, Skinner died suddenly at a CERN meeting in Geneva, in January 1960.

At the personal instigation of the University's Vice-Chancellor, Jim Cassels, now at Cornell, was lined up to succeed him. Cassels' period in office coincided with a major Departmental reconstruction. Even before arriving back in Liverpool, he had ordered the almost immediate closure of the 37-inch cyclotron. The synchrocyclotron, however, continued in operation until 1968. In one of the later experiments (1968), pions from the synchrocyclotron allowed the determination of the neutron-neutron scattering, contributing to knowledge of the real nucleon-nucleon force. As part of the reconstruction, a new geophysics group was created in 1962, which was at the forefront of the creation of plate tectonics at that time – it still exists but is now part of the Department Earth Sciences. Cassels also decided subsequently that Departmental research needed still more diversification, particularly into areas of Condensed Matter Physics, and, in 1970, he set up new groups in Mössbauer spectroscopy and surface physics.

From 1962 a new national laboratory was being built at Daresbury in Cheshire under direction of Merrison, with Liverpool contributing significantly to the accelerator design. A 4 GeV electron synchrotron accelerator at Daresbury (NINA) started operating in 1966. In nuclear physics, the tandem Van de Graaff enabled the high-resolution work on level properties in the lighter elements to be extended to elements of higher atomic number. When the Oliver Lodge Laboratory opened in 1969, the Department acquired what became and has remained the main centre for the research activity, with the Chadwick Laboratory being retained for teaching. By the time that Cassels relinquished his position, in 1974, the Department had acquired much the same structure as it has today.

References

1. Draft of retirement speech, autumn 1946.
2. C. D. King (ed.) *Chadwick's Scientific Legacy*, Conference, Liverpool 1999.
3. Seminar on James Chadwick, Liverpool 1988.
4. M. Oliphant, *Rutherford – Recollections of the Cambridge Days* (Elsevier, 1994).
5. Chadwick Centenary Lecture, Liverpool 1991 (unpublished).
6. J. Rotblat, 'Leaving the bomb project', *Bulletin of the Atomic Scientists*, August 1985, 16-19, quoted A. Brown, *The Neutron and the Bomb* (Oxford University Press, 1997), 172.
7. Interview with A. Brown, London, 1994, A. Brown, *op. cit.*, 172.
8. Brown, *op. cit.*, 178.
9. C. D. King, *Chadwick, Liverpool and the Bomb* (PhD thesis, Liverpool, 1997), 73, quoting Chadwick / Wiener interview, April 1969.
10. Letter to C. D. King, 25 February 1995, quoted King (ref. 9), 75.
11. King (ref. 28), 67. 31. *ibid*., 129.
12. PME 25 February 1944.
13. PME 5 March 1947.
14. T. Kelly, *For Advancement of Learning* (L*iverpool University Press*, 1981.

Postscript:

‘Physics at Liverpool’ meeting a resounding success!

“It was beautiful, and no-one will ever see a sight like this again.”

Thus spoke Dr Mike Houlden during his lecture on “Nuclear and Particle Physics to the Present”, part of the History of Physics Group’s celebration of 125 years of physics at Liverpool, on December 10th 2008. He was talking about a “live” observation of particle tracks in the 2 metre bubble chamber at CERN in Switzerland, which he encountered during his PhD in the Film Analysis Group in the late 1960s. In those days the bubble chamber was the state-of-the-art way of recording particle interactions; while it may have been a beautiful spectacle, analysing the tracks involved lots of hard work, including making meticulous measurements on photographs, and this was done back in Liverpool, using “teams of ladies to scan and measure in the day, and men to measure overnight” (because it was not considered proper for ladies to work at night!)

Mike’s talk was accompanied by many images of the equipment and the people who built and used it, going back over the past 50 years. I found it a compelling and deeply moving experience; somehow, Mike was able to communicate to us the excitement of being involved in particle physics at Liverpool, his pride in the achievements of his colleagues and even his sense of nostalgia for a departed era and for some of his colleagues who have also sadly departed. But the nostalgia was kept firmly in its place as Mike brought us right up to date with more recent experiments such as DELPHI at CERN, H1 at DESY (Hamburg), BaBar at Stanford and CDF at Fermilab (both USA), all of which Liverpool has been involved in. In fact his concluding remark was “the past was great; the future looks bright”.

The progress of nuclear and particle physics research at Liverpool has been admirably documented by Dr Peter Rowlands in his excellent booklet, “125 Years of Excellence”, which was distributed free to all who attended. But Mike’s talk somehow brought it all to life; in some cases, literally – for instance, after showing us a photograph of Mrs Rita Legge working on her namesake, a machine known as RITA (Rapid Instrument Track Analysis) in the late 1960s, he pointed out that she was there with us, sitting in the front row!

Mike told us about the early work using the 37″ and 156″ cyclotrons, then took us through the evolution of particle detectors, from bubble chambers to spark chambers to drift chambers, and this historical approach made it easier to comprehend the complexity of a modern collider like the LHC. He also looked at the nuclear structure experiments, using Van der Graaf generators at Liverpool and Daresbury; and finally he took us through the various generations of computers the department has used, from an IBM 360 (a £1 million machine which needed 12 operators but only had 512k of memory!) used in the 1960s, to the modern MAP2 supercomputer.

This was the last of the four talks that made up the event; all were good, and the other three featured such giants of Liverpool physics as Oliver Lodge, Lionel Wilberforce, James Chadwick, Joseph Rotblat, Otto Frisch and Herbert Fröhlich. I had travelled all the way from Brighton to Liverpool (and back again) in a day to hear these four talks, and had wondered, more than once, whether it would be worth the effort, but I needn't have worried. In fact, Mike's talk alone would have made it worth all the travelling.

