Louis Harold Gray, 1905-1965

J. F. Loutit and O. C. A. Scott


Email alerting service

Receive free email alerts when new articles cite this article - sign up in the box at the top right-hand corner of the article or click here

To subscribe to *Biogr. Mems Fell. R. Soc.*, go to:

http://rsbm.royalsocietypublishing.org/subscriptions
LOUIS HAROLD GRAY

1905-1965

Elected F.R.S. 1961

LOUIS HAROLD (HAL) GRAY was not a product of his times; that is to say he was no opportunist who cleverly adapted his talents to the current circumstances. Rather he was a maker of scientific history and his genius would have been as apparent in any other age.

Particularly would he have been at home in London three centuries earlier. It has been recorded (1)* that the beginnings of the Royal Society stemmed from the urge in ‘a small group of learned men who were interested in the Experimental, or New Philosophy as it was then called . . . to meet occasionally in London for talk and discussions at the lodgings of one of their number’. The urge to meet with his fellow men for their mutual benefit by discussion of matters of science was characteristic also of Hal Gray. The New Philosophy which some would now equate with the scientific method owed much in England to Francis Bacon (one time of Trinity College, Cambridge) and would have delighted a seventeenth-century Gray. It was the natural revolution of the Renaissance period against medieval dogma and the confinement of formalistic scholasticism.

Further the New Philosophy was not subject-limited, and its exponents considered and discussed Physick, Anatomy, Geometry, Astronomy, Navigation, Statistics, Magnetics, Chymicks and Natural Experiments (2).

The twentieth-century Gray (also a product of Trinity College, Cambridge) was reared in an age when the cult of specialization for learning more and more about less and less was at its most fashionable. Gray and the few others of his ilk by some instinctive process foresaw that escape from this confinement depended on those with sufficient breadth of understanding somehow encompassing the new philosophies of the twentieth century and synthesizing the advances of physical, chemical and biological sciences into new concepts. In the process new disciplines are defined and named. This process the superficial reviewer might mistake for fission of accepted branches of science, whereas in fact fusion has occurred. Radiobiology and molecular biology are cases in point and Gray was the Fellow who fathered radiobiology.

* The numbers in parentheses refer to the list of references on p. 212.
Early life

Gray, who was born on 10 November 1905, records that his father and mother were poor. Presumably also there was no tradition of distinction for the family history does not extend beyond his grandparental generation.

Hal was an only child. It was with his mother (née Amy Bowen) that he enjoyed many practical things—paper-hanging, mending sash-cords, arts which they learnt not from books but from watching craftsmen. Being poor they ‘did up’ almost the entire house, inside, at one time or another. From his father he derived a love of fresh air, games and simple walking. When he was quite small they went for long walks on Sunday mornings—Barnes, Wimbledon Common, Queensmere, Richmond Park, and home. Father, Harry Gray, had little ‘conversation’, but was fond of figures. On these walks Gray, the son, delighted in being given simple problems concerned with the buying and selling of apples and oranges as exercises in mental arithmetic. So thoroughly did he enjoy them that he asked over and over again for another problem.

He went first to Latimer School from which at the age of 13 he won a scholarship to Christ’s Hospital. Thenceafter he saw his mother and father only at holiday time. This was just after the first world war (1918) when his father had been working very long hours. They loved to come to the school for ‘half-terms’, but his mother came little at first as she was nursing at home a favourite sister (Sarah Bowen) who eventually died of cancer. This aunt set before Hal an extremely high standard of unselfishness. She was ‘lady’s maid’ to Lady Smith Dorien and was greatly beloved. It was with her that he did his first bit of carpentry—later an absorbing hobby—making a bookcase out of a sugar box cut in half, nailed together and painted. It was very primitive but he was very proud of it, and it served as a bookcase at home for many years.

In the classroom at school, science was his consuming joy. Science and maths were the only things that really mattered to him. Of Latin, French, English, etc. he did only just enough not to impede his progress in science. (When he finished at the University he had read only about a half-a-dozen non-scientific books.) The masters at Christ’s Hospital who had a special influence on him were Chas. Browne (Head of Science), and Hyde (‘Dido’) who instructed him in maths and was later his House Master (Barnes B). He was very fond of both. Browne was specially important to him for several reasons. He found himself behindhand in actual chemical knowledge, and Chas. Browne encouraged him to ‘catch up’ by doing experiments and writing them up at home in the holidays. Also, Browne was cultured, and had wide horizons which were specially displayed in his home on Sunday evenings where meetings of the ‘Philosophical Society’ (for Science Grecians) were held and the boys were served tea and cakes by Mrs Browne. One holiday, Chas. Browne took as many Science Grecians as could come to the (then) Cancer Hospital in Fulham Road. Gray’s only memory was of
Major Philips dropping bananas into liquid air and taking them out quite brittle. After Gray left school Mrs Browne died of cancer but he was not conscious that these early contacts with cancer had any influence on his later career.

At 18, science, especially ‘molecular physics’, as typified by Crowther’s excellent little book which he read eagerly, was his absorbing interest. Mention should also be made of Kelsey his physics master. He was a very bad disciplinarian indeed, and was mercilessly ragged; but he was a good physicist who wrote excellent notes. These Gray enjoyed learning; they seemed so much more erudite, thorough, straightforward and elegant than the text-books, and no doubt helped him to get an ‘Exhibition’ to Trinity at Christmas 1923. He liked the notes too (even when difficult to understand) because they made good use of maths, including the calculus. Practical physics was done with pins and prisms on a drawing-board, and with homemade batteries and potentiometers. Kelsey invited him to stay with him for one or two weeks during at least one summer holiday at his cottage on the Isle of Wight.

