C. K. INGOLD AT UNIVERSITY COLLEGE LONDON: EDUCATOR AND DEPARTMENT HEAD

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The outstanding scientific work of Christopher Kelk Ingold (1893-1970) was the focus of considerable discussion, celebration and evaluation during the year of the centenary of his birth. In addition to understanding his prolific and highly original scientific output as a pioneer in the application of physical methods to organic chemistry and, indeed, as a founder of physical organic chemistry, it is also important to examine other aspects of Ingold's career, in particular his role in shaping the institutional context in which he developed his work(1). From 1930 until his death, Ingold was attached to a major international centre, the Chemistry Department of University College London. From 1937 to 1961, as its Head and Director of Laboratories, continuing the policies of his predecessor on chemical education and the organisation of research, he developed a very distinctive chemistry department.

Ingold arrived at University College London to take up its second Chair of Chemistry with his reputation already firmly established. The outline of his education and career is well known(2). He began his tertiary education at the Hartley University College in Southampton where he took an external BSc of the University of London in 1913. This was followed by a period at Imperial College London (Associate of the Royal College of Science, 1914), three years working under the War Office for the Cassell Cyanide Company, and then three years as a research chemist for them in Glasgow. He qualified as an Associate of the Institute of Chemistry in 1919 and also gained a University of London MSc in that year. Ingold was keen to resume academic life and, in 1920, he returned to Imperial College as a demonstrator and subsequently a lecturer(3), gaining his DSc in 1921 as well as the first-ever Meldola Medal of the Institute of Chemistry (for a promising young scientist) in 1923 and becoming a Fellow of the Institute of Chemistry in that year. While at Imperial, Ingold worked with Jocelyn Field Thorpe (1872-1940)(4); his research thrived and, in 1924, he was made an FRS at the very young age of thirty.

In that same year, he became Professor of Organic Chemistry at the University of Leeds, a position which he held for six years. In later years, Ingold would say that Leeds was where(5):

> I did my chief personal *pedagogic* research, finding out by trial and error how to present organic chemistry to students more rationally and less empirically than was formally [*sic*] the custom - as a science rather than an art. (We have done a lot more since on the integration of the branches of chemistry, but that is another story.)

It is that 'other' story with which this paper is concerned.

Early Years at UCL

The UCL chair which Ingold took up had recently been retitled from 'Organic Chemistry' to simply 'Chemistry'. Apparently innocuous, the change is actually quite significant for understanding the outlook of the department which had the famous physical chemist, Frederick George Donnan (1870-1956) (6), as its head. From the time of the reconstitution of the University of London in the early years of the century, the UCL Department of Chemistry had had two chairs: one of General Chemistry and one of Organic Chemistry. It was known late in 1929 that the organic chair would fall vacant in the autumn of 1930 and Donnan took the opportunity to restructure, proposing that both Chairs be retitled simply 'Chair of Chemistry'(7). Because they were technically chairs of the University of London, of which Uni-

versity College London was one of the federated members, such a change had to be approved by the University Senate as well as the College authorities. Speaking as the representative of Imperial College, Ingold's former collaborator, Thorpe, objected strongly, arguing that teaching and research in organic chemistry would be undermined in the University just at a time when the subject was of increasing importance to industry. Donnan was straight with the relevant University Subcommittee; its minutes noted that he proposed the change even if it might mean a temporary diminution in teaching and research in organic chemistry(8):

> ... so that the new Professor may develop the application of physico-chemical concepts to Organic Chemistry. He [Donnan] considered that twenty-five years hence wave mechanics and the electronic ideas will displace what is now known as Organic Chemistry; he [Donnan] states that no chemist exists at present who has done such work but that one man may be capable of beginning to work on these lines.

Donnan himself had promoted this view of chemistry for some years and it would seem that he clearly had Ingold in mind (9). The full Senate did not receive that part of the Subcommittee's minutes, but the extract it did receive clarified Donnan's departmental orientation more generally. It was an orientation which Ingold was to share and further(10).

> University College has every intention of furthering in every possible way the study of Organic Chemistry, and ... it is not intended to replace the Chair by a Chair of Physical Chemistry. The wish of the College is to bring organic chemistry, like chemistry, into a homogeneous science, which may, and it is hoped will, advance on a broad front, making as much use as possible of the results, methods and theories of physical and chemical science. In the past there has been too much subdivision and too much specialization, and there is now urgent need for bringing together in close relation of all these arbitrary divisions of chemical science. The new professor will be bound to do his utmost to further the progress of organic chemistry. In order to give University College the necessary freedom for progress and advance, both as regards teaching and research in all branches of chemistry, it is desirable that the two Professors be styled simply 'Professors of Chemistry'.

C. K. Ingold, D.Sc., 1921

It was an internationally famous department that Ingold joined, built up particularly on the inorganic and physical side by Sir William Ramsay and by Donnan who had succeeded Ramsay as Professor in 1913 and become Head of Department in succession to J. N. Collie in 1928. Donnan had been largely responsible for re-establishing the department after the First World War, and, perhaps as a consequence, by 1930, he had more or less ceased to be an active researcher himself, though he remained active as an editor and masterly author and his reputation continued to attract students. He was at the height of his powers as an organizer of science, an international figure who enjoyed close relations with industry.