Jim Grozier.

Next Group Meeting

This year is the *International Year of Astronomy* and our summer meeting will be held in the Cavendish Laboratory, Cambridge, on the general theme of the telescope. The main meeting will be held on the 8th when Professor Malcolm Longair will be speaking on 'Radio Astronomy in Cambridge'. Other speakers have yet to be finalised but it is also hoped that we can arrange some visits on the following day, including a visit to the Whipple Museum. It is also hoped that overnight accommodation can be arranged at Fitzwilliam College but as yet we have no further details as regards costs etc. Further details will be circulated later.

Radiation in the Round – a Spherical Geiger Counter

Dr Eric Finch,
Trinity College Dublin

Geiger counters are probably the most familiar type of nuclear radiation detector, and especially so for the general public. Dating back to Geiger's work in Manchester with Rutherford in 1908, they are relatively simple in construction and continue to be widely used. The usual design is a cylindrical cathode surrounding a central wire anode, with a suitable gas filling in between. Radiation entering the counter then creates free positive ions and negative electrons inside it.

This customary cylindrical geometry gives rise to a very high electric field near the anode. As a result the number of ions and electrons produced is multiplied up by many times. These charges are collected by the electric field between the anode and cathode, and a much amplified electrical signal results in the external circuit[1].

In the case of penetrating gamma rays only a small fraction incident on a Geiger counter is actually detected; the rest of the radiation simply passes straight through. Furthermore, for a cylindrical counter the fraction detected depends on the direction relative to the counter axis from which the gammas come. To make the sensitivity as uniform as possible with direction, Geiger counters with spherical geometry were therefore developed, in which a small spherical anode was mounted at the centre of a spherical cathode. The first such counters were designed in 1939 by Brown and Evans[2]. Robley Evans was a leader in the use of radioisotopes in medical research, and he went on to write the classic text 'The Atomic Nucleus', published in 1955[3].

Spherical Geiger counters never became common, so we were delighted when an example of one was recently presented in 2008 to the School of Physics in Trinity College Dublin by Mrs Chris Jacob (Fig 1). Her late husband, Brian Jacob (1938-2001), designed and built several such counters around 1962 for his Trinity College Dublin MSc[4].

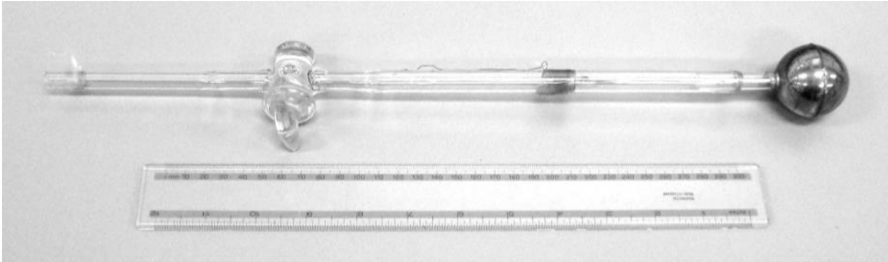


Fig 1. A spherical Geiger counter made by Brian Jacob and presented to Trinity College Dublin

His supervisor, Cyril Delaney, had at one time worked in the Massachusetts Institute of Technology with Robley Evans. Brian Jacob subsequently wrote up his work for publication[5,6].

The work arose out of an investigation into the flux of gamma rays in a caesium-137 irradiator used for genetic experiments on plants. It had been found to be difficult to map with any accuracy the gamma radiation field in such an irradiator with a conventional cylindrical Geiger counter. This was because the detector response depended strongly on the direction of the incoming field. It was realised that, in contrast, the weak angular dependence of the response of a spherical Geiger counter would make measurements of the irradiator flux field much simpler. In fact, one of the spherical Geiger counters built by Brian Jacob had a response uniform to ±2½% over almost all angles.

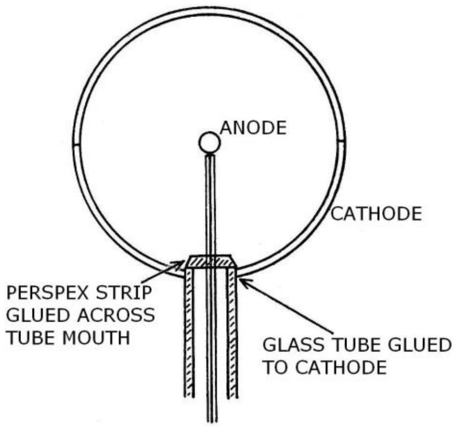


Fig 2. Section through counter. The perspex strip does not seal the tube end but has an opening to allow the counter to be evacuated and filled with gas through the tube

The cathode was typically a brass sphere of about 20 mm radius and wall thickness 1 mm (Fig 2). To maximise the counter efficiency, this thickness was chosen to be thin so as to avoid unnecessary attenuation of the incident gamma rays; however, the detection of gammas in a Geiger counter effectively takes place at the cathode rather than in the counter gas, so the thickness had to be at least comparable with the range of the most energetic electrons produced in the wall. The anode was a steel sphere of 1.6 mm radius. The counters were operated with a 9 to 1 argon/alcohol mixture introduced through a glass tube fixed to the cathode. All joints, including the glass-metal ones, were glued with Araldite.

