A HISTORY OF

THE DEPARTMENT OF PHYSICS IN BRISTOL

1876-1948

WITH PERSONAL REMINISCENCES

by

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AUGUST 1956

PART I

In the early days of University College, Bristol, the subjects of Physics, Mathematics and Engineering, were so inter-related that it was some years before any one of them acquired complete departmental independence. Indeed, the Physics Department carried Electrotechnics - as Electrical Engineering was then called - until the foundation of the University in 1909. In an account of the birth and growth of the Department of Physics in the College, references to parallel developments in Mathematics and Engineering must therefore naturally be included.

When the College was founded in 1876 and opened in the Autumn in a house in Park Row, it had procured by advertisement six members of an academic staff, including a Professor of Chemistry, a Lecturer in Physics and a Lecturer in Mathematics. It is recorded in the biography of Silvanus Phillips Thompson* that, having graduated at the Royal College of Mines some months earlier with Honours in Physics and Chemistry, he applied for the Chair in Chemistry. He was a Quaker and was already known to a member of the Fry family, whose sons he had coached during a University vacation. Though he was not successful in his application for the Chair in Chemistry, he was shortly afterwards offered the lectureship in Physics, which he accepted. The salary was £150 pa with a half-share in the fees of students enrolling in his classes. A grant of £125 was also made to 'Physical Science, for apparatus to illustrate lectures'. With this sum he set out to found a department, given 'a damp cellar as a store-room for apparatus and two rooms on the second floor as lecture room and laboratory'.

He was able to supplement this meagre equipment in two ways: (i) by using apparatus that he had already collected as personal property, (ii) by ransacking the garrets of the City Museum. In a letter to his father on the 1 December 1876, two months after arrival in Bristol, he refers to his find of 'an ocean of fine apparatus. Two glorious air pumps (one must have cost £60) in good condition but more than an inch deep in dust and quite forgotten. Also 70 cells of Wollaston's battery. A large plate glass electric machine. A battery of 12 Leyden Jars each of 2.5 gallon size! and an Atwood's machine worth at least £50 at the present moment, besides a lot of lesser apparatus'. It must be presumed that in some way he secured a transfer of these items to the College, as I recognise some of them as still in use in my early College days.

On the same day that Thompson was appointed, W.R. Bousfield, BA (Camb) was elected lecturer in Mathematics and Applied Mechanics. A year later J.F. Main, BA (Camb), DSc (Lond) replaced Bousfield, with the title of Lecturer in Mathematics and Applied Mathematics. But on the 15 May 1878, it was decided to give professorial status to both these appointments at salaries of £300 pa plus half the fees from their students. Behind this decision was the wider intention to initiate some teaching in the scientific principles of engineering. Thompson's Chair, to which he was appointed at the age of 27, was in Experimental Physics, but Main was given the title of Professor of Mathematics and Engineering. On the other hand, it was Thompson who taught Geometrical Drawing and Surveying, and was authorised to spend £35 on surveying instruments; Metallurgy was included in Chemistry under Professor Letts.

Under these conditions it was not long before Main sought further help. In November 1878, Hele Shaw, who had been a student of the College, was given a post under him;

* By Jane and Helen Thompson (Unwin), see Physics Library, University of Bristol.

the Governors agreed to this request from Main on the understanding that the College 'is put to no expense in the appointment'. In the following May, Main relinquished fees up to £100 pa to enable the appointment to be continued.

But three years later, in 1882, when Main left the College to become Assistant Professor in the Royal College of Science and Mines, another re-arrangement took place. Hele Shaw, who had been lecturer in Mathematics, Mechanics and Engineering, was appointed Professor of Engineering, while the Chair in Mathematics was dropped and the subject placed in the hands of a lecturer. Shaw's salary was £250 plus quarter fees from all classes taught by himself (with a total minimum salary of £300 pa).

At the same time, Silvanus Thompson, who so far had worked single-handed in Experimental Physics, was allowed a demonstrator, C.C. Starling (whose salary in terms of precedent was met by Thompson himself). Among the duties of the demonstrator it was specifically stated that he should assist in fitting up the Physics and Electrical Laboratories. This was no doubt connected with the fact that plans were then maturing for a move from Park Row to the brow of the hill, the site of more permanent buildings, the first instalment of which had already been occupied by Arts two years earlier. Early in 1883, the three departments of Physics, Mathematics and Engineering took up their new quarters in the building which today is at the back of the Car Park in University Road. Thompson took this opportunity to stress that his laboratory had never possessed any apparatus of the nature and quality of standard instruments, appropriate and indeed necessary to a Physics Department. He submitted to the Finance Committee a list at a cost of £685.10.0; but presumably the full request was not granted, as the records only show receipts for £317.

The next few years were undoubtedly critical in the fortunes of the College. The first wave of enthusiasm at the start of the College had spent itself; fees were actually dropping and the prospects of increased local support were dim. It was a period of stringent economy and frustration. But in 1884 Thompson managed to secure recognition of Starling's post as a Demonstratorship with pay by the College. Shortly afterwards Starling left and E.A. O'Kieffe, Bachelor of Engineering of Ireland, took his place.

Meanwhile the control of Mathematics appears to have passed into the hands of Hele Shaw. Edward Buck, who in 1882 replaced Professor Main as lecturer in Mathematics, does not appear to have made any mark in that subject, because a year later the records report him as giving assistance to the Professor of Classics! In November 1884, D.E. Selman, an old student, was appointed lecturer in Mathematics, and Assistant to the Professor of Engineering. Appeals were made for more space by both Thompson and Hele Shaw; the want of a drawing office for Engineers was severe, and there was reference to the fact that the joint use of a lecture room by the two professors called for great forbearance on both sides!

But no relief could be provided by the Council of Governors. It was therefore not unnatural that men of enterprise should feel that the future of Bristol was too uncertain to refrain them from applying for attractive posts elsewhere. So it happened that in 1885 Bristol lost Hele Shaw to a Professorship of Engineering in Liverpool, and Silvanus Thompson to the Principalship of Finsbury Technical College. His lecturer, O'Kieffe, left with him.

Although Silvanus Thompson made no striking contributions in the field of experimental research in Physics while he was at Bristol, he was a man of drive and energy who served the College well. Reference to his original papers in Journals such as the Philosophical Magazine suggests that they were more of the nature of notes which arose out of his teaching than investigations of a more fundamental character. He was indeed a teacher of the first rank. Active as a popular lecturer in the City and its neighbourhood, he was also much in demand throughout the country, ranking in the class of John Tyndall and Thomas Huxley, famous in this respect in the same era. It was at Bristol that he wrote his remarkable textbook 'Elementary Lessons in Electricity and Magnetism' which appeared in 1882. As a grounding to more ambitious works, it came to be regarded more as an institution than as a mere book. It was reprinted eighteen times before a new edition appeared in 1895, which was reprinted another twenty-one times by 1914, when a third appeared. But it is also interesting to record that though his main contributions to electrical engineering came later in his career, it was while he was at Bristol that he embraced the cause of technical education and its importance to the nation. In this field he was one of the pioneers in this country.

The age of electricity in the service of man, he said, was just beginning. He complained that the College Council consisted of men who had no apprehension of the enormous and rapid developments which were taking place in the knowledge and teaching of electricity. Ever since his undergraduate days he himself had paid regular visits to the Continent, and in particular to technical institutes such as those at Charlottenberg and Zürich. He was increasingly impressed by the need for improving technical education in Britain, so much so that he was prepared to go anywhere in the country to lecture on themes such as: The Age of Electricity; The New Electric Light; Technical Education, where it should be given; Apprenticeship, scientific and unscientific and so on. It was in these matters one must feel that his heart lay, and when he expressed his dissatisfaction at the progress he was making as an original investigator in Bristol he blamed the conditions there, the answer surely must be that he assigned a higher priority to his other interests in a busy life. And who should criticise him when his work as publicist and teacher was so outstanding?

With the departure of Thompson in 1885, Physics again became linked directly with Engineering by the appointment in September of J. Ryan (MA Camb, DSc Lond) as Professor of Experimental Physics and Engineering. At this low ebb in the tide of progress of the College, it cannot be said that in reputation Ryan ever competed either with those he displaced, or indeed ultimately with his junior colleague, A.P. Chattock, who was appointed demonstrator in Physics two months later. The substitution of one Professor for two was clearly a measure of economy. Drastic action was taken a year later when William Ramsay (later Sir William), as Principal and Professor of Chemistry, suffered a reduction in salary of £100 pa; and it was decided to terminate the Chair in English and History and re-advertise them at a lower salary. Strong protests in the end limited this action to salary adjustments! But when some months later Ramsay left for University College, London, the post of Principal was down-graded to that of Dean and combined with that of a professorial chair. By this means Conway Lloyd Morgan, holding the chair of Geology, Biology and Zoology, was appointed. It was believed in certain circles at the time that the prime mover in the matter of these economies was Bishop Percival, on the ground that men should not

work in a University for money, but for love of their subject; otherwise they should seek employment elsewhere.

Ryan himself from all accounts must have been a rather lovable character. He had gifts as a cartoonist and punster. His annual Christmas cards designed and illustrated by himself were full of topical political allusions in racy humour; and his brogue was Irish. Chattock, his demonstrator, had had an early training as an electrical engineer under Kennedy at University College, London. From there he joined the firm of Siemens, where one of his tasks was to design a small portable accumulator for use in the first production of Gilbert and Sullivan's 'Iolanthe'. Those who are familiar with the opera will recall that the fairies are equipped with a light in the centre of their foreheads. By strapping one of these accumulators on each fairy's back to supply the current, electricity was used it is said for the first time on the English stage on the opening night in 1882. Chattock had hoped while with Siemens that he would have opportunities for independent work, but he was disillusioned when he was censured for designing a novel type of galvanometer without permission. He was informed that the sales of the firm's present product were still entirely satisfactory and his instrument was never put into production. So he left industry and returned to University College, London, to study on this occasion more Physics under Carey Foster.

As a member of an old County family in Solihull, Warwickshire, Chattock had a certain measure of financial independence which enabled him to act in this way until a suitable academic post was available. On the other hand, it was a desultory kind of training which left him with no paper qualification in the subject, though he subsequently became a member of the Institute of Electrical Engineers, and still later, in 1911, an Honorary Doctor of Science of the University of Bristol, a year after his retirement from the Chair of Physics.

After two years in Bristol Chattock left to spend two years (1887-9) in Liverpool as assistant to Oliver Lodge. Lodge and Chattock had previously met at University College, London, and Chattock had then shown interest in Lodge's experiments on the discharge of Leyden jars through cotton covered wires. Lodge was making an early form of Lecher wire experiment, in which the potential antinodes in the discharge along the wires could be observed in the dark by the corona glow from the cotton fibres. In later life Oliver Lodge told me that Chattock had suggested to him that he ought instead to be studying the conditions in the ether outside the wires, because it was here that electromagnetic waves, so far undiscovered, might be found. Lodge added 'If I had taken that young man's advice, I might have discovered electric waves before Hertz did'.

In 1889 Chattock returned to Bristol to a full lectureship in Physics, Ryan being quite prepared to give him a free hand in developing the subject. By then the peak of the financial crisis in the College seemed to have passed, and that year saw the resuscitation of the Chair in Mathematics by the promotion of Selman to a Chair. Yet his salary of £170 plus 1/4 fees compared unfavourably with that of the first Professor of Mathematics 11 years earlier when the figure was £300 p.a. plus 1/2 fees. Moreover, the record of procedure reads oddly today since it is reported in the Minutes of the Council that the decision to revive the Chair was taken after the terminal examination papers in Mathematics had been examined by Archdeacon J.M. Wilson, who reported that they were of a standard which would justify the status!

Chattock's salary on his return was £150 pa. During his absence in Liverpool he had been replaced by L.N. Tyack at half his salary, and on his return Tyack was retained as an additional member of the department. In the summer of 1890, Selman retired from the Chair of Mathematics, and again the status of his successor was not immediately professorial. F.R. Barrell, MA (Camb), BSc (Lond) who was appointed to a lectureship and was elevated to a Chair in 1893. At the same time Chattock was given a Chair in Physics and Electrotechnics at a salary of £150 pa plus 1/4 fees. Barrell, with a superior paper qualification, received £25 pa more. That academic salaries at that period ran low may be gauged from the fact that a demonstratorship in Engineering at £75 pa attracted 29 candidates.

Chattock differed very much in personality from Silvanus Thompson. Both were excellent lecturers, but whereas Thompson was a publicist who joyfully took an active part in the practical affairs of the outer world, Chattock was modest and very reserved; he shunned scientific gatherings of his contemporaries, and few physicists were personally acquainted with him. Yet within his department he regarded the teaching of his students as the first claim on his time both in the lecture room and in private discussions with them individually. A born investigator of marked originality and experimental skill, the present age would have found a different niche for him in which he would have been relieved of all administration and committee work that he abhorred, and allowed to follow his own nose, aided perhaps by two or three young collaborators with whom he could establish friendly and sympathetic relations.

After his death I discovered among his papers a fat notebook filled with unpublished experimental data labelled 'The electrochemical equivalent of gases, 1890'. He was then trying to measure the mass to charge ratio of the carriers in discharge from a point, a form of discharge which outside of the corona is unidirectional. He was never satisfied with the assumptions underlying the results that he obtained, though he collected evidence for 'the constancy of the atomic charge'.

Having watched a laboratory grow from a mere handful to an important centre of research, I myself know what stimulus to original thought can be mutually derived from the contact of acute minds in the same Department. But in this period and for some years to come, Chattock was carrying out pioneering work in compete academic solitude, in a field into which the Cavendish Laboratory with its band of young workers under J.J. Thomson broke so dramatically some years later. I have sometimes wondered what enhancement of reputation he might have acquired had he been at Cambridge and not isolated in Bristol; more akin to that of C.T.R. Wilson than to Rutherford, but certainly not remaining as he did, a man with no medals, whose election to the Royal Society was delayed until he was 61 years of age.

This work led him to investigate in detail the phenomenon of point discharge and of the 'electric wind'. He deduced the critical field at the surface of the point required to initiate discharge, by suspending the point and measuring its attraction to a charged plate (1891). Incidentally he showed that the explanation of the backward motion of 'electric windmill' given in textbooks of that date was quite misleading. Then 7 years later he made a determination of the mobility of both positive and negative ions in gases by measuring the pressure of the electric wind on the plate in a point-plate discharge. He read an account of this at the British Association Meeting at Bristol in 1898. Rutherford had just published his own method, applicable to negative ions

only, but though the subject was therefore of great interest at the time, Chattock did not then write up his work in detail. With characteristic caution he waited for 18 months, spent in checking his results by a different experimental set up. By then Zeleny had published his results on both signs of ions by yet another method, and it is therefore to Zeleny that priority is usually given in monographs of the period.

But the first subject in which he published work at Bristol was Magnetism. Reference will be made below to his paper on the 'Energy of the Amperian molecule', and to his later classical work on gyromagnetism; but originally his interest in Magnetism started in 1887 with the design and construction of a magnetic potentiometer, an ingenious instrument useful for investigating magnetic fields in inaccessible places or for studying magnetic leakage. To his regret it received little attention at the time, but years later it was resuscitated by A. Campbell at the National Physical Laboratory, and still later used by Ellis at the Cavendish and by L.F. Bates. Finally it was put on the market in this country and on the continent for use in a teaching laboratory.

The advent of a Professorial Chair for Chattock in 1893 also saw the first appearance of a research student in the Physics Department. F.B. Fawcett who was associated with Chattock in magnetic work in 1894, also attempted to make standard resistances of the order of a megohm by sputtering a film of platinum on to a glass plate, cutting its surface to give a zigzag path and immersing it in oil after heat treatment. His boxes were the only megohms available in the laboratory in my student days. S.R. Milner was the next research student; he made a standard determination of the heat conductivity of water with Chattock in 1899, and later was Professor of Physics at Sheffield and a Fellow of the Royal Society; Miss Walker (later Mrs Milner) and E.H. Dixon were associated with Chattock in mobility work in 1901. A prominent student of the same period, but in electrotechnics, was R.C. Clinker later a valued member of British Thomson-Houston at Rugby until his assistant, J.D. Fry, appeared on the scene, to be promoted to the post of demonstrator in 1898 and later to a lectureship; after the foundation of the University he was given a 'service degree' of Bachelor of Science. Shortly after the conclusion of the first world war he was appointed a physicist at the Chemical Defence Establishment at Porton, and finished his active career there as its Scientific Superintendent.

Fry was associated with Chattock in the production of a sensitive gauge for measuring minute differences in pressure. This problem had already arisen in Chattock's measurements of the pressure of the electric wind. T.E. Stanton, who had replaced Ryan early in 1900 as Professor of Engineering, wanted a sensitive gauge for measuring the pressure of atmospheric wind on structures. The gauge Chattock designed for him, in which the recording surface was a liquid bubble anchored to the end of a glass tube projecting into a second liquid, could measure a tenth of a dyne per sq cm (10^{-3} mm of water) and detect a change of even less. Subsequently this gauge became a standard instrument for all the early wind tunnel investigations in aeronautics in this country. A few years later I was to have considerable experience in the use of this gauge in my work in collaboration with Chattock. I can also recall using it in some unsuccessful attempts in 1904 or 1905 to detect (a) the possible effect of a strong electric or magnetic field on the viscosity of a gas, and (b) the vapour pressure of a smell!