Ingold's first task at UCL was to build up an independent research presence; only one student had moved with him from Leeds(11). Apparently Ingold made it clear to Donnan almost immediately that he wished to deal with the College administration on his own behalf rather than through the head of department(12). Ingold received a start-up grant of £1000 from the College, at a time when the departmental grant was only about £3000 p.a., on the grounds that the organic laboratories had been rather allowed to run down(13). By 1932, an assistant lecturer post in organic chemistry was authorized though, in a move that was to become characteristic of his later administration as head, Ingold extracted a quart of staffing from his pint of resource by appointing his two star researchers (C. L. Wilson and E. D. Hughes) to senior demonstratorships instead, arguing that there was

a very restricted field at the time, and it would be better to wait for the right person to fill the lectureship(14). It is thus hardly surprising that Ingold was successful in establishing a separate identity at University College London and by the middle 1930s, students recognized two very definite 'sides' to the department(15). At the same time, it is also remembered as having been a remarkably harmonious, open and mutually supportive department(16). Publications flowed steadily. Ingold, by contrast with Donnan, was an extremely active researcher as an individual, and was not linked in with industry in the same intimate way. In terms of research style, Ingold's students worked more as a group; that is, several of them tackled particular projects focussed on an overall goal towards which Ingold was working, a marked contrast with Donnan's *laissez-faire* style (17). At the same time, Ingold planned his researches like long-term strategic campaigns, advancing across a very broad front. However, Ingold's personal style as a supervisor was apparently similar to Donnan's(18).

As a doyen of British chemistry in this period, Donnan was an accomplished fund-raiser, especially from Imperial Chemical Industries and from the Government, and his was by far the larger of the two groups at UCL so far as senior researchers were concerned. But as Donnan approached retirement, the department entered a period of instability. Considerable funding which the department had enjoyed from the ICI Research Council came to an abrupt end on 30 June 1936 when ICI closed down its UCL laboratory(19). So when Ingold became Head of Department and Director of the Laboratories by a process of 'natural' succession in October 1937, he took over a department in much reduced circumstances (20).

An Overview of Ingold's Headship

Snapshots of the department's staffing, funding, student numbers and numbers of publications at the beginning and end of the period 1937-38 to 1960-61 provide an overview of the institutional aspects of Ingold's headship. The number of academic staff increased markedly and steadily from fifteen to twenty-seven full-time members, including five professors and five readers, plus fourteen honorary members of staff in the latter session(21). Furthermore, the academic staff were much better supported by technical staff in 1960-61, with a third of the staffing budget devoted to the latter in that academic year. The size of the establishment does not provide a full account, particularly of the research complement, as UCL was characterized by a steady stream of research visitors who brought their own funding(22).

Throughout Ingold's headship, chemistry had the highest internal grant in the College, increasing from £13,800 to £125,300(23), a long way ahead of all other departments. Although by 1960-61 physics was better-funded overall owing to much higher external grants. Interestingly, despite the fact that Ingold applied fairly steadily for funds to ICI, the Chemical Society, the Royal Society, the University of London and, in later years, to the Department of Scientific and Industrial Research, external grant income was not particularly high for the department(24). Instrumentation was the main focus of bids; an £1800 grant was received for an infrared instrument in 1937-38, while the equivalent figure in 1960-61 was £24.5k for a mass spectrometer. While an improvement on the absence of funding in 1937-38, the amount for externally-funded staff in 1960-61 was in fact very little different from that in 1935-36 when the department had enjoyed ICI funding under Donnan. The period was marked by an escalation in costs caused partly by changes in chemistry itself as it became more dependent on expensive instruments, while a push from government for expansion in student numbers, with no commensurate funding, also affected costs. Throughout the 1950s, the department experienced continual financial difficulties, as did the College as a whole(25).

Although not an avid committee-person, in addition to those committees on which he served *ex officio*, Ingold took care to participate in the key decision-making and funding committees in the College(26) and in the University. Such was Ingold's administrative style, that colleagues were shielded from financial concerns. As one department member put it, the money simply turned up(27). Ingold was a centrist in administration, taking most major decisions himself, though E. D. Hughes (1906-1963)(28) did many of the routine tasks.

Again comparing the first and final years of Ingold's headship and considering the growth achieved in staffing and funding, the continuity in student numbers(29), both undergraduate and postgraduate, is remarkable. In 1937-38, 39 students earned BScs, when 13 Ph.D.s were awarded. The figures for 1960-61 are 38 and 15, respectively. The continuity in the number of publications by department members is also striking. The department, as a whole, published 94 papers in 1937-38, of which 9 were by Ingold. In 1960-61 the deparment published 100 papers, with 7 by Ingold(30). A more detailed inspection of the intervening period shows, however, that this apparent continuity was actually a major achievement because of the extreme disruption caused

by the war which began only two years after Ingold assumed the headship.

The UCL chemistry department continued to operate throughout the war, but it was evacuated in two parts to Wales causing numerous administrative difficulties, not least in liaising with the host institutions. The BSc General Degree students went to Bangor while the BSc Special Degree students and the post-graduates went to Aberystwyth, where Ingold also went. Both parts had skeletal staffing because several academics undertook war work elsewhere. A hope of moving back to London after the first year was thwarted when the College was bombed, the department sustaining serious damage. Thus, after the war, Ingold faced the major task of rebuilding the department physically, as well as replacing a number of well-established staff who, having departed for war work, found other employment afterwards. Although it arose out of adversity, and may not have been seen as such at the time, this in fact gave Ingold an opportunity to develop his own staff team, since a number of Donnan's senior people were among those who left(31). To rebuild the staffing complement rapidly, Ingold recruited heavily from students of his own research school, sometimes in a rather informal manner(32). Of seventy new members of the teaching staff who joined the department during Ingold's headship from 1937 to 1961, forty-eight (68%) were former students of the department and thirty of those had done both their BSc and their PhD there. Even discounting thirty-two (22 UCL PhDs) of the seventy who were on the staff for only a single year as temporary assistant lecturers, internal recruitment was a marked feature of the department under Ingold's headship(33).