**The Trinity College period**

Gray went up to Cambridge not much interested in biology, and very ignorant of the subject. He had done none officially at school, though the broadminded Chas. had tried to correct his bias in favour of the physical sciences by giving him a book on general biology to read (if he liked) in the holidays. Nuclear physics was so exciting in those days that it left no room for biology. One holiday he evidently stumbled upon the barrier-layer rectifier principle, because he could get ‘2LO’ on the crystal receiver he had built by placing the ‘cat’s whisker’ on the brass case only (not on the crystal). By deliberate investigation, he extended this chance observation to getting 2LO by a pointed piece of electrolytic copper touching lightly on electrolytic copper foil. He did not ‘publish’ this. He wanted to try first still further copper, chemically deposited, as he supposed that the rectification must be due to the occasional atom (or cluster of atoms) of impurity.

At Cambridge, aiming at taking Part I of the Natural Sciences Tripos at the end of his second year, Gray read physics, maths and chemistry for the first year and won a ‘Senior Scholarship’ (perhaps on the strength of his knowledge of nuclear physics); but he did poorly enough in ‘Mays’ to be advised to add mineralogy for the second year. This he did, and succeeded in getting a First in Part I at the end of the second year. The ‘mineralogy’ was helpful in the Part II Physics ‘Classical’ paper the next year as it gave him a good start on a question which involved wave surfaces in a material in which the coefficients of refractive index were different along three mutually perpendicular axes.

Having obtained a First in Part II Gray was honoured by admission to membership of the Cavendish Laboratory during that Augustine period 1928-1933 with Rutherford as Caesar, Thomson, Wilson, Blackett,
Cockcroft, Chadwick, Ellis, Aston et al., an inspired circle. Chadwick was his official supervisor and Ellis a mentor, much sought after and liked.

Coulson (3) who was contemporary with him at Cambridge describes Gray's research activities then:

'Gray plunged into a study of the interaction of radiation with matter. First he studied cosmic radiation, though at that time it had not yet been so christened. In order to throw light on the vexed question whether this radiation consisted of fast \( \beta \)-particles or ultra hard \( \gamma \)-rays, he studied the absorption of known \( \gamma \)-rays, verifying the theoretical predictions of the Klein-Nishina formula only just developed, following Dirac's relativistic theory of the electron.

'Next, he began his major study, to lead to his Ph.D. and a prize fellowship at Trinity, on the absorption of hard \( \gamma \)-rays. Tarrant had shown that the absorption coefficient per electron varied irregularly from element to element. First Gray showed, by comparisons of \( \gamma \)-rays from thorium C" and radium C, that there must be some additional mechanism to that described by the Klein-Nishina formula for electrons. Next he showed that this is not appreciably influenced by the forces binding the electrons to the atom. It now looked as if the incident \( \gamma \)-rays were exciting the nuclei to higher levels, and so characteristic secondary radiation would be emitted when the nuclei returned to their ground states. In a paper printed immediately before Chadwick's famous paper reporting the discovery of the neutron, Gray and Tarrant, by observing the radiation scattered at a large angle, where the usual Compton scattering was small, showed the existence of this secondary radiation. It appeared to be almost isotropic.

'Later enquiry showed that it could not be "characteristic radiation" of the absorbing systems, since it showed differences for radium and thorium sources. Nor could it be neutrons. It was to be identified with the annihilation of a positive and negative electron. Furthermore, these electrons must have been first produced together as a pair. This fitted with their energy, as shown by absorption measurements, and with the proposal, first made a year earlier by Blackett and Occhialini, that such annihilation should take place. Thus a whole new chapter in physics had been completed—rounded off a year later when Gray showed that there appeared to be no similar annihilation of helium atoms.'

While writing his thesis he got engaged to a Girtonian (née Frieda Marjorie Picot) who started to interest him in literature as a relaxation. The College Fellowship enabled him to stay on for three more years of research in nuclear physics. His fiancée, as she then was, came back to Cambridge as an 'out-student' of Newnham, and at the end of two years was awarded a II 1 in the Theological Tripos. She had done all the work for this, as also the previous work for her English Tripos (II, 1), either by reading Braille or by being read to.

Life was very happy for him, both in the laboratory and on the simple home front. At the Cavendish he occupied part of the large laboratory in
which the Cockcroft-Walton experiment was performed, and in which the neutron was discovered by Chadwick. It was also during this period that Anderson, in California, discovered the positron. Dirac was a familiar figure in Cambridge and at the Cavendish.

