Departments of Physics
Mathematical Physics
Mawson Institute for Antarctic Research

BRAGG CENTENARY
1886 – 1986
UNIVERSITY OF ADELAIDE

Some reflections on
PHYSICS AT THE UNIVERSITY OF ADELAIDE

Edited by E. H. Medlin
1986

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Preface to pdf edition by Keith M. Briggs

The original document was edited by E. H. Medlin and first produced as a typescript in 1986. At some unknown time and by an unknown person, it appeared in html at www.chemphys.adelaide.edu.au/physics/history/. The following copyright notice is attached to the html file: "Unless expressly stated otherwise, the University of Adelaide claims copyright ownership of all material on this Internet site." The document appears to have been converted by optical character recognition, as typical OCR errors such as O for 0 appear. I have converted this html to pdf using pdfLaTeX. I have tried to keep to the original document format as closely as possible. This explains the inconsistent capitalization of chapter and section titles and quotation styles. These errors were corrected: *Rontgen* for *Röntgen*; *Wurzburg* for *Würzburg*; *except* for *excerpt*. There is an error in note (61) where a Greek letter, probably α, is missing before "-rays".

Keith.Briggs@bt.com 2006 August 7 10:05

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Chapter 1

Introduction

Many people have collaborated in the attempt to collect raw material for this 1986 Bragg Centenary. It has not been a straightforward task even to attempt to collect complete and accurate data over the 100 years since 1886. There are inconsistencies between Acts, Statutes, decisions by the Council, Registrarial practices and so on, not to mention the (wholly understandable) vagaries of departmental approaches to their origins and histories.

Most of us engaged in this exercise are (well-intentioned) amateurs and, as such, have felt privileged to assemble the material for plundering in good time by the real professionals. We have been awed by the professional expertise by Rod Home, Susan Woodburn and Pamela Runge but we have had to press on, regrettable errors and omissions no doubt notwithstanding. We hope that we have prepared a reasonable base for serious reflection and scholarship.

The graduate list presented herein is that of the Bragg Centenary Commemoration Programme supplemented by those past B.Sc. students who have responded to our public call to identify themselves with one or the other of the three departments involved. With regard to Prize and Scholarship winners we have deliberately restricted ourselves to achievements whilst in Adelaide.

Certain biographical material was available for some of the many graduates and staff who have achieved distinction in other parts of the world. That material is insufficiently complete to justify inclusion. For the time being, it is regretted that names will have to speak for themselves.

The essential criterion applied in the listing of academic staff has been that the positions and incumbents should have been listed in the University Calendars. Records of distinguished visitors are very incomplete and partial listing was judged to be invidious; the same is true of the general staff many of whom served with distinction over many years. It is to be hoped that this regrettable defect will be corrected, and quickly.

The Committee that conceptualized these Celebrations, under the general stewardship of W.G. Elford, was:-
P. Berry-Smith
A. Del Fabbro
A. Ewart
H.S. Green
R.B. Potts
S.G. Tomlin
E.H. Medlin (Chairman)

Thanks are due and acknowledgement is made to the following for their generous services:-

Peter Berry-Smith, Basil Briggs, Don Creighton, Albert Del Fabbro, Graham Elford, Alan Ewart, Maxine Ewart, David Fearnside, Oliver Fuller, Mary Genovese, Wayne Hocking, Rod Home, John Jenkin, Keith Merry, John Prescott, Pamela Runge, Peter Schebella, Arlene Shaw, Stan Tomlin, Rosemary Vasey and Susan Woodburn. The dedication of Alan and Maxine Ewart, of Albert Del Fabbro and of Arlene Shaw is particularly

acknowledged.

The Celebrations have been strongly supported by ”The University of Adelaide Foundation” and our gratitude is expressed and hereby recorded.

Finally, the whole occasion has been endorsed as an Official South Australia Jubilee 150 Event. The discipline of physics is now practiced in three buildings. The main Physics Building was the first gift of a building (1926) to the University by the State Government and commemorates its Diamond Jubilee this year. The other two buildings commemorate two of our greatest scholars, namely Sir William Bragg and Sir Mark Oliphant. We are privileged to share our Celebrations not only with the comet but also with the community, which we aim to serve, and especially during this Official Event with our presentations from Professors Stephen Bragg, Frank Close, Paul Davies, Freeman Dyson and Brian Matthews. Harry Medlin. 1 April 1986.

Chapter 2

Advertisement and offer of employment

3.

STREETS'

ADVERTISING OFFICES,

30, CORNHILL, LONDON, E.C.

25nd Oct 1885

WEST-END OFFICES.— 5, SERLE STREET, W.C.

PROOF OF ADVERTISEMENT.

Oxford University Gazette Oct 16th

THE UNIVERSITY OF ADELAIDE.

ELDER PROFESSOR OF MATHEMATICS AND EXPERIMENTAL PHYSICS.

THE Council invite applications for the above Professorship. Salary £800 per annum. The appointment will be for a term of five years, subject to renewal at the discretion of the Council. Salary will date from March 1, 1886, and the Professor will be expected to enter on his duties on that date. An allowance will be made for travelling expenses. Applications with testimonials should reach Sir ARTHUR BLYTH, K.C.M.G., Agent General for South Australia, 8 Victoria Chambers, Westminster, London, S.W., not later than December 1, 1885.

OCTOBER 13, 1885] *CAMBRIDGE UNIVERSITY REPORTER* 47

The University of Adelaide

ELDER PROFESSOR OF MATHEMATICS AND EXPERIMENTAL PHYSICS

THE COUNCIL invite applications for the above Professorship. Salary £800 per annum. The Appointment will be for a term of Five years, subject to renewal at the discretion of the Council. Salary will date from the 1st March, 1886, and the Professor will be expected to enter on his duties on that date. An allowance will be made for travelling expenses. Applications, with testimonials, should reach Sir Arthur Blyth, K.C.M.G., Agent General for South Australia, 8, Victoria Chambers, Westminster, London, S.W., not later than the 1st December, 1885.

4.

17 Decr 85

Sir,

I beg to inform you that you have been selected for the appointment of Elder Professor of Mathematics and Experimental Physics in the University of Adelaide, and to request that you will proceed to the Colony as soon as you can conveniently do so, as it is desired by the Council that you should enter upon your duties by the first of March 1886.

The salary is £800 per annum commencing from the 1st day of March next year, and the appointment is for a term of five years from this date, and subject to renewal at the discretion of the Council.

I shall be glad to see you as soon as possible, and as early in the day as convenient, in order to arrange about your passage to the Colony.

I am, Sir,
Your obedient Servant
Arthur Blyth
Agent General.

W.H. Bragg Esq
[illegible] House
Market Harborough.

Chapter 3

THE LIFE AND WORK OF SIR WILLIAM BRAGG

THE JOHN MURTAGH MACROSSAN MEMORIAL LECTURE FOR 1950[1]
by Sir Kerr Grant
Emeritus Professor of Physics
University of Adelaide

3.1 INTRODUCTION

The celebrated autobiography of Benvenuto Cellini begins with the words "it is the duty of all men who during their life-time have accomplished anything of merit to write an account of their life with their own hand". In default of such a self-recorded history it may perhaps be said with equal justification that this obligation devolves upon the contemporaries or successors of a famous man to see that the story of his life and deeds is fully and faithfully recorded in order that posterity way know what manner of man he was to whom it owes a debt of service or achievement. This pub-

[1]Reproduced by courtesy of the University of Queensland

lic duty is, in fact, one of those specifically laid down in the terms under which the John Murtagh Macrossan Foundation was established, and it has been previously honoured on many occasions in this series of lectures.

In selecting the "Life and Work of Sir William Bragg" as another to be commemorated under this Foundation, the Professorial Board of the University of Queensland has made no unworthy choice; in honouring me with an invitation to undertake the task, reason was doubtless found primarily in the fact of my succession to him in the Chair of Physics in the University of Adelaide.

The association thus entailed with his former colleagues on the staff of the University, his relatives and friends in Adelaide, and old students who attended his classes does indeed place me in a privileged position to obtain from them and from other sources, first-hand information concerning the man himself and the details of his life while he lived among them; further, it was, no doubt, assumed that a Professor of Physics might be expected to posses, at the least, a general acquaintance with those aspects of Physical Science, to which, in the main, Bragg's researches and discoveries belong.

I can only hope that such advantages ass I may possess in these respects may serve in some degree to outweigh the disadvantage of my inexperience in the art of literary presentation in this field.

But whether or not the choice of a biographer has been wisely made, it was at any rate a wise decision not to postpone too long the interval between the death of the subject of the biography and the collection and recording of the factual data which must form the foundation for a story of his life.

The apocryphal elements in the life-histories of many famous men warn us how soon in the absence of reliable temporary records, many things we would wish to know concerning their lives are either irrecoverably lost, incrusted with the lore of legendary fiction or shrouded in the mists of myth. How soon too, does the opportunity pass for the biographer to secure from the relatives, friends and acquaintances of one deceased, direct testimony concerning his personal characteristics, the circumstances of his daily life and all the trivial yet nevertheless significant actions and events without knowledge of which he can at best prepare a mere factual record devoid of the human appeal and living semblance of a ”flesh-and-blood” portraiture.