Ingold's Policies - Reform of the London BSc

During his tenure as Head, except for distancing himself from industry, Ingold to a large extent carried on Donnan's policies. In particular, Ingold brought to fruition the reform of the London BSc in Chemistry long advocated by Donnan and he also worked on the expansion of the Department in both the undergraduate and the postgraduate areas.

With regard to the BSc, the UCL Department had been from the 1920s in almost constant negotiation with the University of London. Under the regulations in force when Ingold took over, the syllabus and most examinations were set by the University, while the teaching was done in the federated schools and colleges. UCL sought greater autonomy at the College level. Donnan had pressed for the Colleges to set their own papers for the degree examination arguing that the University syllabus did not allow scope for the emergence of local approaches. In keeping with Donnan's view of the primary importance of physical chemistry, the overall thrust of the UCL campaign was to emphasize the importance of physics for the student of chemistry. After two years of debate, the Colleges were finally permitted in 1928 to set for a pilot four-year period two out of the six examination papers themselves, one in physical and one in organic chemistry(34). In 1931, six years after UCL's initial suggestion that all practical examinations be College-based, it was finally agreed that this could be permitted in the case of organic chemistry(35).

In October 1932, Donnan, Ingold and O. L. Brady(36) became members of a subcommittee of the University's Board of Chemical Studies to consider the revision of the BSc. It reported a year later that the London Special BSc, which was a two-year degree, after an initial foundation year known as the Intermediate BSc year for which an increasing number of school final examinations gave exemption anyway, was far too overloaded to cover both the fundamentals of chemistry and contemporary developments. Students often concentrated on the latter at the expense of the class of their degree. The proposal was that the Intermediate BSc year be dropped from the degree to allow the teaching for the Special BSc degree to be lengthened to three years(37). This change was rejected by the Academic Council of Senate to which the Board of Chemical Studies reported (38). Five years later in March 1939 (such was the speed with which the Colleges reached agreement), some modest changes in the distribution of papers among the subjects were agreed(39). Ingold immediately used the changes as an argument to win some funding for a modest expansion of the UCL chemistry buildings(40), but implementation was soon suspended owing to the war(41).

This suspension gave an opportunity for those who favoured the change to three years to reopen the issue, and it was hotly debated during the war; Ingold was active in the debate throughout. His influence on the new degree and the continuity with Donnan's emphasis is clear. Explaining the new rationale, Ingold said(42):

> A revolution has occurred in chemistry in my lifetime; and it is continuing and cannot be resisted. When I began, chemistry was almost wholly a mass of empirical observation with a little regularity, but without either reason or coherence.... Today, however, the outlook is quite changed. The whole of chemistry is bound together and rationalised by physical principles;...Thus the hit-or-miss empiricism is being limited, and a scientific method built by which

> results can be achieved more quickly and with less wasted effort than before.
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> It is part of this development that the barriers between the conventional divisions of chemistry are breaking down to the point at which while many problems cannot be assigned to one division only, there are hardly any problems assignable to one division which cannot be assisted by the ideas associated with another.

The regulations that were to stay in force until after his retirement were put in place. The BSc Special Degree became a three-year course with students being required to take four course-years worth of ancillary subjects which had to include at least one year of mathematics and two years of physics(43). Thus physics and mathematics became central. The fourth course-year could be either botany or geology. To Ingold, the aim of the BSc was to prepare students to undertake research, preferably his own students in his own department(44). A number of chemists expressed considerable scepticism about the value of the new degree for training chemists for industry. Indeed, Ingold saw the chemistry degree as a 'foundation' for future study and resisted collaboration with either Chemical Engineering or Biochemistry at the undergraduate level(45).

The Unity of Chemistry

Ingold was very consistent in developing the educational principles outlined above. They applied to research as well as to undergraduate teaching and their implementation can be seen in his staffing policy. On the eve of taking up the headship, he made this policy very clear when making the case for his choice of Donnan's successor(46). Ingold argued that the Chemistry Department should be run as a whole, not in three separate branches of inorganic, organic and physical chemistry. Most members of the department were specialists, but their specialisms crossed the three branches and 'there is frequent transgression of boundaries'. The incumbent would be expected to give a considerable number of lectures to post-graduate students, to participate in seminars, give private information and advice to independent research workers and expert assistance to colleagues. Therefore it was necessary to have a spread of expertise in the department, both in terms of fields and in terms of techniques. Despite his view of the unity of the three branches, an inorganic chemist with a theoretical emphasis was sought, because organic chemists currently there, he argued, were actually very physical in their outlook(47).

> The most important branches of theory which require to be represented in this way are quantum mechanics, statistical mechanics, thermodynamics, the theory of spectra, of solutions and of reactions. Actually the representation of quantum mechanics needs improvement, but the Department is rather well provided in all the other subjects at the present time. The branches of technique at present practised include infra-red, Raman and ultraviolet spectroscopy and electron and X-ray interferometry.

So at the very start of his headship, Ingold stated his vision of the Department as an intellectual unity, but also as a wide-ranging collection not only of knowledge, but of techniques on which all individuals should be able to draw (48). And the recruiting that Ingold did was to continue to follow this pattern of balancing fields with techniques in order to make sure that new developments in chemistry were available to the research effort as well as to spread the expertise for teaching. He also tended to seek out specific individuals, as was the practice at the time.

For example, in 1945, he wanted to add an X-ray crystallographer to the staff and invited G. A Jeffrey to consider the post. Although Jeffrey, feeling .that Ingold wanted him to provide a service rather than work on the development of X-ray crystallography(49), preferred to take an appointment at Leeds, he expressed himself willing to assist in the post-war re-establishment of X-ray work at UCL(50).

