CAVENDISH'S CROCODILE AND DARK HORSE: THE LIVES OF RUTHERFORD AND ASTON IN PARALLEL

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Ernest Rutherford and Francis Aston were born a world apart but both would become two of the most influential physicists of their time. Their separate training, under the direction of J.J. Thomson at the Cavendish Laboratory, shaped their future and allowed both men to develop and apply their considerable skills in experimental physics. It also catalyzed their careers and ultimately led to each receiving a Nobel Prize. Although they had very different characters, Rutherford and Aston became close colleagues and confidants who spent considerable time together within the confines of the Cavendish Laboratory, at Trinity College, and elsewhere in Cambridge. They also traveled the world in company, usually as part of a group or British delegation of scientists attending conferences and meetings overseas. This article parallels the lives of the two men. It describes how they came to work at the Cavendish, their scientific accomplishments and accolades, and their activities and interactions away from the laboratory. © 2007 Wiley Periodicals, Inc., Mass Spec Rev 26:713–723, 2007

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I. HAVELOCK AND HARBORNE

Ernest Rutherford and Francis Aston were both born in pastoral or semi-rural settings, though a world apart from one another. Ernest Rutherford was born on August 30, 1871 in Spring Grove near Nelson on the north tip of the south island of New Zealand. He was the 4th child of 12 born to James and Martha Rutherford (Eve & Chadwick, 1938; Cockcroft, 1946). His father hailed from Scotland and worked as a wheelwright, engineer and later a flax miller. His mother was an English teacher, who with her widowed mother, immigrated to New Zealand from England in 1855. Martha saw to it that her growing offspring were educated before they attended school. She also maintained that they attended church on Sunday, frequently attending multiple services on the Sabbath (Campbell, 1999).

In 1883, the growing Rutherford family moved north to Havelock in the Pelorus Valley on the southern shores of Marlborough Sound. Here, James and his brother had earlier established a flax mill. Despite their hard work, the mill had mixed fortunes and James took other odd jobs to supplement the family's income. All family members were expected to pitch in to help with the running of the household. The young Ernest (Fig. 1) would be sequestered to mind his younger siblings, gather firewood, grow and pick vegetables, and take care of a small group of livestock. Outside of his chores, school, and church, Ern was free to explore and play in their local surrounds with his siblings and other local children. The family's largely happy but simple life was shattered in early 1886 when two of Ern's younger brothers, Herbert and Charles, drowned after falling overboard on the sound. Martha was particularly affected and held an older boy from another family, George Price, accountable for their deaths. She ruled her children would not spend time with Price again. Entering adulthood, Price was shunned by many of the locals in the small town. He would later take his life (Campbell, 1999). Ern, like Francis Aston, would eventually outlive all his brothers.

Francis Aston was born 6 years and 1 day after Rutherford on the outskirts of Harborne in Camomile Green, England. Like Rutherford, he was born the second son, a privilege that usually afforded those from the poor and working class families an opportunity to establish a career different from their father. Aston's father William, like his own father, was a metal broker supporting the nailmaking trade and metal industry in Harborne and neighboring Birmingham. Francis' mother, Fanny Charlotte, was the youngest daughter of Isaac Hollis who, with his brother, sons, and other partners, established and ran a series of gunmaking businesses in Birmingham and greater London (Hevesy, 1948). This descendancy afforded the Astons a degree of financial security and they lived in a large home known as Tennal House at the intersection of Tennal road and Church lane (Hevesy, 1948). The home was backed by small local farms and provided the Aston children a place to roam and play. Francis' interests in the scientific and mechanical were evident early on. As a young boy, encouraged by his father, he would study the formation of soap bubbles and the action of acid on metals, and would fabricate home-made fireworks. A disused loft at the home was later made available to Francis to pursue his talents and became, in effect, his first laboratory (Hevesy, 1948). His sister Helen, 13 years his junior, has recalled her brother blowing glass and winding coils of wire to make a crude X-ray device (Hevesy, 1948). Wilhelm Röntgen's experiments, and particularly his

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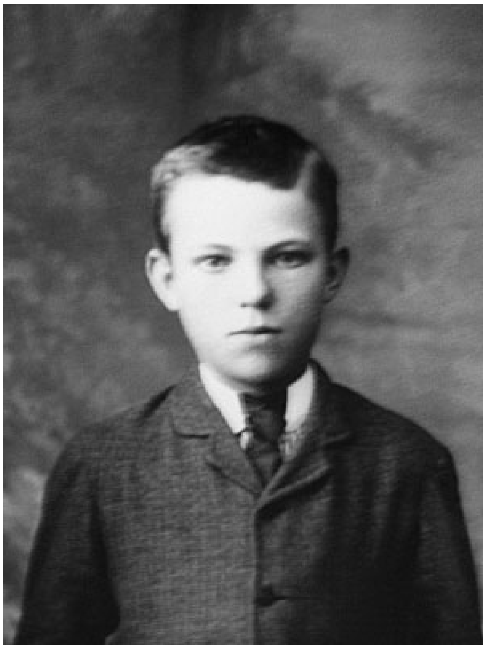