Already, in the case of Sir William Bragg, two only of his former colleagues on the staff of the University of Adelaide - Sir William, Mitchell and Sir Douglas Mawson survive, and only two relatives by marriage - Miss L.G. Todd and Mrs. Guy Fisher are now resident in Adelaide.

3.2 Sources of Information

His only, surviving son, William Lawrence (now Sir Lawrence) and his only daughter Gwendolen (Mrs. Alban Caroe) are resident in England. Sir Lawrence Bragg has been so kind as to send to me excerpts from an autobiographical statement of his father concerning his early life prior to coming to Australia.

Miss Lorna Todd has furnished me with a most interesting statement setting forth her reminiscences of Bragg’s associations with her father, Sir Charles Todd and his family culminating in his marriage to her younger sister. Sir William Mitchell also has told me much concerning his colleague during his tenure of the Chair of Mathematics and Physics in Adelaide University. Sir John Madsen, who was Lecturer of Electrical Engineering in Adelaide during the last years of Bragg’s term as Professor of Physics and who co-operated with him in research work, still recalls clearly the conversation in which Bragg told him of the new point of view at which he had arrived regarding the nature of alpha-rays, a point of view which subsequently led to a triumphal march of successes in experimental research. Others, whose acquaintance with him was of a more limited character such as that of student to teacher - have contributed items of personal recollection.

My own opportunities of a close personal acquaintance with Bragg were unfortunately few, comprising only one brief meeting in Melbourne shortly prior to his departure to England; subsequently, occasional meetings and conversations during my visits to England in 1919, 1927 and 1931, and occasional correspondence.

Of literary sources available to me the most valuable as a record of his work and picture of his personality is the excellent obituary written by Professor Andrade of London University for the Royal Society of London.

A full appreciation of his scientific achievements could, of course, only be based upon a critical study and evaluation of - the numerous papers contributed by him to the proceedings of scientific journals, or as set forth in the several books in which the contents of these were collected and integrated. It is neither my intention nor my prerogative to attempt more in these lectures towards such an appreciation than to endeavour to indicate the salient points in method and the main results of his researches. Sir Lawrence Bragg has informed me that it is his intention to write a full biography of his father and an account of his scientific work when in a few years time his retirement from office will afford him the leisure to undertake the task.

In the realm of popular exposition Bragg was an acknowledged master. Several lecture-courses which he gave at the Royal Institution are published in book form. These also aid his biographer in his efforts to attain the difficult goal of ”presenting a life-work in full and significant delineation”.

3.3 Heredity

William Henry Bragg was the son of Robert Henry Bragg who, at the early age of 25, gave up a post in the British Merchant Navy to purchase and cultivate a farm in the village of Westward near the town of Wigton in Cumberland. His mother, Mary Wood, was the daughter of the Vicar of the parish.

There seems to be little evidence to permit of a decision on the controversial and invidious question as to whether the son owed his outstanding intelligence to his father or to his mother. Moreover, in the light of the science genetics, the question is over-simplified, the grand-parents and even remoter progenitors are claimants also to whatever congenital merit or demerit is assigned to any one of their descendants.

Heredity, despite the mathematical regularities which the work of Mendel and his successors have revealed in its operation, can play strange tricks. The appearance in their off-spring of characteristics which neither parent is eager to claim as his (or her) donation - I have been told - a not infrequent source of marital altercation; the occasional Emergence of individuals of exceptional ability from a line of undistinguished ancestry (such illustrious names as those of Newton, Faraday and Einstein immediately occur to a physicist) may seem even more inexplicable.

On the other hand there is abundant evidence to show that, in common with other physical and mental characteristics, exceptional ability can and does descend from generation to generation. In England we have as illustrious instances of hereditary scientific genius the families of Darwin, of Herschel and of Huxley. There is already sufficient evidence to justify the addition of the name of Bragg in his honourable gallery.

The possession of exceptional scientific and mathematical ability is fully attested for two generations in the achievements of father (W.H.) and son (W.L.); less well known is the possession of distinctive artistic talent by the father (W.H.), his second son Robert (killed at Gallipoli) and his daughter Gwendolen (now Mrs. Alban Caroe). I learn from Miss Todd that the genes of genius have persisted into a third generation. Sir Lawrence Bragg's eldest son has had a distinguished scholastic career in mathematics at Rugby and at Cambridge, where, in succession which is probably unique, he is a Scholar of Trinity. In the second son the gene of artistic ability is again strongly dominant.

3.4 Childhood and Early Education

Both Bragg I s parents died young - his mother when he was only seven - and the responsibility of providing him with a home and education was willingly accepted by an uncle, William Bragg, who lived in the town of Market Harborough in Leicestershire, and had played a part in the re-establishment of the local grammar school.

In some notes written by himself at the age of 70 concerning his early life, which I owe to the courtesy of Sir Lawrence, Bragg has given an interesting account of his experience at this school. It was not a very large one. " I was one of the six boys", he said "with which it opened. At the end of the first year I was given a scholarship exempting me from payment of fees. At the prize-giving - there were many more than six boys at that time - my name was called out and I went up to the desk to get the scholarship, not knowing what it was. I was puzzled and disappointed to go back empty-handed."

The precocity which is a common if not an invariable indication of future genius, was not lacking in the school-boy Bragg. At the early age of eleven he entered for and passed in the "Oxford Junior Locals", the youngest boy in England to get through.

His home life during this period, despite the care and affection bestowed upon him, was perhaps unfortunate in respect of the narrow religious atmosphere which prevailed, with its insistence on an unquestioning acceptance of prevalent orthodox beliefs.

At the age of 13, having probably reached the limit of the school's capacity to go further, his uncle sent him to King William's College in the Isle of Man. Here he rapidly developed a proficiency in his studies - and especially in mathematics - on the one hand and in school sports on the other.

This latter accomplishment was fortunate, for he confesses to having been a shy and retiring boy - though it seems likely that this may have been due mainly to the fact that he was younger than his classmates - and to excel in games was probably then, as now, a school boy's surest passport to popularity with his fellows. He rose, at any rate, to be Head of the school. In 1880 he entered for the examination for Scholarships at Trinity College, Cambridge, and was awarded one, but on advice of the authorities, delayed his entrance for a year.

It was in this year, at the age of 18 - a critical period in the emotional life of an adolescent - that the school he attended was, in Andrade's words, "swept by a storm of religious emotionalism" in which Bragg by reason of the revolt of his reason and sympathy against the irrational and inhuman dogmas of Athanasian theology, was involved so deeply as to recede rather than to progress in his studies and failed at the next scholarship examination to equal his previous performance. Nevertheless, he was awarded a minor scholarship and entered Trinity College, Cambridge University in 1881

In this new environment where - unless the social and intellectual climate of Cambridge was very different then from what it is today - at atmosphere of spiritual freedom and intellectual tolerance envelops the formalities of religious observance and the dogmas of theology this brief unhappy interlude of religious melancholia could not endure, and the young Bragg entered upon a new life full of interest and enjoyment.

He now lived and worked as a student in Trinity College he has told in his own words, written in 1927.

> ”I went up to Cambridge in 1881, taking the rather unusual course of beginning work there in the Long: I suppose I was in Cambridge six weeks or so, July and part of August. But I forget the exact date. I had rooms in master’s Court. I appreciated thoroughly the beauty of the whole place; and I liked going to Routh’s classes. It was lonely, because I was doing the unusual thing: and I had no companions. But it was good all the same. As a scholar of the College I went up every Long afterwards: it was always a jolly time. Very few restrictions: just the regular classes three times a week with Routh, and the preparation for them. After that tennis in plenty: boating on the river above Cambridge, and the summer weather, and Cambridge looking its best. I tried during that preliminary long to get through an exam that would excuse me the Littlego: and I failed in Latin, which seems to me now to be very odd, as I had studied Latin from the time I was seven and given a lot of schooling time to it, and worked conscientiously too! I had to take the Littlego, in November after all.
>
> Cambridge gave me a good time, of course: although I might have done mach better if I had known more or been more easily sociable. I ought to have gone to lectures on other subjects than mathematics, and taken an interest in other things. It simply did not occur to me. I could not afford, or thought I could not afford, to join the Union or the Boating Club: which cut of f a good many opportunities. I had none of those experiences

> of discussion of the world and its problems with other young men, which many men seem to look back upon with so much pleasure. I worked at the mathematics all the morning, from about 5?7 in the afternoon and an hour or so every evening, and then bed fairly early. Every afternoon I played a game, generally tennis, or went for a walk: my tennis was fairly good, so that I always found people ready to play."

There is an omission of a sentence or two in this excerpt which can be made good from Andrade's obituary; it refers to the congratulations received from friends on his success in the Tripos examination. One of these was A.N. Whitehead, later of world-wide reputation as a mathematician (he offered a derivation of the principle of relativity alternative to Einstein's) and philosopher (he is now Professor of Philosophy at Harvard) "who came and shook me by the hand saying 'may a fourth wrangler congratulate a third."' He had been fourth the year before.

After his crowning success, Bragg continued his mathematical studies and sat for the more advanced examination, Part III of the Tripos, as it then was. of the result of this he says, humorously, "I believe that none of us did too well, but nearly all got Firsts because the Senior Wrangler did not do any better than we did and they could not give him a second.