> On the other hand, if you intend to wait until crystallographers are a little more plentiful and there are problems such as the one you mentioned which you would particularly like tackled in relation to your own work, then I am quite free, in fact encouraged, to consider some form of cooperation between us.

Shortly afterwards, in a change of tack, instead of seeking someone in the early stages of an academic career, Ingold recruited an established scholar who would have independent research interests but might be expected to contribute to the training of a new pool of expertise. In 1947, Kathleen Lonsdale, already an FRS, joined the Department as Reader in Crystallography. Ingold very much admired her early work on the structure of hexamethylbenzene and hexachlorobenzene which was done while they were both at Leeds. That seemingly anomalous appointment, anomalous because she was a physicist not a chemical crystallographer, is explained by Ingold's policy of recruiting to have a balance of expertise to draw on, including for his own research(51).

> It is considered that a general chemical research institute, having the balance and coherence at which the Department of Chemistry aims, should carry a

> strong crystallographic school.... The established research activities [here] are such as to illuminate, and would themselves be enriched by, many of the interests which might be expected to develop in a strong crystallographic section.
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> Furthermore, it is expected that a crystallographic section, such as that contemplated, would also develop as a teaching unit, directed to the production of trained crystallographers, for which the demand is considerable, whilst training facilities are inadequate(52).

Later, when Ronald Nyholm(53) an established and innovative inorganic chemist, was recruited back to the department as a Professor to boost research in inorganic chemistry and to reform the teaching of the subject, a desideratum which had been signalled at the time of the reform of the London BSc(54), Ingold himself was keen to pursue with him some work on inorganic reaction mechanisms, by analogy with organic reaction mechanisms(55). Another strategy for bringing new techniques to the department was to send members of staff to departments elsewhere to learn them. For example, Clifford Bunton was sent to Columbia in 1948 to learn about the latest developments in mass spectroscopy(56).

Ingold, however, gave colleagues scope to pursue their own interests even when they diverged from his(57). He also took a great interest in their welfare at a personal level. In 1956, for example, he was concerned about the financial circumstances of some junior staff with young families and he feared their loss to institutions elsewhere or to academia altogether. Quoting US precedents, Ingold arranged with Sir Sydney Barrett, a Director of Albright & Wilson and former member of the UCL staff in Donnan's time, for a grant of £400 per year over three years to be used discretely to supplement the salaries of certain key staff(58).

Ingold also expounded his educational outlook in response to a request by the College to each Department early in 1944 for post-war reconstruction plans. In contrast to the modest efforts of some other beleaguered heads, Ingold submitted a twenty-page statement on the 'Future Needs of the Chemistry Department'(59). Regretting that, before the war, they could only take about 30% of their own BSc Specials on to do research, what he called for was an expansion in students, staff and accommodation(60). The argument contained an important statement of educational principle as regards research training(61):

> ... it has never been the practice in this particular Chemistry Department to foster 'mass-produced' research (where large numbers of students contribute to a single problem, in which methods are standard, the results more or less assured, and the students little more than a pair of hands). No criticism is implied of this method of organizing research in some subjects (e.g. chemotherapy): it's merely felt that it does not provide the best training for students. Thus [here] each research student means a special, time-consuming, thought-occupying problem for some member of staff, who has personally to take the main burden of carrying out those parts of his students' research which demand considerable experience (e.g. the development of new technique, or the reduction of data), besides doing the more routine work of daily advice and supervision. There is literally no end, except that of exhaustion, to this work, which makes such heavy demands on the time and strength of the staff that it is felt essential, not only to increase the ratio of research students to staff, but rather to provide for an increase in research students which is proportionately smaller than the increase of staff recommended.

Among the specific requests for expansion were: the elementary lab agreed before the war, facilities for between five and eight new lecture and practical courses, plus facilities for research training for twenty more postgrads. In addition, he called for the institution of a third chair in chemistry, arguing that despite the discussions at the time of the filling of the last professorial vacancy, there was still no theoretician on the staff [though, in a characteristic piece of Ingold administrative argument, if a chair were established, he would wait for the right person to appear and not necessarily appoint a theoretician(!)]. From the point of view of staffing, a third established chair was needed, he argued, to give a proper lead to research because so much of the time of the head, at least 75%, was taken up with administration, plus consequent college and external roles, that research time was severely squeezed. In addition, five more full-time staff in other grades, adequate funding for student demonstratorships and the incentive of internal promotions, plus twelve extra non-academic staff were required to meet modern technical demands(62).

> Furthermore, although divergent views have been held with the relation of academic science to industry, the view of the Chemistry Department must be recorded that, not only for the sake of its students, but also for the good of the country, it must maintain and even strengthen, its connexion with chemical industry, subject only to the principle that its senior staff should concern themselves only with the strategy of research, the tactics being primarily the business of the Department's more able old students.

Broadly, the plans were fulfilled. The third chair was finally established in the College's estimates for the

1948-53 quinquennium as part of a balanced expansion of the chemistry department to cope with the government-instigated lengthening of the curriculum and the addition of specialist courses with a view to greater research productivity and a higher output of trained scientific personnel. It was noted as part of the case that all other major departments in the country had three chairs, so UCL had in fact been behind. (Of course, in most departments, the three chairs would have been assigned to the three different branches and been run almost as separate fiefdoms.) Ingold nominated to the post his long-time collaborator who then held a Chair at Bangor, E. D. Hughes, to cover organic chemistry so that Ingold could be free to concentrate on physical chemistry. Such was the coverage of theoretical chemistry which the chair had been pencilled in to secure(63).