FIGURE 1. Ernest Rutherford in childhood, ca. 1880. Reproduced with permission from Rutherford's Den, Christchurch, New Zealand.

image of the bones and wedding ring of his wife's hand, had attracted international public attention in the late 1800s, and had fascinated Aston.

II. EDUCATIONAL OPPORTUNITIES

After attending Spring Grove, Foxhill, and Havelock Schools, Ernest Rutherford was admitted to Nelson College in 1887 on his second attempt following in the footsteps of his older brother George. He did so, by necessity, on a scholarship as the Rutherfords could not provide their children with a private education. For the next 3 years, Ernest received an annual stipend and subsidized board at the college. He was a likeable, if somewhat shy, student who valued the educational opportunities afforded to him. He studied hard and became Dux of the school in 1889. After an early education at the local parish school in Harborne, the similarly studious Francis Aston was admitted to Malvern College where he was a boarder from 1891 to 1893 (Rosser, personal communication). His older brother Henry had also attended the college a year earlier, but presumably demonstrated less academic ability, and left after only two terms to start employment.

Rutherford's and Aston's interest in science was catalyzed at college but blossomed when they attended university. Rutherford attended Canterbury College (now the University of Canterbury) (Fig. 2) in 1890. In 1892, he received a B.A. after study in Latin, English, French, Mathematics, and Physics. He studied the latter under Professor Alexander Bickerton known as ''Bicky'' to his students. Bickerton, who at times received the ire of the college, has been described as ''heterodox in his views and erratic in his methods.'' Rutherford though was to pay tribute, later in life, to his early lecturer's approach to teaching stating ''*He had lectured in an interesting way . . . and he made (his) students very enthusiastic*'' (Campbell, 1999; Smith, 2000).

Rutherford's abilities in mathematics and physics won him a senior scholarship to study for a Masters degree in these subjects. The physics course required that he conduct some original research. Ern elected to extend an undergraduate experiment to determine if iron was magnetic at very high frequencies of magnetizing current. The experiments were sensitive to vibration and, hampered by the lack of suitable laboratories at Canterbury, Rutherford and Erskine wrote to the University's registrar to request permission to use a den (Fig. 2 inset) under the lecture theatre. The letter of April 2, 1894 reads in part: *''Sir, We the undersigned respectfully request the gown room below the mathematical lecture room for the purposes of conducting electrical researches. . . . The vibration of a wooden building is fatal to the accuracy of these observations. Even in the large hall a passing vehicle or a step at the hall door interrupts observations for several minutes. . . . We have the honour to be your obedient servants, E. Rutherford & J.A. Erskine''* (Rutherford's Den, Arts Centre, Christchurch, New Zealand). The registrar sympathized and Rutherford got his first ''laboratory.'' Today his equipment, the letter, den, and lecture theatre, featuring a painting of Bickerton above the lectern, all form part of a museum dedicated to Rutherford's life (Rutherford's Den, Arts Centre).

Aston left Malvern and was admitted to Mason College in 1894 (Hevesy, 1948). Mason College (now part of the University of Birmingham) had, in contrast to Canterbury at the time, resplendid science facilities having been established in 1875 with a large endowment of some £200,000 by industrialist and philanthropist Sir Josiah Mason. Aston's physics lecturer was Professor John Henry Poynting, the man who would later recommend him to his close friend Joseph John (J.J.) Thomson. Francis graduated with a Bachelor of Science degree in 1898 specializing in organic chemistry and was awarded a Forster scholarship to conduct research with Prof. Percy Frankland on optical rotation. Aston left university to work in industry for 3 years as a brew chemist at the Butler & Co. Springfield brewery in Wolverhampton but by 1903, with the help of Poynting, he returned to Birmingham as a research scholar. Upon the death of Aston's father, he took leave to travel around the world, visiting countries as far afield as Australia (Hevesy, 1948; Downard & DeLaeter, 2005; Downard, 2006). On his return, Aston was appointed a demonstrator in October 1909, on a salary of £150 p.a., but his skills were not in teaching. After only a term, he gladly accepted an offer from J.J. Thomson to work at the Cavendish as his research assistant. Aston would advance Thomson's studies to separate the isotopes of neon which Thomson had investigated using his parabola method in a cathode ray tube.