One of the counters was used to measure the gamma ray flux distribution in an arrangement of caesium-137 sources simulating an irradiator. The results obtained were in good agreement with those from earlier indirect methods of measurement, and thus confirmed that this type of counter provided a rapid and accurate method for determining such fluxes.

Brian Jacob went on to become one of Ireland's foremost geophysicists, and in 1990 was appointed senior professor of geophysics in the School of Cosmic Physics at the Dublin Institute for Advanced Studies. Honours awarded to him included his election to Membership of the Royal Irish Academy in 1998. His several obituaries[7] describe how he developed the methods of controlled source seismology (the use of explosives, for example), and applied them to the study of the deep geology of Ireland and surrounding areas in a series of major projects which he led.

Brian Jacob 1938-2001

He was particularly proud of the successful RAPIDS (Rockall And Porcupine Irish Deep Seismic) projects. These greatly enhanced the understanding of the complex continent-ocean transition off the west coast of Ireland. They also provided the framework needed for the offshore hydrocarbon exploration which has proved to be so important and productive for Ireland.

The Geiger counter presented by Chris Jacob now forms the centrepiece of a small display in the Hamilton building of Trinity College Dublin. This display commemorates a century of Trinity's work in the physics of radioactivity and radiation detection. As well as also featuring physicists such as the Nobel laureate Ernest Walton (1903-1995), who, with Cockcroft, split the atomic nucleus in 1932, the display begins by summarising the achievements of the distinguished geophysicist John Joly (1857-1933). A Fellow and Royal Medallist of the Royal Society, and at one time an assistant to George Francis FitzGerald, Joly studied radioisotopes in rocks and made estimates of the age of the earth. During his long and varied career in Trinity he also developed new methods of thermometry, calorimetry, and colour photography, and was a pioneer in the use of radiotherapy for cancer treatment.

Acknowledgements

Trinity College Dublin's School of Physics is indebted to Mrs Chris Jacob for her kindness and generosity in presenting one of the spherical Geiger counters made by her late husband, together with a copy of his MSc thesis and associated papers and correspondence. I myself would like to thank her for our valuable conversations together. I would also like to thank Professor Denis Weaire of the School of Physics for his inspiration and support for this project, and Professor Aftab Khan of the University of Leicester, a long-time colleague and friend of Professor Jacob, for his help and guidance.

References

1. See, for example, Delaney, C.F.G. and Finch, E.C. (1992) *Radiation Detectors*, Clarendon Press, Oxford, pp 97-107.
2. Brown, Sanborn C. and Evans, Robley D. (1939) Discharge Counters of Unconventional Geometry, *Physical Review* 55 (11), pp 1133-1134.
3. Evans, Robley D. (1955) *The Atomic Nucleus*, McGraw-Hill.
4. Jacob, A.W.B. (undated, but probably 1963) Geometrical Considerations in Nuclear Radiation Detectors, MSc thesis, Trinity College Dublin.
5. Jacob, A.W.B. (1964) Spherical Geiger Counters for γ-ray Flux Measurements, *International Journal of Applied Radiation and Isotopes* 15, p 533.
6. Jacob, A.W.B. (1965) Design and Use of Spherical Geiger Counters, *The Scientific Proceedings of the Royal Dublin Society Series A* 2 No. 5, pp 43-46.
7. See, for example, Khan, Aftab (2002) Brian Jacob 1938-2001, *Astronomy and Geophysics* 43 (1), pp 1.32-1.33.

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Geometry & Physics:
James MacCullagh (1809-1847), Life & Achievements

May 14, 2009 Hamilton Mathematics Institute, Trinity College Dublin.

The event is dedicated to bicentenary of one of the greatest Irish mathematicians and physicists, James MacCullagh, who occupied the Mathematics and Natural Philosophy chairs at TCD. The HMI event is planned to be followed by unveiling a memorial plaque at James MacCullagh birthplace in Co.Tyrone.

Speakers:

James Bennett (Oxford)
Olivier Darrigol (Paris/Berkeley)
James Lunney (TCD)
Samson Shatashvili (TCD/IHES)
David Spearman (TCD)

More details at http://hamilton.tcd.ie/events/jmcc
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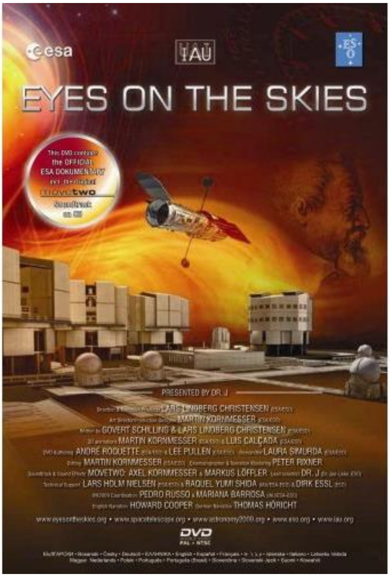
Reviews



DVD details from:

www.eyesontheskies.org.

Book details:

Wiley VCH

ISBN-13: 978-3527408658

132 pages *Hardback*

£16.99

Reviewed by Kate Crennell

'Eyes on the Skies' is the name given to the DVD and accompanying glossy book produced for the International Astronomical Union (IAU) which is celebrating the International Year of Astronomy in 2009 to commemorate the invention of the telescope 400 years ago. The movie is presented by Dr Joe Liske, a professional astronomer from the European Southern Observatory. In addition to his narration there are animations, computer simulations and time-lapse footage from observatories.