The turning point and middle life

Clearly, there was no lack of excitement in nuclear physics, but Gray began to find it not completely satisfying. Through his wife as she was by then, who had become a lay-preacher in the Methodist Connection, he became a member of certain Methodist youth groups whose members tried, according to their lights, to live strictly in accordance with the New Testament faith. They undertook various social activities corporately, such as setting up in a cottage, which they largely redecorated themselves, a family who were not real gypsies, but whom they found living in appalling 'stench' in a caravan as a result of falling on hard times (1932). It was at about that time, when Gray was becoming aware that there were perhaps things the world needed more urgently than nuclear physics, that he received a message, through Chadwick, that a hospital in London wanted a physicist to assist in the measurement of radium and X-rays used in the treatment of cancer. He decided at least to investigate the matter, came to Mount Vernon Hospital, was attracted by the Director, Sir Cuthbert Wallace, and by J. C. Mottram, the pathologist, who was using *Vicia* seedlings in an attempt to compare the biological efficiency of X-rays and γ-rays. The problem of measuring the X-ray and γ-ray energy absorbed in a root tip was a challenge; it looked as if it might yield to ‘cavity theory’ methods. As the hospital had only recently changed its speciality from tuberculosis to cancer and there had not been any physicist on the staff previously, the scope of the appointment for which he was being interviewed was quite undefined. After discussion with Professor Hopwood and Professor Russ, who were Professors of Physics in the Medical Schools of Bart's and the Middlesex respectively, he accepted the appointment (at a salary less than his aggregate earnings in Cambridge) on the understanding that his routine duties would be minimal so that most of his time could be devoted to research. On this account he was allowed to continue to hold his Trinity Fellowship for the remaining, fourth, year. This supplemented his salary, which at first was paid out of British Empire Cancer Campaign funds. After a year or two he became Prophit Scholar of the Royal College of Surgeons, and B.E.C.C. support became limited to the provision of equipment on a very simple scale through the block grant made by the Campaign to the hospital.

For the first year or so at Mount Vernon Hospital he had no technician, and did his own machining and construction of apparatus.

He began to gain some understanding of cancer from Sir Cuthbert Wallace, who took him on his ward rounds, and from J. C. Mottram. He was much indebted to both, especially perhaps to the latter, who was interested not so much in the classification of disease from the observation of
stained sections under the microscope, as in the dynamics of the growth process. Gray started to learn some biology by reading, in every available spare moment, books recommended by Mottram, and by attempting certain biophysical measurements, such as the permanent recording (by means of a Lindemann Electrometer) of the distribution of the bio-electrical potential along the length of a bean root. This was additional to the research which he carried out in collaboration with Mottram, which was essentially into the pure physics of dosimetry.

With his future line of work in mind, he had, before leaving Cambridge, secured the collaboration of Dr F. Gordon Spear in looking for an effect of Oliphant’s (D-D) neutrons on hens’ eggs. No effect was observed, which convinced him that if the biological effects of neutrons were to be studied, a much more powerful neutron source would be needed. He discussed with John Read, then on the staff of the Radium Beam Therapy Research Unit in London, the possibility that he would join in the project of building such a high current accelerator at Mount Vernon Hospital. Read agreed in January 1936, and, greatly daring, Gray asked the B.E.C.C. for a sum of money, £400 in the first instance, with which to buy components for a 400kV (D-D) neutron generator. With the help of J. G. Wyatt, who had already joined him as workshop technician, and a further £100 from the B.E.C.C., they built the machine and were obtaining their first biological results by 1938. Almost at the same time, John Lawrence and Paul Aebersold published the results of biological experiments made with neutrons generated in the 33 in. cyclotron of E. O. Lawrence. The biological efficiency of the Mount Vernon Hospital neutrons relative to X- or γ-rays was much higher than that of the Californian neutrons because the former were of considerably lower average energy. A dose unit, applicable equally to all types of ionizing radiation, was defined which, both in concept and magnitude, was almost identical with the rad; but Read and Gray infelicitously named it the ‘energy unit’ and 15 years were to elapse before the International Commission on Radiological Units and Measurements defined the ‘rad’ as the unit of absorbed dose in 1953.

Read and Gray parted company during the war. Gray would have refused military service had he been called upon—as a member of the Fellowship of Reconciliation he had taken the Pledge of the Renunciation of the Method of War several years previously, and had asked for a ‘tribunal’. However, his age was always just above the ‘call-up’ age. He declined an invitation to go to Cambridge to carry out neutron research which was said to be part of the ‘war effort’.

To understand this side of Gray’s character one can cite John Read:

‘The great influence Gray had with me was somewhat weakened by a certain impracticability in his nature when dealing with other people. In 1936 he organized a party of us to go for a holiday in Bavaria, and he was very eager to do what he could to promote friendship between nations. On a tramp, miles in the country, we came across an old peasant woman trudging
along with a great load on her back. Gray rushed up to her and asked to be allowed to carry it. Seen through her eyes she was accosted by a strange man dressed in outlandish clothes, speaking German with an unfamiliar accent with evil designs on her baggage. She clutched it tightly and hurried on as fast as she could. A trip for the party to a salt mine near Salzburg was organized, where we were taken round the tunnels by a guide. At the end he evidently expected a tip. There was no special reason why we should have left the collecting of this to Gray except that his strong personality had conditioned us to sit back and let him organize affairs. But it did not occur to Gray that anyone should expect a tip for doing his duty, and the venomous look the man gave us as we left showed that on this occasion we had not succeeded in promoting friendly international relations. Gray urged negotiation with the Nazis. He made the mistake of populating the world, in his imagination, with people like himself, believing that they held contrary views and behaved differently simply because they had not seen the Light. This had only to be explained to them clearly and patiently and they would respond.'

It was during the war, while working alone, that Gray felt the urge to discover the cellular basis of root growth inhibition by radiation, as distinct from the use of this effect simply as a criterion for the equality or otherwise of two conditions of irradiation. In this he had the expert collaboration of Mrs Scholes, who, though serving as a technician, had the skill and knowledge of a graduate in botany. Together, they accumulated an immense amount of observational data, both macroscopic and microscopic, which was not published till Gray had moved on to become a member of the staff of the Medical Research Council's Radiotherapeutic Research Unit at Hammersmith Hospital.