III. JOINING J.J.

Arguably, the common link that had the greatest impact on the lives of Rutherford and Aston was their training under J.J. Thomson. By continuing his studies at Canterbury for a B.Sc.

FIGURE 2. Cavendish College, New Zealand ca. 1880. Inset shows the interior of the den, situated in a basement to the right of the building, where Rutherford performed his first research experiments. Reproduced with permission from Christchurch City Libraries History Photograph Collection.

degree in chemistry and geology, Rutherford was eligible to apply for an Exhibition of 1851 scholarship. The scholarship was established to allow graduates of universities within the British Commonwealth to conduct research in the U.K. Every second year, one scholarship of £150 p.a. was available to graduates from New Zealand. Rutherford's application was successful but only because the first awardee declined to accept the offer (Campbell, 1999). J.J. offered the young New Zealander the opportunity to work in his lab at the Cavendish, and Rutherford left New Zealand for Cambridge in late 1895 (Fig. 3). Rutherford was to become Cambridge University's first research student from another university after Cambridge *"lowered its nose and opened its doors to outsiders"* (Campbell, 1999) to admit other graduates. Rutherford joined Trinity College at the recommendation of J.J., although at first he resided outside of the university in a private lodging. The environment proved to be one Rutherford, then 24, reveled in though he and the other "outsiders" were not always well received by the Cambridge boys, some of whom demonstrated to undergraduates to supplement their income. In a letter home to his future wife Mary (May) Newton, he wrote, "*There is one demonstrator on whose chest I would like to dance a Maori war-dance*" (Campbell, 1999).

Undeterred, Rutherford advanced his experiments conducted in New Zealand studying the frequency of oscillating currents and showed solid materials had the same dielectric constants when subjected to currents at high frequencies of oscillation as they did in steady fields. He later improved the sensitivity of the detector to study the period of electromagnetic waves over a great distance (Campbell, 1999). Rutherford also studied the velocity of ions produced by Rontgen Rays in various gases (Thomson & Rutherford, 1896; Rutherford, 1897). He first measured the ionization current between two parallel plates, then switched off the rays and applied a high potential across the plates to attract ions of a common charge to one of them and measured their charge. From this, their combined velocity could be derived. Excited by these experiments, Rutherford is said to have remarked that *"Ions are jolly little beggars, you can almost see them"* (Millikan, 1939). He was quick to demonstrate his abilities in experimental physics and took full advantage of the opportunities afforded to him working in one of the premier physics laboratories of the time.

In 1898, with his 1851 scholarship to shortly cease, Rutherford along with another Cambridge demonstrator applied for a recently vacated junior Professor of Physics at McGill University in Canada. J.J.'s support was pivotal to his success. In his letter of recommendation he wrote, *"I have never had a student with more enthusiasm or ability for original research than Mr. Rutherford. . . . I should consider any Institution fortunate that secured the services of Mr. Rutherford as a Professor of*

FIGURE 3. J.J. Thomson and his research students in 1898. Rutherford is standing behind Thomson seated front and center. Reproduced with permission from reference Campbell, 1999.

Physics" (Campbell, 1999). His departure to Canada in September 1898, at just 27 years of age, preceded Aston's arrival. The pair first met only after Rutherford returned to England permanently in 1907. Shortly thereafter, Rutherford was to scale the heights of scientific achievement with the award of a Nobel Prize largely for the work he began in Canada.

IV. NOBEL PRIZES—BUT IN CHEMISTRY?

The work of Becquerel and the Curies in France on the unusual properties of the newly discovered radioactive elements led Rutherford to commence work on the radiation from uranium, radium, and thorium when he took up his appointment in Canada. He discovered two types of particles emanating from radium, referred to as alpha and beta particles, which could be absorbed on aluminum foil in a ratio of 100 to 1 (Rutherford, 1903). The spontaneous instability of uranium and thorium led Rutherford and Frederick Soddy to propose that the rate of decay of these materials was constant in unit time and was found to be in proportion to the rate of formation of the emitted particles (Rutherford & Soddy, 1903a,b). This spontaneous transformation of one element to another was hailed as a ''new alchemy.'' Investigating the properties of the particles, Rutherford examined the deflection of alpha rays with both electric and magnetic fields in 1903 (Rutherford, 1903). He later determined the ratio of charge to mass of the particle and suggested it bore a likeness to an atom of helium with a mass of 4 and a charge of +2e (Rutherford & Hahn, 1907; Rutherford & Geiger, 1909). The velocity and energy of these particles was also investigated and this promoted efforts to examine the ''stopping power'' various materials would have on the particles (Rutherford, 1910).