In the middle nineties the financial state of the College was somewhat relieved by a local appeal for funds which on the standards of these days was moderately

successful. But despite this, or possibly due to an unwillingness on his part to fight and bargain for his own share, Chattock continued to meet all the expenses of his researches out of his own pocket.

After taking classes in other subjects in the College for a year, I entered the Intermediate BSc course in Physics in 1899. Since from that year onwards I can speak with so much more direct knowledge, it seems appropriate to break off at this point and deal with subsequent events in separate parts.

PART II

I entered the department with practically no knowledge of Physics. But it would be an unimaginative student who did not receive inspiration from Chattock's lectures. Except in the first year when Tyack gave two lectures a week, every lecture in every year in the department was given by him, whether in Physics or in Electrotechnics, and I attended all of them.

Except in the old Universities, the study of Science by an undergraduate was then directed towards the external degree of the University of London. The day of the provincial University had yet to come, and in the London Colleges themselves there was no internal examination. The Intermediate BSc was a four subject examination, and in a final honours course three subjects were taken, with Honours in one of them; in my case Chemistry and Mathematics with Physics. Two of us in a class of five took Honours in Physics; my fellow student, T.F. Sibly, obtained a first, and I a second class. This had the consequence that he, not I, was awarded the 1851 studentship offered each year to the College for a suitable candidate for the two years of postgraduate study, which was often the prelude to entry into the academic profession and was commonly spent in Germany. Sibly incidentally switched within a few weeks to one of his second subjects, became a geologist and ultimately Vice-Chancellor of Reading University. However, owing to the resignation in 1902 of Tyack who joined the Wesleyan Ministry, a vacancy arose in the College which in 1903 I was invited to fill as an Assistant Lecturer.

The content of the Physics degree course then was very different from that of today, not merely because the twentieth century was in its infancy, but because so little mathematical technique was expected of a candidate. Sibly, for instance, was an example of a man who obtained London First Class Honours without taking Mathematics beyond the stage of the Intermediate course in the syllabus of which, be it recalled, the Calculus itself was not then included! No doubt this did not prevent a number of teachers, Chattock among them, from making free use of the elements of the Calculus. Yet such was the prevalent attitude towards the subject that distinguished men like J.J. Thomson and J.H. Poynting, well equipped mathematically, went out of their way to write a series of Physics textbooks to degree standard in which roundabout proofs were given to avoid even the use of a differential coefficient or an integration symbol. Their books and others, such as those of Edser, copying their bad example, were sold in large numbers all over the world. There must have been many physicists of my generation who were brought by 'the hard way' to such knowledge of theoretical physics as they ultimately possessed, so creating a distinction between theorists and experimenters much more clear-cut than it is today.

I do not recall my first contact with Chattock personally. But in a later year when we had become intimate friends, he told me that he had a vivid memory of me at a laboratory session early in my course, when I addressed him with some query. He left me, so he said, murmuring to himself 'I don't think that I am going to like that young man, he's too perky'! Yet in the end I owe more to him for his friendship and help than to any man I have known.

He invited me to collaborate with him in two investigations he was then making: (i) an off-shoot from his association with Stanton, in the early days of the use of a Pitot tube for measurement of wind velocity. We set out to investigate its behaviour over a wide range of speeds and particularly at low speeds; (ii) a study of point discharge in pure hydrogen in closed vessels, and in particular the changes in pressure due to oxygen clean up and to the temporary occlusion of gas molecules carried by the ions to the electrodes. This work was a carry-over from his earlier attempts to measure 'the electrochemical equivalent of gases'. We got rather bogged down in both these problems. The Pitot tube investigations were never completed until everyone else had ceased to be interested in them, and even then left uncertainties at very low speeds. Owing to the striking effect of small quantities of impurities the point discharge problem was under study for nearly five years; but in the end it led to useful results, particularly when combined with mobility measurements in pure hydrogen at atmospheric pressure in which the negative wind pressure was found to be immeasurably small. This result, and the fact that normal wind pressure values were restored by the addition of minute traces of oxygen was important evidence of the electronic nature of the initial negative ion and of associated clustering phenomena. Reference will be made to subsequent work on this subject.

Perhaps one of the most exciting events of this period in the laboratory was the arrival in 1904 of a liquid air machine, made by Reynolds and Branson, the senior partner of which was a brother of the Professor of Geology. Whether for that reason it was obtained cheaply, I do not know. But it was a machine full of faults. The laboratory had no mechanic in those days and we all struggled with it, spending days of work for every pint of liquid air we got from it. This was all most unfortunate as we were early in the field in possessing a source of low temperatures with possibilities of interesting work available to us. After a few years it was scrapped. Yet it was novel and exciting at the time.

But teaching duties were still very handicapped by lack of sufficient apparatus. It was always necessary to plan the laboratory classes beforehand in detail to ensure, for instance, that the only *two* resistance boxes available were not wanted in *three* places. There was, for instance, only one good ammeter reading to one ampere, a hot-wire variety. The following incident has been attributed to me, demonstrating in an elementary class in my early days. Instruction in the use of verniers was essential to all elementary students, and a convenient illustration was the setting and reading of a Fortin barometer, calibrated in two scales, centimetres and inches, with different verniers. Students could in this way conveniently check their own results by finding the number of centimetres in an inch.

The twentieth student waiting to be allotted an experiment at 2.15 pm: *Myself* : 'Oh read the Fortin Barometer'. *Student* : 'Please Sir, I did that last week'. *Myself* : 'Oh! Well! read it again, it may have changed'!

It was in supplying the needs of first year laboratory work that J.D. Fry became very useful. He devised and constructed the apparatus for a number of instructive, and in some cases quite novel, experiments. Some years later when a little more laboratory help was available, these were made up in sets of 24 of each, so that he could have a class of this size all doing the same experiment, by which he could judge the relative speed, accuracy and understanding of individual students.

The first course of lectures that I gave was one of eight or nine on 'Conduction of Electricity through Gases' delivered in the Spring of 1904, and dealing mainly with the spate of discovery in that field during the previous decade. I had on two previous occasions addressed the Students' Physical Society founded in 1901, and of which I was the first Secretary. My first paper to it was at its second meeting when I talked about 'Anomalous Dispersion' and illustrated the phenomenon experimentally with a thin prism of cyanine dye that I had constructed. My second lecture to the Society on 'Radioactivity' early in 1903 was more successful and may have influenced Chattock to offer me the Assistant Lectureship and to choose the subject of my first course of lectures.

In the session 1904-5 at my first lecture to a large class of Intermediate and medical students I must have been nervous, because in introducing the subject of scales of temperatures I spoke of that of Reamur as going 'from 8 to naughty'. A lecture or so later, in Mechanics, I confidently lengthened the string holding a can full of water rotating in a vertical circle; alas, it hit some apparatus suspended from the ceiling and drenched me with water! However, I never really lost grip of discipline - a pathetic occurrence if it happens, as I realised later in the fate of a colleague of mine.
There was no time for research in term except at week-ends. Wednesday afternoon was free from classes, but an evening laboratory was held on that day from 7 to 9 at which a number of local schoolmasters and others, seeking some qualification such as a London Pass Degree, attended assiduously. This had to be carefully organised in the afternoon with experiments laid out to save their time as much as possible. We had many testimonials to the value of this work. One man, F.B. Young, a teacher at Merrywood Secondary School, ultimately passed on to research work in the evening, left school teaching in 1915 and finished his career as Superintendent of the Admiralty Research Laboratory at Teddington.

It was at about this time that a valuable bequest of books and journals in Mathematics and Physics was made to the College by the will of T.H. Exley, deceased, a retired schoolmaster from Cotham. It contained in particular long series of back numbers including Poggendorf's Annalen der Physik back to the beginning, Comptes Rendus and Royal Society Proceedings and Transactions. The name of Exley is now perpetuated in the departmental Library of the Laboratory. Late in 1904 a gift of £250 from Francis Fry and P.J. Worsley to assist electrotechnics was largely spent on instruments, a number of which were also used to relieve the pressure in pure physics. A room in the new Vincent Stuckey Lean building (blitzed in the last war) was allotted to the department for this subject (Appendix I). But it was not until 1907 that Chattock received a major relief in the teaching of electrotechnics by the appointment of O.J. Williams as lecturer in that subject.

Viewed in retrospect, life must have been settling down to a rather dull routine because I have always remembered the first impression made upon me by Morris Travers who was appointed Professor of Chemistry in 1904, shortly after he had

obtained his FRS at the age of 32. After the interview at which he was appointed, Chattock brought him into our ill-lit laboratory in the basement and introduced Fry and myself to him. After his departure I said to Fry 'That's like a breath of fresh air'. With his enthusiasm and energy he seemed to blow away the cobwebs of musty surroundings. Though I later discovered that he could also be described as a whirlwind disturbing both good and bad in a cleaning-up process, he is entitled to full credit for the fact that a real drive was put into the movement to establish a University of Bristol from the day of his arrival, and that he was a catalyser in the process.

Some months later he was responsible for an exciting 1/4 hour in the department. He had at some stage noted in the department a store of old X-ray gas tubes. Following upon Röntgen's discovery in 1896, Chattock had immediately secured a tube and a large induction coil and he was early in the field in obtaining photographs of patients from the Infirmary, who were brought up to the department for the purpose. Many old gas X-ray tubes remained in the laboratory as relics of those days, and Travers, speculating on the reason for the blue colour that the glass of these tubes had acquired, asked if he could destroy a couple of them to analyse it. Some weeks afterwards he (the first man ever to see the light of Neon in a spectral tube filled with a residue of unknown gas) rushed into our room saying: 'I may have got a new element from that glass of yours. Give me a spectroscope quickly'. Using the trace of powder that he had brought, a platinum wire and a Bunsen, I illuminated the slit while he looked down the telescope. 'Ugh' he said, 'Copper'! and then stalked out of the room leaving me to clear up the remain, and never referring to the matter again.

The first scientific conference I ever attended was the 1904 meeting of the British Association which in those days had a prestige so high that authors of important discoveries would delay publication in order to announce them on the occasion of the annual meeting. The 1904 meeting was at Cambridge, and it was my first visit to the Cavendish Laboratory. It has interested me to recall what I have remembered of that meeting, and even more so what I had forgotten. It must surely have been one of the most distinguished gatherings of physicists in the history of the Physics Section; yet of all their contributions, there are only three which have remained in any detail in my memory.

The first could almost stand as a testimonial to the value of visual aids in education - I remember it so clearly. It was a demonstration by R.W. Wood of the anomalous - as it was then called - dispersion of sodium vapour, familiar to many students of Physics as illustrated in the frontispiece of his textbook of Physical Optics. Wood was a constant visitor to Great Britain in those days and clearly found an atmosphere congenial to him and his particular experimental genius. Starting with an empty bench and finishing only 30 minutes later with a ruin of devitrified glass, wet cotton waste and sputtering sodium metal, we had witnessed a demonstration which in simplicity, elegance, and slickness of manipulation, I have never seen excelled.

The second was a discussion on the so-called N rays claimed by Blondlot to have the properties of a weak beam of X-rays yet refractable by a prism. A show of hands disclosed a surprising number of eminent people who had tried, and failed, to repeat the results, subsequently proved to have been purely subjective in origin. The incident may have warned me early in my academic life of the trouble that can be caused by failure to make suitable experimental checks before rushing into print with sensational results.

The third item was a paper by Kelvin who, with an inflexibility of opinion which is often the penalty of old age, advanced a molecular model for the emission of a-particles from polonium, as the last attempt to save the conception of an indivisible atom. This seems strange reading today when 'atomic energy' is a term on every lip. But it must be remembered that Kelvin had belonged to a generation which hoped that by levers and screws it might pluck out the heart of the mystery of the Universe. I, on the other hand, only two years earlier as an undergraduate, had been following Rutherford's early papers on radioactivity, at one stage twelve in one year from his pen alone in the Philosophical Magazine. Not only were they easy to follow, but they aroused such absorbing interest in me that I awaited the arrival of each monthly number as if the next instalment of a serial story. So I listened to Kelvin on that occasion with some youthful impatience.

Several relatively uneventful years followed until in 1908 I secured leave of absence to spend the summer term and half the vacation in the University of Berlin. In those days no grants were available for foreign travel and my limited savings would not permit a longer stay, particularly as I was due to be married on my return. But the visit gave me a break and a new experience which brought me into association at colloquia and lectures with Rubens, Nernst, and younger men such as Franck and Pohl, even though it was not long enough to justify embarking upon a research problem.

This is not the place to record the events which led to the foundation of the University in 1909, but I was present at the annual dinner of the University College Colston Society when the President, George Wills, announced the gift of £100,000 from his father, Henry Overton Wills, which finally determined the issue. But prior to that, I think in 1906, a small chance incident occurred, such as history can provide many examples, which profoundly changed the subsequent course of events. In those days University College shared a single telephone line with the Blind Asylum then occupying the present frontage of the University at the top of Park Street. Professor Travers picked up the 'phone one day to find it in use at the Blind Asylum, listened in and discovered the Asylum preparing to negotiate a sale. He rushed to the Chairman of Council pressing him to intervene with a bid even if the money was not there. He did so with some hesitation (so I have been told) and with the aid of certain promises of donations, secured the property.

This acquisition included a field bordering Woodland Road, used by the Blind for football with a ball containing a bell. When it became clear that the foundation of a University was assured, it was decided to plan for an extension of laboratories on the site of this field. Physics was in consequence offered the basement of an L-shape building to be erected, the upper floors of which would be occupied by Chemistry. Chattock with his experience over a period of years of dripping ceilings from overflowing chemical sinks above his laboratory, rejected the proposal, preferring to rely on additional accommodation to be set free by the departure of Engineering when the University opened. Though holding a junior post I pleaded with Chattock to change his decision, with a vigour that almost led to strained relations between us. Right seemed to be on my side when Physiology was linked with Chemistry and the architect arranged the accommodation of the two subjects in separate wings; free from the possible objection that Chattock had earlier raised! Yet I have more than once since realised that, had the move been made then, the accommodation provided for

Physics would have been so superior to the old quarters that Harry Wills could not have seen any reason to choose Physics for his benefaction about 10 years later, and it is very unlikely that the conditions necessary to develop an important research school in Bristol would subsequently have been present at any time between the wars.

In October 1909 the first session of the new University opened. Its advent brought some immediate changes in the department. By arrangement with the Society of Merchant Venturers and in terms of the Charter, the Engineering Department of University College moved to the Technical College in Unity Street, at the bottom of Park Street, where the Faculty of Engineering was set up and remained until 1955. With Engineering went Electrotechnics from the Physics Department to join in the foundation of the Department of Electrical Engineering in the Faculty. On the other hand, the Society gave up degree teaching in Physics and Chemistry in which they had previously had courses for the London BSc, and their staff of one lecturer in each department came up the hill to the Science Faculty. The additional member of staff that Physics thus received was Illtyd Williams, BSc (Wales). He was about 10 years older than I was and was hardly of the academic calibre of some of his subsequent colleagues. But he was intensely loyal to the department and willingly burdened himself with many routine duties until his retirement in the late nineteen thirties.

Under another clause of the agreement with the Society there was also to be an exchange of apparatus whereby anything pertaining to the teaching of electrotechnics was transferred to the Technical College, while we were to receive anything set free by the cessation of degree classes in Physics in the College. This was temporarily somewhat disastrous in its consequences to us, because not only was our equipment superior to theirs but on the electrical side it was used for Physics as well as electrotechnics. The negotiations for a settlement were one-sided, as the participants were ill-matched; on the one hand Chattock, to whom bargaining was a distasteful procedure foreign to his nature, and on the other hand, Julius Wertheimer, the Principal of the College, astute and skilled in the preliminaries of a business deal. The result was that the Physics Department not only lost much electrical apparatus which took several years to replace, but in return it received only one instrument, a sugar polarimeter, which Chattock returned to them for use in their evening classes since it was an inferior duplicate of an instrument already in the department!

This removal of Engineering from the College building set free space, some of which was adapted for use in Physics. In particular the Engineering Workshop (Appendix I) was divided into a Junior Laboratory and a Lecture Room now occupied by Geography. It will be seen later that the old boiler house, turned into a Store, played an important part in the events leading up to the erection of the Wills Laboratory.

But the departure of Engineering from the building had other consequences in the organisation of the Science Faculty. In particular it left the Physics Department without any workshop facilities at their disposal near at hand in cases of need. That in its turn drew attention to the poor conditions of service of laboratory assistants in general and the desirability of improving the field of recruitment. Previously we had relied for laboratory assistance on the services of one youth, usually little more than a boy, in virtually blind alley employment. Indeed, for years past, Chattock, conscious of this, had either personally coached each lad in turn in elementary mathematics and English, or paid someone else to do it out of his own pocket, in order to improve the

chances of employment of a more permanent character. The first few shillings I ever earned came as a fee from Chattock to take his place on one occasion.