**Maturity**

During World War II great technological developments had taken place leading to directed nuclear fission and to higher rated and more reliable high energy machines. After the war the Medical Research Council (Secretary, Sir Edward Mellanby, F.R.S.) hastened to adapt its policies to the new and expanding needs of peace-time research. To take care of the biological aspects of developments in nuclear physics the existing Radiotherapeutic Research Unit at Hammersmith Hospital was enlarged and diversified. New units and groups were formed to intensify the study of the biological action of radiations (radiobiology) and apply the newly available radiations and radioactive materials to clinical use (sometimes called nuclear medicine). Gray was specially recruited by the percipient Mellanby to be senior physicist at the Council's Radiotherapeutic Research Unit (Director, Dr Constance Wood). Specifically Gray was to develop techniques which would promote the use of radioactive isotopes and to apply to radiobiological research the electrostatic generator which was being built by Boag and Howard Flanders.
The new staff which Gray recruited, Norman Veall for radioisotopes, Stephen Pelc for autoradiography, Alma Howard and Shirley Carter for cytology and later Tikvah Alper, Michael Ebert and Oliver Scott together with other names cited formed a combination which has now become of historic significance in British radiobiology.

The most important item of equipment for the unit was to be the medical cyclotron. It was to serve three purposes:

(a) to produce those isotopes (mostly of short life) not available from reactors;

(b) to supplement and extend the range of high LET radiations available from the electrostatic generator for radiobiological research; and

(c) to provide neutron beams suitable for a clinical trial of neutron therapy.

A new building would obviously be required to house the cyclotron (appropriately shielded) and to provide rooms in which could be carried out the processing of isotopes, the clinical use of isotopes of short life, and the clinical administration of neutron therapy. It was decided also to instal in this building an 8 MeV linear accelerator for an experimental trial of super-voltage X-ray therapy. There were two alternative designs for the accelerator: one, a cavity-resonator type proposed jointly by Newbery (one of the M.R.C.’s own physics staff) and Wilshaw at the G.E.C.; the other, a travelling wave type proposed by a team under the direction of D. W. Fry at the Telecommunications Research Establishment at Malvern. After several years of experimental work, the latter type was preferred and a contract was placed with Messrs. Metropolitan Vickers for the construction of a machine to design specifications supplied by Mr Fry. For the building of the cyclotron a senior cyclotron engineer (John Gallop), his first assistant (Derry Vonberg), and several further members of the team were appointed (1948). Planning all these projects, negotiating for land, supplying information to the firm of Ramsay, Murray & White, the architects chosen for the building, took much time and left little for personal research. The Director of the Unit, Dr Constance Wood, was a radiotherapist by training and naturally relied heavily upon the advice of her engineers and physicists, of whom Gray, as senior, was generally spokesman.

In 1949 three events happened to coincide: the retirement of Sir Edward Mellanby from the Secretaryship of the M.R.C.; a general financial crisis with devaluation of the currency; and the submission of the final drawings and estimated cost of the proposed new building, which proved to be much more than was originally estimated.

A review de novo of the cyclotron project was called for, including a separate justification of the expenditure in the light of each of its proposed three uses. As a result of numerous reports and many discussions, the project was deemed, by a narrow margin in the Council’s appropriate Committee, to have been justified, but the specification of the machine was demoted.
from the original 60 in. to 45 in. The decision to continue with the project was due in no small measure to the inspired advocacy of Gray and Spear.

Following this period of stress and delay, the group proceeded to the task of building the cyclotron, developing isotope methodology, and conducting radiobiological research. It is easy to imagine that it would appear to some that the scientific work of the Unit was not leading to medical discoveries commensurate with their heavy financial commitment. In fact, some of the most widely-quoted papers, and most widely-used techniques (such as stripping film autoradiography) as well as classical results such as division of the DNA synthetic cycle into the G₁, S and G₂ periods, were contributed by members of the Unit's staff at that time; and those who saw, day by day, the excellence of the engineering which was going into the building of the cyclotron had no doubt at all that the outlay would prove in the long run to have been a sound overall investment for medical research.

The delays inevitable with an engineering project of this magnitude were nevertheless such as to cause frustration. In such circumstances the differing backgrounds and aspirations of the clinical Director, Dr Wood, and the non-clinical Deputy Director, as Gray had been for some years, led to personal difficulties and tensions between them. This divergence by 1953 had become acute. By then Gray was convinced that oxygen could be important in radiotherapy. In 1952 he had been struck by certain similarities in the effect of oxygen on the response to irradiation of five different plant and insect tissues, which had come to his notice in the course of preparing a review paper. He circulated an internal document (copies still extant) on certain proposed lines of investigation into the effect of oxygen on chemical solutions, mammalian cells in culture, and animal tumours, upon which at least five members of the Unit were concentrating their attention. By the beginning of 1953, the principal results of these investigations were known. Although these results were extensively discussed with medical colleagues the matter was not taken up at the clinical level.

In the difficult circumstances of a schism between Director and Deputy Director, Gray after presenting his case to the Medical Research Council, resigned. He was given six months leave of absence with pay. The Council would indeed have been very willing for Gray to be remustered in another of their Units whence such an offer had immediately come. However, a new proposition arose.