Thinking that he would be retiring in 1958, Ingold took steps early in 1957 to create more time for research by easing himself away from some of the administrative burdens of the headship, transferring them to Hughes(64), and thus recognizing formally a situation that existed *de facto*(65). Ingold was still very much in charge, however, and carried on with certain aspects of administrative work. Early in 1958, he fronted a case for a completely new chemistry building(66), that which was eventually opened in 1970 as the Christopher Ingold Laboratories. Again the context was one of desired expansion. Accommodation limits, he argued, meant that a maximum of 144 undergraduate chemistry special students plus 96 ancillary students and 122 research workers could be accommodated in their very outdated building which was unsuitable for running modern equipment in an instrument- dependent science. In the heady days of science expansion, he wanted to increase the undergraduate numbers to 240 specials with 375 ancillaries and a research complement of 200 (150 of whom would be postgraduates).

Here again was an opportunity for a re-statement of educational principles, which had remained remarkably constant. The UCL system, which had been in place since Donnan's time, was that all researchers attended the advanced lectures given by senior colleagues, plus the colloquia given by students and visitors at various stages of research. There were several concurrent series. (Ingold's pointed and precise interventions at colloquia were keenly anticipated by students, who both feared and admired them(67).) There was, he argued, research going on in all the main areas of chemistry and this policy of mutual support encouraged much cross-fertilization. 'Massively organized research teams are avoided as lacking educative features which diversity can provide'. Ingold retired formally from his Chair of Chemistry and Directorship of the Laboratories in the summer of 1961, becoming Professor Emeritus but he retained a role as a special lecturer 'to keep the chair warm for a successor' as he put it(68).

After retirement, Ingold continued to expound his educational philosophy as an advisor to new universities abroad and in Britain(69). In the early years of his retirement, on the occasion of his visiting the about to be independent University of Ibadan in Nigeria, he delivered a lecture called 'The Education of a Scientist'(70). Citing a world transforming scientific revolution over the preceding twenty-five years, he argued that there were consequences for scientific education. Some scientific understanding would be necessary for all and thus reform would have to start in the schools where science and the study of modern languages should be fundamental. Thus schools would have to be less specialized. And he also argued for a year between school and university, a sort of foundation university year, where students could be weaned from exam coaching to truly independent study.

At university level, Ingold argued for what he called, in a phrase that will find resonance in the current university climate, 'live' science teaching, that would be done by active research workers who could convey the excitement and wonder of science's continual unfolding and dynamic development. The best researchers were the best teachers, he declared. Furthermore, a student had to have technique, which meant studying with a master for several years of research under personal guidance. To be really effective, the mature scientist had to work as part of a group pooling expertise as no one could expect to master individually an adequately wide field given the complexities of modern science. It was a case of cross-fertilization.

Although, in this talk he argued that educational changes were necessary, the educational views he espoused in terms of departmental organization showed a remarkable continuity with those he articulated at the very start of his headship. The UCL chemistry department in Ingold's period was unique in Britain in being organized around the concept of the unity of chemistry(71). And the reason for its uniqueness is perhaps best understood through some advice which Ingold gave to the then fledgling University of East Anglia in 1962(72).

> As a purely personal opinion on this subject, I would suggest that, while the Departments of Mathematics, Physics and Chemistry are young, each should be built up with a sense of unity by and around <u>one</u> pro-

> fessor, who should be a man sympathetic towards and interested in the whole of his professed subject, even if he himself works on only in one corner of it. [sic] As the departments and staff are enlarged, it will surely be necessary to bring into some of them a second and perhaps a third professor: but this should not be done until the original professor feels the need of a colleague of equal stature; and when it is done, the big Department itself should remain single and united, with one of its professors designated as the administrative head. The reasons for these recommendations are, (a) that the fewer the frontiers, the more fruitfully and economically can the available resources in space, equipment, and money be used; and (b) that, given a wise head, the fewer the frontiers, the stronger and more scientifically effective is the collaborative spirit that can be developed.

With his truly astonishing breadth and depth of scientific understanding and strong personality, Ingold was one such wise head.

ACKNOWLEDGMENTS

I would like to thank the Chemistry Department of University College London for its assistance and patience and especially those current and past members who have been so generous with their time in granting interviews and/or corresponding at length. I am also grateful to the authorities of the University of East Anglia and the University of London Library for permission to quote from materials in their keeping. In particular, I should like to express my appreciation to University College London for their co-operation in making records available to me and their permission to quote from them.

REFERENCES AND NOTES

1. This paper is a somewhat abridged version of one which appeared in The British Journal for the History of Science, 1996, 29, 65-82. I am grateful to the British Society for the History of Science for permission to reprint. Earlier versions were presented to the Royal Society of Chemistry, Annual Chemical Congress, Historical Group Symposium H/1 "C. K. Ingold (1893-1970): Aspects of a Life's Work," University of Southampton, April 6, 1993; and to the American Chemical Society, National Meeting, Historical Division Symposium, "Christopher K. Ingold, Master and Mandarin of Physical Organic Chemistry," Chicago, August 24, 1993. I learned a great deal from participants in these symposia as well as from participants in the Royal Society of Chemistry, Perkin Division, "Ingold Centenary Symposium," which was held in the Christopher Ingold Laboratories of University College London on the date of the centenary of Ingold's birth, October 28, 1993.
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3. J. F. Thorpe to Mr. Gow, September 24, 1919. The initial arrangement was that Ingold would be given three years' leave from Cassell, J. F. Thorpe to the Rector, October 11, 1919. [Professor J. F. Thorpe, Correspondence 1915-1919, Imperial College London Archives, KC/9/7]. Ingold's enthusiasm extended to expressing willingness to accept a £100 (25%) cut in annual salary (H. B. Baker to Mr. Gow, September 23, 1919). [Professor Baker, Correspondence, 1912-1932, Imperial College London Archives, KC9/6].
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8. University of London, Report of a Meeting of the Academic Council of Senate Subcommittee in Science, February 24, 1930 in University of London, Academic Council of Senate Minutes, March 3,1930; University of London Archives, AC 1/1/30.
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10. University of London, Report of a Meeting of the Academic Council of Senate Subcommittee in Science, 1929-30, February 24,1930 in Senate Minutes, 1929-30, March 26,1930; University of London Archives, ST 2/2/46.
11. Professor H. J. Shine [UCL: BSc 1945], Texas Tech University, Personal Communication, April 11, 1996, reported a conversation in which C. L. Wilson indicated that only he had made the move. It was at this time that E. D. Hughes joined Ingold from Wales.
12. C. K. Ingold to Provost, October 22, 1931; University College London Records Office, Chemistry Miscellaneous Files, File 31/3/6.
13. UCL Finance Secretary to F. G. Donnan, December 2, 1930; University College London Records Office, Chemistry Appointments, File 31/4/4. (This may of course have been merely a bargaining ploy; it would be difficult to conclude from it anything about the state of the laboratories during Collie's final years and Robinson's brief tenure.) UCL Secretary to C K. Ingold, December 2, 1930; *ibid.*