Returning to England in 1907, Rutherford accepted the Langworthy Chair of Physics in Manchester where he could be closer to the research community in England. Here he worked with Hans Geiger to accurately count the number of alpha-particles emitted from a gram of radium (Geiger and Rutherford, 1911). Working with Ernest Marsden, they also found that traces of gas in the tube through which the alpha-particles passed could have a significant impact on the counts detected (Rutherford, 1911). This phenomenon was ascribed to the scattering of the alpha-particles but the irreproducible nature of the scattering was puzzling. As Geiger has recounted ''*One day (in 1911) Rutherford, obviously in his best of spirits, came into my room and told me that he now knew what the atom looked like and how to explain the (occasional) large deflections of the alpha-particle*'' (Rutherford, 1914). Rutherford had realized that their results indicated that the atoms of gas must be hollow, thus leading to his theory that atoms had their mass concentrated in their center; the so-called nuclear-theory of the atom. When the alpha-particles avoided a collision with the atomic nuclei they would reach the detector. In contrast, when they scored a direct hit they would be violently scattered. This description of the atom, with some refinement, remains to this day.

The far-reaching consequences of Rutherford's research led him to being nominated for a Nobel Prize. He had been first nominated for the Physics prize on the eve of his departure from

McGill by fellow Professor of Physics John Cox (Campbell, 1999). But this nomination arrived too late to be considered by the committee in 1907. He was instead considered for and awarded the Nobel Prize in 1908. J.J. Thomson was also to nominate Rutherford as did Svante Arrhenius of Sweden. Arrhenius had envisaged the physics prize for Max Planck and the chemistry prize for Rutherford to get awards for two atomic physicists. His plan backfired when a mathematician argued against Planck receiving the physics prize alone, but Rutherford's nomination stood after several reviews (Campbell, 1999). So, to Rutherford's amusement, he was to be awarded the chemistry prize "for his investigations into the disintegration of the elements, and the chemistry of radioactive substances." He did not have the strongest affection for chemistry. Reflecting his bias, he is quoted as saying *"all science is either physics or stamp collecting"* (Birks, 1962). He is also said to have joked that the only thing faster than a nuclear transformation was the transformation of physicists into chemists.

Aston, also a physicist by any definition, similarly received a Nobel Prize in Chemistry given the fundamental significance of his discoveries to the field. His award came in 1922 for his discovery of isotopes and enunciation of the whole number rule. This was achieved through the detection of isotopes, and the measurement of their masses, for many of the stable non-radioactive elements using his hand built mass spectrograph at the Cavendish. His first instrument, reported on in 1919, had a resolving power of approximately 1:130 and an accuracy of mass measurement of 1 in 1,000 (Aston, 1919a).

V. BACK AT THE CAVENDISH

After World War I, those fortunate enough to return to Cambridge faced a difficult future. The war had cost Britain many lives and its economy. Monies for further research were scarce. J.J. elected to take the opportunity to resign as Director of the Cavendish having served in the role for 35 years after an offer to take on the role of Master of his beloved Trinity College at the age of 62. Rutherford was approached as his replacement and accepted the offer (Crowther, 1974). Given that J.J. was to stay on and conduct research, Rutherford was at pains to establish lines of responsibility. This left little doubt to anyone that Rutherford was now in charge, and the new Prof. brought a noticeable change to the laboratory. Whereas J.J. was an amiable retiring character whose presence in the laboratory was sometimes innocuous, Rutherford was both seen and heard. His voice would ring through its corridors and was said to precede him. This intimidated some of the new students and startled others. A sign intended for the new Director was hung overhead in one of his research laboratories (Fig. 4).

Rutherford's arrival at Cambridge in mid 1919 coincided with Aston publishing measurements made using his first mass spectrograph (Aston, 1919a). After the war, Aston returned to the Cavendish Laboratory from Farnborough where he had worked on aeronautical coatings with inspiration to improve upon Thomson's parabola apparatus. Like Thomson's apparatus it employed electric and magnetic fields to deflect ions, but the two fields were located in different regions along their path. Unlike