With improved laboratory facilities giving better opportunities for training a young lad entering its service, the new University now began to feel some responsibility in this matter. The appointment of a mechanic provided with a small workshop within the department became the first necessity; the addition of a boy, to help the laboratory assistant previously working alone, though incidental was also desirable. It happened that I had met in a local engineering works a middle-aged fitter, Frank Sargent by name, whose hobby had been an 8 inch mirror astronomical telescope which he had constructed and mounted in his back garden. Some observations on the Red belt of Jupiter which he had made with it had been accepted for publication in the Monthly Notices of the Royal Astronomical Society. He had the kind of training and interests that we wanted, and he held the post of mechanic for about 6 years until he left to take charge of the Observatory at Durham. Thus the grinding of optical surfaces was not unknown in the department a quarter of a century before the arrival of Dr C.R. Burch. Sargent was also quite a competent talker and gave some lectures to students on workshop practice.

But by far the most important event in that period took place at the end of the first session when, having submitted his resignation in the late Spring, Chattock retired at the age of 50. He decided to live in Crowcombe in Somerset and to combine the breeding of poultry with an experimental study of the physical conditions controlling the efficiency of egg incubation.

Chattock was a man of great reserve and it is probable that not even those nearest to him knew all that was passing through his mind when he decided to retire. What can be said for certain is that he hated administration and committee work which in a University was clearly going to be heavier than in the College; and no doubt this was a vital factor in his decision. But knowing his extreme modesty and sensitivity, I would conjecture that added to this was the fact that he had no degree. 'Who am I', I can imagine his saying, 'to be responsible for awarding degrees to my students when I am without one myself?' Moreover there was at that time some friction between the Council of the new University and the body of Professors. Council anxious to secure a staff worthy of University status, yet with some influential members unsympathetic to the tenets of academic freedom and security decided to serve notices on three Professors of University College as being unworthy to fill the corresponding University appointments. One of these was Chattock's closest friend on Senate. Though notices of dismissal were later withdrawn from two of them, Chattock may well have felt that Council's decision was indicative of change in atmosphere quite uncongenial to him: indeed without a paper qualification his own re-appointment might have been a close call. But he was far too respected by prominent members of Council for this to have been true.

The Chair of Physics was advertised and Council, determined not to rely on any recommendation from Senate in a decision which by Statute was ultimately theirs, set up an independent selection Committee of its own. Senate's short list was J.G. Gray of Glasgow, Frank Horton, S.R. Milner and A.W. Porter. The Minutes of Council do not disclose their list, but I saw it at the time and, if my memory serves me correctly, it was of five names none of whom Senate had selected. When forwarding its list to Council, Senate added that, in its opinion, 'none were fully up to the standard they

would regard as desirable for a Chair in the University of Bristol'. Council, though without any special confidence in Senate's opinion, were frankly disappointed, and even surprised, that no Fellow of the Royal Society had applied. So pending further enquiries they decided to make no appointment for the time being. They were not to know that in later years Horton, Milner and Porter were all to be elected to the Fellowship. The Autumn of 1910 therefore found me in charge of the Supplementary Medical and Intermediate examination, with C.G. Barkla as external examiner, and in November I was appointed acting head of the department for the Session 1910-11. My salary as Lecturer at this time was £180 pa, and I received an additional £40 a term for my extra responsibilities as acting head.

Chattock's departure forced upon me most of the advanced teaching in the Session 1910-11, but for the latter half of it some relief in demonstrating was secured by the temporary appointment of Miss P.M. Borthwick who, with graduands in alphabetical order, was the first student to be admitted to a BSc degree in the University.

When the old buildings of the Blind Asylum were successively brought into use, plans to move the University Library to them from the Vincent Stuckey Lean wing were under consideration. Feeling that a new Professor, had he been appointed, would have been granted extra space and equipment, and with nothing to lose, I emphasised the complete inadequacy of the old quarters for work of University standard. I won my case and was allotted a grant of £1,050 to be spent on fittings and furniture for adapting this room and an adjoining one as laboratories. I was also given an honorarium of £20 for the vacation work I did in making the move! During that session I presented a DSc thesis to the University of London and was awarded the degree.

In October 1911, consent was given for the appointment of an additional Assistant Lecturer, and Dr B. Hodgson, a graduate of Newcastle with postgraduate experience in Germany was appointed at a salary of £250 pa.

In that year R.B. Haldane was made Chancellor in succession to Henry Overton Wills who had died. I carried the Mace at the ceremony of his installation in the Colston Hall. The ceremony included the award of 70 Honorary Degrees - 50 doctorates and 20 masters degrees. With many others, I could never understand how Council and Senate ever agreed to lay on a degree congregation of this magnitude. Nothing on this scale in a University had ever occurred before, and it was not long before a storm of criticism of the University broke out, started by one of its own number, Dr Gerothwohl, head of the Department of French, in an article in the Sunday Observer, and taken up widely in the National press. The earlier dismissal of the Professor of English on the foundation of the University was brought into the attack as a threat to academic freedom and to the study of the humanities; the plethora of degrees, some given to local magnates possibly with a sense of favours to come, was regarded as indicative of lowering academic standards. Criticism of the University's action was without doubt justifiable, but the attack burnt itself out in the end by its own immoderacy and vituperance, though it was not forgotten in many circles for a score of years.

This incident could have had little effect upon my own position, had it not been that at one stage an anonymous writer in the Spectator said that the conditions for work at Bristol were so bad that the Chair in Physics had been vacant for more than two years

because no physicist of any standing would apply for it! Whereas, in fact, there was no reason to suppose that any of the earlier candidates would have refused an invitation to the post. However Council and Senate, who were brought together much more closely through these virulent attacks, took the view that to proceed with filling the Chair under those conditions would be to respond to blackmail; so my post as acting head was renewed for the next session! Perhaps the authorities felt relatively safe in taking this line as the result of a visit in the summer of 1912 from an Advisory Committee on Government Grants to Universities, which were then administered under the Board of Education. I was given to understand that Professor (later Sir Arthur) Rucker of the Royal College of Science, the Physics representative with whom I spent an hour, reported favourably on the department.

And so 1913 passed. I had by that time collected three student demonstrators: H.G. Hughes (later Admiralty Signals), P.A. Mainstone (later Bangor) and G.W. White (later 1851 scholar) for whom in their last year I secured a £5.5.0 honorarium for a few hours work each week. Physics was the first in the field in this respect in the Faculty, but later the plan became general, though applied to postgraduate students in the form of exemption from fees. Indeed, Hughes and White who spent the subsequent year in research then received fee exemption under this scheme. After the war DSIR recognised and accepted this procedure throughout the country as a valuable addition to their training.

But, in the meantime, I was becoming restive with so uncertain a future in front of me. I applied for the Chair in Physics vacant at Royal Holloway College for Women in the University of London, and was interviewed by the Principal and some of her staff. But the appointment was given to Frank Horton who had been one of the candidates for the Bristol Chair three years earlier. Over 20 years later I met the Principal Miss Higgins more than once on social occasions, and on terms sufficiently friendly and light-hearted for me to ask her why she had not chosen me as a colleague in 1913. Whether or not she gave the true reason when she replied that I was too good looking will never be known with certainty!

But in the summer of 1914 there were signs that Senate and Council were preparing to drift no longer and to seek to fill the post by invitation. But whether Moseley, whose name was mentioned as a new star in the firmament, would have been attracted by an invitation is not known because on the 4 August, war with Germany broke out. Immediately a national order was issued that no senior University posts were to be filled until hostilities had ceased. Moseley therefore was never approached and, indeed, about a year later he was killed at the front.

For a time everything was in a state of flux. It must be remembered that in the first world war no general organisation of scientific effort was set up: the war had been in progress for some time before the need for scientists in warfare was recognised as urgent. Men went off to enlist in the Sappers, Gunners or Infantry at short notice or overnight. S.H. Piper for instance, who subsequently joined the department, spent the war from the first day to its last in the Infantry and was fortunate in surviving after serving in Gallipoli, France and Flanders. But later others, mainly through scientific contacts at high level, found themselves at Farnborough or in anti-submarine and sound ranging defence organisations. In Bristol it was not long before Fry departed to Serbia which was under invasion by Austria, and Hodgson was absorbed in the staff of Woolwich Arsenal. I myself was caught up in an appeal for help in the X-ray

department of the Royal Infirmary, receiving wounded from the front in large numbers. The method of locating bullets or shrapnel in the human body by taking two X-ray photographs from different positions was then known. But no-one in the hospital could be trusted to apply correctly the simple principle of similar triangles in order to interpret the pictures! So I was pressed in to operate the plant in the required way, and deduce the data. By attending operations in the theatre I was not only able to keep a check on the results, but also to set up subsidiary electrical gear for the surgeon's use at the table. I can claim no originality for my contribution; indeed later I trained radiographers to do it with equal competence. But learning from my experience how little knowledge and understanding of Physics some surgeons retained by the time they were fully qualified led me subsequently to make the first MB Physics course less academic and more vocational than it previously had been.

In 1915-16 I too left the University to organise and run an Army Radiological Department in Hampshire. I was about to pass on to the Mediterranean when I was summoned back to the University, partly to take charge of the Department which was in danger of disintegrating in my absence, and partly to supervise some investigations which the Admiralty had asked us to undertake as an off-shoot of the anti-submarine station in Suffolk.

Almost immediately after my return in the Spring of 1916, I was brought into personal contact with Henry Herbert Wills for the first time. No-one could have forecasted the future consequences of that meeting. Harry Wills was planning with the architect, George Oatley, the details of the Great Hall of the University, though its completion had been suspended until the end of the war. By a mere accident I heard that the Chemistry Department had been approached with the suggestion that the size of their battery of accumulators should be increased to provide an emergency lighting for the Hall in compliance with Board of Trade regulations relating to licences. Now the Chemical battery had also supplied the Physics Department for the previous 6 years, and an unsatisfactory source it had proved to be when constant voltage was required. I therefore wrote on the 5 April 1916, to Wills as Chairman of the General Purposes Committee to point out this inconvenience, and to ask that the new battery should be placed in my department where it could be put to some use instead of merely being kept charged for an emergency. Harry Wills replied saying that 'there is a good deal in that letter to be carefully considered and I think that it would be very desirable for me to have an interview with you at the University'.

On the 12 April he came to discuss the matter with me and to look for a room in which the battery could be housed; all I could suggest was the old Engineering boiler house to which reference was made above (Appendix I). It was clearly too small. But I was not then to know that the fact that it was too small and that an alternative house for the battery had therefore to be found was ultimately to lead to the gift and erection of the Wills Laboratory, and that the proposal to install a battery for emergency lighting would not merely be abandoned but also forgotten in official quarters. But three years were to pass before a decision to erect the Laboratory was made and the architects, Messrs Oatley and Lawrence, instructed to draw up plans.

The first site for the battery house that we looked at was the grass slope forming three sides of a quadrangle between the departments of Physics and Chemistry upon which two huts for Chemistry have since been erected. This site was large enough to accommodate not only a battery but a power room, a workshop and possibly some

dark rooms for Optics at the back, and I drew up a rough sketch to embody all these departmental needs.

The proposal simmered through the long vacation when I learnt that the Vice-Chancellor, Sir Isambard Owen, objected to it because it destroyed the only piece of green grass in the possession of the University. But by then I had sensed that Harry Wills with his Engineering experience in the Tobacco industry had some sympathy for strengthening the basic science of Physics in the University. So on the 21 October 1916 I sent to him a statement of a general scheme of extension 'as a pressing necessity if the University is to take its full part in the development of science and its application to industry after the war'. I spoke of a new Physics wing as the ideal solution, but I made an alternative suggestion that the Vincent Stuckey Lean Wing should be strengthened and rearranged internally. To this statement he replied a week later. 'It raises (so far as I am concerned for the first time) most important issues.'

The result of this correspondence was that when the architect reported to Wills that from £8,000 to £10,000 might have to be spent in strengthening the foundations of the building to which I had referred he said to me 'I would rather put the money into a new building'. So we set out to find a site for it!

I then sketched a building, echelon-shaped in section, to fit on to a wooded slope between the present Engineering building and Woodland Road. But again Sir Isambard objected, in this case on the ground that it would destroy 'the Grove of Academe', the only trees on land owned by the University. It was a bad site for a building in any case.

We then paced out the dimensions of a field which has since been laid out as the Hiatt Baker botanical garden. 'If it is for sale I will buy it for you' he said. But it was July 1917 before the sale was completed, and a few weeks later the whole affair was in the melting pot again, because when the deeds of the property were examined it was found that there were certain restrictions on the building line which did not leave enough room for the more ambitious laboratory, which by then we were contemplating. Meanwhile Harry Wills had purchased for University extension the Royal Fort estate from the last surviving member of the Tyndall family, an ancestor of which had created Tyndall's Park, but with whom incidentally I could not trace any relationship, at least not within recent generations. The original park of grass and woodland of earlier days had stretched from Queen's Road to Cotham Hill, with the present Elton Road and the part of Woodland Road to the north as carriage drives. By gradual sale the estate had contracted to the Royal Fort House and garden and a triangular sloping field on which Engineering now stands, both of which were included in the purchase.

At this stage Harry Wills invited me to join the Buildings Committee set up to consider the long and short term problems of laying out the Royal Fort Estate.

It was natural that Wills as a munificent donor both actual and potential should be allowed some authority in these matters. On the other hand I do not remember having had a single private conversation with Sir Isambard Owen, the Vice-Chancellor, in the whole course of the negotiations leading to the gift of the laboratory of the study of its plans. Indeed, when he opposed the earlier plans of building on the grass plot and the 'Grove of Academe' I was never sure whether he was encouraging or discouraging

further negotiations. Of course he may have been reluctant to disclose University policy to me since I was not a member of Senate; and he may not have wished to give me any grounds for thinking that on the cessation of the war I had the Chair of Physics in my pocket. I know that one member of Senate, Fawcett, Professor of Anatomy and for many years Dean of Medicine, was always bitter about the choice of Physics by Wills for his benefaction. He maintained that Sir Isambard, a medical man himself, ought to have advised Wills that the most pressing need of the University was a new Medical building. He may indeed have been right; it still has a high priority today nearly 40 years later! But in fairness to Sir Isambard, it must be said that Harry Wills was not an easy man to lead and it was impossible to drive him. He could be quite inflexible at times in following his own ideas. Moreover he was not favourably disposed towards the medical profession at the time, because an offer by him to give £100,000 to the Royal Infirmary and the General Hospital provided that they amalgamated into one institution, had just been refused. He told me that in consequence he had decided to build a home for incurable gentlefolk which would be independent of them in management. This was the origin of St Monica's Home which he endowed with more than a million pounds.

The Buildings Committee which I then attended had before it an outline plan of buildings in the grounds of the Royal Fort arranged round a large quadrangle with eight towers (similar to the present Physics tower) at prominent points and a central feature on the west side along University Walk, as depicted in the plan (Appendix II). The immediate purpose of the meeting was the siting of a 'hostel' for men students. But I argued that Physics should be incorporated in this great building programme and I complicated the issue still further by putting in a plea that the sloping triangular field on the City side should never be built upon but laid out as a botanical garden. Unfortunately I was completely ignorant of the fact that a plan was afoot to persuade Harry Wills to give up his country house and to take up his residence within the precincts of the University at Royal Fort House: to start immediately upon a big building programme virtually on his doorstep did not fit in with their plans and in consequence I incurred the particular displeasure of a good friend of the University and legal adviser to the Wills family, Mr Napier Abbot. My consternation can be imagined when after the meeting he said to me 'I am very annoyed with you. You have cooked our goose and done a lot of harm'. However some seven or eight years later in an issue on Council concerning procedure by the Society of Merchant Venturers, I took up a point of view which pleased him greatly and he passed a chit along to me which read 'I forgive you all the past'!

But the net result was that Physics was allotted a site in this proposed great quadrangle and Wills chose another home in Clifton which, in my opinion, he would have done in any case. Also the idea of laying out a botanical garden was accepted, but on the site at the end of Tyndall Avenue which Wills had originally bought for Physics. The sloping field that I had advocated was thought to be too exposed to South-West gales to be suitable for the purpose. Finally it was decided not to mix up residential accommodation with laboratory developments and so Physics remained as the only immediate building project!

It was first proposed that Physics should occupy most of the front flanking University Walk. But when I started to sketch it out, I realised that I was going to be the first to break into an old landscape garden with the inevitable destruction of some beautiful trees, and of the only semblance to a 'campus' in possession of the University.

Becoming increasingly reluctant to do so, I found an excuse for shifting the site to an orchard on the north side of the garden where a theatre wing could be set up in an L-shaped building without destroying the scheme of the central corridor which Wills envisaged as carried through all four side of the quadrangle.

With nothing destroyed but the orchard, an already ruined Cromwell House and the stables of Royal Fort House, the Henry Herbert Wills Physics Laboratory stands there today; its architecture must be judged in the light of the complete plan then envisaged and which presumably will never now be put into operation.

From the stables had already disappeared a carriage and pair which carrying one or more of the five Miss Tyndalls had been a familiar sight emerging into Woodland Road from the gates of the garden in earlier days. In that connection I am reminded that a few years later a newcomer to the academic staff visiting elderly friends in Clifton had enquired about the origin of Tyndall's Park. She asked further whether a Professor of that name at the University might be a member of the same family. 'I think that is very unlikely' was the answer 'the Tyndalls of the Fort were carriage folk'.