14. C. K. Ingold to the Provost [Allen Mawer], September 27, 1932; University College London Records Office, Chemistry Appointments Files, File 31.
15. Dr. D. W. Gillings, formerly of ICI Central Research Instruments Laboratory [UCL: BSc 1936, PhD 1938], Interview, March 30, 1993; Dr. T. P. Nevell, formerly of UMIST [UCL: BSc 1936, PhD 1939, DSc London 1967] and Mrs. V. Nevell, formerly a school Head of Science [UCL: BSc 1938], Interview, April 17, 1993.
16. For example, Dr. Catherine [Tideman] Le Fevre, formerly of the University of Sydney [UCL: BSc 1931, MSc 1952, DSc], private communication, July 21, 1994.
17. Dr. D. W. Gillings, Interview, Ref.15. Dr. J. H. S. Green, formerly of the National Chemical Laboratory [UCL: BSc 1950, PhD 1953], Interview, June 7,1993.
18. Dr. G. S. Hartley, formerly Director of Research at Pest Control Ltd (Fison's) [UCL: BSc 1927, DSc 1937], Private Communications, April 1,1993 and September 26, 1994. A Donnan researcher from 1927 to 1932, Hartley feels in retrospect that he was left very much to his own devices and would have appreciated more active supervision. Dr. J. L. Moilliet, formerly of ICI Dyestuffs Division [UCL: PhD 1932], Interview, April 22, 1993, felt the same. Ingold's similar style was noted by students from the 1940s and 1950s; Prof. Alwyn Davies of UCL [UCL: BSc 1946, PhD 1949, DSc], Interview, 1990; Prof. D. J. Millen of UCL [UCL: BSc 1943, PhD 1947] and Prof. J. H. Ridd of UCL [UCL: BSc 1948, PhD 1951], Interviews, May 18, 1993; Dr. D. Davenport of Purdue University [UCL: BSc 1947, PhD 1950], " Gradus ad Parnassus: The Faraday Society Discussions of 1923, 1937 and 1941," ACS National Meeting, Ref. 1, August 24, 1993. This should of course not be taken to imply that Ingold was not aware of students' work. See J. H. Ridd, "Sir Christopher Ingold," J. Chemical & Physical Society (UCL), 1973, 4, No. 2, 15. Certainly from the 1940s, E. D. Hughes acted in some instances as a kind of "gatekeeper" for Ingold as, in effect, did Ingold's wife, Edith Hilda Ingold; Prof. H. J. Shine, Interview, August 24, 1993; Dr. J. H. S. Green, Ref.17; Prof. B. Challis formerly of The Open University [UCL: BSc 1957, PhD 1961], Interview, May 24, 1993.
19. R. E. Slade, Proposals Re University College, March 11, 1936, ICI Millbank Archives, Box 96, ICHO/RES/0075. See Gerrylynn K. Roberts, "Dealing with Issues at the Academic-Industrial Interface in Interwar Britain: University College London and Imperial Chemical Industries," Science and Public Policy, **1997**, *24*, forthcoming.
20. University College London, Minutes of the College Committee, June 1, 1937; University College London Records Office.
21. Compiled from University College London, College Calendar, 1937 and 1960.
22. During the period of Ingold's headship, 191 'registered' research visitors came for various periods; Record Cards held by University College London, Chemistry Department. Data compiled by Janet Garrod at the Open University for Gerrylynn K. Roberts, "Chemists Prosopography Project." There were also numerous unrecorded very short-term visitors.
23. Compiled from University College London Records Office; University College London, Minutes of the College Committee, Appendices, 1937-38. For 1960-61, see University College London, Minutes of the Standing Committee of Professorial Board on Departmental Grants, May 25, 1960 and April 27, 1961. As an indicator of relative monetary values over theperiod, professorial salaries roughly trebled during these 31 years.
24. Kathleen Lonsdale, from 1947, and Ronald Nyholm, from 1955, had a marked effect on grant income as they were both active in applying for external grants to support students and post-doctoral researchers as well as for the expensive equipment required by their respective researches. See University College London Records Office, Miscellaneous Grants Files, *passim*.
25. University College London Records Office, University College London, Minutes of the Standing Committee of Professorial Board on Departmental Grants, *passim*. For a specific example, see C. K. Ingold to Provost, February 11, 1955; University College London Records Office, Chemistry Miscellaneous Files, Chemistry Departmental Grant, File 31/3/37.
26. 1934-61, Academic Staff Appointments and Promotions Committee; 1934-37, Grants and Loans Committee; 1937-40, College Committee; 1943-59, Planning and Building Committee; 1950-60, Finance Committee; 1952-61, Departmental Grants Committee; 1943-50 and 1952-61, Technicians Committee. University College London Records Office, Staff Record Card for Sir Christopher Kelk Ingold.
27. Prof. D. J. Millen, Ref.18.
28. C. K. Ingold, "Edward David Hughes 1906-1963," *Biogr. Mem. Fellows R. Soc.* **1964**, *10*, 147-182.
29. BScs compiled from Pass Lists published annually by the University of London, and PhDs from annual issues of University of London, List of Higher Degrees Awarded. The BSc figures include only those taking the Special Degree, not the General Degree. Ignoring three aberrant years during the change-over in London regulations, the UC department's graduates amounted to roughly 18% of the total number of Special Chemistry BScs of the University of London, with the later 1930s and later 1950s having figures on the higher side of the average. The PhD figures fluctuated rather more from the average of 17%, with generally larger numbers overall from the 1950s onwards; "Chemists Prosopography Project," Ref. 22).
30. Compiled from University College London, Calendar or Annual Report, depending on the year. Ingold preferred to publish papers in blocks which tackled a problem from a number of different angles. See C. K. Ingold to R. E. Slade, October 6, 1941; ICI Millbank Archives,