The DVD runs for about 60 minutes, roughly evenly divided into seven chapters, with an additional 8 minute Bonus with background information on how the DVD was made and the IAU

1. **New Views of the Skies**

This chapter describes the first telescopes, the people who made them and the problems they had. A Dutchman made a refracting telescope in 1608 but only thought of using it for seafarers in the war between Spain and the Netherlands. Galileo made one later but was the first person to use it for astronomy. The reflecting telescope overcame the problems of casting larger glass lenses. This section comments on both William and Caroline Herschel, (see our newsletter no 15, 2002 about the Bath Science walk). The sharp eyed amongst you may notice the image of the Herschel House living room showing a globe and small telescope. The producers had found our website image and asked me to provide a larger version for use in the movie.

These early astronomers drew the images they saw through the telescope on to paper, parts of these early drawings are shown in the DVD. Since we know that Galileo was blind when he died, some of his later published images may have been distorted by his defective vision.

2. **Bigger is Better**

In the early 20th century the United States developed larger telescopes and by then astronomers had realised they needed to use high-altitude sites. George Ellery Hale developed the telescopes at Mount Wilson and Palomar Mountain. Now photography was used to record the visual images and spectroscopy to determine which atoms were present in the planets and stars.

3. **Technology to the Rescue**

In the 1970s and 1980s new technologies were used with better telescope mounts. Thin and/or segmented mirrors were made and attempts to use adaptive optics and interferometry to deal with the blurring effects of the Earth's atmosphere.

4. **From Silver to Silicon**

In the 1980s astronomers were no longer dependent on photography for recording images, which are now stored digitally using soild-state detectors. Development of software for storing, accessing and analysing these images has revolutionised astronomy.

5.**Seeing the Invisible**

This describes instruments to collect information in wavelengths other than the visible which is all the early astronomers used.

6.**Beyond Earth**

The development of satellites orbiting the earth in the 20th century has brought the possibility of studying infra-red, ultraviolet and X ray astronomy outside the earth's atmosphere. The Hubble telescope has produced many astonishing images since its optics were corrected by space-walking astronauts. You can buy a fascinating book '*15 years of discovery using the Hubble telescope*' from the European Homepage for the NASA/ESA Hubble space telescope at:

www.spacetelescope.org/hubbleshop/webshop/

7. **What's Next?**

This last chapter discusses forthcoming projects both ground and satellite based.

Although I am not an astronomer I enjoyed this DVD very much, and can thoroughly recommend it to anyone interested in the History of Physics.

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Note for those of you near Oxford

The Oxford Museum of the History of Science has a special exhibition *'The English telescope from Newton to Herschel'* from 15th October 2008 to 22nd March 2009.

They also have a series of lectures on Tuesday evenings at 7pm at the Museum on the following telescopes, The William Herschel and Hubble telescopes Jodrell bank, the Lovell Telescope and e-Merlin, the Gemini telescopes, the Pierre Auger Observatory.

For further details see their website at: **www.mhs.ox.ac.uk**
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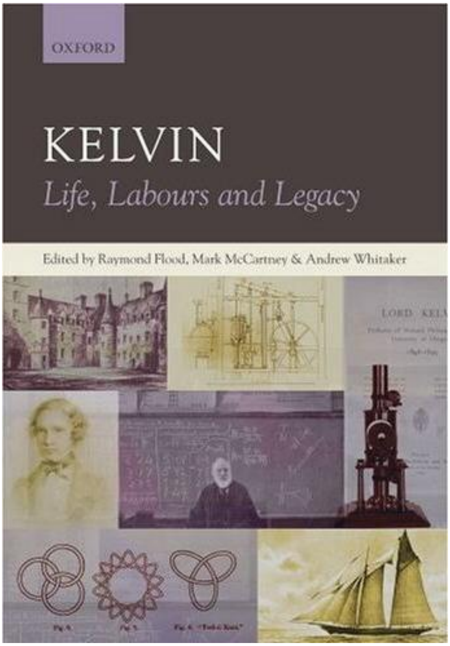
'Thomson: Temperatures and Telegraphs'



Kelvin:
Life, Labours and Legacy

Raymond Flood, Mark McCartney and Andrew Whitaker

Oxford University Press 2008

ISBN 978-0-19-923125-6

568pp Hardback £55

Reviewed by Emeritus Prof. Derry W Jones
Chemical and Forensic Sciences, University of Bradford

To many physicists, Kelvin is the name of a temperature scale and that of half a physical effect, the Joule-Kelvin (or Joule-Thomson). William Thomson (1824-1907) was knighted in 1866 and created Baron Kelvin of Largs in 1892, the first British scientist to be ennobled for his services to science and industry. In the latter half of the 19th century he was the most widely known British scientist and his ingenuity, enthusiasm and persistence were largely responsible for the ultimate success of the Atlantic submarine telegraph. In 1896, 2500 guests gathered in Glasgow in a splendid celebration of his 50 years as Professor of Natural Philosophy at Glasgow and he had been elected to membership of 100 learned societies worldwide. His later honours included the O.M. and appointment as Privy

Councillor in 1902, and election to Chancellorship of Glasgow University in 1904. From the early 1840s Thomson published some substantial treatises and 660 papers (many as sole author), as well as patenting over 60 inventions.

But between the publication of one of the early biographies, by Silvanus Thompson[1] in 1910, and the fine one[2] by Crosbie Smith and Norton Wise in 1989, Kelvin's reputation had waned while his extensive pioneering contributions to classical physics are little known to undergraduates. A 2004 biographer[3] even uses the subtitle "The genius and tragedy of William Thomson".