Though his intentions were clear, it was not until March 1919 that the first gift from Harry Wills of £100,000 was announced, followed by another £100,000 a year later. In March 1919 he also provided me with funds for an eleven weeks tour of Universities and other centres in the USA and Canada, three of which I spent with George Oatley, the architect. On my return I was greeted with the news that I had been appointed to the Henry Overton Wills Chair of Physics without interview or advertisement. By then presumably my selection for the post was inevitable.

But when the time approached for placing the contract for the building there was still no suggestion of an endowment fund without which it could be said that the University had been landed with a white elephant. If after its completion many rooms in the laboratory were to be unoccupied through lack of funds, transfer of some of them to other departments pressed for space by the great post-war bulge in student numbers might become inevitable. So I decided to forestall that possibility by choosing the department with which I would be prepared to share the building. In January 1920 I therefore suggested that the third floor of the building should not be set out with laboratory fittings but as a Mathematics Department, which would share a joint library with Physics. Six months later I tried to force action by writing to Harry Wills explaining my fears and suggesting that the size of the building should be halved so that an endowment fund could be established. I had however to be content with a verbal reply given with half a smile 'I don't say that I will not endow it when it is completed'. The building contract was given in June 1921 to Messrs Willcocks & Co. or in person, John Ward.

Then in the following Spring Harry Wills died. He bequeathed to the University a body of shares which yielded over £20,000 pa to be devoted to buildings and endowment. I had been elected to Council in the Autumn of 1920 and I managed to secure a decision on Council that 'not more than £4,000 a year' should be set aside from this fund to supplement the annual grant of the department when the new building approached completion. In the end however this grant was made from general funds, because Council accepted the advice of its Treasurer and later Chairman, Stanley Badock, that the interest on the Wills benefaction should be

allowed to accumulate to provide a series of University buildings with the capital sum left intact. Indeed, Manor Hall, the second residential hall for women, the Dental Hospital and an extension to the Library, were all built from income accumulated in this way.

In the light of present knowledge, this financial procedure may be thought of as over-cautious, particularly during the years of slump in the early thirties. Badock was not prepared to accept the argument of Keynes that this was the ideal time to build because labour was then at its cheapest, though the one academic member of the Finance Committee, Professor Andrew Robertson, advocated this policy. Additional buildings such as an extension of the Library out to Woodland Road, and a preclinical Medical building, both then envisaged and still required today, could have been erected at perhaps one-fifth of present costs. Badock had the support of the widow of Harry, Dame Monica.

The Autumn of 1919 saw the beginning of the post-war bulge of ex-service students, many of whom were given ex-service grants for University education. To accommodate them, all elementary lectures were duplicated and an additional temporary laboratory was provided by filling the present car park in University Road with an army hut and equipping it with an apparatus grant of £2,500. Other huts were procured for mathematics and erected on the present Engineering site.

To meet the rush of undergraduates several student demonstrators appointed including E.G. Hill (later Admiralty) and L.S. Palmer (later Professor at Hull). One reaction from the first world war, repeated on a far larger scale after the last war, was the greater importance attached to adequate laboratory assistance. In the Autumn of 1919 Harold Venn, who had been a laboratory assistant at Clifton College and had served the war as a Territorial in the Engineers, was appointed Steward with two boys under him, and Sargent's place as mechanic was filled by a highly skilled toolmaker, Muckle from Woolwich Arsenal. Muckle lasted about 10 years before giving up through ill health. At the time of writing this account Venn has just left the University at the retiring age, after 37 years of valuable and efficient service, characterised by his willingness, tact and imperturbability and the happy personal relations he established with everyone both within the laboratory and among his fellow-workers in the University.

But my first concern then was to strengthen the senior staff in some way. I had been in touch with Chattock throughout the war and had been able to help him in his work on the Physics of incubating chickens by devising two instruments for the study of hygrometry in confined spaces, one of which he used for measuring the humidity under a broody hen without disturbing her. But his main poultry investigation completed, I was glad to find that, under the changed conditions since his retirement, he welcomed an offer of £400 pa for five years to return to the University with no administrative or teaching duties, but with a free hand in the field of research.

Great changes in the subject of Physics had taken place since his University College days. While farming in Somerset for 9 years great development of the quantum theory had occurred and had passed completely over his head. So steeped was he in the Victorian classical tradition that he found the new conceptions almost too bewildering to accept. He never really understood the language. Indeed, his first thought on return in October 1919 was to take up again a problem on the Energy of an

Amperian Molecule which had led to a negative result in 1894. On the assumption that the molecules were rotating carriers of electricity, he had then argued that if you had an iron specimen magnetically saturated so that the plane of rotation was normal to the field, then if the magnetising field was suddenly increased the speed of rotation would be reduced, and by the principle of equipartition of energy the specimen would cool. He failed to detect the effect, but put forward the possibility that by waiting longer under better conditions of heat insulation it might have been observable. Coming back to it in 1919 he felt that modern vacuum technique supplied the answer to the insulation difficulty. I had to advise him of the changed state of atomic theory and put him in touch with various papers in the field of magnetism which had appeared while he was away.

The work of Einstein and de Haas on - as Chattock himself later rightly called it 'the Richardson gyromagnetic effect' - was one of them. Chattock picked this out as an experimental problem after his own heart. If the magnetic properties of a substance were entirely due to the rotation of electrons, then if its magnetisation was suddenly changed the specimen should be subjected to a mechanical torque, such that the ratio of the angular momentum to the magnetic moment should be 2m/e for a classical model and m/e for a quantum mechanical model. So far no-one had carried out measurements on these lines of sufficient accuracy to distinguish between the theories. Chattock's brilliant work with L.F. Bates carried out on his return, settled the issue in favour of the quantum theory to an accuracy of within 1%.

This was Chattock's last essay in experimental Physics. Indeed, it led in 1924 to his retirement into private life again before the full period of his appointment had elapsed. His shyness and reserve had increased with years, and he found himself being dragged into discussions on the theoretical consequences of his work, particularly on one occasion when Zeeman visited the laboratory. He just could not think in terms of quantised orbits, and he felt that he ought to be able to do so if he continued in the post. So he relinquished his salary, though for a period he still retained a corner in the laboratory and even published a paper later with G.C. Grindley on animal behaviour and experiments on memory in chickens. But within this period he had been elected in 1921 to the Fellowship of the Royal Society. It happened that O.W. Richardson while external examining at Bristol met him for the first time when the gyromagnetic work was beginning to show promise. Surprised to learn from me that Chattock was not a Fellow he took appropriate action, though it was not possible to find the requisite six Fellows to sign his form from *personal* knowledge of him without two or three eminent physicists drawing upon their imagination!

In the meantime other departmental changes had taken place. Three rooms in the basement of Elmdale House, the property of the University for a few years, had been allotted to the department, and one of these was set aside for the apparatus of Chattock and Bates, mainly operated only at night when traffic and electric trams had ceased to run. Hodgson resigned in October 1920, and in January 1921 S.H. Piper, BSc, DSO, then a lecturer in Nottingham University College, was appointed in his place. The records for the Session 1921-22 show as a matter of interest that the department grant for the year, exclusive of salaries and wages, was £285. In the Autumn, W. Sucksmith from Leeds, and H.E. George from Oxford, were appointed Assistant Lecturers. Sucksmith settled in to 19 years service in the department, but

after his election to the Fellowship of the Royal Society in 1940 he was appointed to the Chair at Sheffield. George resigned after 18 months to take up school teaching.

January 1924 saw the appointment of H.H. Potter, BSc (Bristol), PhD (London) as Assistant Lecturer. Potter had previously been the holder of an 1851 Exhibition under O.W. Richardson at King's College. In the Autumn, Sucksmith was given a full lectureship.

In that year two Yarrow Professorships had been created by the Royal Society. One of them was awarded to O.W. Richardson, who toyed very seriously with the idea of holding it in Bristol; the University even went so far as to issue an official invitation to him. Unfortunately progress on the building had been slow, indeed deliberately slow in order to accumulate a reserve fund from the interest on the capital already in the possession of the University. Quarters for Richardson were therefore not likely to be available for at least a year and the negotiations broke down.

It was during these years that a remarkable young man, P.A.M. Dirac, had been a student of the University. He started by taking first class honours in Engineering in 1921, but his advisers thought that he was more fitted for a career in Mathematics, so he came up the hill to spend two years in the Faculty of Science under Professor Hassé. Since he was never stretched, Hassé advised him to take as many of the Part II lectures in Physics as the timetable permitted. In this way it was I who first introduced him to Maxwell's work in Kinetic Theory of Gases and to the principles of the Quantum Theory. But I cannot pretend that I inspired him to take up a line that brought him a Nobel Prize only ten years later; indeed I have sometimes wondered what he thought of my lectures! It is interesting to recall that when in 1923 he obtained a first in Mathematics also, steps were immediately taken to see that he was accepted for postgraduate work in Cambridge. Today in like circumstances he could have remained in Bristol with equal profit, and have adorned the distinguished theoretical school since established in his *alma mater*.

Some years later I gave three fully experimental lectures on Light intended for VIth form school pupils. At the end of the first lecture a man in late middle life approached me to ask whether I was going to tell them about the Quantum Theory. Having heard my reply that at most only passing reference could be made to it, he enlightened me on his interest in it by saying 'I have a son called Paul Dirac who is said to be the world's expert in the subject and he cannot explain to me what his work is about. I was hoping that you would'! This was Dirac's father, a teacher of modern languages at Cotham Secondary School.

In 1924-5 M.G. Bennett was appointed Research Assistant. He was engaged firstly upon radio direction finding work for the Radio Research Board, and then on the obscuring power of smokes and of powders in suspension in a programme for the Porton Chemical Defence Station on the Committee of which I was an adviser. In the next year G.C. Grindley, a recent Bristol graduate, was appointed as an assistant to me in work on mobility of gaseous ions. I developed with him some new methods of measuring ionic mobility in gases, and with L.R. Phillips (later British Council) had analysed the effect of organic impurities of different chain length and dipole moment clustering around the ion. In other fields Sucksmith had continued the gyromagnetic work after Chattock and Bates had left, and Potter joined in magnetic work in an X-ray study of Heusler alloys. Piper was breaking entirely fresh ground by applying for

the first time the X-ray reflection technique to the study of long chain hydrocarbons and acids and making the first measurement of the length of a CH_2 group from a linear relation between chain length and the number of carbon atoms in the molecule.

These men formed a useful research team, but we all had a pretty heavy teaching load, and it was quite clear that to become prominent in British Physics, the Laboratory must include on its staff some men whose main function was research. Moreover, of most importance, there should be among them a theorist* of sufficient standing to attract a small group working preferably on problems related more or less directly to experimental work in progress.

With good recommendations from Manchester and Cambridge, J.E. Jones, who on marriage changed his name to Lennard-Jones, seemed the best choice, his interests then lying in the estimation of the forces between atoms and ions in terms of power laws of the distance between them. In 1925 he accepted the offer of a Readership in Mathematical Physics at £700 pa, the salary of a Chair being then £900.

The session 1926-7 saw the creation of two Henry Herbert Wills Research Fellowships: L.C. Jackson from Nottingham who was working in the field of paramagnetism, was appointed in December, followed six months later by H.W.B. Skinner, from Cambridge. The condition attached to these posts was that the holders could be called upon to devote not more than 25% of their time to teaching. But it was always intended that though other members of the staff might be expected to have heavier teaching responsibilities, the disparity in opportunities between Fellows and Lecturers should not be so great as to be a source of grievance or of friction within the laboratory.

In August 1927 Lennard-Jones was given the title of Professor of Theoretical Physics, though at that stage the University had not accepted the principle of a permanent set-up of two Chairs in the department. He was also given a Research Assistant, Miss B.M. Dent, a Bristol graduate in Mathematics, who remained for a few years before becoming Librarian to the Research Department at Metropolitan-Vickers Electrical Co. at Old Trafford.

On the 27 October 1927 the Laboratory was officially opened by Sir Ernest (later Lord) Rutherford, President of the Royal Society. Honorary Degrees were given to him, Sir William Bragg, Sir Arthur Eddington, Professor A. Fowler, and, to give the ceremony an International flavour, to Professor Max Born from Göttingen and Professor Paul Langevin from Paris. Many leading physicists accepted an invitation to the ceremony, to a banquet in the evening, and to formal lectures the next morning from Born and Langevin.

To a new generation it may seem that I have given in unnecessary detail this account of a gift of £200,000 and the spending of it. Today such a sum and much more can be spent on a single item of equipment and expenditure in general is on a totally different scale. But herein perhaps a future historian may find material with which to contrast the two periods, even though they are only about a quarter of a century apart. I can

* Through reference to old papers, I find that I had advocated such an appointment in a report on the future of the department as early as January 1917 before I knew that I should be given a Chair.

certainly testify that this gift, at that time the largest in the history of Physics in this country, struck the headlines; and given to a University which in all was less than a thousand strong, it certainly caused surprise. I believe the story to be true of one eminent physicist, whose name I have not been able to trace, who arriving with others for the opening ceremony stopped near the gate at the Fort to look up at this new imposing building. Then turning round to notice the street sign across the road he pointed his finger saying 'Look! Tyndall Avenue! My God! What swank!'. But called upon to propose a vote of thanks to Rutherford after his address, I was careful to say that buildings and equipment in themselves did not bring success, and that the outcome would depend on what use men and women made of the opportunities so provided. I can only say today that the distinction that my late colleagues brought to the department in subsequent years far exceeded any expectations that I had at that time.

PART III

In making reference to the new Laboratory it has on some occasions been referred to as the Henry Herbert Wills Physics Laboratory and on others as the Henry Herbert Wills Physical Laboratory. It is a matter of no consequence, but in point of fact, early references of mine speak of it as a Physics Laboratory, whereas in the original gift by Wills himself the word 'Physical' is used and departmental notepaper for some time has been so headed. But the title which appears inlaid in wood at the head of the departmental notice board placed in position in 1927 is 'Henry Herbert Wills Physics Laboratory' and there is something to be said for retaining it permanently.

Few buildings exist which are without faults, some unsuspected until disclosed by use, some due to bad judgement and some imposed by the nature of the site or other circumstances prevailing at the time of erection. I cannot escape responsibility for a large share of them in the Wills Laboratory. But I must confess that when I suggested that Physics should be accommodated within the Royal Fort grounds, I did not then realise that I was committing the University to a building of a degree of stability and permanence not normally associated with laboratory construction.

George and Harry Wills were men of simple tastes and interests. As public spirited citizens of wealth in Bristol they set out to follow the example of early donors of much older centres of learning by endowing the University, of which their father Henry Overton Wills was the Founder, with buildings which centuries hence would be a source of pride and enrichment to the City. In 1912 buildings of reinforced concrete were beginning to appear in this country. But when as donors of the main building in Queen's Road they were pressed to mark its period by replacing stone entirely by this material, they rejected the proposal because no-one would predict how reinforced concrete would stand up to exposure in all weathers for centuries to come, whereas stone had already been proved to stand the test. It was also in this spirit that Harry followed with his gift to Physics as part of his Royal Fort plan of buildings seven years later.

He himself had received some early training in Engineering which gave him a special interest in those aspects of the tobacco factory of Messrs W.D. & H.O. Wills. On retirement he had taken up the planning of buildings as a special hobby. Indeed, the portrait of him in the University Reception Room depicts him holding a set of plans. He had views on construction which no argument could shake. One was that all fittings and materials should be of such a quality that no repairs are required for 50 years; hence bronze window frames to avoid rust; partition walls, though adjustable in position if required, made of the best brick with cement mortar; and Keen's cement plaster everywhere because it does not flake like lime. Another was that supply pipes or cables must not run exposed along walls because they act as dust collectors: by all means have them fully accessible, but in floor channels with hard unshrinking teak covers and from which vertical pipes lead where required to wall or table points. And finally any floor in the buildings should be rigid enough to support running machinery with negligible vibration, and this, he said, had not been the case in his factory. Sample sections of flooring of three different thicknesses were therefore laid over the basement at one end of the building. But whereas I was of the opinion that the lightest floor was of adequate stability, he insisted on the heaviest!

But while it is therefore true to say that no-one nowadays would dream of copying the plans of the Wills Laboratory, it would be quite false to imply that the daily work the laboratory, whether in teaching or research, has been inconvenienced by these novel features of laboratory design. The only major trouble has come when the position of a partition wall has had to be altered or a hole driven through a floor. Until rapid cutting tools are invented for penetrating cement and brick of the highest quality, a job of this kind will continue to smack of a major operation.

But with no hope *ever* of changing the height of the room I was responsible for making them about two feet higher than I would otherwise have suggested. This has been criticised as so wasteful in space, but it has had one unexpected advantage. Recent demands for additional accommodation have been partially met by the insertion of galleries in some of the research rooms, and these would not have been possible in rooms of lesser height!