Box 447, ICHO/CFD/4472(ii); and "Report on Grant for Apparatus and Chemicals Session 1942-43," C. K. Ingold to R. E. Slade, September 13, 1943; ICI Millbank Archives, Box 447, ICHO/CFD/4472(iii). This caused occasional frustration among research students who might have a considerable wait before seeing their work in print; Ridd, Interview, Ref. 18. This policy also allowed Ingold to minimise and dodge criticism by publishing fairly comprehensively on topics.

31. C. F. Goodeve, G. S. Hartley, R. J. Le Fevre, O. J. Walker, and C. L. Wilson all went elsewhere. Of these, Wilson was the only "Ingold" appointment. Some had already been looking for other posts before the war.
32. R. J. Gillespie of MacMaster University [UCL: BSc 1944, PhD 1949], "One Hundred Years of Superacid Chemistry," ACS, National Meeting, Ref. 1, August 25, 1993 and RSC Perkin Division, "Ingold Centenary Symposium," Ref. 1, October 28, 1993; Ridd, Interview, Ref.18.
33. J. H. Ridd, "Sir Christopher Ingold," Ref.18 and "Chemists Prosopography Project," Ref. 22.
34. University of London, Minutes of the Board of Chemical Studies, March 25, May 6, June 8, 1926; January 27 and June 8, 1928. University of London Archive, AC 8/11/1/2.
35. The UC initiative is recorded in University of London, Minutes of the Minutes of the Academic Council of Senate, October 13, 1924. University of London Archive, AC 1/1/25. For the final decision, see University of London, Minutes of the Board of Chemical Studies, June 5, 1931. University of London Archive, AC 8/11/1/2.
36. "Oscar Lisle Brady (1890-1968)," *Chem. Brit.* **1968**, *4*, 554, was then reader in Organic Chemistry at UCL.
37. University of London, Minutes of the Board of Chemical Studies, October 21, 1932; December 15, 1933. University of London Archive, AC 8/11/1/2.
38. University of London, Minutes of the Board of Chemical Studies, July 22, 1942. University of London Archive, AC 8/11/1/3.
39. University of London, Minutes of the Board of Chemical Studies, March 17, 1939. University of London Archive, AC 8/11/1/3.
40. University College London Records Office, Minutes of College Committee, July 4, 1939, Appendix X.
41. University of London, Minutes of the Board of Chemical Studies, January 26, 1940. University of London Archive, AC 8/11/1/3.
42. C. K. Ingold, "Education in Chemistry: The Aim of the Revised Regulations in Science Degrees," *Brit. Chemist*, **1953**, *35*, No 3, 2-4, on p. 3.
43. University of London, Minutes of the Board of Chemical Studies, July 22, 1942; July 14, September 21, and November 4, 1943; May 4, 1944. University of London Archive, AC 8/11/1/3.
44. C. K. Ingold, "Education in Chemistry," Ref. 42.
45. See *Brit. Chemist.*, **1953**, *35*, *passim*; Professor M. McGlashan of UCL, Interview, November 14, 1993; Professor B. E. C. Banks of UCL Department of Physiology [UCL: MSc(Biochem) 1956, PhD 1959], Interview, June 14, 1993.
46. The College's View on the New Chair, late 1936- early 1937, University College London Records Office, Chemistry Miscellaneous Files, File 31/3/5.
47. University College London Records Office, Chemistry Miscellaneous Files, File 31/3/5. As regards quantum mechanics, Ingold expressed disappointment that Edward Teller had left after only a short spell in the department as a refugee in the 1930s. See Edward Teller, "A Word of Thanks," *J. Chemical and Physical Society* (UCL), **1976**, *4*, No. 3, 16.
48. In constructing his ICI-funded research programme, Donnan had similarly sought to build a team of varied expertise across fields and techniques which could be shared. Among the principal researchers were experts in X-ray crystallography, electron diffraction, the reactions of active nitrogen, high energy discharges, colloids and surface phenomena. A current member of staff's spectroscopic expertise was also cited. "Proposed Organisation of Scientific Work at University College Chemical Department by Members of the Research Staff at Imperial Chemical Industries, October 1928, ICI Millbank Archives, Box 321, ICHO/CFD/0395.
49. Professor G. A. Jeffrey of the University of Pittsburgh, Private Communication, August 13, 1993. Jeffrey was at the start of his career. He had done post-graduate work in the late 1930s and worked during the war for the British Rubber Research Association.
50. G .A. Jeffrey to C. K. Ingold, August 27, 1945, University College London Records Office, Chemistry Appointments Files, File 31/3/9. The offer of collaboration was not, in the event taken up, see Ref. 49.
51. Prof. H. J. Milledge of UCL Department of Geology [UCL: PhD 1951], Interview, November 17, 1993. Prof. Milledge notes that Lonsdale certainly did no service work for the department and, except for some joint research with Professor Craig, her interests were quite separate.
52. "Statement of the Case for the Establishment of a Readership in Crystallography in the Department of Chemistry," University College London Records Office, Minutes of the College Committee, June 4, 1946, Appendix X.
53. "Sir Ronald Sydney Nyholm, 1917-1971," *Chem. Brit.*, **1972**, *8*, 341.
54. C. K. Ingold, "Education in Chemistry," Ref. 42, p. 4.
55. Margaret E. Farago [Baldwin, UCL: PhD 1959], "Ingold and Inorganic Reaction Mechanisms," RSC, ACC, Ref. 1, April 6, 1993 and Fred Basolo, "Base Hydrolysis of Cobalt(III) Amines," ACS National Meeting, Ref. 1, August 25, 1993. Nyholm received a UCL PhD in 1950. See also, C. W. Shoppee, Ref. 2, pp. 368-9.
56. "Professor Ingold's Application to the DSIR for equipment for the development of a special research," en-