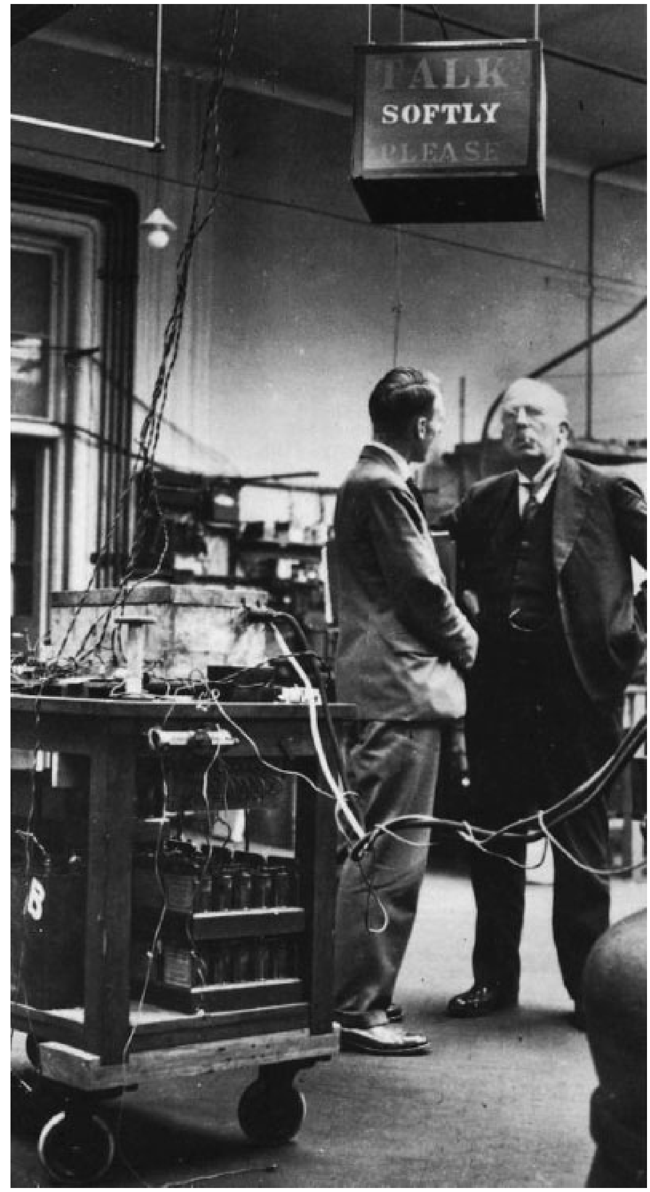

FIGURE 4. Ernest Rutherford with Jack Ratcliffe in the Cavendish Laboratory. An overhead sign was intended for the laboratory's Director. Reproduced with permission from reference Campbell, 1999.

Thomson's method, in which particles with the same *m/z* value, but different velocity, were distributed along the parabola, Aston's mass spectrograph focused to these ions to the same point. This focused beam offered a significant improvement in sensitivity to allow the introduction of finer slits to improve mass resolution and accuracy. The instrument was an immediate success easily resolving the two isotopes of neon (Aston, 1919b). The isotopes of chlorine were also resolved and by 1922 on the publication of his first book (Aston, 1922a), Aston had studied some 30 non-radioactive elements (Aston, 1920; Aston, 1922b). It transpired from Aston's result that the masses of all isotopes were near integers leading to enunciation of the whole number rule. This also resulted in the realization that the atoms of all elements were composed of common subatomic particles; what are now called protons.

Aston's mass spectrograph was constructed of a glass flight tube that had to be evacuated to achieve a good vacuum and that vacuum had to be held long enough to conduct his measurements. A leak led Aston to explore the instrument to locate its source (Aston, 1911) with all the dexterity of his favorite fictional detective Sherlock Holmes. Rutherford would remark that if Aston was seen with a smile on his face it was because his apparatus had developed a leak and Aston would happily spend the next 2–3 weeks to locate and seal it (Mann, 1976).

Aston's measurements were refined with subsequent improvements in the mass spectrograph (Squires, 1988). He reported on the improved performance his second and third in 1927 and 1937. Still by the 1930s, data obtained by Kenneth Bainbridge in Pennsylvania suggested that some of Aston's mass measurements were in error (Bainbridge, 1933). Specifically, the masses of hydrogen and helium were reported to be too low (Bainbridge, 1933). It was left to Rutherford to approach Aston with the news. Reportedly, Aston was not too receptive to the idea. He nonetheless repeated his measurements and found this to be the case (Aston, 1936). The episode sparked a verse, entitled "Aston's Dilemma," penned by one of Rutherford's students Albert Kempton that was sung with much fanfare at the Cavendish annual black tie dinner in 1935 to the tune of "Villikins and his Dinah."