The position in which we found ourselves in the first session of the Laboratory was that we have acquired a second Professor and two research fellows without absorbing by any means the whole of the additional £4,000 pa grant. Moreover, seven years of accumulated interest had yielded an additional sum of about £95,000, with the result that when all building and equipment costs had been met a sum of nearly £40,000 remained. The interest on this residue covered for nearly twenty years all the additional occupational charges such as increased rates, supplies, porters and cleaning, and allowed as well an annual sum of £250 to be set aside to build up a reserve for repairs.

It was immediately clear that the first call upon the surplus funds must be the provision of more technical help. Firstly it was arranged that Miss B.M. Dent combined the duties of Research Assistant to Lennard-Jones with the post of part-time departmental librarian. A second mechanic, T. MacKeegan, was added to the Workshop.

Again the existence in the department of two batteries of accumulators together with a good deal of electrical equipment, made the appointment of an electrician very

desirable. Fortunately we had already had on the staff John Priest, who appointed as a laboratory boy seven years earlier had been taking evening classes at the Technical College for the Higher National Certificate in Electrical Engineering, and he was therefore already qualified for such a post. He is still with us and has in addition to these duties assisted in many ways the research programme as, for instance, recently on the electrical gear of balloons for the study of cosmic rays by the photographic emulsion method.

But perhaps the most interesting appointment made in the Autumn of 1927 was that of John Burrow to the post of Glassblower. Burrow in the previous summer had taken a Pass BSc Degree, but during his course had acquired a great interest in glassblowing, although we as his instructors were mere amateurs at the craft. Faced with the alternative of elementary school teaching he enquired from me what the possibilities were of becoming a scientific glassblower. The enquiry coming just when we were about to look out for one, I approached Thomas Loveday who had replaced Owen as Vice-Chancellor in 1922. Loveday's remark was 'A University graduate wishing to take up a skilled trade? Give him every encouragement! What do you suggest?'. My answer was the Summer School at Leiden University for two to three years and employment in the Wills Laboratory in the meantime. And so it happened. Burrow became the leading man in the country in his craft, a pioneer in the field of copper pyrex glass seals and during the war in the design at the prototype stage of short wave oscillators in copper and lead glass for the Admiralty. He also acted as adviser to several electrical firms called upon to make these oscillators in large quantities in the war effort, and he himself trained a number of others to copy his technique. He has been invaluable in a number of the experimental fields with which the laboratory has since been associated, my own work on mobility of ions, the low temperature work initiated by L.C. Jackson, the soft X-ray investigations by Skinner, the properties of thin metal films by Appleyard and Lovell, and more recently the work of Dr J.W. Mitchell. He is now a 'recognised teacher' in Laboratory Arts and is still going strong.

By then also the Laboratory was badly in need of a Secretary. Today it seem strange to recall that less than 30 years ago the idea that any one department could find work to justify a full-time Secretary was not acceptable to the authorities. Important documents, it was felt, could always be typed in the Registrar's Office. But it so happened that I was in a position of quite exceptional freedom, Loveday as Vice-Chancellor seemed to see in the budget of the Physics Department a complicated financial problem which in my view never existed. The result was that subject to the proviso that I did not commit the University to permanent appointments to an extent which might in a few years become a liability, I was given practically a free hand in collecting both personnel and equipment. Moreover I could use in a given year the whole of the £4,000 grant, or set aside some of it as a reserve to be tapped at any later time. This procedure also applied to certain other research funds acquired later, such as the Rockefeller gift referred to below. It was a happy state of affairs for me at this stage in the development of the laboratory, and in my view facilitated a healthy and efficient growth in its early years. But the position entirely changed at the end of the war when the sudden growth of the department used up all its reserve funds, and the change in the value of money made the pre-war income at my disposal entirely inadequate to meet even normal requirements under post-war conditions. It was then clear that the system of financial control must be common to all spending departments

and, indeed, that the interests of the department might actually suffer under any other procedure.

So in 1928, with a substantial surplus available from the £4,000 grant the decision to appoint a Secretary was mine, though I naturally consulted the Registrar to ensure that the salary for the post was in line with others in secretarial grading. Even so, however, I established a precedent because it was not long before other departments put in claims for secretarial assistance which could not be resisted by the Finance Committee.

Miss Alice Masters (now Mrs Terry) who was selected for the post was the niece of Sir William Bragg and an Australian by birth. For the past 28 years she has not only given most valuable service as general secretary to the department but has entered into its life in a very special way. Until my retirement she was also my confidential secretary, and I was indeed fortunate in receiving such loyalty and enthusiastic help. Every student in the laboratory has met her and many have given her their confidence and received from her sympathetic and helpful advice. Her friendly acts and hospitality to newcomers, including in particular young research workers sometimes with their wives, from foreign countries or the Dominions, has often helped them to settle down into English life and in Bristol as a happy place to work in. She still counts among them personal friends now scattered over the world whose earliest memory of her may have been when they arrived in England for the first time from overseas as she herself had done at the age of 20. At scientific conferences organised in the Laboratory her bowls of flowers on the tea table, and her personal service behind the counter have often given a pleasant feminine touch to the proceedings.

Finally, I cannot refrain from making a reference to Mrs Greed. Originally a parlour maid to the Misses Tyndall at the Royal Fort, and wife of their coachman and gardener living at the Lodge at the gate, she became portress to the Laboratory on the death of her husband in 1927. Until her retirement in December 1950, she spent her days in giving personal attention to all of us. The Laboratory through us became her life and she did not survive long after ageing years forced retirement upon her. But from her savings, through a life during much of which parlour maids and porters were ill-paid, she bequeathed the sum of £1,000 to give assistance to those members of the non-academic staff of the Wills Physics Laboratory 'who may be in misfortune or distress either by reason of accident, ill-health, old age or otherwise'. In any history of a laboratory it is right and proper that men and women of the maintenance staff who contribute so much to its life should receive mention, because unlike the academic staff they leave behind them no record of published work by which they can at least in part be judged.

While this consolidation was proceeding the general research policy of the Laboratory was exercising our minds. Many centres in the past have acquired or maintained their reputation by specialisation in a given field of work: Atomic Physics at Cambridge under J.J. Thomson, X-ray crystallography at Manchester under Lawrence Bragg, Low Temperatures at Leiden. Now I never had any delusion that a school of international repute was likely to grow out of my own line of work, the mobility of gaseous ions. Lennard-Jones on the other hand was beginning to command attention in fields of interest to physical chemists and we seriously considered making a concentrated effort in that direction. But after some tentative negotiations to this end with a prominent Oxford physical chemist had come to nothing, we let matters take

their own course by collecting some young men to assist existing members of the staff, leaving in abeyance any question of a later concentration of effort in a more restricted field. Though the somewhat unusual diversity of interest which still exists in the Laboratory arose in this way seemingly as a second best, it has proved to have merits of its own and to have enhanced the reputation of the Laboratory, while at the same time helping to widen the background of young physicists trained therein.

In one way it was perhaps fortunate that we had to look to other Laboratories to supply the young recruits in question. Considerable inbreeding at that stage would have had its dangers and at the same time the news that Bristol was a place with good facilities, and where posts were occasionally available, became more widely known in a shorter time. On the other hand the state of our honours school at that time was rather alarming and one which I did my best to refrain from mentioning within the University. In Appendix III, Graph A shows the number of undergraduates taking Physics Part II, Graph B the total number taking Physics at any stage, omitting medical and dental students, through the years. It will be noted that in the first session of the new Laboratory, with all its attendant publicity, there were only two Part II honours students, and *none at all* in the session after that! The figure only twice exceeded six before 1946-7. More striking still is the fact that the decline in total numbers taking Physics after the first world war continued not only after the bulge was exhausted but except for fluctuations continuously until it reached a rock-bottom of under 60 students in 1937-8. So that undergraduate numbers were dropping steadily through the ten years in which the international reputation of the Laboratory was becoming firmly established! So let us now return to that aspect of its life.

In the Spring of 1928 the Department of Scientific & Industrial Research offered me a research assistant of some years standing for three years, if I could find a suitable man. The Cavendish Laboratory was the natural centre in which to seek one in the first place and Skinner advised me of the existence there of a young man, C.F. Powell. But he was not among the three candidates selected by Chadwick and Ellis for interview, possibly because as a research student working under C.T.R. Wilson they were unaware of his potentialities. I left Cambridge without making an appointment, but in a subsequent interview at Bristol I had no hesitation in selecting Powell for the post, thereby not only starting an association of great value to me personally, but providing the University with a future Nobel Prizeman.

In Appendix IV I have endeavoured to collect a list of subsequent postgraduate and academic appointments, though in what follows some of them receive mention for particular reasons.

The first man to arrive under his own steam was D.C. Rose (now Ottawa) in 1928, a Canadian who decided to spend his second year in Bristol instead of both years at the Cavendish. The first postgraduate grant was given in the Autumn of that year to J.H. Lees who had recently graduated at Cambridge; followed by R.L. Brett, Commonwealth Fellow originally from Leeds. They were both assigned to Skinner. In the following session Wallace Harper arrived with his wife who had been Physics Tutor at Newnham. They both became closely identified with the life of the Laboratory: his wife who became ‘Mac’ to us all from her maiden name MacKenzie, quite voluntarily also contributing much to it in laboratory supervision and teaching.

It soon became apparent that some whom we would like to have chosen were not prepared to face the insecurity of a studentship which must normally be of limited tenure. On the other hand it was felt that a research grant of the order of £300 pa would probably attract young men of high promise from the Continent, who would jump at the chance of even a year's experience in England. So in order in the first place to feed the subject of molecular physics, by then Lennard-Jones' main interest, two Germans were selected and awarded a research grant of £300 pa for the Session 1928-9. G. Herzberg already beginning to be recognised as an authority in band spectra brought into the laboratory that technique, using a metre vacuum spectrograph designed by Skinner. M. Delbrück, Prussian by birth but cosmopolitan by nature, a theoretical physicist recommended by M. Born, brought with him intellectual stimulus, critical judgement and social entertainment which gave help and pleasure to many and sundry, even though he never published anything as the result of his stay. In recent years he has been a Professor of Biology in an American University. These were subsequently followed by K. Wieland from Zürich, M. Stobbe from Germany, killed later fighting the Russians on the eastern front, and C. Zener from USA (1932-4).

But we knew that by such appointments we should be overspending the £4,000 grant and eating up the reserve we had earlier accumulated, and therefore if they were to continue, fresh endowment must be secured. In the summer of 1927 and again a year later I had approached Professor A. Trowbridge, the European Director of the Rockefeller Foundation at that time, pressing him to pay us a visit. I had previously met him at Princeton in 1919. One evening in November 1928 two representatives of the Foundation, W.E. Tisdale and Lauder W. Jones were found by me at 6.30 pm inspecting the building from the outside. I quickly contacted Lennard-Jones and we took them out to dinner and started negotiations. It was soon clear that the idea of a general endowment fund in unspecified fields would find no favour with them. So we plunged for the subject of Molecular Structure and the chemical borderland of Physics, in which the new conceptions of wave mechanics were likely to find important application. This was a natural choice to make, because not only had Bristol been early in the field in promoting a wider study of theoretical physics in this country, but also because the Foundation representatives were clearly interested in Lennard-Jones' ideas on the matter. Moreover they gave proof of this by offering him a six months Fellowship to work with Max Born in the Göttingen Institute, which the Foundation was already supporting. However it was not until the Autumn of 1930 that the offer of a gift of £50,000 was made by the Foundation, coupled however with the proviso that an additional £25,000 should be provided from local sources, to be used to endow in perpetuity the second chair, at that time occupied by Lennard-Jones. After another rather sticky period of months until January 1931, Mr Melville Wills, brother of Harry, was induced to give the sum required, though he left us with the impression that he did so with reluctance, feeling that he was being almost blackmailed by the Foundation. With the income from another £75,000 now available, since the second chair was already in being and financed from the £4,000 grant, the financial future of the Laboratory seemed secure for a number of years to come.

In June 1931 several members of the Laboratory were given more permanent status in the University - Skinner as Lecturer in Spectroscopy, Powell as Lecturer, and H C Webster as Assistant Lecturer.

Relations with the Foundation continued to be cordial: Rockefeller Fellowships for study abroad were awarded within the next few years to Skinner for 1993-4 at Zürich, and later to E.T.S. Appleyard a newcomer who unfortunately died in 1939. Under the same scheme a Siamese, L. Brata, and a Romanian, H. Mayer, Fellows of the Foundation, elected to spend their time in Bristol. But after that the activities of the Foundation had to be curtailed for financial reasons, and help to Physics and Chemistry was cut out of their programme.

At that time Sir Frank Smith, Secretary of DSIR, was very concerned lest British Industry should suffer from an over-concentration in atomic and nuclear physics, and he stressed the fact that metallurgy was getting little or no help from physicists in this country. With this in mind, in the Spring of 1932 DSIR offered Lennard-Jones a research assistant provided that he would interest himself in the theory of metals and alloys. This was clearly an offer with potentialities for the future which it was important to accept and within a short time Dr Harry Jones, then at Cambridge, arrived to take up the appointment. But only a few months later Lennard-Jones accepted the Chair of Theoretical Chemistry at Cambridge and he left at the end of that year.

Now though in the appeal to the Rockefeller Foundation drawn up in 1928 we had stressed the importance of developing the field of molecular physics in Bristol, no obligation of any kind was imposed by the Foundation in their subsequent gift. So in seeking a successor to Lennard-Jones I took the view that we must get the best possible man irrespective of his field of work. I took men of seniority like Piper and Skinner into my confidence, a policy that I never hesitated to adopt when appropriate, and I had no hesitation in recommending Senate and Council to invite Nevill Mott, then only 26 years of age, to the Chair. He accepted subject to the condition, which we accepted, that he could remain in Cambridge until the Autumn of 1933.

By the time he arrived Harry Jones had dug himself into the problems of metal theory and experimental work on metals was also in progress. Skinner, after a relatively unfruitful period (from his point of view) looking for a possible phase relation between X-rays incident upon a crystal and the emitted electron waves, had started to investigate the excitation of atoms in the solid state by electron impact. This led him later to the study of the soft X-ray spectroscopy of metals in which he subsequently published work of fundamental importance and interest. Sucksmith had completed his beautiful experimental work on the gyromagnetic ratio of paramagnetic substances and with Potter had been studying the structure and magnetic properties of single crystals of iron and nickel. Potter extended the work to include Heusler alloy, and they were also jointly investigating specific heat changes at the Curie point. In the field of the solid state there was also Piper's X-ray work on long chain compounds and that of Jackson on the temperature variation of the susceptibility of paramagnetic salts, which with characteristic accuracy and thoroughness he carried out with the ingenious susceptibility meter devised by Sucksmith.

So Mott who at Cambridge had been carrying out his well-known work on the quantum mechanical interpretation of collision phenomena, came into a department with fields of interest quite different from his own. No-one could possibly have criticised him if he had continued his speciality and lost no opportunity to reorientate the interests of others in the laboratory in the same direction. Instead he decided to switch his own interests to metal theory, on which he said his ignorance was

profound. No more fortunate decision could have been made by him, not only departmentally but also in the interests of the subject of the solid state which he has since made peculiarly his own. He arrived in Bristol in the Autumn of 1933, and within six months he was publishing work in this field; his well-known treatise on the Theory of Metals and Alloys with Harry Jones was published in its first edition in 1936.

In the Session 1933-4 Jones was given a lectureship in theoretical physics and three George Wills Research Associateships were created, to which R.W. Gurney, E.T.S. Appleyard and W.R. Harper were appointed. A research studentship named after Chattock was created and filled by Norman Thompson whose degree work and doctorate thesis I had examined at Sheffield. But since 1939 this post has apparently disappeared from the scene.

In March 1933 I was elected a Fellow of the Royal Society, Lennard-Jones, though by then at Cambridge, appearing in the same list.

Reference has already been made to the use of laboratory funds to attract foreigners on short stay contracts. But as a result of the rise of Hitler to power in 1933 in Germany many physicists there found themselves out of their posts and in dire need. Despite the fact that we might well be committing ourselves to more than short term appointments, we felt that we must play our part by co-operating with the Academic Assistance Council in their efforts to place some of these scholars in appropriate employment. It so happened that in 1933 an invitation to spend six months in the department had been sent to Walter Heitler at Göttingen under our scheme for attracting promising foreigners on a short stay contract. In replying to accept the invitation he said that it had arrived by the same post as the intimation that he had been dismissed from his University post. Heitler was of the reputation that justified a permanent post which indeed he held until 1941 when he left for Dublin*. But feeling also that we ought to dip into the Rockefeller Fund to help others even though of less achievement, we gave grants to L. Frank and K. Fuchs, two young men who had nearly completed their work for the German PhD when facilities were withdrawn from them. Senate allowed them to count their previous work in Germany as equivalent to the Bristol BSc degree, and to embark upon a three year course of research. They were exempt from fees and given maintenance grants. Frank died during the war and Fuchs left for Edinburgh in 1938 after taking his PhD Degree. His subsequent history is known to many. The next to arrive was H. Bethe in October 1934, but he only stay 4 months before leaving for the States. Then followed H. Fröhlich who remained with us until his appointment as Professor of Theoretical Physics at Liverpool in 1948; H. London who stayed until 1942; K. Hoselitz who worked with me on ionic mobility for two years before transferring to magnetism under Sucksmith; and finally H. Heitler who joined his brother here in 1938.