The main causes of this lack of remembrance of Thomson's science were perhaps the unexpected discoveries of the electron, X-rays and radioactivity at the end of the 1890s and the later emergence of relativity and quantum theory. Soon determinism evaporated and there was less devotion to mechanical models. Like other 19th century scientists, Thomson believed that the same laws applied to all scales of phenomena. Also, as the century turned, there was a shift at the Cavendish (which Chair Thomson had declined in 1871 and subsequently) from Thomson's kind of engineering physics towards purer research in particle physics. Thomson appreciated the academic tradition of Cambridge and its collegiate structure but he preferred the broader background of students in Glasgow and the readier opportunities to meet industrialists and engineers.

At the centenary of Kelvin's death, Flood, McCartney and Whitaker have attempted further re-evaluation and rehabilitation through editing a collection of 16 self-contained essays by distinguished physicists, mathematicians and historians, mostly from Ireland (where Thomson was born) and Scotland. They begin with two biographical chapters and end with Andrew Whitaker's 30 page reflection on the Kelvin legacy.

Two chapters describe some of the engineering achievements of William Thomson and of his talented elder brother James (1822-1892) who, after graduating in mathematics and natural philosophy from Glasgow in 1840, gained experience as a construction engineer. From 1851 James practiced as a civil engineer in Belfast; environmental engineering needs led to two of his inventions, the centrifugal and jet pumps. There followed 16 years in the Belfast chair of Engineering until he took up the corresponding Chair in

Glasgow in 1873. Stressing the complementary approaches of the brothers at the intersection of science with engineering and technology, Peter Bowler describes William as a physicist with a strong interest in engineering and James as an engineer with a strong interest in physics. The brothers collaborated in thermodynamics and they shared a genuine desire that their inventions should help the community together with an expectation that patentable ideas should also benefit themselves. In his chapter on William Thomson's engineering, Bernard Crosland leaves no doubt that he regards him as one of the greatest engineers of the 19th century. Indications of peer recognition 1891-3 included the Presidentship of the Institution of Electrical Engineers and the Institute of Marine Engineers as well as Life Membership of the Institution of Civil Engineers. Examples from these fields of his many instrumental and engineering inventions are the measurements of electrical detection and transmission leading to the Transatlantic telegraph, the mariner's compass, and the heat pump for refrigerating cargoes and controlling the environment of buildings.

Six chapters deal in some detail with individual branches of classical physics to which William Thomson made significant contributions. A long article by C.W.F Everitt (whose father studied at Finsbury under Thomson's biographer Silvanus Thompson) in the Legacy section considers attitudes to the ether concept of eminent late 19th and early 20th century scientists, while five chapters recount Thomson's interactions (often by letters) with other scientists, especially Faraday, Fitzgerald, Joule, Maxwell, Stokes and Tait. Indeed, a strength of this volume is that the majority of the articles involve scientific contemporaries of Thomson, thus providing some commentary on Victorian physics.

William Thomson was born near Belfast in 1824 and lost his mother before he was six. In 1832, his father, James Thomson, an Ulster Scot, took the family to Glasgow on his appointment as mathematics professor at Glasgow College. A.D.D Crack describes how the older boys, James Jnr and William, were educated first at home, in both Belfast and Glasgow, and then studied classics, mathematics, natural philosophy and chemistry at Glasgow College to qualify for BA in 1838. William took further courses at Glasgow and enjoyed long family holidays in Paris and Germany (to learn the languages) and London before going up (by a series of mail coaches) to Cambridge in October 1841. He was a high-spirited and energetic undergraduate who studied intensively but also read widely, boated and swam. In the Mathematical Tripos of 1845 William Thomson was only second Wrangler but won the Smith prize; election to a fellowship at Peterhouse and a lectureship in mathematics followed.

In his introductory biographical chapter, Mark McCartney details the manoeuvring on the part of James Thomson Snr to ensure that his son acquired the background, contacts and experience appropriate to a Chair in Glasgow. Thus, during a 4½ month postgraduation visit to Paris, William attended lectures at the Sorbonne and spent long days assisting Victor Regnault with experiments. The latter experience taught him the virtues of precision and patience in experiments. It also led Thomson, following his election in 1846 to the Chair of Natural Philosophy at Glasgow, to establish a teaching and research laboratory. Part of Thomson's legacy to British science was the creation of this first physics laboratory in a university, enabling students to experiment rather than merely to observe demonstrations.

Of Thomson's close scientific friendships, that with Sir George G. Stokes (of Stokes and anti-Stokes lines in fluorescence) (1819-1903), described in Alastair Wood's chapter, deserves first place. Stokes, evidently a shy, modest, cautious Irishman, grandson of a Dublin Professor of Greek, was Lucasian Professor of Mathematics from 1849 to 1903 and Secretary of the Royal Society 1854-1885, when he was elected President. Stokes communicated frequently with many scientists but his correspondence with Thomson, to whose array of ideas he was a lifelong sounding board, alone amounted to 656 letters. After the death of James Thomson Snr in 1849, William wanted Stokes to apply for the Glasgow Mathematics Chair but Stokes, an Anglican, could not permit himself to conform to a different Protestant denomination, the required Presbyterian Church. Both men were much exercised by the problems of the luminiferous ether, envisaged as an all-pervading viscous liquid or jelly. In Thomson's case, this was especially evident during his 20 extempore Baltimore lectures of 1884; these are described both in Elizabeth Garber's chapter on atoms and molecules and by Everitt reflecting on myths and bogus accounts of ether theories.

