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EDITORIAL

Rutherford's Nucleus and the CERN Experiment

A hundred years ago Ernest Rutherford received the Nobel Prize. Ironically, the man widely regarded as the pre-eminent experimental physicist of his times was presented the Nobel prize for chemistry in 1908. The award recognized Rutherford's researches 'concerning the disintegration of elements and the chemistry of radioactive substances'. Soon after in 1911, the nuclear atom arrived; a result of Rutherford's experiments on alpha particle scattering. The world of science has been transformed in the years that have followed, by a spectacular succession of advances in physics which have revolutionized our understanding of matter, chemistry and biology. Bohr's original conception of the model of the atom, electrons revolving in discrete orbits around Rutherford's nucleus, is a picture with which most people are instinctively comfortable; the analogy with the planets and the sun seems to provide a bridge between the seen and the unseen. The atom has proved to be more complex in the century since Rutherford and Bohr. So too, has the nucleus. Some decades ago in a misguided bout of literary enthusiasm, I picked up a copy of James Joyce's *Finnegans Wake*. It is a book that is impossible to understand by simple-minded readers and I did not get far. Years later I realized that a word which launched a new revolution in particle physics was indeed a creation of Joyce. The term 'quark', which transformed the comfortably simple picture of Rutherford's nucleus, was borrowed from Joyce's famous, but largely unreadable, book. The realization that the nucleus was still to yield many secrets and held the key to understanding the forces between elementary particles has fuelled research in nuclear and particle physics over the last few decades. Unlike the early years, theory has outstripped experiment, with experimental tests of theory becoming extremely expensive and forbiddingly complex.

In the last few weeks there has been unprecedented attention in the popular press and television on the starting up of the Large Hadron Collider (LHC), at a site near Geneva. This is an experiment on a scale that might even have astounded Rutherford. When fully operational (and even as I write the first reports of the inevitable technical problems that always arise, have appeared) beams of protons, traversing an enormous circular path in opposite directions, at speeds close to that of light, must collide. These spectacular collisions must release debris, which will hopefully provide new insights not only into the nucleus, but into events that happened when the Universe was born, immediately after the 'Big Bang'. Paradoxically, for the uninitiated observer, probing the deepest recesses of the atom seems to provide clues to understanding not only the genesis of the universe, but also illuminates the nature of another current favourite amongst astrophysicists—dark matter. The CERN collider, by all accounts, is an engineering marvel and testimony to the power of international cooperation in 'big science'. It is also a European triumph, surviving successfully in the aftermath of the demise of the Superconducting Super Collider project in the United States. The real experiment will begin soon but cautious voices have already been raised, which suggest the search for the 'God particle', as the Higgs boson has been dubbed, may go on far a while. On the sidelines, public interest has been kept alive by a rekindled controversy involving Stephen Hawking and Peter Higgs, the theorist whose work predicts the existence of the as yet unobserved particle that bears his name. There is a pervasive feeling that these new high energy experiments may yield surprises, providing particle physics a new lease of life, in an era increasingly dominated by other sciences, seemingly more deeply rooted in the problems of everyday existence. High energy physics is an esoteric area, where common words like 'colour' and 'string' acquire connotations so far removed from everyday experience, that even James Joyce might have been left bemused. The LHC experiment has suddenly catapulted high energy physics to the position of the 'poster boy of science', in the press. An experiment that promises to unveil fundamental constituents of matter, address events at the creation of the universe, provide insights into dark matter and even involve that perennial favourite, the black hole, cannot fail to excite the imaginative mind. Curiously, all discussions of the LHC experiment are dominated by theoretical physicists; the experimenters seem to be faceless. Modern day big science requires such large teams, with groups having diverse skills, that the individual retreats into anonymity. Conflict and competition, which sometimes seem to play so much of a part in the history of science, appear to have little place in mammoth projects, where cooperation and organization are the key to success. Particle physics has indeed come a long way from the days of Rutherford.