Another important acquisition to the department was secured in 1935 by the appointment as Research Associate of Dr C.R. Burch. Burch had been a well-known figure in the research department of Metropolitan-Vickers, who amongst other things

* It may be interesting to place on record that in Mathematics Professor Ronald Hassé entirely on his own initiative collected over £250 from a number of Bristol citizens, a sum which served to finance for one year Hans Heilbronn, then a promising young pure mathematician and now Professor of Pure Mathematics in this University.

had transformed high vacuum technique by his extraction of low vapour pressure lubricating grease and oils. Having subsequently become interested in the figuring of surfaces in optical systems, he sought and accepted an opportunity to continue the work in Bristol. By his personality and experimental genius he has since enriched the Laboratory of which he is still a member. He was elected to the Fellowship of the Royal Society in 1944, was awarded the Rumford Medal in 1954 and has been holding a Warren Research Fellowship of the Society since 1948.

By about 1936-7 the Laboratory found itself in the forefront of British physics by the quality of the staff collected in it, and the variety of techniques in operation.

On the one hand there was Mott himself supported by Jones, Fröhlich, Gurney and others. Aided by the Electrical Research Association Fröhlich became interested in dielectric breakdown, and Gurney's association with Mott in the theory of the latent photographic image and of electronic processes in crystals was particularly fruitful. Heitler was more individualistic in his interests which spread to different fields including magnetic cooling and nuclear spin. There were also experimental groups headed by Skinner and by Appleyard. Skinner was joined in the field of soft X-ray spectroscopy by H.M. O'Bryan (from USA) and Appleyard collected A.C.B. Lovell, a Bristol graduate, to break fresh ground in the study of thin films of the alkali metals deposited *in vacuo* by evaporation. At Mott's suggestion Potter was studying the temperature coefficient of resistance of certain alloys, while Thompson was making an interesting study of the resistance of bismuth and the Hall effect.

Again L.C. Jackson, with little help, had gradually been building up a low temperature plant so that liquid hydrogen and liquid helium were available not merely for his own work but for others in the department. He supplied liquid hydrogen for Pearce and myself for the measurement of the temperature coefficient of mobility of positive ions in pure helium, and for Appleyard's work on thin films. London's investigations on high frequency resistance at helium temperature could never have been carried through without his personal assistance. And finally he himself was later to complete his own important and novel measurements on the thickness of the helium II film.

But while there was clearly in this programme some concentration in the study of the solid and liquid states of special interest to the theoretical team, some other work was proceeding with satisfaction and profit. Piper was in collaboration with A.C. Chibnall first in London and then in Cambridge, investigating by X-rays the structure of waxes of interest in the study of the metabolism of plants. Burch was already perfecting his figuring technique of glass surfaces and had collected a recruit in E.H. Linfoot, lecturer in Pure Mathematics. Burch suggested to him that he should take up the problem of the 'Schmidt Plate' as a method of correcting aberrations. Linfoot, now at the Cambridge Observatory, has since become a leading expert on that subject. Finally there was my own small group on ionic mobility in pure gases and the effects of known concentrations of impurity.

Yet at the teatable and at coffee parties in private homes discussions were rife on the successes in nuclear physics at Berkeley and at Cambridge, and these raised the doubt whether in the future any Laboratory would acquire full international prominence unless some branch of nuclear physics was a subject of experimental investigation within it. Many informal discussions took place on policy, centring around what type

of machine should be installed. Both Skinner and Harper had shots at making a modification of a Van de Graaff machine, but finally Powell led a group in erecting on the fourth floor a 700 KV Cockcroft generator embodying a few improvements of his own. It gave a highly focussed proton beam passing through a hole of about 1 sq mm which the beam itself had burnt out when incident upon a plate of quartz. It was while he was constructing an automatic cloud chamber to use with the generator that Blau published in Nature a picture of a track produced by a cosmic ray in a photographic plate. Instead of waiting for the completion of the cloud chamber, Powell exposed a plate to the proton beam at grazing incidence. He was so impressed with the result that the chamber was never completed! He believed from the start that with improved technique the method not only could be made quantitative but would have special virtues in its application. This view was quite contrary to conclusions of previous workers, one at the Cavendish in particular as late as 1936. He satisfied himself (and incidentally us who watched the work) that he was justified in his belief by studying a few reactions which had already been analysed by cloud chamber and counter techniques.

At the same time the work on cosmic rays was followed up by Walter Heitler (who exposed plates at the Jungfrau Observatory and analysed them on his return) and by G. Fertel, killed 10 years later on the cyclotron he was helping to construct at Birmingham while on leave of absence from Bristol. It was in this work that the need for thicker and more concentrated emulsions first became clear, but the outbreak of war put an end for the time being to the experiments that Messrs Ilford had started upon at Powell's suggestion.

Another feature less common in that period than today and one which gave wider publicity to the department was the series of small International Conferences that Mott was responsible for organising and to attend which selected foreign guests were relieved of expenses from departmental funds. Four days on the Metallic State were spent in the Summer of 1935; another four days in 1937 on the Conduction of Electricity in Solids, with discussions opened by Pohl and Hilsch on Processes in Halide Crystals, and by de Boer on Semi-conductors. A third Conference of three days on Internal Strains in Solids finished only 7 weeks before war broke out in 1939. Finally, in the months of tension before the war in 1939, it was realised in high quarters that if war broke out more trained personnel would be required for research and development in Radar which had been secretly developed, and Cockcroft was given the task of securing several teams of physicists to man Radar Stations round the coast for a period during the long vacation. Bristol was the only provincial University to provide a complete team to man a station, in this case at Poling in Sussex. Mrs Harper rented and ran a house there for a team of Mott, Skinner, Sucksmith, Harper, Fertel, Burrow, David (a postgraduate student) and Griffin (a laboratory assistant). They were there when war broke out on the 4 September 1939, though soon to be absorbed in various phases of the war effort elsewhere when regular troops took over the routine work of the station.

It had already been arranged that in the event of war King's College, London, would be evacuated to Bristol. C.D. Ellis, Flint, Alan May, Champion and Chapman, with their laboratory staff arrived, and we made arrangements to share out the teaching for both degrees between the two staff. But whereas Ellis insisted on retaining his staff and postgraduate students in the hope of creating his own war group, we cut ourselves to the bone in supplying service to research establishments. Mott soon joined Anti-

Aircraft Command, Skinner the unit that was to become Telecommunications Research Establishment, Harper, Thompson and Fertel the Admiralty, and so on. After two years Ellis took the same steps and he himself left Bristol.

But after the invasion of France in 1940, the Laboratory filled up to capacity. Firstly a group of Admiralty Signals arrived to occupy the second floor and to absorb three-quarters of the facilities of the workshops and staff. The 700 KV Cockcroft generator on the fourth floor was also dismantled, and indeed never re-erected, although £2000 was obtained from the Admiralty in compensation. Burrow and his glass shop became the centre of some of the important developments in Klystrons and other Radar devices, and Admiralty staff joined Tressider our head toolmaker in the Workshop. Some members of the laboratory also co-operated with the group which included a small firm, Redcliffe Radio, given quarters on the ground floor because of loss of premises twice through bombing. The group remained throughout the war under the happy and fruitful leadership of Dr R.W. Sutton.

At the same time in 1940 the Ministry of Education introduced the wartime scheme of student bursaries which in the case of Physics included training in radio as part of the degree curriculum. This brought a big influx of students to both Bristol and Kings. 'The Principles of Radio' was instituted as a subsidiary subject and studied by honours students for two years and by others for one year plus a summer vacation special school. The honours curriculum was shortened to two years and one term, though a six week's course was also included in the last long vacation.

The winter of 1940-1 saw Bristol suffering from a number of bombing raids and still more alerts. In one of the raids a bomb at the top of St Michael's Hill blew in all the windows on that side of the laboratory, the associated suction wave pulling some of them out in the corner of the L of the building on the other side. A large stone also came through the glass roof of the loft. But the laboratory was never called upon to stand the test of a direct hit, and in due course the war ended to begin a new phase of development.

In the closing phases of the war Mott was head of a theoretical group at the Armament Research Department at Fort Halstead. When he left it to return to Bristol we arranged that he should bring with him A.F. Devonshire as a research associate, and J.W. Mitchell as Lecturer for the 1945-6 session. D.F. Gibbs also came to us at the end of 1945 to the post of Lecturer. In June 1945 Occhialini arrived to spend three years with Powell. He had come to England from Brazil by invitation from the British Government to join the British Atomic Energy team, but, with the success of the bomb trial in New Mexico, policy changed and foreigners were excluded. We took on Occhialini in the first place partly to relieve DSIR in an embarrassing situation, but in the following spring we agreed to finance him from departmental funds. D. McGill came in 1946: he was a pre-war schoolmaster with Admiralty experience who was brought in to organise and control the more elementary teaching, and he remained until 1952. H.F. Kay, an X-ray crystallographer from Manchester and Cambridge, was appointed to a lectureship in 1947. In 1947 also, following a meeting of the Faraday Society which was held in the Physics Theatre, Charles Frank accepted an invitation to join Mott's team in what proved to be a happy association. In the summer of 1948 P.H. Fowler, son of R.H. Fowler and grandson of Rutherford, took his degree and in view of his wartime record was elected to a Grade III lectureship: E.B. Mendoza was also appointed at the same time.

The most striking sequel to the war in its effect on the department was the change in the attitude of industry to the employment of physicists. Before the war relatively few Bristol Graduates in Physics secured industrial posts. Reference has been made earlier to the smallness of our undergraduate school between the wars. Indeed it was then customary to admit to the department any student who had the necessary matriculation qualification, and the head of a science department not only advised them but also felt some personal responsibility in the task of placing them in employment after graduation. A change first set in when after 1940 students of physics were reserved for training and then directed into the various phases of the war effort after interview in the department by Dr C.P. Snow and his deputy H.S. Hoff representing the Ministry of Supply and the Services. Numbers leapt up because of this demand, but as Graph A in Appendix III shows they also continued high afterwards, because the growing applications of the subject in government centres and industry maintained the demand. So by the time I retired entry had become a highly competitive process, with only about one sixth of our honours school supplied from local sources. We found Snow and Hoff replaced by a variety of emissaries, so that the students were mostly able to make their own choice from several organisations competing for a promise of their services weeks before they were even sitting for the final examination. After my retirement I asked Piper how they were coping with the constant visits to the laboratory for this purpose. He answered: 'We have now got that taped, we have reserved Fridays for teaching.'

In these post-war years the whole financial outlook has changed to an extent which has made efforts of which we had been quite proud twenty years earlier seem rather small beer. Graph D in the Appendix covers the following figures of expenditure for 1927 when the Laboratory was opened, for 1938-9 before the war, for 1947-8 my last year of office and for 1952-3 when Mott left.

	1927-8	**1938-9**	**1947-8**	**1952-3**
Academic salaries	£6,500	£12,800	£19,400	£32,700
Number of postgraduate workers	6	20	50	64
Number of technical staff	7	10	33	43
Wages	£1,100	£1,500	£7,100	£19,400
Departmental Expenditure	£950	£1,200	£6,800	£22,800

Before the war the general natural development of the department received some financial assistance from DSIR, the Electrical Research Association and the Academic Assistance Council to aid refugees. In the post-war period the department's share in increased Treasury Grants covered more than the increased costs of living and enabled additional appointments to be made, including a number on the technical staff.

At this point special reference may be made to the great development of the technical staff of the department, which has been one of the special features of the post-war period. When I was a young man it used to be said that in a continental laboratory the thing that distinguished an Englishman from his fellows was his independence of the services of technicians. Indeed occasion sometimes arose when he would be watched by them doing his own glassblowing, carpentry or metal work, and so getting on with his work while they were waiting in a queue for workshop assistance. Such conditions probably helped to develop resourcefulness in experimenters in the days of 'sealing wax and string' and contributed to the reputation of this country in the experimental fields of those days. But progress always involves some losses on the other side of the balance sheet, and the increase in complexity of experimental techniques and in tempo have now made maximum technical assistance inevitable if a laboratory is to remain in the forefront of scientific advance.

In addition to increased grants direct from the University, considerable sums have also accrued to the department from outside sources, over £7,000 in the year I retired and more than double that a few years later. These grants included £1,000 a year from Messrs Kodak to assist Mitchell's* programme of work on photographic processes, and sums of varying amounts and at various times from the Iron & Steel Federation, Anglo-Iranian Oil Co., ICI, the Electrical Research Association, and Diamond Corporation, the Paul Fund of the Royal Society, and DSIR. These funds enabled a number of short term appointments to be made including: G. Wyllie (1946-50); J. Friedel from Paris (1949-52); Szigeti to work with Fröhlich; W.K. Burton (1947-51); and N. Cabrera (1947-49) to work with Frank; G. Occhialini (1945-48), C. Lattes, U. Camerini (1946-51), C. Franzinetti (1947-50), R. Dalitz and D. Perkins to work with Powell.

Since 1946 the contribution by DSIR to the work of Powell has been substantial. Throughout the war his work on nuclear processes by the photographic method had been slowly ticking over, though the technique did not prove yet to be sufficiently advanced for use in the uranium fission programme. Then came the time in 1945 when Messrs Ilford were free to take up again, and with success, the production of an emulsion with greater silver content. Immediately rapid progress could be envisaged if the necessary team of physicists and plate scanners could be assembled. The war over, a Nuclear Physics Committee of DSIR drew up plans for the erection of machines in a number of centres involving the expenditure of large capital sums. Bristol sought no machine, but an annual grant for Powell's work - in 1946 the Committee gave £21,000 to cover a period of five years for that purpose. Then from the summer of 1945 a period of several years of feverish activity set in and it became a commonplace event for me to take the lift the fourth floor, to ask if they had anything new to show me and rarely to be disappointed, even though at first it was only examples of large and small scattering phenomena and disintegration stars

* Mitchell was elected to the Fellowship of the Royal Society in March 1956.

known as rare events in an expansion chamber but now observed in profusion on one photographic plate exposed to a cyclotron beam or to cosmic rays. But visitors were more frequently shown a whole gamut of the events on a screen in the darkroom by a microprojection arrangement set up by Occhialini and christened by him 'the Telepanto' from (he said) Tele: I see, Panto: everything!' In it the stage of the microscope was given a slow transverse motion by clockwork, and at the same time focussing in depth was put into regular slow oscillation, in order that the viewer could follow tracks dipping into the emulsion or out towards its surface.

Another incident of this period that I like to recall was the discovery in 1946 by Peter Fowler of a collision between a nitrogen and a deuteron nucleus giving rise to four alpha particles. He correctly analysed this event on his own initiative and the work was subsequently published. On only two occasions have students of mine published original work before graduation. The first was E.G. Cox in his final year in 1926. But Fowler's discovery was made while he was working in the long vacation waiting for the start of only the second year of his honours course.

In order to speed up the work the next step was to collect more unskilled but intelligent scanners, whose task was to examine plates and record what they saw. A year or so later this group, greatly expanded in number, became known to some as 'Cecil's (Powell) beauty chorus'. The task of making large polythene balloons for high altitude flights had then been added to their duties. Then came m-meson tracks, the first discovered by one of these scanners who reported a track of unusual appearance. This led to a competition between the members of the group who, knowing by now what to look for, finished by finding some every day.

The excitement of the discovery of the π-meson was intense and the occasion was such that Occhialini of undoubted rationalistic outlook could only express his feelings by going into the R.C. Cathedral to light a candle! And there was still to come the electron sensitive emulsion to complete and round off the whole story. Powell himself as the originator of the technique as a quantitative tool was elected a Fellow of the Royal Society in 1949, as its Hughes medallist in the same year, and awarded the Nobel Prize in 1950. I found myself sharing in this excitement in a rather special way. In informal talks with students from time to time I had told them of my student days when I was able to follow with eagerness and without the slightest technical difficulty, month by month in the current journals, the actual growing point of a great new development, the phenomenon of radioactivity. I questioned whether any of them or their successors would ever have quite the same experience. Then from 1945-8 I watched it happening again. But this time I did not follow it by reading journals, I witnessed it in my own Laboratory. And once more, at this early stage at least, the results were simple and direct, and interpretable from first principles. It was as though I had travelled a full circle and could sing a Nunc Dimittis to retire from office without regret, and, indeed, not without some measure of relief. Indeed, my contribution to the laboratory from 1945 onwards had been little more than that of an administrator of routine. I found myself in October 1944 sharing the Vice-Chancellorship with Loveday until April 1945, and from that date alone until the 1 February 1946, in that office as Acting Vice-Chancellor. My own pre-war research equipment had all been cut down and dismantled in 1940 to make room for others, and I felt no great urge to start it all up again afterwards for so short a period. My normal date of retirement was the 31 July 1947, but Mott was anxious to have another year to consolidate his work after the war before settling down to a life of greater

administrative responsibility. He persuaded Senate and Council to invite me to continue for another year so that I retired only two months short of my 67 birthday in 1948.