Owing to the generosity of an anonymous donor the British Empire Cancer Campaign was able to found a radiobiological laboratory at Mount Vernon Hospital. Furthermore, the British Empire Cancer Campaign created Gray a Nuffield Fellow in November 1953 at the end of the six-month period, part of which he had spent in Liège and part in Stockholm, and Director of their Research Unit in Radiobiology with terms of reference which placed him in the scientifically ideal position, from his point of view, of being Director of a radiobiological research Unit with no responsibilities outside that of carrying out fundamental research in radiobiology in relation
to the general problem of cancer—its cure and understanding. The sadness he had felt at the break-up of the excellent team at Hammersmith was to a considerable extent offset by the fact that some members of the team, on the radiobiological side, joined him at Northwood, while some others obtained good and appropriate appointments in departments devoted to medical and biological applications of nuclear physics. He decided to switch his main interest from the influence of LET in radiobiology to the study of initiating events on the microsecond time scale, by means of a very high current linear electron accelerator, and, of course, to some of the numerous ramifications of the question of the influence of oxygen on the radiotherapy of tumours which had been opened up by the Hammersmith team during the 1952-1953 period.

B.E.C.C. Research Unit in Radiobiology

Gray returned to Mount Vernon Hospital to establish the new Unit in September 1954. The team at that time consisted of J. W. Boag, who was, however, seconded to work with Professor Rotblat at St Bartholomew’s Hospital Medical School in the absence of accommodation and radiation sources at Mount Vernon, O. C. A. Scott (later Sir Oliver), who had been a research student at Hammersmith, a secretary, and R. R. Ransley, technician. A visiting worker from America, Dr Eleanor Deschner, completed the group. Accommodation was primitive in the extreme. Gray was given the use of a building erected during the war as an emergency ward, which lacked a proper heating system. During the first winter he could be seen seated at his desk wearing an overcoat with a scarf round his neck, but nevertheless working long hours with undiminished good humour.

Gray’s contribution to the Annual Report of the B.E.C.C. for 1954 still makes the most interesting reading. In it will be found the definition of the term ‘reproductive integrity’, a concept which has been of the greatest use in cellular radiobiology and which Gray considered carefully before accurate mammalian cell survival curves became available.

In the following March the group was joined by Professor Ernest Pollard on sabbatical leave from the United States. In collaboration with Deschner, Gray began a most detailed study of chromosome breakage in the Ehrlich ascites tumour, using methods which had been pioneered at Hammersmith by Dr Alan Conger, a visiting American cytologist. This work called for a vast amount of tedious, time-consuming, experimentation which was necessary to establish the base lines before new work could be undertaken. The need for perfect equilibrium of gas phase and liquid phase in the experiments on the oxygen effect on these cells taxed even his powers of careful experimentation, and unfortunately much of the first year’s work had to be thrown away owing to the failure to get the experimental conditions correct. In fact, it was not until the work of Howard-Flanders and Alper on bacteria had been performed that this project with the Ehrlich ascites cells was placed on a really sound basis.
In October 1955 Dr John Hunt from Saskatchewan joined the group to develop equipment for spin resonance studies in irradiated materials.

The year 1956 saw a great expansion of the work at Mount Vernon. The new building was completed and occupied, although it was not officially opened until the following year. The design and lay-out of this building were the result of Gray’s deep thought on the most economical use of space for a radiation laboratory, and it is a tribute to his planning powers that no fundamental errors of design have been discovered in the ten years that the building has been in use. Surprisingly, his one omission from the plans was a room in which to make the tea, in view of his addiction to the drink (symbolic teapots are still to be seen decorating the floor of his office).

Alma Howard, whose work on auto-radiography with Pelc had already attracted wide interest, and who had been a member of the original Hammersmith team, joined them on 1 January 1956, and a microbiologist, David Dewey, was brought in to work initially on problems in biochemistry related to radiation. Visitors from abroad included Professor Herman B. Chase of Brown University who worked on radiation effects on the skin and hair of mice, Dr W. Rodger Inch who had developed work on the oxygen electrode and Dr John Read on sabbatical leave from New Zealand who used this period to write a book on radiation effects on the bean root. Boag began to assemble the electron pulse generator and the machine came into operation in the following year. At this time Gray had hoped to use this machine not only for pulse radiolysis but also in combination with electron spin resonance methods. The former technique has, of course, proved to be extremely successful and has indeed brought about a revolution in radiation chemistry. The latter approach proved to be of less value at Mount Vernon.

On 20 May 1957, His Grace the Duke of Devonshire, Chairman of the B.E.C.C., officially opened the new building and immediately afterwards the Unit acted as host to the Radiation Research Visiting Club, the organization which subsequently developed into the British Association for Radiation Research.

In September of this year, Professor F. O. Green, a chemist from Wheaton College, and Dr R. J. Horsley from Hamilton, Ontario, joined the Unit as visitors.

In collaboration with Dr M. Ebert of the M.R.C. Experimental Radiopathology Research Unit, Dr Howard had begun her studies on the radioprotective effect of inert gases. Boag and Dewey carried out some experiments on the effect of single 2 μs pulses of electrons delivered by the linear accelerator on vegetative bacteria, and Dr E. L. Powers, from the Argonne National Laboratory, and Boag, experimented similarly on bacterial spores. These experiments marked the beginning of an exciting new phase of radiobiology which might be called pulse radiobiology.

In an attempt to find a radiosensitizer which would simulate the effects of oxygen, the paramagnetic ion Co²⁺ was tested to see whether it had an influence on aerobic radiosensitivity of mammalian cells.
In 1960 work was reported on the influence of pre-irradiation storage of ascites tumour cells on radiation sensitivity. Dewey investigated the effects of \(N\)-ethyl-maleamide, a sensitiser, and glycerol, a protector, on \textit{Serratia marcescens}.