As Aston was working in the lab one day
The Prof. came to him and thus did say:
"Now Aston, my boy, don't you think you might be
Just a tiny bit out in O sixteen to He?"
"No, no", Aston cried, "it could never be so;
My honour I'll stake on my Helium to O.
These foolish suggestions are very jejune,
As my new apparatus will show very soon."
For weeks and for months Aston's cry was the same.
"For your faults and failings must I take the blame?
If you cannot manage to understand Boron,
Then it's you and not I that must be the moron."
As light came to Paul in old Judea,
So to Aston it came as a splendid idea
That if his masses would not agree,
'Twere much better if he changed them and not Kenneth B.
And so he decided to start work again,
Measuring the masses against oxygen.
How great his delight when it did transpire
That the masses of H and He were much higher.
Now all you young fellows, take warning of this;
If with your results there is something amiss,
Don't treat all your critics as meddling riff-raff,
But remember the case of the mass spectrograph.

The song was apparently well received by all those in attendance, with the notable exception of Aston himself. He was not amused.

Rutherford's and Aston's research accomplishments, though different in their conception and design, shared a common focus that resulted in an improved understanding of the composition and structure of atoms. Rutherford achieved this by studying what he called "exploding" atoms whereas Aston provided experimental proof for different forms of stable ones resolved in the gas phase using a mass spectrograph (Aston, 1935).

VI. CAVENDISH'S CROCODILE AND DARK HORSE

Few people had as much praise for Rutherford as Peter Kapitza. A Russian engineer, Kapitza had lost his family in epidemics that followed the Russian revolution. On a visit to England, he approached Ern about joining the Cavendish. Rutherford was at first discouraging given the overcrowded state of the laboratory but eventually relented. Kapitza was at first a little intimidated by Ern and began to refer to him as "the Crocodile." He wrote home to his mother *"I am a little afraid of him. I work almost next door to his office . . . (and) I have to be very careful with my smoking. If he could catch you with a pipe in your mouth you're in trouble. But thank God he has a heavy tread and I can recognise his footsteps a long way off"* (Campbell, 1999). One story goes that the nickname was so coined because the fearsome crocodile in the children's tale Peter Pan could be heard from far away because it had swallowed an alarm clock.

To leave a lasting monument to Rutherford at the Cavendish, Kapitza commissioned a work by Eric Gill to chisel a crocodile on the outside wall of the laboratory (Fig. 5). The work was conducted in secrecy and was surrounded by a tarpaulin until its disclosure. A second carving inside the laboratory was, at first, less well received. Rutherford's nose, some thought, was too large. Rutherford's good friend Niels Bohr was sent a photograph (Campbell, 1999). He thought it to be a good likeness so the carving stayed.

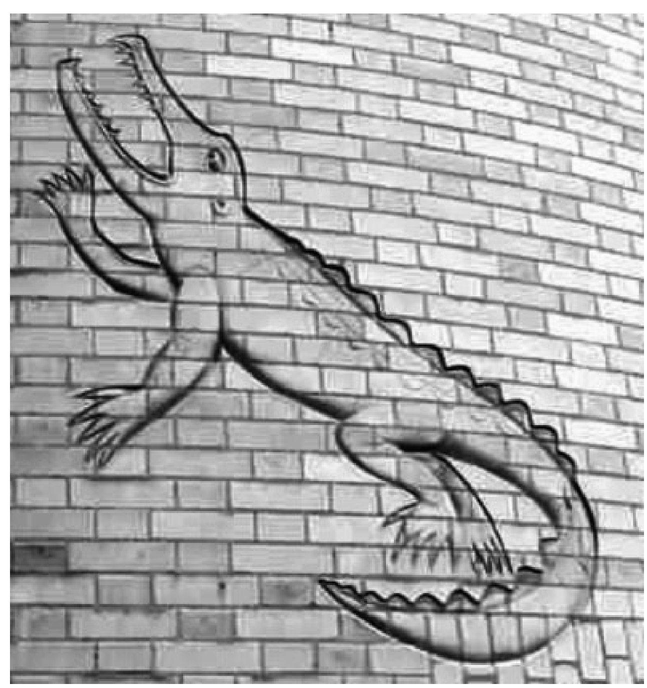

FIGURE 5. Crocodile image dedicated to Rutherford on the wall of the Mond Laboratory, University of Cambridge. Adapted from photograph released in public web domain: http://commons.wikimedia.org/wiki/Image:Rutherford_crocodile.jpg

Aston was given no such accolade but, given he was a very private man with a somewhat elusive demeanor, if he were to be represented in animal form, a dark horse would have been a fitting portrayal.