3.5 APPOINTMENT TO THE ADELAIDE CHAIR

Bragg, in his reminiscences, tells the story of how he came to apply for and be appointed to a Professorship in the University of Adelaide. In 1885 the Chair of Mathematics and Physics had been rendered vacant by the resignation of Professor Horace Lamb, who was the first occupant at the date when the University was established in 1874 and who now wished to return to England, where he had been offered the Chair of Pure Mathematics in the Owens College, Manchester. According to a practice still customary, the vacancy was advertised in the English press. Bragg had seen the advertisement but had not though of applying, believing that his youth (he was only 23) and entire lack of teaching experience would make his chance of appointment negligible. However, on his way to a lecture by J.J. Thomas (afterwards famous for his discoveries in the realm of atomic physics) he was joined by the lecturer, with whom he also had social acquaintance. The conversation turn on the Adelaide Chair. As a result of Thomson's advice Bragg telegraphed an application - it was the last day of entry.

There were only a few applicants and Bragg was one of the three on the "short list" selected for interview. The interviewers were Professor Lamb, J.J. Thomson, and the Agent-General for South Australia, Sir Arthur Blyth. They also called in, to assist them in making a final choice, an Adelaide man who happened to be in London at the time. He was Mr. (afterwards Sir) Charles Todd who certainly did not know then that he was helping to bring to Australia not merely a professor but his own future son-in-law.

Another applicant much senior to Bragg was a Senior Wrangler of great ability whose claim to preference was, however, discounted by, his partiality for the contents of the bottle which, if it sometimes cheers, too often inebriates. So the choice fell upon Bragg, to whom it was first conveyed by a telegram from Australia that same evening, worded "As new professor of Mathematics and Physics in Adelaide University would you give some particulars of your career." Bragg's delight in an appointment which offered him, in his own words, "an assured position, a salary beyond all expectation (£800 a year), a new country with all the adventure of going abroad to it, and a breakaway from being a subject, to be now my own master" was tempered by the distress which the prospect of losing him caused to his worthy and benevolent old uncle to whom he was evidently as dear as a son, a distress, however, relieved by pride in ″his nephew the professor″.

Fifty years later Bragg could still recall and record the enthusiasm and excitement of the preparations for departure: the novel experiences of the voyage to Australia in the largest vessel of the P.&O. fleet - the ″Rome″ of 4,500 tons - and his efforts to learn something about physics (for his studies at Cambridge had been confined to Mathematics alone) during the voyage by reading Deschanel's Electricity and Magnetism!

Long years afterwards, when I paid him a visit in London and congratulated him on his appointment as Fullerian Professor of Chemistry in the Royal Institution, he said with humorous enjoyment: ″The joke of it is that I always seem to be appointed as professor in subjects about which I know nothing.″ It was true, no doubt, that when he went to Adelaide he knew little or nothing of the formal physics of the text book; possibly true that when he took the Fullerian Chair of Chemistry not much more of text-book Chemistry. But these deficiencies of academic knowledge had the advantage of leaving him with a clean sheet on which to write his own self-acquired knowledge on these subjects and, as one of his most distinguished disciples (Dr. W.T. Astbury) says: ″He had the most amazing faculty of taking up a subject on which he had only the foggiest ideas to begin with and quickly improving it out of all recognition.″

From the first day of his arrival Bragg thoroughly enjoyed his life in Australia. He was fortunate in that the acquaintance already made in London with Charles Todd - who was Director of the Adelaide Observatory ? immediately opened to him the door of a delightful domestic circle comprising in addition to the father and mother, three daughters and two sons. Very soon he, with a new friend, the late Dr. Alfred Lendon, became a regular Sunday afternoon and evening visitor at the Observatory home. We were a cheerful party there,″ writes Miss Lorna Todd (who was eight years old at the time). "Fierce arguments over religious and social subjects were the order of the day amongst the men. The irresponsible and illogical chatter of my sisters" (thus irreverently did this child of eight characterise the conversation of her older sisters) "delighted him most. It was a revelation to a young man who had been taught to weigh every word he uttered, and he blossomed under the cheerful and inconsequent atmosphere."

A very natural and happy sequel to this idyll of domesticity was the marriage in the year 1889 of William Henry Bragg to Gwendoline, third daughter of Sir Charles and Lady Todd.

Of this marriage there was issue to sons, the first, William Lawrence (now Sir Lawrence, Director of the Cavendish Laboratory); the second, Robert, who was killed in the Gallipoli misadventure of World War I, and one daughter Gwendolen (Gwendy) now Mrs. Alban Caroe of London.

Bragg, from the very first, was marked as a born teacher and lecturer. Professor Andrade says (quoting - no doubt from hearsay - some Adelaide source) that in his early days "he was one of the least impressive of lecturers." If there is any justification for all this disparagement it may rest either on his complete inexperience in the art of lecturing or in his disdain of the use of rhetoric in which one of his colleagues, himself a master of that "poison of sincerity" was wont to appraise the quality of another's oratory.

Students who, at a later date, attended his lectures have one and all agreed in crediting him with exceptional powers of lucid exposition, so much so, indeed, that they accuse him of having been able to invest his discourse on abstruse topics with an altogether delusive simplicity. His interest and influence in educational matters soon spread beyond the precincts of the University. The curriculum of the secondary schools in South Australia, as more or less in all Australian States, dominated then as it is now by the public examinations syllabus, and, in particular, by the subjects demanded for matriculation, was still modeled on that of English public schools with their almost exclusive emphasis on the ancient languages and mathematics. Any scientific subject, if grudgingly permitted an hour or two a week of the timetable, was taught largely as an exercise in memorisation of the text-book with little or no appeal to observation, lecture-demonstration or laboratory exercises* *by the student.

Bragg was not long in raising his voice in criticism of this defect and in pleading the claim of science to be regarded as an educational medium of high practical value.

At the commemoration address which he gave in December, 1889, he concedes, doubtfully, the claim that the classical system of education ”may perhaps develop in the younger generation the capability of fulfilling duties in certain traditional ways,” but, he continues, ”it does not so train their minds that, having a knowledge of the tools that modern science provides and judgement as to what may be done with them they may strike out for themselves new kinds of Work and new methods of working.”

In the same address and on subsequent occasions he strongly advocated the introduction of practical work in school physics. ”Every year,” he said, ”I have answers from book-taught candidates which show a practical ignorance of physics.” To emphasise his views he relates an amusing story of a youth’s answer to an oral examination to the question:

”What is the use of a compass?”

After much hesitation came the answer:

”To find the latitude and longitude.”

On the examiner asking ”Could you do it?” the examinee promptly replied: No, Sir, but YOU could.”

So far as the schools went, his exhortation, if heeded at all, led only to the casual and perfunctory performance of an extremely elementary type of practical exercises in physics in one or two of the larger schools. But, in his own University classes, systematic practical courses were very soon established, he himself for many years acting as instructor with little or no junior assistance.

His scientific interest seems to have turned, immediately after the assumption of his duties, from mathematics to physics. Indeed the mathematics required for the Cambridge University examinations in those days was perhaps not of a type to inspire many to pursue it further. From the first he found particular pleasure in demonstrating, both to his students in the routine lecture-courses, and in public lectures and conversaziones, the more novel and spectacular miracle of scientific discovery. In these latter his young wife's social talents proved an invaluable asset.

Success in presenting the results of scientific research to a popular audience, unacquainted for the most part with the basic facts and principles of the special science in question, demands from the lecturer not merely a thorough understanding of his subject but the ability to translate the technical terminology of science into the language of every-day usage. In this art, Bragg was singularly gifted. In the light of the nature of his subsequent achievements it is interesting to note that in 1895 the subject of a course of extension lectures was "Radiation"; in 1896 "X-rays"; in 1897 "Sound". Undoubtedly the task of preparing these lectures and the experience gained in the technique of experimental demonstration must have served to lay a solid foundation of knowledge and skill which stood him in good stead in his future researches in the fields of radio-activity and X-rays.

Bragg also followed with keen interest the news which reached Australia from time to time of the remarkable discoveries and developments which were at this time (1895 and onwards) taking place in Europe in these last-named subjects and in wireless telegraphy.

But he did more than merely read about them and talk about them.

He promptly set about reproducing them by his own efforts with the very slight amount of technical assistance and meagre stock of instruments and apparatus which his laboratory possessed. Especially was his interest aroused by the discovery of X-rays by Professor Röntgen of the University of Würzburg in 1895. Röntgen published his discovery in December, 1895; news of it reached Australia in a brief cable in January, 1896.

In common with Professors of Physics in other Australian Universities, Bragg was immediately stirred to find means to produce this new kind of "invisible light".

X-rays are produced by the impact of an electron stream on any solid object and to realise this all that is essential is an evacuated glass bulb into which are hermetically sealed two metallic electrode, and a source of high tension electricity. The type of vacuum-tube used by Röntgen when he made his immortal discovery, was first designed and constructed by Sir Wm. Crookes and employed by him in his researches on the passage of electricity through rarefied air; the high-tension electricity was supplied by a Ruhmkorff induction-coil. The meagre equipment of the physics laboratory in those days did not include a Crookes tube and to have imported one would have meant a delay of several months. Fortunately Bragg's laboratory assistant, Mr. A.L. Rogers, was skilled in the art of glass-working and by Bragg's direction at once proceeded with the attempt to construct a small tube. In this he was ultimately successful, but before the first tube was satisfactorily completed a citizen of Adelaide, Mr. S. Barbour, returned from a visit to England bringing with him two Crookes tubes purchased from a British firm. With the co-operation of Professor Bragg remarkably good radiographs were taken with these tubes.