closed with C. K. Ingold to Provost, October 15, 1948, University College London Records Office, Chemistry Miscellaneous Files, File 31/3/24. Professor C. A. Bunton [UCL: BSc 1941, PhD 1945], now at the University of California, Santa Barbara, Interview, August 25, 1993.

57. Millen, Ridd and Davies, Interviews, Ref. 18.
58. University College London Records Office, Chemistry Miscellaneous Files, Chemistry Staff and Consultancy Work 31/3/61, correspondence in October and November 1956.
59. The Future Needs of the Chemistry Department, January 31, 1944. University College London Records Office, Post-war and Finance, 1939-1945, ff. 277-297.
60. Of the 259 members of the 1929 to 1937 cohort of BSc Specials, 72 (28%) went on to UCL PhD's. Another 15 students, did an MSc or DSc. In addition, during that period, some 32 students who had done BScs elsewhere did a PhD at UCL. Thus during the period overall, the postgraduate cohort was about 40% of the size of the undergraduate cohort while UCL graduates comprised two-thirds of the PhD cohort. In fact, during Ingold's headship, the percentage of UC undergraduates staying on remained remarkably similar, although they were a smaller segment of the total postgraduate cohort. Of the 661 students who completed BSc Special Degrees in Chemistry at UCL between 1938 and 1961, 173 (26%) went on to take PhDs there by 1964; that is 46% of the 370 UCL Chemistry PhDs awarded between 1938 and 1964. [Chemistry has been taken to include Crystallography.] "Chemists Prosopography Project," Ref. 22.
61. The Future Needs of the Chemistry Department, Ref. 59, f. 282. Interestingly, as mentioned above, Ingold's own approach to post-graduate tasks, though not one of "mass-production", was to organize students to work on different angles of a particular problem in which he was interested. Some of the work would be quite routine and, on occasion, might repeat that of previous students. Several of my interviewees made this point.
62. *Ibid.*, f. 292. This was rather a contrast to Donnan's integrationist model.
63. Proposal for a Third Chair of Chemistry, n.d. [c. December 1947]; and D. B. Pye [Provost], File note of conversation with Professor Ingold, n.d. [c. December 1947]. University College London Records Office, Chairs of Chemistry Files, File 31/2/2. Still using the need for a theoretician as an argument, in 1954, Ingold negotiated the institution of a fourth chair in chemistry with special attention to theoretical chemistry. The "theoretical" qualifier was attached for tactical reasons within the University and was soon dropped from the title once the chair was taken up by D. P. Craig [UCL: PhD 1949], who was indeed a theoretician. Kathleen Lonsdale was awarded a personal chair, so there were five chairs in the department.
64. Correspondence between C. K. Ingold and B. Ifor Evans [Provost], January 28, 1957 - February 15, 1957. University College London Records Office, Ingold File, File 31/1/27. In the event, the retirement age for professors was raised to 67, so Ingold stayed on until 1961. [Provost to C. K. Ingold, June 17, 1957. *ibid.*]
65. C. K. Ingold to B. Evans [Provost], March 29, 1956. University College London Records Office, Ingold File, file 31/1/27.
66. Professor Ingold's Memorandum on Rebuilding the Department of Chemistry, February 1958. University College London Records Office, Chemistry Files, File 31/3/76.
67. Most of my interviewees have made this point.
68. C. K. Ingold to Provost, May 31, 1961. University College London Records office, Ingold File, File 31/1/27.
69. With regard to the new University of Lancaster, see "Lecture to the Lancastrian Frankland Society, October 19, 1962," Churchill College Archives Centre, Cambridge, Todd Collection, 11/18.
70. C. K. Ingold, The Education of a Scientist, Ibadan, 1963. UCL had a formal relationship on behalf of the University of London with Ibadan to help it make the transition from an institution whose students took London degrees to an independent university. Ingold wished to accept the invitation, he said, because the Department there had been largely built up by old students of UCL. Four Englishmen who did UCL BScs and received UCL PhDs in 1950 made careers at the then University College of Ibadan, as did a Nigerian who received a PhD in 1959; "Chemists Prosopography Project," Ref. 22.
71. It was also unique in its lack of preparative organic and bioorganic chemistry, which made it very different from other departments.
72. C. K. Ingold, "University of East Anglia: First Thoughts on a Plan for a Faculty of Science," September 12, 1960; The Registry, University of East Anglia. Emphasis in the original.

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