In this story I have said little of my indebtedness to my academic colleagues. But their help and loyal support has been so varied in kind and degree as to make acknowledgement in brief terms quite impossible. I must however make one exception to speak of Stephen Piper with whom I was associated for a greater span of years than any of them. Piper was not only my right hand man in the department from the day of his appointment in 1921, but we also shared life together on family holidays and walking tours, in Dominion travel and on the tennis court. The general organisation of the day to day teaching was in his hands, and he never allowed anything to interfere with his own part in it. Indeed he was a man with such a deep sense of responsibility - as exemplified by his national service in two world wars - that to say 'Oh Stephen will look after that' was at times a temptation too hard to resist. Moreover his active interest in the affairs of the University Union gave him a knowledge of students far beyond the confines of the department and he was a man who secured their confidence. His sense of humour and of the ridiculous, coupled at his best with a lightning spontaneity of phrase, enriched our experience. He made no heavy weather when he caught two students kissing in a darkened Optics Laboratory. He merely said to the man 'Kindly remember in future that it is I who demonstrate in this department.' One year he noted that the list of titles of papers published from the department included: 'Necking in chromium bars'; 'Localised necking in thin sheets'; 'Creep on virgin surfaces'. The chuckle with which he read them out was a warning to the authors to choose less ambiguous titles in future!

In my view he has never been given the full credit due to him for his pioneering work on the structure of aliphatic compounds because independent workers in the Royal Institution in the same field were able to follow up the problem at full speed with no teaching or administrative duties to distract them. I was therefore glad to find that on my retirement he was given the title of Assistant Director and still more pleased when in 1951 he received the full recognition of a professorial chair in the department for the last three years of his academic life.

The choice of Mott as my successor, and of Powell to the Melville Wills Chair vacated by him, was never in doubt. When Mott accepted the Cavendish Chair of Experimental Physics at Cambridge in 1954 the University was fortunate to find M.H.L. Pryce willing to vacate the Wykeham Chair of Physics at Oxford to accept the Henry Overton Wills Chair that Mott vacated. The high reputation that Frank had in the meantime acquired through his work on dislocations in solids and the mechanism of crystal growth was at the same time recognised by the creation of a special Chair for him in the same year. He had been elected a Fellow of the Royal Society six months earlier.

But the full history of the department since 1948 is a subject for others to write at some future date.

Appendix I

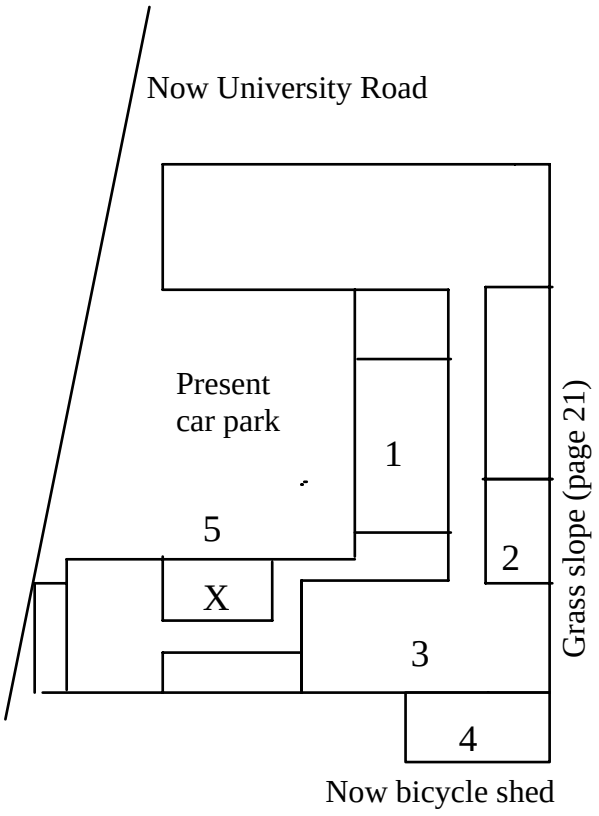
1. Physics Lab 1883-1927

2. Physics Workshop 1910-1927

3. Engineering Workshop until 1909 then Physics

4. Engineering Boiler House (Page 21)

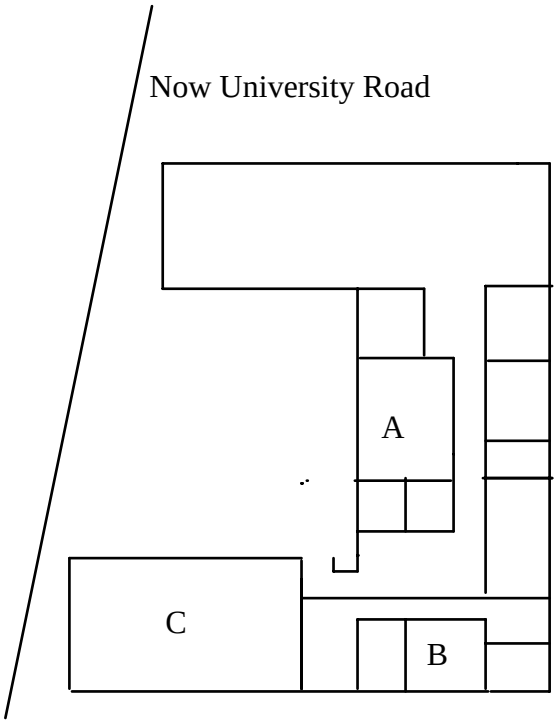
5. Vincent Stuckey Lean Wing: Ground Floor ocupied by Physics 11911-1927, but Room X used for Electrotechnics 1907



Suite of rooms around A - Physics until 1911

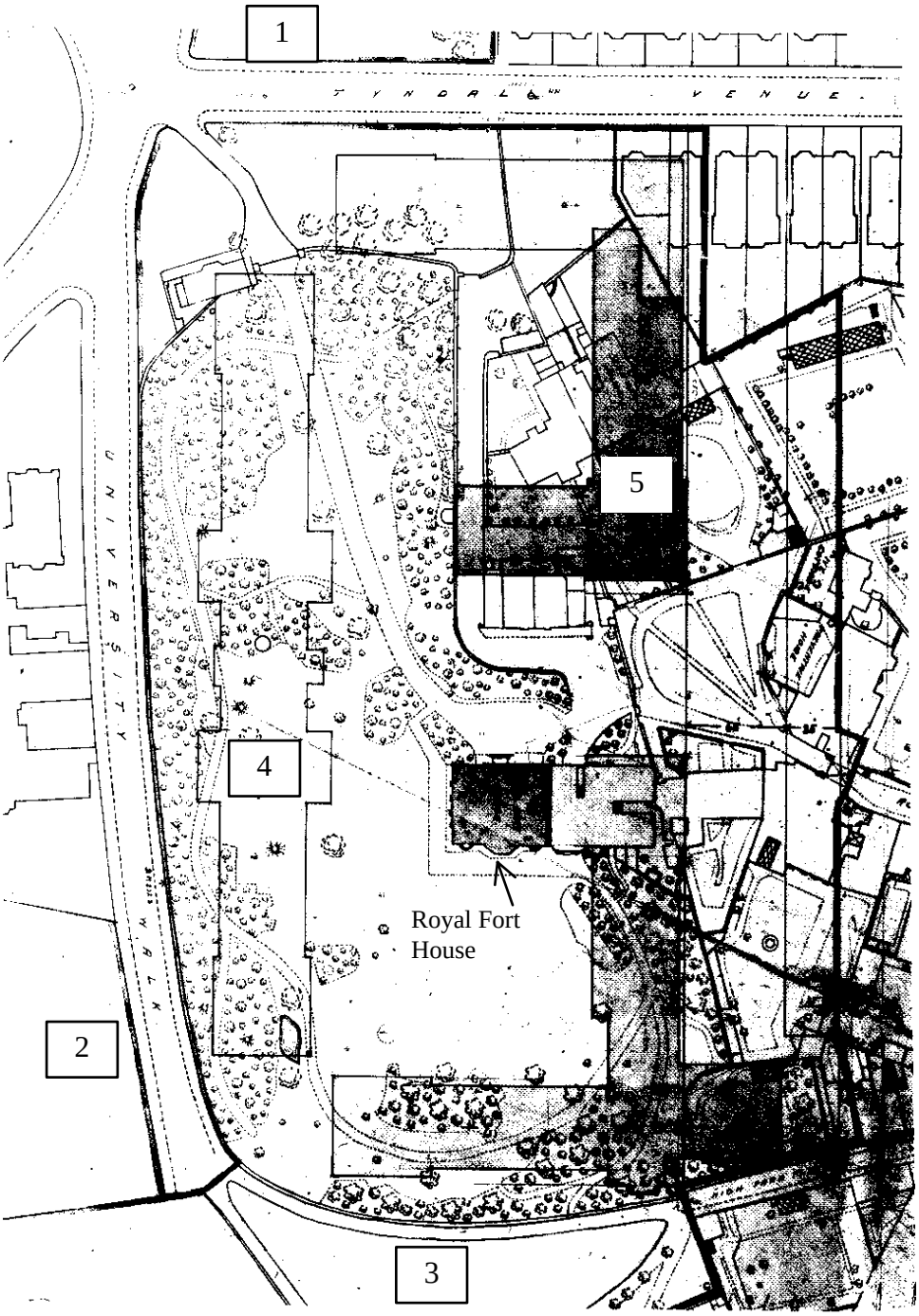
Suite of rooms around B - Physics 1911 - 1927

Vincent Stuckey Lean Wing, upper floor C (page 21)



APPENDIX II

GREAT QUADRANGLE to be erected on the ROYAL FORT ESTATE. Proposed in 1917



1. Field originally bought for Physics (Page 18): Now Botanic Garden, (later Senate House).

2. “Grove of Academe” (Page 18)

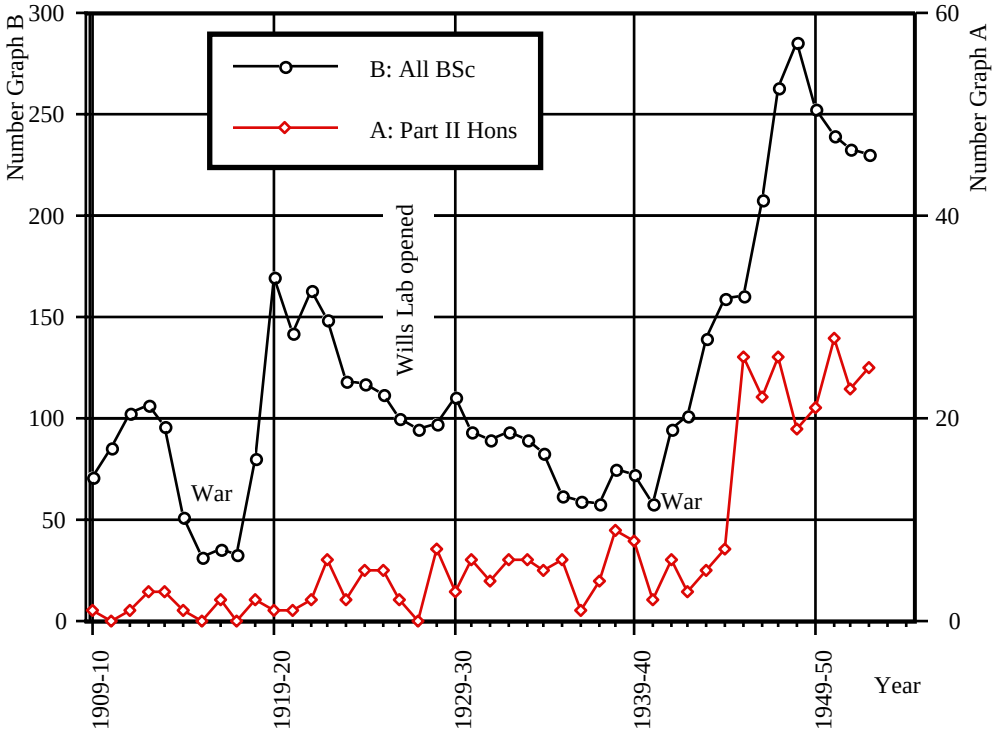
3. Sloping triangular field (Page 19)

4. See page 19

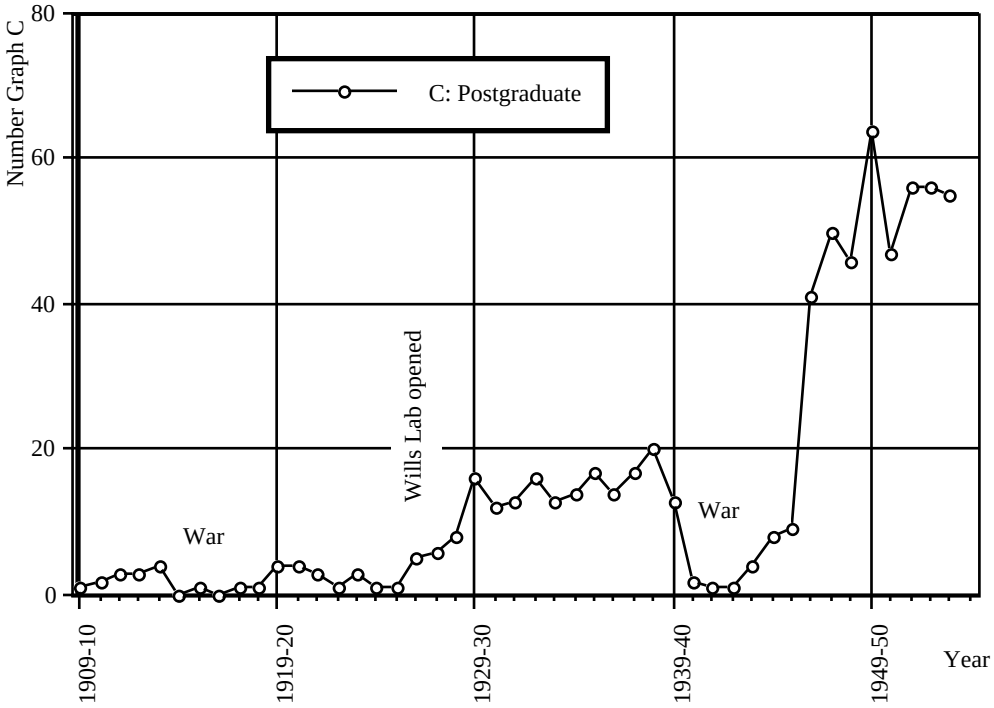
5. Final site for Physics

APPENDIX III

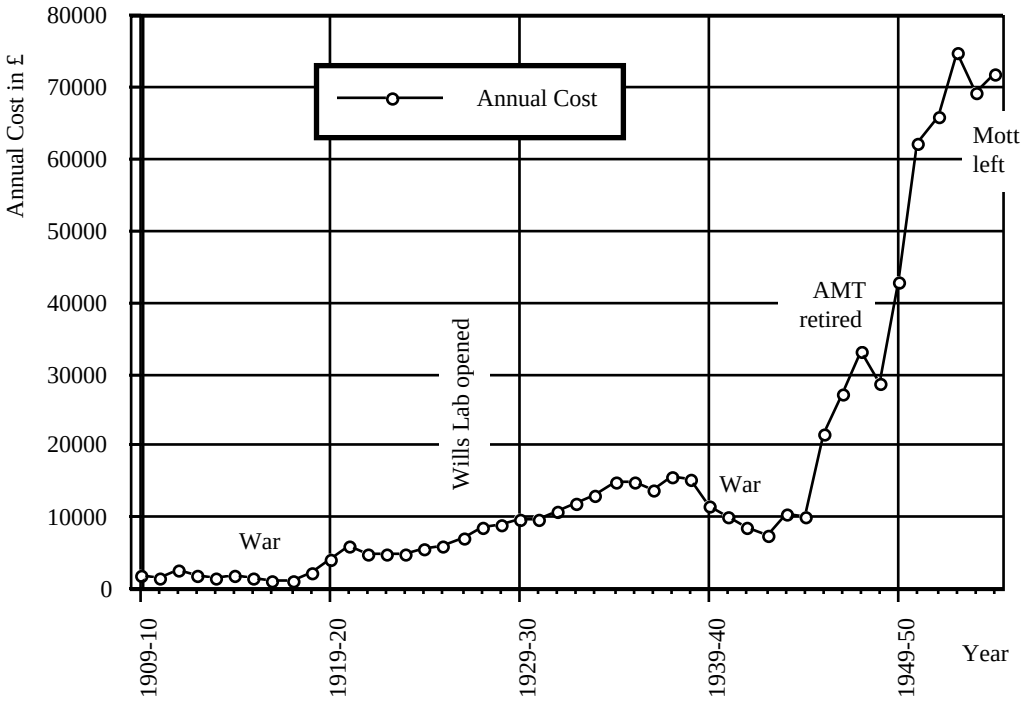
Physics Undergraduate Numbers
A: Part II Honours
B: Honours, Pass and Subsidiary, inter. BSc



Post-graduate Numbers



Salaries, Wages and
departmental expenses



PHYSICS DEPARTMENT -

UNIVERSITY COLLEGE, BRISTOL

UNIVERSITY OF BRISTOL

later known as

H.H. WILLS PHYSICS LABORATORY

List of Professors, Readers and Senior Lecturers, Staff, Research Assistants, Research Workers and Post-graduates