Subsequently Mr. Rogers made and evacuated many tubes which were successfully employed in medical radiography.

Professor Bragg's eldest son, William Lawrence (now Sir Lawrence) was a child of five at the time of these experiments in which, nevertheless, he was on one occasion a participant. In his foreword to the publication of Messrs. Watson and Sons' book entitled "Salute to the X-ray pioneers of Australia", Sir Lawrence writes: "I well remember my father's first experiments with X-ray tubes, although I was only six years old at the time. I think I must have been amongst the first to be employed as a patient. I had smashed my elbow badly by a fall and was taken to a cellar in the University for the exposure. The flickering greenish light, crackling and smell of ozone were sufficiently terrifying to impress the incident deeply in a child's mind. When I think, however, of the early experiments, the interest which they aroused in medical men in Australia is not their chief significance to me! I see them as fore-runners of my father's interest in the ionisation of gases leading to his experiments with X-rays from radium and finally the experiments on the diffraction of X-rays by matter which we carried out together."

The letter "X" which Röntgen chose to designate this new type of radiation, had reference of course to his confessed ignorance of their true nature. (His tentative hypothesis: "Ought not the new rays to be ascribed to longitudinal vibrations in the ether?" was fallacious.) It was not until 1912 that the experiments of von Laue in Germany, confirmed and extended in the next year by the Braggs, father and son, definitely proved them to be essentially identical in character with ordinary light. But among the apparatus which Bragg left behind him in the Physics laboratory was a large prism made of pure sulphur. On the testimony of Sir Lawrence Bragg, quoted in the publication just referred to, this was made with the special object of testing whether a beam of X-rays would be refracted in passing through this prism. If this recollection is correct it shows that the problem of elucidating the nature of X-rays was already occupying the elder Bragg's attention many years before its final solution. (I am personally somewhat doubtful of the correctness of this opinion, recalling the answer given to my question by Professor R.W. Chapman who as a lecturer under Bragg was in a position to have first-hand knowledge that the prism was used for experiments on the refraction of electric (Hertzian) waves.)

In the same year in which Röntgen discovered X-rays a young Italian, Guglielmo Marconi, was experimenting in his home town of Bologna on the transmission of signals by means of wireless telegraphy. Coming to England (his mother was Irish) in 1896 he found encouragement, financial support and technical assistance from the British General Post Office, and we all know of the remarkable developments in wireless communication which followed. In 1898 Professor Bragg was granted a year's leave of absence to visit England with a commission to inquire into matters of educational interest. His contacts with many eminent men of science must have created an interest in this new method of communication, for soon after his return he began experimenting in wireless transmission, first within the University and then from a transmitting station in the Observatory grounds to Henley Beach - a distance of about five miles. I quote from Miss Lorna Todd's lively account of this event: "I think I am right," she says, "in saying that the first wireless pole to be erected in Australia was in the Observatory grounds. A receiving pole was put up on the sand-hills at Henley Beach. My brother-in-law did much experimental work there. One afternoon I remember that my father asked me to pack tea and drive down with him to Henley Beach, saying he would send a 'wireless' to say that we were coming. I felt a very 'doubting Thomas' as I packed a specially nice tea and tied paper around the blackened picnic billy-can (there were no thermos flasks in those days). However, when we got within sight of the tall pole on the sand-hill there was my brother-in-law waving his arms and his cap, as thrilled as any schoolboy that the message had come through. It seemed a miracle. Both he and my father were almost boyish in the delight and the fun of the discoveries then being made so rapidly in science.”

3.6 FIRST ORIGINAL RESEARCH WORK IN ADELAIDE

It has been a matter of remark by some who have discussed or commented upon Bragg’s scientific career that his entry into the arena of scientific research should have been so long delayed.

It was not, in fact, until he had attained the age of 46 and had occupied the Chair of mathematics and Physics in the University for 18 years that he published anything of a quality entitling it to be considered as an important contribution to existing knowledge.

This long interval during which his genius for experimental research lay latent, is indeed an exception, though by no means a solitary one, to the general rule that creative imagination and scientific activity are at their highest in the spring-time or early summer of life.

In Bragg’s case there are plausible grounds of explanation for a seasonal retardation.

As already stated, his natural interests were those of the physicist, rather than of the ”pure” mathematician, yet his whole academic experience previous to his election to the Adelaide Chair had lain exclusively in the former discipline. Thus before he could even glimpse the horizon which bounded the great sea of existing physical science at that date - a horizon more-over which was expanding so rapidly that it continually receded from the voyager pursuing it - he had an immense leeway to make up.

It is, of course in that unknown land beyond the horizon that lies the realm of scientific discovery, the realm of ”research”.

But that word had 'not, half a century or earlier ago, even in scientific circles - and certainly not in the politics of University finance - attained the portentous significance which to-day entitled it to vie in blessedness with "Mesopotamia" of sacred utterance.

Research had not yet acquired the status of a professional business. Rather was it then regarded as a natural and unforced by-product of academic employment and intellectual interest; subordinate, nevertheless, to the performance of the professor's contractual obligation to train his students in the discipline of his special science, and to serve the general public as an authority and consultant on whom reliance could be placed for trustworthy information or wise counsel in all matters relating to his particular province of expert knowledge. It was in such a light, doubtless, that Bragg would view the responsibilities of his post.

His teaching duties at the outset were not onerous - there were in his first year only two students in the laboratory - but he did not hesitate to enlarge them whenever he saw occasion and opportunity.

For the benefit of those who could not attend during the day - mainly teachers in secondary schools - he instituted night-lectures and practical work, which he conducted.

Sir William Mitchell has told me of the surprise and pleasure which he felt when, on his arrival to occupy the chair of English in 1894, he found that a branch of the British Teachers' Guild in which he had been interested in Scotland had already been established by Bragg in Adelaide. The high esteem in which he was held by the teaching profession and the gratitude and affection which they felt towards him were publicly expressed in tributes paid to him at a Teachers' Conference held in July, 1908, shortly after his decision to accept the invitation from Leeds University had been announced.

It need not be denied that other and distracting human influences competed strongly with the ”divine curiosity” which is the stimulus to the task of intellectual pursuits. Bragg was no indoor recluse; he was athletic in body as he was active in mind. He had a love for all healthy outdoor sports and pastimes and indulged his liking in actual participation. By his own account (already quoted) he played tennis well and no doubt, found in it pleasant opportunities of social recreation.

He took up golf and became one of several devotees among his colleagues (Mitchell and Henderson were fellow-practitioners of that Royal and Ancient game) and become so proficient that in the year 1907 he was beaten in the championship contest only on the last two holes of the course by Henderson. He introduced the Canadian game of lacrosse to South Australia and was for several years captain of the North Adelaide Lacrosse team.

To these athletic proclivites he added artistic talents of no man order. He sketched and painted in water colours with the hand and eye of a true artist. His wife shared with him this delightful talent - her teacher, Mr. H.P. Gill, would speak of her as a ”first-class artist ruined by marriage”. During holidays husband and wife would sometimes sketch or paint, in company, a scene that took their fancy.

Gifted with a good musical ear, he not only enjoyed music but was himself a competent performer on the flute, an accomplishment which, on the testimony of Professor Andrade, he still practiced in his later London years.

Possessor of a fine presence and of all the social graces, he was a popular guest at social functions and entertainments whether public or private.

Fortunate in a happy marriage, blessed with and devoted to a family of two sons and a daughter, it might well be thought that he would have found his life in Adelaide so full and satisfying as to exclude all thought or wish of change or adventure either in the world of reality or the world of ideas.

But underneath all the pleasant preoccupation and lighter interests of his life there smoldered the urge to creative intellectual effort, nourished by the news of one great discovery after another in physics, and awaiting only the moment of inspiration to break out in action. Neither was this period of latent activity wholly devoid of all contribution to science.

In 1891 he contributed a paper to the Proceedings of the A.& N.Z.A.A.S. entitled "The elastic medium method of treating electrostatic theorems" and, as a sequel to this, in the following year another on "The energy of the electrostatic field", published in the Transactions of the Royal Society of South Australia. This latter he amplified and presented again at the Brisbane meting of the Association in 1895.

These papers are all in the true Faraday-Maxwell tradition, in which the mathematical theory of electric and magnetic fields is based on analogy with the state of an elastic medium under stress.

They were essays in mathematical physics which put known results in a new light, ingenious variations on well-established theory, but they contained no result of importance previously unknown, and they neither reported nor suggested new lines of experimental research.

The occasion initiatory to such suggestion came with the duty of preparing the presidential address to Section A of the A.& N.Z.A.A.S. at the Dunedin meeting of the Association in 1904.

It is a recognised duty of sectional presidents to present to their section a resume of important recent advances in some branch of their special science. This was a time when new and surprising discoveries were revolutionising basic ideas in regard to the nature of matter, of electricity and of radiation and the mutual relations of these entities to one another.