Thomson's friendship and collaborations with Peter G. Tait (1830-1901), Senior Wrangler in 1852 and Professor of Natural Philosophy at Edinburgh from 1860, forms the subject of Raymond Flood's contribution. Together the two northern wizards, as Maxwell called them, eventually published in 1867 their influential 727-page *Treatise on Natural Philosophy* (known as T and T), followed by *Elements of Natural Philosophy* in 1873. In his chapter on thermodynamics Iwan Morus considers how Thomson attempted to reconcile the mechanical equivalent of heat experiments of his friend James Joule - they first met in 1847 - with Sidi Carnot's Theory. A shorter chapter by Denis Weaire compares the Irish 'heroes of Victorian science' George Fitzgerald (1851-1901) and Lord Kelvin.

This new collection of essays certainly provides some indication of the range of Thomson's science and technology. Everitt registers that during 1849-50 alone Thomson published papers on air circulation in buildings, crystal magnetism, electricity, ice regelation, magnetism theory, steam engines and thermodynamics. John Roche claims that there was a touch of genius - and unbounded energy - in his contributions to a variety of fields. Writing on magnetic field concepts, Roche highlights how Thomson's penchant for representing physical processes by analogues and models (though not expecting a model to be an exact replica) was complemented by his ability to present Faraday's ideas mathematically; expression in numbers he regarded as the beginning of knowledge. He was reluctant to give up his obsession about the mechanical foundation of electromagnetism and optics. In his later years, Thomson presided over both the British Association and the Royal Society and he received serious nominations for the Nobel prize. However, Whitaker hints that he was thought to be patronising to geologists and biologists over the age of the Earth and evolution (about which there was a notable conflict with T.H Huxley).

Unlike Stokes and Tait, Thomson was a great traveller between May and October when not teaching at Glasgow. His active involvement with consulting engineers and instrument manufacturers arising from the electric telegraph project and his many other inventions made him very wealthy. From boyhood he had a love of the sea; he spent months at sea on (sometimes quite dangerous) cable-laying expeditions in the 1850s and 1860s, while many of his instrumental patents were to improve safety in navigation. Wealth and nautical interests converged with the purchase in 1870 of a 126 ton yacht on which he spent many summers; in 1874 he sailed in it to Madeira to become engaged to and marry Fanny Blandy and bring home his vivacious second wife. A baronial country seat, Netherhall 25 miles from Glasgow, and a London house in Belgravia were other consequences of Thomson's successful 19th century entrepreneurism. This went as far as designing commercial products: unpopular in some academic circles for much of the 20th century but more fashionable again now. Thomson was thus one of the first entrepreneurial academic scientists who marketed scientific knowledge. The private yacht has an echo with a contemporary scientist, Craig Venter of the Human Genome Project, who has successfully combined science, sailing and business.

In a careful retrospective assessment of Thomson's calibre, Whitaker points out that at an early age he was able to meet on equal terms great mathematicians such as Cauchy, Gauss and Green and to interact fruitfully with Faraday. He concludes that from 1840 onwards, Thomson played a leading part in all the major developments in classical physics and was involved in a multitude of inventions. Additionally, he made an immense contribution to international electrical standards, to nomenclature and other commissions and to the structure of science generally. The editors of this book make a strong case for Thomson's distinctive position in the history of physical science.

There is some overlap in this compilation, particularly about the early life of Thomson and on the treatment of the ether, but this is acceptable if the chapters are to be self-contained. Except for a few in Oliver Penrose's statistical mechanics chapter, there are hardly any formulae in the book. Most chapters are referenced with notes and the book has a satisfactory index; there are rather few illustrations except in Crosland's engineering chapter. The first two and last chapters in themselves provide a good summary of the education, career, achievements and legacy of Thomson as viewed from a 21st century perspective. The inner chapters provide expanded accounts of Thomson's contributions to separate fields of science but also together provide a view of the controversies and communications between leading scientists in the second half of the 19th century.

As a postscript, a special issue of the N/L[5] links James Thomson Jnr, engineering and physics, and the enterprising manufacture by impecunious academics well into the 20th century of commercial optical instruments in

Glasgow. The founders of the company Barr and Stroud Ltd were the friends Archibald Barr FRS (1855-1931), who had been on an assistant to James Thomson Jnr and subsequently moved from a Chair at Yorkshire College (the precursor of Leeds University) to succeed him in the Glasgow Chair of Engineering in 1890, and the dynamic William Stroud (1860-1938), Professor of Physics at the Yorkshire College from 1885 until he moved full-time to Barr and Stroud in 1909. Stroud had been taught at Bristol by Professor Silvanus P Thompson (*William* Thomson's biographer) and was succeeded at Leeds by W.H Bragg.

References

1. Silvanus P Thompson, *The Life of William Thomson Baron Kelvin of Largs*, 2 volumes. London: Macmillan, 1910.

2. Crosbie Smith and M. Norton Wise. Energy and Empire. *A Biographical Study of Lord Kelvin*. Cambridge University Press, 1989.