For some years, Gray himself had taken a particular interest in the electro-chemical cell developed by Paul Hersch for the measurement of oxygen tension, and, despite his administrative and other duties, he found time to make himself an expert in the handling of this particular piece of equipment which was used for the micro-assay of oxygen in dissolved liquids and oxygen in the gas phase. As a result of this work, Gray and Dewey influenced many radiobiologists throughout the world to control oxygen tension at the time of irradiation with greater care than had previously been the case.

Dr R. E. Steele from Stanford University, and Boag, reported preliminary experiments on the observation of transient products in sample radiochemical systems. Dr G. Froese from Ontario, using an oxygen electrode, measured the relationship between oxygen tension and respiration rate in ascites cells, and showed that the level of oxygen tension which is critical for oxidative metabolism is much lower than the critical level for the change in radiation sensitivity.

In 1961 Gray again demonstrated his versatility as an experimentalist, and his capacity for absorbing the essentials of a new discipline, when he carried out some work on the haemoglobin dissociation curves for mouse and rat blood, and he also began some work on radiation carcinogenesis in an attempt to see whether radiation could be regarded as an ‘initiator’.

Meanwhile, in 1959 the Association for Radiation Research had decided to organize the second International Congress for Radiation Research in 1962. Gray had been elected Chairman of the organizing committee, as well as President of the Congress, and he gave an enormous amount of his time and energy to the detailed planning of this meeting. Dr Alma Howard was elected General Secretary and Dr Scott was a member of the Organizing Committee. Thus, a great deal of the organizational work in connexion with the Congress became centred on the Unit, with the inevitable result that experimental work was, to some extent, put on one side. As the Chairman, Gray was almost over-anxious, taking upon himself the main burden of responsibility for the success of the Congress. This stress was to last for two years.

During this period, despite the disruption brought about by the Congress, some exciting experimental work was carried out in the Unit, Dr E. J. Hart from the Argonne National Laboratory, with J. W. Boag, announced the discovery of the spectrum of the solvated electron (which had, however, been independently observed at Manchester). Dewey was later investigating the apparent radiosensitization of 6 amino-nicotinamide, which subsequent careful work showed to be due to a most interesting experimental artifact.

Many of his friends felt that Gray over-taxed himself in his efforts for the
Harrogate congress, and it was clear that he was extremely exhausted in the autumn of 1962. In January 1963 he had a stroke of great severity which kept him away from the Unit for five months. He never fully recovered the use of his left hand, and it was a great sorrow to him that he could no longer carry out the fine cabinet making, which had been a hobby and a relaxation to him for many years. With great courage he set about the task of rehabilitation and, contrary to the advice of his friends, he insisted on accepting an invitation to give a series of lectures in Japan in March 1964. Despite his disability, he took immense trouble with this series of lectures and made a very great impression on his Japanese hosts.

Earlier Gray had made the acquaintance of H. B. Hewitt and was very much impressed by the accurate quantitative studies on tumour transplantation which he had carried out. It was soon suggested that Hewitt should join the radiobiology unit, but before this could be brought about it was necessary to build a new animal house. There were long delays involved in arranging for the finance, and later for the construction of the necessary new building, which was not completed until the end of 1962. Since that time Hewitt has built up his animal colony and continued his valuable studies on in vivo radiation survival curves.

In the last year of his life, Gray, for the first time, revealed a certain lack of faith in his own powers and in the future of the Unit, and he even feared that the Unit might be closed down and the work brought to a stop. It was sad to his friends to see that tasks which had once been easy for him were becoming a labour and trial. Despite this undercurrent of sadness, he nevertheless continued to throw out new ideas until the day of his death. His thoughts about radiation carcinogenesis which were announced in his Bertner Award Lecture in 1964 have already proved of great value for the interpretation of data in this field. Ever since his first paper on the oxygen effect in 1953, he had kept closely in touch with the clinical developments in connexion with the use of high pressure oxygen in radiotherapy, developments which appealed to his humanitarian as well as his scientific interests.

In the last few weeks of his life he had become intensely interested in the clinical possibilities of combining a new instrument, the cathetron, with high pressure oxygen in the treatment of carcinoma of the cervix, and he was delighted to hear the night before he died that there were exciting possibilities for this combined treatment.

The list of Gray’s publications during the period between 1953 and his death gives a rather misleading impression as to the breadth of his scientific interests. Throughout this time he was taking the keenest interest in nearly every area of radiation biology, and by means of his referee reports, on material submitted for publication; by his personal discussions with scientists from all over the world, he was exercising a continuous and beneficial influence on most areas of radiobiology. Despite this passionate concern for scientific truth, however, human beings always came first with him and it is perhaps symbolic that the morning of the day on which he was
struck down with his first stroke was spent arranging for the admission of a junior technician into hospital—a task which could easily have been delegated but which he felt it was his duty to do himself.

**Societies and Committees**

Though Gray could be readily persuaded to concern himself with service for the common weal, undoubtedly what most fascinated him was discussion and the exchange of ideas. For such activities are societies formed. The British Institute of Radiology was a long established and catholic body which catered for many interests. Gray was a Member, sometime President and honorand through the Roentgen Prize and Faraday Medal. Despite the existence of such bodies there is nevertheless need for smaller and more specialized groups. Such a one is the Hospital Physicists' Association of which Gray was founder member and also sometime President.