Röntgen in 1895 had discovered X-rays; J.J. Thomson, in 1897, had experimentally proved the existence of a universal type of electrical subatom or corpuscle (now called the electron); Max Planck of Berlin had shown that light is radiated from atoms only in wave-pulses carrying energy quanta proportionate in amount to the frequency of the waves. Einstein, in the same year in which he published his epoch-making paper proving the relative character of space-extension and of time-duration had also suggested an atomic aspect in the nature of light as a explanation of its power to eject electrons from surfaces on which it fell. Niels Bohr of Copenhagen had successfully applied Planck's quantum theory to solve the riddle of atomic spectra; the Curies, man and wife, following upon Henri Becquerel's discovery of the radio-activity of the metal uranium, had isolated a new element, radium, a million times more active. Rutherford had analysed the radiation from radium and its products of disintegration and shown that it contained three entirely distinct kinds of rays - which he called the alpha (α), beta (β) and gamma (γ) rays.

Into this last, as yet only partially explored territory of the science of radioactivity now entered Bragg. It came about in this way.

He chose as the topic of his presidential address, "Some recent advances in the theory of ionisation".

Ionisation is a phenomenon which, as he states, "furnishes one of the principal methods by which the strange new properties of radioactive substances are made manifest and studied".

Neither air nor any other gas in its normal condition conducts the electric current. But, when irradiated by a beam of ultra-violet light, or of X-rays, or of any of the three kinds of radiation emitted by radioactive substances, or when traversed by fast-moving electrons, a small fraction of the molecules of a gas normally uncharged or neutral may acquire either a positive or a negative charge by losing or gaining one or more electrons. These electrically charged molecules are termed "ions", the gas is said to be "ionised" or in a state of "ionisation", and if a voltage difference is applied between two rods or plates of metal immersed in the gas, the ions drift under the influence of the electric force towards one or the other, thus effecting the transfer of electricity which constitutes an electric current.

Already in 1904 a vast amount of experimental work had been carried out by scientists in investigating the nature and properties of ions, the laws of the ionisation-current and the properties of the various kinds of ionising agencies, in particular, the so-called alpha, beta and gamma rays of radium. and other radioactive substances

Bragg made a critical examination of the information thus available on the penetrating and ionising powers of these three kinds of radiation (alternatively, of the absorption which they undergo in passing through matter) . He came to the conclusion that there was a radical difference in these respects between the alpha rays and the other two, concluding that whereas the main reason for the reduction in intensity and ultimate extinction of a beam of beta-rays in passing through matter lay in the scattering of its moving electrons due to the repulsive forces exerted upon them by the fixed electrons of the atoms through which they passed, the alpha rays, by reason of their being nearly 2000 times as massive as an electron, suffered little or no such deviation from this cause and thus pursued a straight path until their initial velocity and energy were exhausted by the work done in ionising - or at least ”exciting” - atoms through which they passed.

If this conclusion proved to be correct, it indicated, said Bragg, the following practical applications:?

(1) A means of identifying any species of radioactive element - provided it was an alpha-ray emitter - by observation of the range of its rays in air;

(2) a method of ascertaining what and how many different alpha-ray emitters were contained in a sample of any radioactive material;

(3) a method of comparing atoms of different kinds in regard to their ”stopping power” for alpha-rays.

His conclusion as to a limited but definite range for alpha-rays was supported by an experiment described by Madame Curie.

A think film of the radioactive element polonium was placed on a metal plate. Parallel to this and at an adjustable distance were fixed two other plates an inch or two apart, the space between serving as an ionisation-chamber. The plate nearest to the radioactive source had a hole in it through which rays could pass.

It was found that ionisation resulting from entry of rays through this hole took place only when the distance from hole to polonium film was less than 4cm., indicating that the alpha-rays from polonium had a maximum range in air of that order.

On his return to Adelaide, Bragg promptly made preparation for an experimental attack on this problem. With the aid of a grant of X500 from a generous friend of the University he was able to purchase a small quantity of radium bromide and the necessary instrumental equipment. The Ionisation-chamber he himself designed and had constructed in his small workshop by a highly skilled mechanic, Mr. A.L. Rogers. In principle it was similar to that employed by Marie Curie, but it incorporated two vital improvements. In the first place, the actual ionisation-chamber was made very shallow, and the plate with the hole in it was replaced by a sheet of thin metal gauze which afforded easy access of the rays to the chamber. This enabled the effect of the rays to be measured at successively varying distances from their source. Secondly, by mans of stops placed vertically above the radium??covered plate it was ensured that only the rays which travelled perpendicular to the plate could reach the ionization-chamber, so that the same number of rays, if any, entered the chamber whatever its distance from the source.

Just as important as the provision of the instrumental equipment was the fortuitous and fortunate discovery and employment as an assistant of a young countryman named Kleeman.

This young man while employed as a blacksmith in the country town of Tanunda, had brought himself under Bragg's favourable notice by soliciting his help in the solution of some mathematical problems. Correspondence resulted in an offer to Mr. Kleeman to come to Adelaide and, while pursuing his studies, to pay his way by acting as an observer in the experimental work on alpha-rays.

He turned out to be well-suited for this tedious employment; precise, careful and tireless in taking, day after day, the many hundreds of readings of the electrometer required to determine the "ionisation-curves" which showed the relation between the distance of the shallow-chamber from the source and origin of the rays, and the ionisation within it which measured their effects.

The results of these experiments vindicated Bragg's expectation to the full.

As the distance of the chamber from the radium or other radioactive source was increased - starting from a distance of about I inch - the ionisation increased with it up to a very definite limit, after which it abruptly diminished to a zero value. If the source of the rays was radium without admixture of any of the other radioactive products of its disintegration, the maximum distance or range of the rays was 3 12 cm. If, however, these products, namely radon (formerly termed "radium emanation"), radium A, radium B and radium C were present, the complete ionisation curve showed unmistakably the emission of alpha-rays from four of these and indicated ranges of 4.1 for radon, 4.7 for radium A and 7.0 for radium CF (radium B emits beta-rays only).

These results not only demonstrated the correctness of Bragg's views;

they furnished at the same time a convincing confirmation of the disintegration theory of radioactive transformations which had been put forward by Rutherford and Soddy only four years earlier, during their brilliant partnership in radioactive research at McGill University. Realising this, Bragg immediately sent a letter to Rutherford - who was still at Montreal - informing him of the results of his experiments, and, as he subsequently avowed, "eagerly awaited his reply."

When it came, warmly praising this new method of attacking the many still unsolved problems of radioactive phenomena, Bragg doubtless felt assured that any doubts he might have had as to the importance of his discoveries, could be cast aside and, with such assurance, from that time went confidently forward not only to extend his researches on alpha-rays but to embark on a fresh voyage in another sea as yet imperfectly explored: the nature of X-rays.

Parenthetically, it may be stated here that this first correspondence with Rutherford was not his earliest contact.

When Rutherford, at the age of 19, having been awarded that 1851 Exhibition, was on his way from New Zealand to England - where he was to become a research student in the Cavendish Laboratory (then under the direction of Sir J.J. Thomson) his ship called at Adelaide and he took the opportunity to pay a hurried visit to the University and call upon the Professor of Physics. He found him in a photographic dark-room trying to make a Hertzian oscillator work - presumably it was intended for use in the experiments on wireless waves already referred to. Rutherford had brought with him the "magnetic coherer" for the reception of Hertzian - or "wireless" - waves which he had invented while still a student in Christchurch. "Thus," says Professor Eve, in recording this incident, "there occurred a fourfold coincidence: Bragg, Rutherford, oscillator and detector."

3.7 EARLY WORK IN ADELAIDE ON X-RAYS

They say that the tame tiger, having once tasted human blood, becomes thereafter a dangerous man-eater. Bragg, in his experimental research on the alpha-rays, having once tasted the joy of discovery, similarly realised his true vocation, and from then on followed the gleam of his ″one true light″ to the end of his days.

As an initiation to experimental research the work on alpha-rays was well chosen. Here was a clear-cut problem to which experiment could and did yield a definite solution.

Once solved, however, and obviously related questions such as the stopping-power of the different species of atoms for the rays cleared up, he was content to leave it to others to apply the method to f ill in blank spaces and to elaborate refinements while he himself turned his attention to the more extensive field of the mysterious X-rays.

As already stated, Röntgen himself could do no more than offer a suggestion as to their possible character. A strong similarity to light was shown in the fact that X-rays travel in perfectly straight lines from point to point, in their power to ionise air or other gas, to affect the photographic plate and to cause certain minerals to emit fluorescent light. Yet an essential identity in their nature seemed to be excluded by reason the failure of all attempts to reflect them from the surface of a mirror or to bend their path by passing though a prism.

Even the possession of a wave-like character was put strongly in doubt by the apparent absence of two effects which are common to all kinds of waves, viz., the ″interference″ of one beam with another identical beam to produce a partial nullification, and the power of all waves to bend in some degree around an obstacle placed in their path, known as ″diffraction″. On the other hand, if a corpuscular character were attributed to them, their pursuance of a straight path, undeviated by the influence of the strongest electric or magnetic fields, showed that they carry no electric charge, whether positive like alpha-rays, or negative like the beta.