VII. GOG MAGOG

The Gog Magog golf course on the southern edge of Cambridge became a focal point of many discussions and frivolity between Rutherford and Aston and their golfing partners (Mann, 1976). On Sunday mornings Rutherford would drive down to the Backs collecting Aston on Queens Road. May Rutherford would sometimes accompany them in fine weather preferring to walk around the course with the group rather than take part in the game. A regular foursome who played during term comprised Rutherford, Aston, Rutherford's son-in-law Ralph Fowler, and Geoffrey Taylor (Fig. 6). All fellows of Trinity College, the group would sometimes distract and disturb others on the green and became known as the ''Trinity circus.'' Fowler and Aston were the better players, so to sustain a fair game, Rutherford would most often pair with Aston, and Fowler with Taylor. Rutherford reportedly developed a degree of competence in the game although he had an unusual stance (Mann, 1976). Being a provocateur, and well aware of Aston's sporting competitiveness, Rutherford is said to have deliberately sliced a ball into the bunker on occasion just so he ''*could hear Aston complain about having to get it out*'' (Crowther, 1974).

The golf course was also reported to be the place where Rutherford and Aston discussed the name that should be given to the heavy atoms Aston had detected. Rutherford suggested ''isotopes,'' a word coined earlier by Frederick Soddy. In Soddy's own words, ''*The same algebraic sum of the positive and negative charges in the nucleus, when the arithmetical sum is different, gives what I call isotopes or isotopic elements*'' (Aston, 1935). The discovery of the neutron responsible for the mass difference among isotopes was to come later (Chadwick, 1932).

During one golf game, in which Rutherford and Aston played against Charles Darwin and Frederick Mann, the group reached the 13th fairway where a vigorous straight shot would place the ball on the green (Mann, 1976). It was Aston's turn to drive first with Rutherford to play the ball on. Aston, anxious to put the ball close to the hole for his partner, drove the ball violently down the fairway. His shot sent the ball long but its direction was out and it veered into the rough. Rutherford, sensing the formidable challenge he now faced of putting the ball on the green, quipped with some sarcasm ''*What's the matter with you Aston? Done a couple of days' work? You ought to have a holiday!*'' Aston had no teaching commitments and less academic responsibilities than most of his fellow players so that, when not conducting experiments, was seen by some to take a more leisurely approach to his life and work, particularly during the 1930s. Indeed, one of Rutherford's students Marcus Oliphant, who came to know Aston during this time, has controversially referred to him as ''*the laziest man in physics*'' (Downard & DeLaeter, 2005). Oliphant is seen sitting uncomfortably beside

FIGURE 6. Ralph Fowler, Francis Aston, Ernest Rutherford, and Geoffrey Taylor. Source: Reference Mann, 1976.

Aston, himself next to Rutherford, in the 1936 photographic record of members of the Cavendish Laboratory (Fig. 7).

VIII. TRAVELING IN COMPANY

Outside of Cambridge, Rutherford and Aston would often accompany one another on trips abroad, usually as part of a group or British delegation of scientists attending conferences and meetings overseas. Attending the Volta Congress meeting in Como, Italy in 1927, the pair was photographed together, with Rutherford looking unusually sheepish in the background (Fig. 8). The conference was held on the hundredth anniversary of the death of Alessandro Volta.

They sailed together aboard the steamship Nestor to attend the British Association for the Advancement of Science (BAAS) meeting in South Africa in 1929 accompanied by Rutherford's son-in-law Ralph Fowler and his daughter Eileen. Beginning in 1884, the BAAS spread its wings to engage with scientists the world over by holding meetings in Canada, Africa, and Australia. The extended sea voyages required travelers to make their own entertainment in addition to organized deck games and events. Rutherford wrote home to his wife while aboard the Nestor. *"Dearest May, The passengers are on a whole largely middle aged or ancient like myself . . . Our party at table is quite a lively one. Ralph's laughter easily beats the best. . . . Eileen is in good form and enjoying herself . . . "* During a fancy dress contest, he wrote *"Aston at our table came dressed as a Malay and looked cool and attractive. Eileen went as a milkmaid . . . I got into my red gown . . . and a mock trial, in which I was judge . . . went off well"* (Campbell, 1999).

Both Rutherford and Aston traveled widely late into life (Fig. 9). The pair were to travel together again in 1937 to attend the Indian Science Congress in Calcutta to mark its silver jubilee. Rutherford was to lead the BAAS delegation with Aston to receive an honorary doctorate from the University of Calcutta. But Rutherford never made it. His health took a turn for the worse and to the surprise and sadness of all who eventually attended the meeting, Rutherford died on October 19, 1937.