3. David Lindley. *Degrees Kelvin*: *the Genius and Tragedy of William Thomson*. London: Aurium Press, 2004.

4. J Craig Venter. *A life decoded*. London: Allen Lane, 2007.

5. M J Cooper, William Stroud. *IoP History of Physics N/L*. Special Issue (Barr & Stroud), October 2005.

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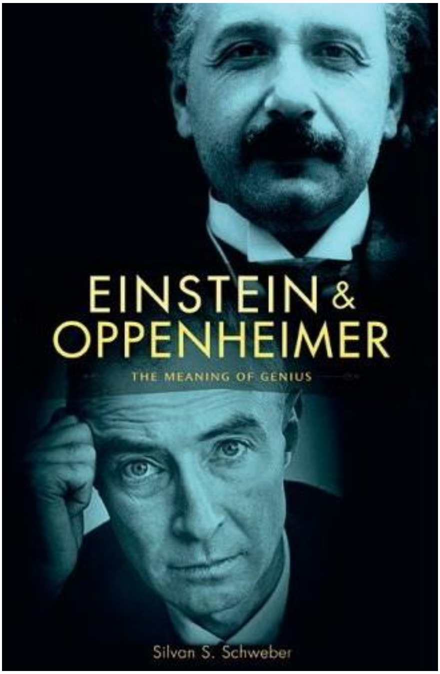

Einstein and Oppenheimer
The Meaning of Genius

Silvan S. Schweber

Harvard University Press 2008
ISBN 978-0-674-02828-9

432pp Hardback £22.95

Reviewed by:
Dr. Peter Rowlands

Schweber's study is like a modern version of Plutarch's *Parallel Lives*, and follows on from his earlier comparison of Oppenheimer and Bethe in *In the Shadow of the Bomb* (Princeton University Press, 2000). For Schweber, Einstein and Oppenheimer were both 'great' in the sense defined by Isaiah Berlin: each took 'a large step, one far beyond the normal capacities of normal men, in satisfying, or materially affecting, central human interests' (2). The 'great' in this sense need not be geniuses, though both men clearly were. Einstein was great because of his extraordinary scientific accomplishments; Oppenheimer was great, partly because of his success as a teacher at Berkeley, but more significantly because of his role as director of the Los Alamos Laboratory during the Second World War.

With Einstein as a scientist and as a peace activist (chapter one), we are on relatively familiar ground; his involvement in the establishment of Brandeis University (chapter two) shows him in a less familiar light, particularly in the disagreements which led to his withdrawal from the project. This certainly expands our knowledge of Einstein's life and character, but has little connection with his activities as a scientist. Oppenheimer, by contrast, is a much less well understood figure, and much of the interest in this book centres on his enigmatic character.

His 'emotional balance' was always 'delicate' (p 143). There was an extraordinary incident, at Cambridge, early in his career when he tried to poison Patrick Blackett. Though he became a physicist, this was only one of many possible directions that his talents could have led him in, and though he made a Oppenheimer, according to Schweber, 'never fashioned a real self' (p 301). number of genuinely significant contributions between 1926 and 1939, he seems to have felt that, because of a year lost to a bad case of dysentery, he came upon the quantum mechanical scene just a little too late to make a contribution of the same magnitude as, say, Born and Jordan, who followed on immediately from the inventors, Heisenberg and Schrödinger. He seems to have abandoned direct research in physics, after the war, when he was still fully capable of contributing, because he no longer saw the point in doing it.

Both of Schweber's subjects had areas of failure in their later careers, after spectacular early success. Einstein failed to find a unified field theory during a thirty-year search, and was unable to make Brandeis University take on the character he would have wished. Oppenheimer, who famously had difficulties in negotiating his way through the tricky world of post-war nuclear politics, was equally unable make the Institute of Advanced Study at Princeton (where he and Einstein overlapped from 1947-1955) bridge the gap between the disciplines of science and humanities in the way that he felt that it should. Nor was the personal relationship between the two men without its difficulties, and Oppenheimer's public eulogies of his colleague tempered the praise with some sharp criticisms; privately he was even more critical, though he did reflect that he would like to have been 'the young Einstein. That goes without saying.' (p 311)

However, even if he could have been transported back in time to where Einstein began, in 1905, Oppenheimer would not have gone down the same path. He was a totally different kind of character and had a totally different approach to science. Einstein was essentially a loner, determined to go down his own chosen route, deeply committed to the philosophical systems that he adopted, and later on an equally committed activist in the causes he supported. Oppenheimer, who was a man of 'changing identities' (297), abandoning his Jewish roots, for example, for a kind of American nationalism, was, in Schweber's analogy, a great conductor rather than a great composer. He was outstandingly successful when he had a great team in support, as at Berkeley and Los Alamos, but a comparative failure when he tried to bring together individuals with totally different interests and mindsets, as at Princeton.

Fundamentally, also, the two theorists, didn't even believe totally in the same sort of science. Einstein, who was always single-minded, believed that physics would eventually discover a final ultimate theory; Oppenheimer, who never developed a coherent system of philosophy, completely lacked such a vision. He saw physics in a much more pragmatic light. 'He did not believe – and so stated – that one could reconstruct the world from the knowledge of a foundational theory in physics. Chemistry, biology, and psychology are all different realms of nature.' (253) The two philosophies are still with us, but history seems to show that the most successful synthesists have been those who believe in the 'final ultimate theory' with Einstein. However, Einstein was equally committed to the view that the unification had to be based on his programme centred on the general theory of relativity and its unification with electromagnetism, with the ultimate elimination of quantum mechanics, whereas Oppenheimer thought that the next level of unification in physics 'had to be expressed within a quantum mechanical framework' (p 254), and here, I think, history seems to be on the side of Oppenheimer.