Since in all the above respects - save only in far higher powers of penetration - the gamma rays of radioactive substances were identical, they too, were taken to be X-rays. The view generally held as to the nature of X-rays when Bragg commenced his researches was the ”ether-pulse” theory proposed by Sir George Stokes, Lucasian professor of mathematics in the University of Cambridge. According to this, the violent impact of the cathode rays on a solid object would result in an electrical wave-pulse, much as the impact of a bullet on a target gives rise to a short sharp pulse of sound. Such a pulse, it was argued, would not possess the ability of a train of waves to exhibit interference or diffraction effects, nor to undergo reflection or refraction, but would still travel in straight lines with the speed of light and, it was claimed, possess the power to eject electrons from atoms on which it impinged.

It was in this last claim, especially, that Bragg from the first suspected a weakness which he set out to test by a series of experiments.

The experience gained in his work on alpha-rays stood him in good stead, for although there was no question of identity between these and X-rays, the same method of observation, namely measurement of ionisation produced by the rays in a gas, was applicable to both, and the essential equipment for such observation was ready to hand.

Also, Bragg was again fortunate in securing the valuable assistance of a capable collaborator in the person of John Madsen, a Sydney graduate who had been appointed to take charge of classes in electrical engineering under Bragg. Their experiments were directed towards the elucidation of the relations between the gamma-rays and the properties of the electrons ejected by them from atom on which they impinged. Reports of similar experiments made on X-rays by European* *experiments were already available in scientific literature.

The experimental evidence obtained by Bragg and Madsen confirmed Bragg in his doubts respecting the validity of the ether-pulse theory. It pointed with strong probability to a close equality of the energy of the ejected electrons with that of the gamma-rays which expelled them, and to a continuance of their motion in the same direction of travel, hence, Bragg argued, to a direct transference of the energy of the one ray to the other. Such a transfer of energy is easily understood on a corpuscular theory of X-rays - requiring nothing more to explain it than the mechanical laws of colliding bodies - but extremely difficult - to reconcile with any theory of an ever-expanding wave which, obviously, must disperse its energy over a wider and wider surface as it travels on, whereas the speed of ejection of electrons was found to be the same whatever the distance of the sheet of metal from the radium emitting the gamma-rays. Neither, as his experiments proved, did the nature of the metal, whether aluminium, or copper, for example, affect this speed in the least, a sufficient proof that the energy of the electrons was derived from that of the gamma-rays alone and not from a store of energy within atoms through which they passed.

Bragg clearly realised the need for explaining the enormous differences in penetrating power of the gamma and the beta-rays, and the indifference of X-rays to the action of electric or magnetic forces. His explanation was simple, and in the existing state of knowledge, highly plausible.

It was based upon what he termed the conception of a ″neutral pair″. When a high-speed negatively charged electron penetrated an atom, it was assumed that it could pick up from the atom another particle charged with an equal amount of positive electricity which would, of course, neutralise its own negative charge, thus becoming electrically neutral and consequently relatively immune to the influence of both electrical and magnetic fields whether within atoms or without.

By the converse process, just as easy to imagine, of losing this positive partner in penetrating another atom, it would be possible for the X-ray to be reconverted to an electron, which on the assumption of negligible mass in the positive particle removed, would possess the same or nearly the same energy and speed as the original electron which created the X-ray.

Another consequence of the neutral-pair theory, on which Bragg laid stress was, as he believed, confirmed in the indirect nude of ionisation by X-rays. Naturally, if, due to the neutral character of an X-ray and consequent lack or weakness of its external field of force, at atom can exert little or no influence upon a ray passing through it, the X-ray in turn would exert little or no effect upon the atom.

Only when the positive part had become detached and the ray reconverted to a moving electron would its disruptive power come into play. Hence ionisation and the production of cathode-rays from X-rays must go hand-in-hand. This deduction is certainly well verified in the case of the most penetrating X-rays and all the better, of course, in that of gamma-rays whose properties - and especially their penetrating power - correspond to X-rays produced by several million volts.

But with the extension in range of penetrating power to include very ”soft” X-rays, this argument loses all validity and the behaviour of X-rays is seen to fall into line with a general principle governing the exchange of energy between rays and atoms, illustrated also in the fact, already cited, that the ionising power of alpha-rays is at its maximum just at the end of their path.

Bragg’s ingenious neutral-pair theory did not pass unchallenged.

Dr. Charles Barkla of Liverpool attacked it in the columns of ”Nature”, citing in refutation many experimental observations made bry himself on the behaviour of X-rays, and claiming these as being entirely consistent with the ether-pulse theory and inconsistent with a corpuscular.

Bragg replied with equal vigour, stressing, naturally, the results on gamma-rays obtained in the Adelaide experiments.

Since future developments have shown that both theories are untenable it does not seem worthwhile today to assess the merits and demerits of the case either for the prosecution or the defence, but it is satisfactory to be able to report that both disputants have been subsequently awarded the Nobel Prize for their Aork in the very f ield on which they fought and that the award to one, at least, was in part due to the confirmation of his discoveries by the other.

In January, 1909, the Australasian Association for the Advancement of Science met it Brisbane and Bragg was its President. He chose as the title of his Presidential Address: "The Lessons of Radioactivity" and in it he gave a masterly and eloquent exposition of the state of knowledge in this new branch of science at that time. In evidence of his possession of a power of poetic imagination, I will quote one passage from this fine address verbatim. After emphasising the independence of radioactivity of all physical conditions, he goes on to say: "It is clear that we are dealing (in radioactivity) with the most fundamental characteristics of atoms, with the building material and not with the structure; with the inner nature of the atom and not its outside, and it is this which differentiates radioactivity from the older sciences. You will remember how Jules Verne in one of his bold flights of imagination drives the submarine boat far down into the depths of the sea. The unrest of the surface, its winds and its waves, are soon left behind; the boat passes through the teeming life below, down into the regions where only a few strange and lonely creatures can stand the enormous pressure, and driving still further, reaches at last black depths, where there is a vast and awful simplicity. Here 'where no man hath come since the making of the world' the silent crew gaze upon the huge cliffs which are the buttresses of the continents above. It is with the same feeling of awe that we examine the fundamental facts and lessons of the new science."

It was inevitable, as Andrade says, that with his reputation as a physicist of the first rank now established, Bragg should receive offers from other centres of learning. An of fer in 1906 to become the f irst Professor of Theoretical Physics in McGill University - one may suspect a Rutherfordian influence in this - was nipped in the bud by a f ire which destroyed a great part of the University and upset its finances. But in 1908 came a second call to the Cavendish Professorship of Physics in the University of Leeds.

Bragg, eager to prosecute his research work with better facilities than were available to him in Adelaide - he told his colleague Mitchell that he anticipated that chemical analyses which took months to complete in Adelaide would be done in less weeks in Leeds - accepted, and left Adelaide with his family for England in February of the year 1909.

They travelled on the ill-fated ship "Waratah" - it was the return trip of her first voyage. On her second the "Waratah" disappeared without leaving a trace between Ourban and Cape Town.

In a letter which Bragg had written to a friend (Sir Charles Todd) in Adelaide after arriving in England, he expressed very grave concern regarding the sea-worthiness of the ship, based in all probability, on the long time which was taken in recovering from a roll. It is a general principle of oscillatory motion of all kinds that such a slow recovery - in technical terms, a long period of oscillation - is an indication of an approach to instability. At the official enquiry into the loss of the "Waratah" the evidence to this effect given by Bragg helped to elucidate the cause of the disaster.

During the first two years of his stay at Leeds his published scientific papers dealt mainly with the same problem of the relation of X-rays to the secondary electrons ejected by them, or the converse effect.

No doubt the process of settling in with the work of preparing new courses of lectures, new practical courses, perhaps certain unexpected frustrations, limited the amount of time and energy available for taking up researches in new fields.

The situation in regard to the nature of X-rays - whether corpuscular or undulatory - seemed to have reached a deadlock.

Bragg's ”neutral pair” - a forecast of the actual ”neutron” now known to exist - was satisfactory as an explanation of the extraordinary power of the rays to penetrate matter - far exceeded indeed by that of the real neutron - and, as Bragg was the first to maintain, of their inability to ionise gases directly and only by mans of the secondary electrons they create. Cn the other hand, the electro-magnetic wave or pulse-theory offered a more plausible explanation of the polarisation of the rays which, precisely as with light-waves, took place when the rays were scattered from matter through which they passed. An experimental proof that their velocity was identical with that of light would have been decisive for the wave-theory, but the claim made by a German scientist to have proved this equality was rejected by Bragg as unwarranted. The crucial tests for a wave-character, as already remarked, lie in the effects known as ”diffraction” and ”interference”. The situation was, in fact, a striking parallel to that which existed in regard to the nature of light in the time of Newton, 300 years ago.

Newton upheld the corpuscular view of the ancient Greeks on the very same grounds as Bragg for X-rays, namely the sharpness of their shadows and lack of evidence as to their capacity for interference or diffraction. His Dutch contemporary, Huyghens, on the other hand, espoused the wave-theory.