IX. RUTHERFORD AND ASTON REMEMBERED

Rutherford's towering physique and commanding voice made him seem invincible to many. He was never one to be idle and that autumn, while helping his wife May with some heavier garden work, a partial hernia that had discomforted him for several years became more severe. The family doctor was called and he diagnosed a strangulated umbilical hernia. Ern was admitted to a private nursing home and operated on by the Harley Street surgeon Sir Thomas Dunhill. He recovered temporarily and May telegraphed the family in New Zealand with the good news. But 2 days later Rutherford's condition declined, and he passed away the evening of the 19th at the age of 66 (Eve & Chadwick, 1938; Cockcroft, 1946; Campbell, 1999).

Tributes to Rutherford poured in. A eulogy in the New York Times stated "*In a generation that witnessed one of the greatest revolutions in the entire history of science he was universally acknowledged as the leading explorer of the vast, infinitely complex universe within the atom, a universe that he was first to penetrate*." Albert Einstein referred to Rutherford as *"a second Newton"* (Campbell, 1999). J.J. Thomson remembered his former student during his last days at Trinity college college. He wrote:

FIGURE 7. Photograph of members of the Cavendish Laboratory 1936. Thomson and Rutherford are sitting front and center, with Aston on Rutherford's left. Reproduced with permission from reference Campbell, 1999.

FIGURE 8. Top: Francis Aston together with Ernest Rutherford (behind), Arnold Sommerfeld, and Léon Brillouin at the Volta Congress meeting in Como, Italy 1927. **Below**: Group photograph of delegates showing Rutherford and Aston aside one another. Reproduced with permission from Emilio Segrè Visual Archives, Frenkel Collection, American Institute of Physics.

"*He dined regularly in Hall on Sunday evenings and frequently brought distinguished and interesting men of science from other countries as his guests. His personality made him from the first a leading figure in our Society, as indeed it would in any other. It is difficult to imagine any one less like the traditional idea of a College Don than he was. To sit next to him in Hall was most*

FIGURE 9. Aston and Rutherford in discussion late in life ca. 1935. Reproduced with permission from papers of Sir Frederick White, Basser Library, Australian Academy of Science.

invigorating, he was so full of vitality and his conversation so breezy and unconventional that one felt as much refreshed as if one had been for a brisk walk on a bracing day. He was never commonplace, there was nearly always a great deal to be said for his point of view, and he said it very forcibly. I think he enjoyed vigorous discussion. I have heard him say that he liked a good 'scrap' now and then. I never knew him in better form than he was the last time he dined in Hall only ten days before his death. I happened to sit next to him and he seemed in almost exuberant good health and high spirits.

"*He has left behind him memories which will long be cherished by his friends, and his great discoveries will for ever be one of the glories of his college*." (Thomson, 1970). Earl Baldwin of Bewdley wrote of his character: "*His refreshing personality, his dauntless spirit, the merry twinkle of his eye, the exuberance of his ever youthful, ever joyful, enthusiasm. . . . (He was) a peer among men; he was Rutherford*" (Mann, 1976).

Rutherford's ashes were interned in Westminster Abbey in the company of such luminaries as Newton and Darwin. A solemn ceremony was attended by a group of British scientists, dignitaries representing the Royal Society, British Association, Royal College of Physicians, High Commissioner of New Zealand, Cambridge, Manchester, and McGill universities, and family members—his wife May, son-in-law Ralph Fowler, and Ern's niece from New Zealand. His mentor's ashes were to be laid next to him when J.J. Thomson died 3 years later in 1940, coincidentally on Rutherford's birthday August 30.

Aston outlived them both, surviving World War II to die 8 years after Rutherford on November 20, 1945 aged 68. Aston's death attracted considerable less attention, though he probably would have preferred it that way. J.J.'s son Sir George Paget Thomson wrote "*Aston was a man in whom a great zest or life was combined with a simplicity of character almost approaching naivety. . . . He was a conservative in politics as in life, and though he would admit that a change might be good, he preferred it to happen as gradually as possible*" (Thomson, 1946). Above all, "*Aston was a superb experimenter. His first mass spectrograph was a triumph; few but he could have got it to work at all*" (Thomson, 1946). Hevesy lamented in 1948 that "*The hard winds are blowing. The contemporaries of Lord Rutherford who helped him lay the foundations of nuclear science are following one by one their great leader. . . . Rutherford was the man Aston admired more than any one else. From 1919, he was a close friend of Rutherford and, as he has often remarked, benefited to a degree not to be described from the continual help and encouragement of that man 'til his death in 1937*" (Hevesy, 1948). Now it was Aston's turn to leave a legacy few accomplish in their lifetime as *"death came to him with the merciful suddenness for which he had always hoped"* (Hevesy, 1948).

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