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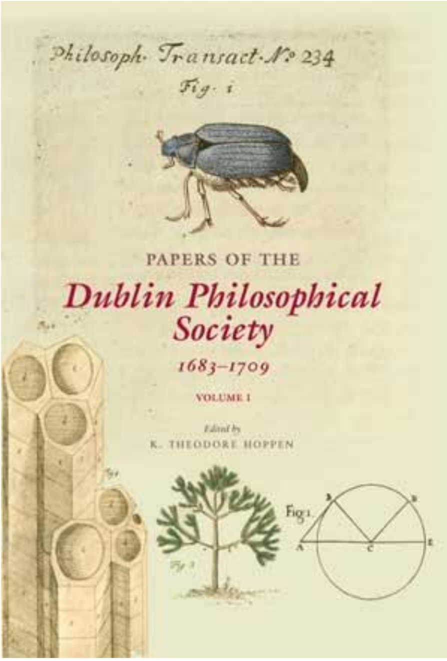

Papers of the Dublin Philosophical Society 1683-1709

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Reviewed by Prof. Denis Weaire
Trinity College Dublin

In 1660, a date of which we will all be reminded in 2010, the Royal Society was founded. When it was re-founded a little later it was given a motto; "Nullius in Verba". Some say it is obscure, but Eduardo Andrade in his history of the Society offers a clear attribution to Horace.: *I do not revere the word of any particular master.* Observation and experiment, rather than written authority, were to be the key to nature.

It was a source of inspiration and a model for many other societies, of which the Dublin Philosophical Society was one. The new spirit was described by Sir George Ashe, speaking for the Dublin Society: I paraphrase:

When by the generous care and noble design of his late Majesty, in instituting the Royal Society, captive truth was rescued from its former bondage, and clouded knowledge began to shine more bright; when instead of words and empty speculations, were introduced things and experiments, and the beautiful bosom of nature was exposed to view [!], *where we might enter into its garden, taste its fruits, satisfy ourselves with its plenty, instead of idle talking and wandering under its fruitless shadows, then philosophy was admitted into our palaces and our courts, began to keep best company, to refine its fashion and appearance, and to become the employment of the rich and the great.*

The Dublin experiment lasted no more than a quarter of a century, but it was the antecedent of not one but two societies that followed in the 18th century, and remain in full force today. First there is the Royal Dublin Society, which still retains a scientific conscience: its members do not spend *quite* all their time stroking the noses of fine horses. And then there is the Royal Irish Academy, currently enjoying one of its very best periods and uniting the sciences and the humanities: in this respect it may be a better model for today than that of the Royal Society.
Recently Dublin was declared *European City of Science* for 2012, pretty much in line with what William Molyneux and his friends would have hoped for in 1683. Just like ourselves they had in mind *applied* as well as pure science. For example, they got quite excited about an invention by someone down in the country, of a new kind of *calash*. If you have holidayed in Morocco you will know what a calash (or *calèche*) is: a small carriage drawn by a single horse. Reading about their excited trials of the new calash, I felt reminded of the poem, the "Wonderful One-hoss Shay", so I looked up "shay" on Google and found it indeed is another word for a calash.

On the more scientific plane, there are two topics that coincided with my own interests. Firstly, there are the earliest discussions of the details of the Giant's Causeway, which has been debated ever since. Only in the last few years have we understood fully how it came about. Secondly there is a truly remarkable paper by Narcissus Marsh, presented in Trinity at one of the very first gatherings of the Society. In this he imagined a new branch of physics, which was to be called *acoustics*. I don't know of any other early examples of this kind of metaresearch: he did not actually *do* the physics, he just conceived of the possibilities, rather like the construction of a strategic “road map” that is so fashionable today. He did so by a quite correct process of analogy with the already well established subject of *optics*, so that, for example, he was able to imagine the counterpart of the microscope in something that should be called the *microphone*.

I am sure we can all find things that resonate with our own interests in the jumble of topics reported here. If you do so, you can explore them from at least four complementary viewpoints: The Minutes, the Papers, the Correspondence, and lastly the lively satires that were written by Dudley Loftus, after he became disenchanted with the Society. It was, he said

..set up for the hindrance of the true and sublime, and the maintenance of sterile and useless learning, directed chiefly to the advantage of two or three of its members.

Begrudgery has always been with us.

The deliberations of the Dublin Society are fully worthy the great care that the Irish Manuscripts Commision and Dr Hopper have lavished upon them. This is an extraordinarily comprehensive work yet, since the Society did not last very long, it can be self-contained in two manageable volumes.

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N.B. At the current rate of exchange the price of £65 from a well known internet book seller is very good value! - *Editor*

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Disclaimer

Letters

Dear Editor,

As a resident of Bingley, West Yorkshire, where Fred Hoyle was brought up, I was especially interested in Jim Grozier's review (Issue 24, p16) of three books on Hoyle's life.Yorkshire Physics News (Autumn 2008) reports that the IOP is to commemorate Hoyle with a blue plaque at Bingley Grammar School.

Hoyle planned to enter nearby Leeds University in 1932, aged 17, to read chemistry, financed by a West Riding scholarship; but a marginal budget cut raised the bar so that his performance in the 1932 Higher School Certificate was not now good enough. Chemistry at Leeds was still the aim when he worked on old Cambridge scholarship-paper examples and then took the December 1932 and March 1933 examinations in Cambridge, all as a stimulus to ensuring greater Higher School certificate success and so securing the West Riding award for Leeds.

In the event, Hoyle was attracted to Cambridge but at Emmanuel he still intended to read Natural Sciences in Part II. Would he have deserted Chemistry for Mathematics, Theoretical Physics (and radar) and Cosmology so soon if he had gone to Leeds in 1932 and so not had the Cambridge experiences of his College scholarship visits?

Derry W Jones

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