The Rutherford era belongs to another day and another age. It is hard to imagine the Cambridge settings of the first three decades of the 20th century when physics, and indeed science, was transformed ('transmuted' might be an appropriate alternative). There are biographies of Rutherford which are valuable but do not, at least for me, capture the essence of the man and his times (*Rutherford: Scientist Supreme*, John Campbell, AAS Publications, 1999). My favourite account of this subject is in a volume penned by C. P. Snow in the mid-1960s, in which the author provides personal impressions of men he knew (*Variety of Men*, Macmillan, 1967; Penguin, 1969). The list is remarkable, beginning with Rutherford and includes G. H. Hardy, H. G. Wells, Einstein, Churchill and Stalin. Snow, a physicist turned administrator and writer, has an uncanny ability to bring his subjects alive. Masterful prose and a keen eye for the quirks of human nature are characteristic features of Snow's writing. Rutherford comes across in Snow's description as a larger than life figure who, more than anyone else, made Cambridge 'the metropolis of physics for the entire word' in the 1920s and 1930s. In Snow's words: 'He was a great man by any standards which we can apply. He was not subtle: but he was clever as well as creatively gifted, magnanimous (within the human limits) as well as hearty. He was also superbly and magnificently vain as well as wise—the combination is commoner than we think when we are young. He enjoyed a life of miraculous success. On the whole he enjoyed his own personality. But I am sure that, even quite late in his life, he felt stabs of sickening insecurity'. Snow recounts a discussion by 'half a dozen men all of whom had international reputations' on Rutherford's place in science: 'Was Rutherford the greatest experimental scientist since Michael Faraday? Without any doubt. Greater than Faraday? Possibly so. And then it is interesting, as it shows the anonymous Tolstoyan nature of organized science – how many years' difference would it have made if he had never lived? How much longer before the nucleus would have been understood as we now understand it? Perhaps ten years. More likely only five.' Rutherford's work set the stage for modern nuclear and particle physics, as Snow states so simply: '. . . he broke up a nucleus of nitrogen by a direct hit from an alpha particle. That is man could get inside the atomic nucleus and play with it if he could find the right projectiles. These projectiles could either be provided by radioactive atoms or by ordinary atoms speeded up by electrical machines'. Snow's 'electrical machines' have evolved over the decades into the Light Hadron Collider, which is now poised to break further into the heart of the nucleus. Snow reflects: 'Rutherford himself never built the great machines which have dominated modern particle physics, though some of his pupils, notably Cockcroft started them. Rutherford worked with bizarrely simple apparatus; but in fact he carried the use of such apparatus as far as it would go. His researches remain the last single-handed achievement in fundamental physics. No one else can ever work there again – in the old Cavendish phrase – with sealing wax and string'. Snow recalls that Rutherford proclaimed: 'I could do research at the North Pole', a sentiment that would have been shared by C. V. Raman.

The days of sealing wax have long disappeared into the pages of history. The run-up to the Large Hadron Collider is a tale of 'politics and high finance' compellingly told by a former Director-General of CERN, Chris Llewellyn Smith (*Nature*, 2007, **448**, 281). Research and development 'on the very demanding LHC magnets' started as early as 1988. Raising finance for a project of this magnitude (current estimates in the press quote figures as high as $8–10 billion) and shepherding the venture through years of uncertainty and changing perceptions of politicians and scientists is an achievement of which the international particle physics community can be justly proud. *Nature* begins a new series of essays on '*Meetings that Changed the World*' with a retrospective on a meeting, that led to the birth of CERN, held in December 1951. Francois de Rose, who chaired that UNESCO meeting, notes that he could conclude the event by saying: 'if it would be difficult to find scientists among diplomats, it was obvious that there were many diplomats among scientists' (*Nature*, 2008, **455**, 174). In looking back at the gigantic LHC project, Llewellyn Smith recalls a statement in *The Times* (London) 'on the worlds great construction projects which asserted that "if those involved didn't lie about the cost, they never would be built"'. While he notes this did not happen in the LHC projections, it may sometimes be necessary 'to approve projects without contingency on the basis of optimistic assumptions . . . if . . . this is the only way to get them approved'.

What will physicists find when the LHC matures in its career as a particle smasher? Leon Lederman, who titled his book *The God Particle* (he claims that his 'editor explained with an eye on the sales figures, "no one has ever heard of Higgs"') asserts that 'we are reaching what the medieval map maker would have denoted *terra incognita*' (*Nature*, 2007, **448**, 310). He provides 'a speculative laundry list' of LHC stimulated advances but suggests that the lesson of history teach us that 'a discovery will be made that was not anticipated by theorists'. That sentiment would have undoubtedly pleased Rutherford, who is reported to have said: 'Don't let me catch anyone talking about the universe in my department'.

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