Only after Thomas Young in England and Fresnel in France had devised experiments which convincingly demonstrated the existence of these effects was the corpuscular theory abandoned in favour of a wave-theory.

Subsequent refinements and elaborations of such experiments has built up a vast body of precise information concerning light-waves and their properties and led to extensions of the realm of optics to include both waves too long and waves too short to affect the sense of sight - the ″infra-red″ and ″ultra-violet″ regions.

It was, at least, a reasonable hypothesis that waves of the same (electro-magnetic) nature might exist of still shorter wave-length than the shortest known ultra-violet.

On the other hand, even to convinced adherents of the wuve-theory of Xrays, there seemed to be no prospect of determining the wave-lengths or obtaining a spectrum of the waves by means of an interference or diffraction effect, since estimates based on Stokes pulse-theory and on the failure of all experiments to find such an effect indicated a value of the weve-length 1000 times less than that of light. Thus, 17 years after the date of nontgen's discovery the true nature of the rays remained undecided. But in 1912 a discovery was made which not only solved this mystery but inaugurated a new era in the Department of Physics of the University of Munich, in this branch of science when Max von Laue, a Privat-dozent was inpsired by a brilliant idea.

3.8 LAUE'S DISCOVERY; W.L. BRAGG'S INTERPRETATIONS; JOINT WORK OF W.H.B. AND W.L.B.

Laue's special interest had been in the electromagnetic wave-theory of light. He had been entrusted with the task of writing an article on wave-optics for the Encyclopaedia of mathematical Science and in doing so had devoted special attention to the theory of the diffraction-grating. He was also well acquainted with the space-lattice theory of crystal-structure, a theory which explains the geometrical characteristics of crystal-form in terms of the arrangement of its atoms or molecules in a pattern which repeats itself throughout the whole volume of the crystal. Thus in a crystal of the cubic or regular system the elementary unit of pattern might take the form of a cube with an atom at each corner, a repetition of which in all directions could result in a crystal having its faces perpendicular to the edges of the cube. Assuming such a structure a simple calculation based upon a knowledge of the density of any crystalline solid and the weight of its molecules gives the average spacing of these as something of the order of one hundred millionth of a centimetre.

Now, although Pontgen himself and others after him had failed to obtain conclusive evidence of the diffraction of X-rays (e.g., in spreading out as light does after passage through a fine slit) yet others believed that photographs of a narrow beam of rays passing through a fine slit did indicate such diffraction. This was strongly confirmed when Koch of Munich devised a photometer which far surpassed the human eye in its resolving power. His measurements on photographs such as that just mentioned indicated a wave-length of one thousand millionth of a centimetre, that is about one-tenth of the spacing of the atoms in a crystal, a relationship comparable to that existing between wave-lengths of light in the visible range and the spacing of lines on a diffraction-grating.

To Privat-dozent Laue, equipped with these elements of knowledge basic to a solution of the problem but as yet held in separate compartments of his mind, there came one evening a student, P.P. Ewald, seeking assistance in his endeavours to solve a problem in wave-propagation concerned with the effect of a three-dimensional space-lattice on electromagnetic waves passing through it.

Laue confesses that he was unable to help Ewald to solve his problem.

But the discussion effected the necessary conjunction of hitherto separated conceptions. He says "The idea came to me to put the question: how would waves behave which are short in comparison with the spacings (of atoms) in a spacelattice? My optical sense furnished an immediate answer. Diffraction spectra must result." Despite adverse comment by his seniors on the staff he obtained permission to put this opinion to the test of experiment. Two young assistants were employed to set up a simple arrangement for this purpose. A fine pencil of X-rays, limited by passage through pin-holes in lead sheets, traversed a thin plate of a copper-sulphate crystal and fell upon a photographic plate. After a few failures, due to erroneous placing of the crystal, the anticipated result was obtained. Surrounding the central spot due to the direct ray were several faint replicas which could only be due to diffraction effects. The evidence was conclusive. At one stroke both the wave-theory of X-rays and the existence of the crystalline space-lattice had found convincing confirmation.

Further experiments were then made - all critics silent now - with refinement in the details of the apparatus and on several crystals of a simpler type, including zinc sulphide, which belongs to the regular or cubic system. Beautifully symmetrical patterns of spots were obtained, the position of which on the plate could be correlated with three whole numbers (replacing the single number in the equation connecting wave-length and direction of diffracted beam in the theory of the one-dimensional grating) each set specifying a set of atoms in the crystal which collaborated in their scattering effects in a certain direction.

For complete correlation, however, of theory and results, an assumption had to be made as to the nature of the elementary unit of pattern in the spacelattice.

Von Laue's assumption of a cube with an atom at each corner was erroneous and to get even an imperfect agreement between his calculations and actual measurement necessitated an arbitrary restriction of the wavelength of the rays to certain specific values.

It was at this stage, that William Lawrence Bragg took up the running. He was at that date (1912) a research student in the Cavendish Laboratory at Cambridge and, as he states, "an ardent supporter of my father's views respecting the corpuscular nature of X-rays." He goes on to say: "During the summer of 1912 we had discussions on the possibility of explaining Laue's pattern (of spots) by some other assumption than that of diffraction of waves, and I actually made some unsuccessful experiments to see if I could get evidence of "X-ray corpuscles" shooting down the avenues between the rows of atoms in the crystal. On returning to Cambridge to ponder over Laue's paper, however, I became convinced of the correctness of his deduction that the effect was one of wavediffraction - but also convinced that his analysis of the way it took place was not correct."

He then proceeds to explain how from a certain secondary feature of the photographs (merely, in fact, the change in shape of the spots with position on the photographic plate) he was led to substitute the idea of a reflection of the rays by planes more or less densely packed with atoms for the scattering of waves from individual atoms on which Laue based his explanation. Also, he found it necessary to replace Laue's simple elementary cube by one in which an atom was situated not only at each corner but in the centre of each face (an arrangement which had been proposed on other grounds by Professor Pope of Cambridge).

Repeating now the calculation with the necessary modifications he found complete agreement with the observed pattem and thereby decisive proof of the essential correctness of Laue's theory. (Thus, nobly, do the rival galdiators in the arena of scientific research come to the help of an opponent who stumbles!)

There followed immediately upon his initial success similar solutions of the X-ray diffraction spectra of several other simple kinds of crystalline salts. The first day of success in the X-ray method of analysing crystal structure had dawned, to be followed, in perennial succession, by thousands of others.

The younger Bragg, in these initial stages, had also at first regarded the space-lattice of the crystal as a regular arrangement in space of individual atoms and used the same method of mathematical analysis as Laue to obtain a picture of that arrangement. But what might have seemed to anyone else an unimportant minor feature of the photographs (as already mentioned it was a change in the shape of the diffraction images with increasing distance of the image from the crystal) led him to an alternative and most illuminating viewpoint. It was to regard the atoms as lying in sets of parallel planes, in analogy to the way in which the vines in a vineyard may be seen as arranged in parallel rows. And just as by changing the direction of observation in the latter case different sets of rows appear in view, so, in a crystal, a multitude of sets of planes, each set packed more or less densely with atoms, intersect it in varied orientation.

When a beam of X-rays penetrates the crystal a swarm of secondary wavelets starts out f rom each and every atom in an atomic plane each time a wave passes over them the aggregate of these forming a new wave-front. Alone, such a secondary wave oould be feeble far below the possibility of detection. But if, as may result from a particular relation between the spacing of the planes, the wave-length and direction of travel of the rays, the reflected waves from successive layers follow one another crest upon crest and trough upon trough - to use a metaphor drawn from water-waves - then their cumulative effect could well be expected to amount to a reflection comparable in strength to the reflection of light from the most perfect mirror. on this being pointed out to him by the distinguished physicist C.T.R. Wilson (inventor of the fog-chamber method of detecting tracks of alpha and other oorpuscular rays) Bragg (jnr.) immediately made the experiment of directing a pencil of X-rays on to a thin sheet of mica and placing a photographic plate in a position to receive both incident and reflected ray.

When the angle of incidence was rightly adjusted, an exposure of a few minutes only sufficed to show the existence of the predicted effect whereas to obtain Laue diffraction-pictures of comparable intensity an exposure of several hours was required. Here, then, was obviously a new and powerful tool of X-ray analysis, and one moreover which could be made to serve a double purpose. Firstly, from the relation between wave-length and direction of travel of the waves and spacing of planes, a knowledge of wave-length would enable a determination of the spacing; secondly, if the spacing is known it is only necessary to measure the angle at which reflection occurs to find the wavelength.[2]

The elder Bragg (to whose work on X-rays after this long digression we now return) immediately reoognised the truth and appreciated the possibilities revealed by Laue's discovery and his own son's interpretation of it, without, however, wholly renouncing his previous arguments in favour of a corpuscular theory. His acceptance of the wave-theory was hailed by Arnold Sommerfield in these wards, written in 1913 in the course of an appreciation of Laue's discovery: "One particularly admirable success of these crystal diffraction photographs is the service they have done in convincing the most renown adherent of a corpuscular theory - W.H. Bragg - and bringing him over into the camp of the followers of the wave-theory."