Particularly in the post-war years there arose a need for a forum where those interested in multilateral aspects of effects of radiation could commune. In the United States of America the Radiation Research Society was founded. E. L. Powers whose ties with Gray were many and firm, writes: (4) ‘The first annual meeting of the Radiation Research Society was held in Iowa City in the spring of 1952. At the invitation of the Society, Hal Gray gave one of the two major addresses. His topic was “Some characteristics of biological damage induced by ionizing radiations”, a masterful summary of the state of knowledge at the time. The Radiation Research Society had just been conceived at Oberlin and born at Washington, and this meeting was its first and an uncertain attempt to realize its goal of uniting physical and biological scientists interested in radiation effects. To many in the Society the choice of Hal Gray was the most appropriate and the most fortunate one that could have been made at the time. A physicist of solid accomplishment and repute spoke knowingly and sympathetically of the complex problems presented by the irradiated biological organism. He threw the challenge to all the varied scientists present; his mood was enthusiasm and optimism, almost gaiety, over the exhilarating intellectual experiences offered. As some of us reflect on the history of this Society that has grown so well since the meeting, we think that he set a tone and an outlook that convinced us that the Society had meaning, that its goals were attainable. Certainly that evening many of us were inspired to look beyond ourselves and our own traditional and sometimes narrow interests.’

Similarly Gray fostered the growth of a British equivalent. For some years a Radiation Research Visiting Club had been in operation. The principle was that laboratories undertaking research in radiation would invite as many outside members as they could conveniently house and entertain to visit for discussions, demonstrations, dinner and combibulation. These informal meetings proved extremely popular amongst physicists, chemists, biologists and radiological physicians. From this Visiting Club the Association for Radiation Research was formed with a more formal set of rules and officers.
but maintaining the freedom of the Visiting Club for the host organization to organize meetings in ways characteristic and convenient for themselves. Gray was the first Chairman of the Association (1958-1960).

It was during this first biennial chairmanship with the uncertain exchequer of a new and small society that a sincere but rather tentative invitation was issued to an informal international committee to hold a second international Congress of Radiation Research in Great Britain. A first Congress has been successfully held in Burlington, Vermont, U.S.A. in 1958. It was generally thought that two earlier bids by other national bodies would take priority. In the event, however, the other two nations subsequently withdrew leaving the Association of Radiation Research figuratively holding the baby. Where some of his more canny associates were dismayed by the financial obstacles, Gray who had been elected to be chairman of an organizational committee was disarmingly confident. Time and the help of some very effective committee members were to prove Gray right. The Congress held at Harrogate in August 1962 was successful in a variety of respects. It was typical of his meticulous concern for detail that in the spring of 1962 he noticed an error in the budgeting which had escaped the attention of the rest of the Committee and, as a result of his personal efforts, was able to raise extra finance for the support of the Congress. When the meeting took place at Harrogate he did not spare himself if he thought his efforts could contribute in any way. For example, though he took no pleasure in delivering the after-dinner speech, he imposed on himself the burden of giving no less than four in one evening to the four sections of the Congress Banquet which had to be housed separately owing to the large numbers who attended the meeting. Thanks to his efforts and those of Dr Howard, it was generally agreed that this Congress was a remarkable success, and it will be remembered as the first radiation congress to pioneer the rapporteur system, which enabled the plenary sessions to cover a wider range of topics than would otherwise have been possible. At this meeting Gray played an active part in the formation of the International Association for Radiation Research.

Anyone as good natured and as public spirited as Gray cannot avoid committee work, and for him this included national and international committees.

The intense interest in both the physical and the biological aspects of nuclear energy following the close of World War II has already been noted. The Medical Research Council was naturally heavily involved in advising the appropriate Government departments, for example, the Ministry of Supply which was responsible for research and development in the physical, chemical and engineering aspects of production of nuclear power and the Ministry of Health for the medical uses of radioactive substances and ionizing radiations. Gray who had recently been recruited as the Council's special expert in the field was heavily involved as Secretary of the Council's Committee of that time—the Committee on Medical and Biological Applications of Nuclear Physics (Chairman, Sir Henry Dale) and as a member of
each of its three sub-committees—Clinical, Protection and Tracer Elements. Within a few years this Committee was split into two parts, one dealing with clinical problems and the other with protection.

Protection against ionizing radiations posed a formidable problem. Fortunately Britain had been one of the leading nations a decade or so earlier in awareness of the hazards of such radiations for medical operatives and through the British X-ray and Radium Protection Committee had initiated codes of protection for the occupationally exposed. At the international level the International Congress of Radiology had set up two commissions—the International Commission on Radiological Protection and the International Commission on Radiological Units and Measurements.

The recommendations of these two commissions in their early work before World War II had formed the basis of the codes of practice adopted during wartime developments of nuclear fission in the U.S.A. The change to peaceful developments led by the United States but followed in Britain necessitated not only extensive revision of former concepts and practices but evolution of much that was new concerning man-made radioactive substances and the genetic problems connected with potential exposure of whole populations rather than a small corps of specialized workers. Gray was in the thick of all the activities on the M.R.C.’s Protection Committee and its Tolerance Doses Panel.

With the passage of time the Medical Research Council’s structure altered according to temporal needs. The Protection Committee in one form or another, under various names and new Chairmen, survived and Gray was an essential member for over 10 years. His leaving the Council’s service in 1953 had not lessened the demand for his advice, either by his colleagues on Committee or by the Council itself which invited him to be Chairman of the Sub-committee on High Energy Radiation and Heavy Particles.