Up to the time of the retirement of Professor A.M. Tyndall in 1948

(This list was compiled by Professor Tyndall and typed after his death by A.T. Terry - October 1961)

PROFESSORS

THOMPSON, Sylvanus P.	Lecturer 1876-8 Professor 1878-85	F.R.S. Principal Finsbury Technical College
RYAN, J.	Professor of Engineering & Physics 1885-93	
CHATTOCK Arthur Prince	Lecturer 1885-7; 1889-93; Henry Overton Wills Professor 1893-1910. Emeritus Professor 1919-23	F.R.S. 1921
TYNDALL, Arthur Mannering	Assistant Lecturer & Lecturer 1903-19; Henry Overton Wills Professor 1919-1948	F.R.S. 1933 C.B.E. 1950
LENNARD-JONES, John Edwin	Reader 1926-28; Professor 1928-30; Melville Wills Professor 1931-2	F.R.S. 1933 Professor of Theoretical Chemistry, Cambridge

MOTT, Nevill Francis	Melville Wills Professor 1933-48; Henry Overton Wills Professor 1948-53	F.R.S.1936 Hughes Medal 1941 Royal Medal 1953 Cavendish Professor, Cambridge
POWELL, Cecil Frank	Research Assistant 1928; Lecturer 1931; Reader 1946; Melville Wills Professor 1948-	F.R.S. 1949 Hughes Medal 1949 Nobel Prize 1950
PIPER, Stephen Harvey	Lecturer 1921; Reader 1933; Professor 1951-54	
FRANK, Frederick Charles	Research 1946; Fellow 1948; Reader 1951-54; Professor 1954-	F.R.S. 1954
PRYCE, Maurice Henry LeCorney	Henry Overton Wills Professor 1954-	F.R.S. 1951 Wykeham Professor, Oxford 1946-54

READERS AND SENIOR LECTURERS

FRÖHLICH, H.	Research 1935; Lecturer 1944; reader 1946-48	F.R.S. 1951 Professor of Theoretical Physics, University of Liverpool
JACKSON, L.C.	H.H. Wills Fellow 1926 Lecturer 1947; Reader 1956-7	Professor of Physics at Royal Military College, Kingston, Canada 1958
SKINNER, H.W.B.	H.H. Wills Fellow 1927; Lecturer in Spectroscopy 1934-46	F.R.S. 1942 Professor of Physics, University of Liverpool
SUCKSMITH, W.	Assistant Lecturer & Lecturer 1921; Reader in Magnetism	F.R.S. 1940 Professor of Physics, University of Sheffield
THOMPSON, N.	Chattock Research Student 1933; Lecturer 1937; Senior Lecturer 1952; Senior Tutor 1954-6	

STAFF

APPLEYARD, E.T.S.	1930	Research Grant	
	1933	George Wills Associate until death in 1939	
BATES, W.J.	1946	Demonstrator	
	1947	Assistant Lecturer	
	1957	George Wills Research Fellow	
	1957-61	Lecturer	
BOOTH, F.	1945	Lecturer	
BORTHWICK, Miss P.M.	1910-11	Assistant Lecturer	
BURCH, C.R.	1935	George Wills	F.R.S. 1944
	1944-48	Associate Fellow	Rumford Medal 1944
	1948-	Royal Society Warren Fellow	
BURROW, J.R.	1927-	Glassblower: Recognised Teacher in Laboratory Arts 1945	
DEVONSHIRE, A.F.	1945	George Wills Associate	
	1951-	Lecturer	
FERTEL, G.E.F.	1938	Research Grant	
	1946-48	George Wills Associate	
FRY, J.D.	1898	Assistant Lecturer	
	1919	Lecturer	
GEORGE, H.E.	1922-3	Assistant Lecturer	
GIBBS, D.F.	1945-	Lecturer	
GURNEY, R.	1933-39	George Wills Associate	
HARPER, W.R.	1929-33	Research Grant	
	1933-39	George Wills Associate	
HARPER, Mrs G.I.	1929-43	Voluntary Teaching	
	1943-47	Lecturer	

HEITLER, W.R.	1933-41	Fellow	F.R.S. 1948 Professor of Th. Physics, University of Zürich
HODGSON, B.	1911-20	Assistant Lecturer	Mullards
HUGHES, H.G.	1920-21	Assistant Lecturer	Admiralty Signal School
JOLIN, Miss D.E.	1919-21	Demonstrator	M.Sc. 1921
JONES, H.	1930-33 1933-37	Research Assistant Lecturer in Theoretical Physics	F.R.S. 1952 Professor of Mathematics, Imperial College, London
KAY, H.F.	1947-48 1948-	Assistant Lecturer Lecturer	
MALCOLM, H.W.	1902-3	Assistant Lecturer	
McGILL, D.	1946-51	Lecturer	H.M. Inspector, Scotland
MITCHELL, J.W.	1945-48 1948-59	Lecturer Reader	F.R.S. 1956 Professor of Research, University of Virginia, USA
MUNSON, R.J.	1936-39 1943-48	Post-graduate Recognised Teacher in Radiological Physics	Ph.D. 1939 A.E.R.E. Harwell
NABARRO, F.R.N.	1938 1946 1948-49	Research Grant Lecturer Royal Society Warren Fellow	Professor of Physics, Johannesburg
O'KIEFFE, B.A.	1884-85	Demonstrator	
POLDER, D.	1946-48 1950 1951-54	Research Grant Senior Lecturer Reader	Philips, Eindhoven
POTTER, H.H.	1924	Assistant Lecturer	

	1928-59	Lecturer	
SACK, R.A.	1942-44 1944-45 1945-47	Assistant Lecturer Temp, Demonstrator in Physics Demonstrator	Ph.D. 1946
STARLING, C.C.	1882-84	Demonstrator	
TANFIELD, D.A.	1945-48	Part-time Demonstrator with lecturing duties	National Coal Board
TYACK, L.N.	1888-1902	Lecturer	
WASSERMAN, G.D.	1947	Research Assistant	
WEBSTER, H.C.	1930 1931	Research Grant Assistant Lecturer	Professor of Physics, Brisbane, Queensland
WILLIAMS, I.	1909-40	Lecturer	
WILLIAMS, O.J.	1906-09	Lecturer in Electro-technics - then to Faculty of Engineering	

RESEARCH ASSISTANTS

			Subsequent Career
BENNETT, M.G.	1924-31	M.Sc. 1924	Operational Research, British Railways
DENT, Miss B.M.	1925-29	Research Assistant and a Librarian	Librarian, Metropolitan-Vickers Laboratory
GRINDLEY, G.C.	1923-25 1925-28	Post-graduate Research Assistant	Lecturer in Experimental Psychology, Cambridge

HEITLER, H.	1938-46 1946-	Research Grant Research Assistant	
LITTLETON, Miss M.J.	1930-37 1937-	Librarian Research Assistant	
LONDON, H.	1935-40	Research Appointment	F.R.S.1961 Deputy Director A.E.R.E. Harwell

RESEARCH WORKERS OTHER THAN BRISTOL GRADUATES or STAFF

	From	Subsequent Career	
ARLEY, N.	1936-37	Copenhagen	
ASHWORTH, F.	1946-49	Metro-Vickers	Ph.D. 1945
BARTLETT, J.M.	1930-31	U.S.A.	
BETHE, H.	1934-35 4 months	Germany	Professor at Cornell University, USA
BHATIA, A.B.	1947-48	India	
BHUHAN, H.C.	1947-48	India	
BOUCHAERT, B.P.	1939	Belgium	
BOURION, R.C.	1945-49	Paris	Ph.D. 1949
BRATA, L.	1930-33	Siam	Ph.D. 1933 Professor at Bangkok
BRETT, G.F.	1929-31	Leeds	
BUSCH, G.	1946-47	Zürich	Professor at Zürich
BURTON, P.C.	1946-47	Kodak, Ltd	
BURTON, W.K.	1947-51	Manchester	
CABRERA, N.	1947-49	Spain	
CATTRELL, V.G.	1947-49	Cambridge	
CAMERINI, U.	1947-51	Brazil	George Wills Associate 1950-51

COHEN, Miss	1929-30		
CUER, P.	1946-47	France	
DAVIS, M.	1946-49	London	Ph.D. 1950 Admiralty Signal Establishment, Baldock
DELBRÜCK, M.	1929-32	Göttingen	Professor at Vanderbilt University, Tennessee, USA
DILWORTH, Miss C.	1945-49	London	Mrs Occhialini
DINGLE, R.B.	1945-48	Cambridge	Professor at University of Western Australia
ELLIOTT, H.A.	1945-48	Cambridge	Ph.D. 1948
FAWCETT, F.B.	1893-1909		
FRANK, L.	1933-40	Germany	Ph.D. 1936
FRANZINETTI, C.	1947-50	Italy	
FRAZER, J.	1930-31	USA	
FUCHS, K.	1933-37	Germany	Ph.D. 1936
GALT, J.K.	1947-48	USA	
GARFORTH, Mrs F.	1946-48	London	
GASCOIGNE, S.C.B.	1938-40	New Zealand	Ph.D. 1942 Commonwealth Observatory, Canberra, NSW
GOLDSCHMIDT-CLERMONT	1947-48	Brussels	
GROSS, P.	1940-42	Germany	
GUGGENHEIMER, K.	1944-47	Germany	
HAWKINS, Miss D.B.G.	1943-53	Edinburgh	Ph.D. 1948
HERZBERG, G.	1929-30	Darmstadt	F.R.S. 1951 National Research Council, Ottawa

HERZBERG, Mrs L.	1929-30	Darmstadt	
HORSEMAN, A.	1946-49	Oxford	Imperial Tobacco Research Laboratory
HOSELITZ, K.	1938-42	Vienna	Ph.D. 1941 Mullard
HUANG, Kun	1945-48	Peking	
HUBY, A.	1946-48	Cambridge	Ph.D. 1950
JONES, J.I.	1938 (for 2-3 months)	Wales	
JOHNSTONE, JE.	1935-38	Belfast	Ph.D. 1938 AERE Harwell
KAHN, B.	1938-39	Germany	
KING, D.T.	1947-51	New Zealand	Ph.D. 1951
KOLODZIEJSKI, R.	Short period session 1947-8		
LATTES, C.M.	1946-47		
LEES, J.H.	1929-32	Cambridge	Ph.D. 1932
LINFOOT, E.H.	1937-48		Asst Director Cambridge Observatory, John Couch Adams Astronomer
MA, S.T.	1939-40		
MacKENZIE, J.K.	1947-49	Melbourne	Ph.D. 1950
MALKIN, T.	1928-30		Chemistry Dept, University of Bristol
MATYAS, Z.	1946-47	Czechoslovakia	
MATHUR, K.	1938-39	India	N.P.L. India
MAYO, H.G.	1916-18		
MAYER, H.	1932-33	Romania	
MERCER, R.L.	1934-45	London	

MISENER, A.D.	1938-39	Canada	
NIJBOER, B.R.A.	1937-38	Holland	
O'BRYAN, H.M.	1938	USA	
OCCHIALINI, G.P.S.	1945-48	Cambridge & Brazil	Hon D.Sc. 1960 Professor at Milan University
OLSEN, H.	1930-31	USA	
PICKLES, A.T.	1938-39	Cambridge	
RAMSAY, W.H.	1945-48	Belfast	Ph.D. 1948
RITSON, D.M.	1946-48	Oxford	
ROSE, D.C.	1928-29	Canada	National research Council, Ottawa
ROSENBERG, R.L.	1947-48	S. Africa	
ROSENBLUM, S.	1946-47	Paris	
SHUTTLEWORTH, R.	1946-49	Leeds	Ph.D. 1949
SIMPSON, J.H.	1946-48	Canada	Ph.D. 1950
SNEDDON, I.N.	1945-46	Cambridge	Professor, University of N. Staffs, Keele
STOBBE, M.	1931-33 and intervals to 1939	Germany	
SZIGETI, B.	1946-48	Hungary	University of Liverpool
TIBBS, S.R.	1936-39	Manchester	Ph.D. 1936
URQUHART, M.	1928-32		
Van der MERWE, J.H.	1947-49	S. Africa	Ph.D. 1950
WANNIER, G.H.	1938-39	USA	
WIELAND, K.	1931-32	Zürich	

WILLIAMS, S.E.	1933-36	Sydney	Ph.D. 1936 Reader at University of Western Australia, Perth
WOODS, H.J.	1928	Oxford	
WYATT, R.M.H.	1945-46	Cambridge	
WYLLIE, G.A.P.	1946-50	Glasgow	
ZENER, C.	1932-34	USA	Institute of Advanced Studies, Chicago

BRISTOL GRADUATES (other than members of staff):
in residence for post-graduate work in Physics

AUSTEN, H.W.	1928-29		
BABER, A.	1935-38		
BANNERMAN, J.A.	1923-24		
BATES, L.F.	1920-22		F.R.S. 1950 Professor of Physics, University of Nottingham
BOWMAN-BEER, H.B.G.	1920-21	M.Sc. 1921	
BRISTOW, J.R.	1937-39	Ph.D. 1940	College of Technology, Cardiff
BROADWAY, L.F.	1927-30	Ph.D. 1930	E.M.I. Research Laboratory
BROWN, D.	1924-26	Ph.D. 1929	Professor of Physics, university of Auckland, N.Z.
BROWN, Miss R.H.	1947-49		Mrs P.H. Fowler
BURGE, E.J.	1946-50	Ph.D. 1950	King's College, London
CONYBEARE, J.G.G.	1935-37	M.Sc. 1938	
COSSLETT, V.E.	1933-35		Cavendish Laboratory, Cambridge
COX, W.F.	1937-38		
DAVID, H.G.	1937-39		C.S.I.R.O. Sydney, N.S.W.

DIXON, E.H.	1900		
DYMENT, S.A.	1923-24		
ESHELBY, J.D.	1937-39 1946-51	Ph.D. 1950	Dept of Metallurgy, University of Birmingham
FLOWER, W.D.	1925-26		
GIFFORD, D.	1946-50		Physics Dept, Bristol General Hospital
GRIMLEY, T.B.	1943-48	Ph.D. 1951	University of Liverpool
GRINDLEY, B.N.	1922-23 1949-50	M.Sc. 1923	University of Cape Town
HEARD, M.J.	1947-49		
HOBBS, Miss E.W.	1915-16		
HULBERT, F.H.	1932-33	M.Sc. 1933	
HUNTLEY, H.B.	1933-34	Part-time post-graduate	Professor at Achimota, Nigeria
ILES, W.G.	1932-4		Imperial Tobacco Research Laboratory
KEOHANE, K.W.	1947-51	Ph.D. 1959	Chelsea Polytechnic
LEACY, T.	1928-29		
LOCK, W.O.	1945-52	Ph.D. 1951	University of Birmingham
LOVELL, A.C.B.	1934-36	Ph.D. 1936	F.R.S. 1955 Director of Jodrell Bank Experimental Station. Knighted 1960
MAINSTONE, P.A.	1913-14	M.Sc. 1914	University College, Bangor
MILNER, S.R.	1895-97		F.R.S. 1922 Professor of Physics, University of Sheffield
MILNER, Mrs W. (née Walker)	1898- 1900		
MANNING, K.H.	1930-31		

MILLARD, D.J.	1947-50	Ph.D. 1951	
MITCHELL, J.H.	1930-33	Ph.D. 1934	Ericssons
MUIRHEAD, W.R.H.F.	1946-50	Ph.D. 1951	Professor of Physics, University of Liverpool
PALMER, L.S.	1918-21	D.Sc. 1933	Professor of Physics, University College, Hull
PARSONS, F.E.L.	1927-28	M.Sc. 1929	
PAYNE, R.M.	1944-47	Ph.D. 1955	Aldermaston
PEARCE, A.F.	1933-36	Ph.D. 1936	E.M.I. Research Laboratory
PEARCE, R.R.	1935-38	Ph.D. 1938	N.P.L.
PHILLIPS, D.J.	1946-49	Ph.D. 1950	
PHILLIPS, L.R.	1925-26		
PIKE, H.H.M.	1930-33	Ph.D. 1934	
PREDDY, W.S.	1943-47	M.Sc. 1948	
PRESTON-THOMAS, H.	1947-51	Ph.D. 1951	National Research Council
RIDLER, K.E.W.	1932-34		
SEARLE, Miss N.S.	1917-18	M.Sc. 1918	
SHEPPARD, P.A.	1927-28		Professor of Meteorology, Imperial College, London
SHORE, J.	1947-48		
SNOOK, Miss L.B.V.	1900-01		
STARR, L.H.	1926-28	M.Sc. 1928	
VOUSDEN, P.	1947-50	Ph.D. 1951	University College, Cardiff
WELLARD, H.J.	1945-49		
WHITE, G.W.	1913-14	M.Sc. 1914	
WOLF, E.	1945-48	Ph.D. 1948	Edinburgh University
WORSNOP, Miss K.	1934-35	M.Sc. 1935	

WORTHY, H.	1934-36	M.Sc. 1936	
YOUNG, F.B.	1910-14	D.Sc. 1919	Director, Admiralty Research Laboratory