At the level of Government, advice begets legislation which in turn begets regulation and code. As a result of the first Radioactive Substances Act the Minister of Health, who had been cited as the responsible minister, was required to set up an Advisory Committee to advise him on the proscription of codes of practice and regulations. Once again Gray was a natural selection and he served on this committee under successive chairmen, ministers, and even ministries until his death.

The association with so many relevant national committees and his own inalienable position, particularly the latter, led to Gray’s recruitment into both the International Commissions mentioned above or their committees. These bodies are still somewhat atypical of international organizations in that the members are not recruited to represent their country but for their personal expertise in a specialized field. Gray was a member of Committee IV (Protection against Electromagnetic Radiation up to 3 MeV and Electrons, Neutrons and Protons) of the International Commission on Radiological Protection for two periods from 1953-1956 and 1956-1959.

As to his activities on the International Commission on Radiological Units...
and Measurements, Dr Lauriston Taylor, the Chairman for many years, writes:

'Gray was elected to membership of the I.C.R.U. at its Copenhagen meeting in 1953. In 1956, he was made Vice-chairman of the Commission, a position which he held until his retirement from the Commission in 1962. Throughout this period he was not just a member; he was active at all times and played a major role in some of the very important decisions reached by the Commission during that period. It was in fact one of the most productive periods of the Commission’s entire history, and I think it can be safely said, that to a considerable measure this was due to Gray’s contributions.

'I can remember many times, when we were faced with some thorny problem involving fundamental science or philosophy regarding radiation quantities and units. Arguments around the table would seem to be endless, until finally I would ask Hal if he would mind looking at the question that evening and seeing if he could give us some help by the next morning. He would retire to his room, open the windows and start thinking. By morning he would almost invariably have a rational solution which would take into consideration most of the feelings that had been previously expressed and which would leave everybody feeling well satisfied.

'Gray’s ability to think through some of our problems so clearly goes back, of course, to his early training and interests, and the fact that he himself had made one of the most fundamental contributions to radiation dosimetry . . . the principle now known as the Bragg-Gray Principle. It should in fact have been called the Gray Principle, for although Bragg had thought about it in another connection, he had not seen through its important long range implications. It was Gray who had the ability to do this, and to express it in a manner which was convincing to everyone who read even his first paper on the subject. If we were to carry the analog back we should probably now be referring to the Crookes-Roentgen tubes.

'The other facets of Gray’s experience which contributed importantly to this was his work in radiobiology where he himself had to work with dosimetric principles. This gave him a strong sense of perspective as to the relationship between the biological effects under study and the dosimetry necessary to study the physical aspects of the irradiation. This experience prevented him from going off the deep end, either by carrying the physical principles to ridiculous extremes or imputing more to them then they were in fact worth. It was his broad sense of balance and judgment that made his contributions so important in a myriad of ways throughout his activities with I.C.R.U.

'Of course, all of this was coupled with his own personality. However strongly he might have felt about a problem, he was able to suppress his own viewpoint and look at a question clearly and objectively. This is not to say that his own viewpoints would not be brought into the considerations, but they would certainly not be introduced in a way that was ever offensive to
anyone. Throughout the world, Gray’s judgment was valued and respected, and his consultation was constantly sought after.

Conclusion

Gray the physicist and radiobiologist was a leading experimentalist of his time. However, in retrospect it was the influence of Gray that was of outstanding importance to science. He was able to communicate much of his own evolution to his fellows, not so much by elegant prose or by fine oratory but by personal discussion. Numerous correspondents attest this, perhaps unconsciously, for descriptions abound of his inimitable and explosive laughter, his evident interest in people as people as well as for their ideas, his natural ability to make and keep friends and of his little idiosyncrasies such as the invariably worn Trinity tie. Perhaps the most illuminating tribute to this man is that sent by his wife to a Guernsey newspaper:

‘Dr. L. H. Gray, F.R.S., whose obituary appeared in The Times today, was intimately connected with the Island of Alderney, where his ashes will be brought to rest in the family vault of his wife’s ancestors. Year by year he came to the Island which he grew to love dearly, wanting his children to be proud of having roots in a place where so much history lies quietly about the soil; and saying, as he watched the sea surges on the great rocks of the Swinge: “I have seen many beautiful places in other parts of the world, but nowhere anything better than this.” He loved to lie on his back in the water at Telegraph Bay looking up at the colours in the cliffs.

‘The Island people knew him not so much for the achievements of his intellect, which have been stressed in the big newspapers, as for the warmth and simplicity of his personality. It is this warmth, as well as inspiration, that is being touched on in messages all over the world.’

J. F. LOUTIT
O. C. A. SCOTT

REFERENCES

BIBLIOGRAPHY


1940d. (With J. Read.) The neutron emission from a generator operating at 300 kV. *Brit. J. Radiol.* **13**, 248-253.


1948a. (With J. Read.) Comparison of the lethal effect of neutrons and gamma-rays on mouse tumours (a) by irradiation of grafted tumours in vivo, (b) by irradiation of tumour fragments in vitro. Brit. J. Radiol. 21, 5-10.


1954b. Conditions which affect the biologic damage resulting from exposure to ionizing radiation. Acta Radiol. 41, 63-100.


1959h. Radiobiological mechanism at the cellular level: lines of investigation which have been opened up by the recent technical developments. *Ibid.* pp. 282-300.


Louis Harold Gray