It was true that Bragg, confronted with the compelling evidence of these new phenomena, could not but accept the wave-theory. But, as remarked above, he did so with a reservation. In November of 1912 he

[2]The relationship of the spacing of the atomic planes in the crystal to the wavelength of the X-rays and the angle at which they impinge on the planes is expressible by a simple equation known as "Bragg's Law".

expressed his views on the matter as follows: "Dr. Tutton suggests that the new experiment may possibly distinguish between the wave and the corpuscular theories of the X-rays. This is no doubt true in one sense. If the experiment helps to prove X-rays and light to be of the same nature then such a theory as that of the 'neutral pair' is quite inadequate to bear the burden of explaining the facts of all radiation. On the other hand, the properties of X-rays point clearly to a corpuscular theory and certain properties of light can be similarly interpreted. The problem then becomes, it seems to me, not to decide between the two theories of X-rays but to find, as I have said elsewhere, one theory which possesses the capacity of both."

Here Bragg enunciates clearly the outstanding paradox of modern physics, the possession by the same physical entity of two apparently irreconcilable characters: wave and corpuscle. It would seem probable that he was not fully aware of the developments which had been taking place in Germany - paralleling his own independent line of thought - following upon the discovery in 1900 of the discontinuous nature of temperature-radiation by Planck, and particularly of Einstein's attribution of a corpuscular aspect to ordinary light - shared with its wave-character - according to which the frequency of the waves fixes the energy of the corpuscles, and which have culminated in the mathematical theory of wave-mechanics. Be that as it may, he immediately appreciated and prepared at once to apply the reflection of X-rays by crystals in experimental investigations. His interest at the outset - as Sir Lawrence has informed me - was directed, not so much towards the determination of crystal structure - which perhaps he regarded as his son's pre-emptive right - but to the reciprocal problem of defining the quality of X-rays in terms not, as formerly, by their power to penetrate or to be absorbed by matter but of their wave-characteristics, namely, wave-length or frequency and intensity.

To this end he devised a beautiful instrument, the X-ray spectrometer (the counterpart of the optical spectrometer used in the analysis of light in the visible, infra-red or ultra-violet regions) which can be employed to weasure not only wave-lengths like the optical instrument but also intensity of X-ray beam. The manner of using it is as follows: A beam of the radiation to be examined is defined in direction by passage through narrow slits in sheet-metal, falls then upon a plate of a perfect crystal - rock salt, calcite or other - which can be rotated in such a way as to throw a reflected beam into an ionisation chamber. The angle made by the atomic reflecting planes in the crystal with the incident beam then gives the wave-length; the value of the ionisation current the intensity.

Sir Lawrence Bragg writes about this instrument as follows:-

> The X-ray spectrometer opened up a new world. It proved to be a far more powerful mthod of analysing crystal structure than the Laue photographs which I had used. One could examine the various faces of the crystal in succession and by noting the angles at which and the intensity with which they reflected the Xrays one could deduce the way in which the atom were arranged in sheets parallel to these faces. The intersections of these sheets pinned down the positions of the atoms in space. On the other hand, a suitable crystal face could be used to determine the wave-lengths of the characteristic X-rays coming from different elements as sources. A 'pure' beam of monochromatic X-rays could be selected by reflection from a crystal and its absorption in various substances measured. It was like discovering an alluvial gold field with nuggets lying all around waiting to be picked up. At this stage my father and I joined forces and worked furiously all through the summer of 1913 using the X-ray spectrometer. Although the description of this instrument was published in our joint names, I had no

> share in its design.
>
> "The capital I brought to the family firm was my conception of reflection and the application in general of the optical principles of diffraction and my success in analysing the first crystals by the Laue method.
>
> It was a glorious time when we worked far into every night with new worlds unfolding before us in the silent laboratory. My father was at first far more interested, in X-rays than in crystals, and left the determination of crystal structure to me with the exception of a paper on diamonds which showed the power of the instrument he had devised. He measured the wave-lengths of the X-ray spectra given by the elements, platinum, osmium, radium, palladium, rhodium, copper and nickel. He identified them with Barkla's K and L radiations."

Moseley's famous experiment of a year later in which he determined the wave-lengths of the X-rays characteristic of a series of chemical elements was a direct extension of these earlier experiments of W.H. Bragg, the main difference in his technique being the substitution of a photographic plate for the ionisation chamber. The elder Bragg's one incursion into crystal analysis - which his son was pursuing concurrently with equal vigour and success - solved the problem of the arrangement of atoms in the diamond, a crystal, it need hardly be said, unique in many of its physical and optical properties. The dimension of the unit cell of its space-lattice - built up of tetrahedra with a carbon atom at each corner of each tetrahedron and one at the centre - is defined by one single length, viz., the distance from every carbon atom to anyone of its four neighbours. This distance is 1.54 Angstrom units.

It is not difficult to appreciate how the remarkable properties of diamond - its extreme hardness and elasticity, its infusibility and insolubility (which have, up to now, frustrated attempts to make artificial diamonds) its high refracting power for light, find a physical basis in such a structure. The tetrahedral character assigned by chemists to the carbon atom which is one of the key-stones of structural organic chemistry is visibly apparent in this model. Another feature, oomiion to carbon compounds of the aromatic class, of which benzene is the simplest exemplar (equally put in evidence in this crystal model) is the existence of a linked meshwork of rings in each of which the atoms lie alternately either slightly above or slightly below a median plan.

The other crystalline form of pure carbon known as graphite differs most remarkably from diamond in many ways - among others in its opacity to light, and in its power of conducting electricity like a metal. The explanation of this difference is to be seen it is space-lattice in which the benzene-ring layers are now separated much more widely, so that rigidity, as between them, is lost and the crystal flakes easily along these layers, behaviour which explains well its property as a lubricant.

3.9 WORLD-WAR 1. WORK ON SUBMARINE DETECTION

This period of intense and fruitful co-operation of father and son was interrupted by the outbreak of the first World War.

To combat enemy submarine attacks on British shipping, the Admiralty had created a Board of Invention and Research for the purpose of obtaining scientific advice on mthods which might be devised for countering this menace. Bragg, an original member of this Board, was appointed "Director of Research on methods of detecting underwater sound," the objective being to locate enemy submarines either by the self-emitted sound of its screw-propeller or engines or (as proved to be far more effective) by the echo from the hull of the submarine of a pulse of sound-waves generated by some form of transmitter carried on a destroyer.

(Water, even when so turbid that a beam of light is transmitted only a few feet, is an excellent medium for sound-propagation.)

Experimental work was carried on, in the f irst place at a naval base on the Firth of Forth; afterwards, when this proved unsatisfactory, at Harwich. Ernest Rutherford was also an active collaborator in this work.

A small team of physicists and technicians worked under Bragg's direction on the problems of devising sound generators for creating an intense bean of high-frequency sound waves on the one hand and receivers suitable for detecting the echo reflected from the hull of the submarine, on the other.

For the former, a modified form of the piezo-electric vibrator devised by Professor Langevin of Paris, was employed; for the latter, underwater microphones or hydrophones. Success was finally achieved in constructing these in such a way as to indicate nor merely the arrival of the underwater sound from a distant source but in indicating the direction from which it came.

While Bragg the father was engaged on this work, Bragg the son was employed upon the parallel problem of locating the position of the eneny's heavy guns by somewhat similar mans, namely the precise times of arrival of the soundwave which accompanied the firing of the gun at several different stations behind the British lines. Here again, a special type of microphone (Tucker hot-wire microphone) was devised which discriminated in favour of the explosive wave arriving from the distant gun as against local noises.

During his stay at Lees a tempting offer had come to Bragg in the form of an invitation to become the Principal of the new University of British Columbia. In some uncertainty of mind as to whether or not he should accept, he sought the advice of his friend Rutherford.

Rutherford's reply to the inquiry is so characteristic of his outlook that I quote a couple of sentences. "I think," he says, "that if I were tired of physical work (does he not mean 'work in physics'?) and had not an idea left to work on, I should consider it an admirable position to occupy one's declining years, but I quite agree with you that it would be very difficult to leave the Physical World (world of research in physics?) at such an interesting time when there is so much to do and so many interesting problems in sight."

With such a hint that, in Rutherford's opinion, administrative jobs are suitable occupations for scientific men only when approaching senility or when vacuity in ideas renders them incapable of further productive work it is not surprising that Bragg declined the position.

But, when in 1915 he was invited to become Quain professor of physics in University College of London University, he accepted, and as soon as release from war-service cam with the ending of the war, resumed his work on crystal analysis. Many other physicists and crystallographers, both in England and elsewhere, impressed with the power of this new weapon - so conclusively demonstrated by the Braggs - began to make use of it in the same f ield of research.

Many modifications in the method of crystal analysis and many extensions of its application, resulted from their work. of these, the most important was due to Bragg himself, when in 1924 he showed that by making a bold yet plausible assumption the principles and technique of the X-ray analysis of crystal structure could be applied to the determining of the structure, not only of inorganic but also of organic crystals - or, at least, of that large class known as aromatic compounds.

The assumption is that the group of six carbon atoms linked together to form a hexagon known as the "benzene-ring" (benzene itself consisting of such a ring plus six hydrogen atoms) may be regarded as a physical ent1ty of definite size and form irrespective of the crystal in which it occurs. Thus naphthalene is to be looked upon not as a molecule containing 10 carbon and eight hydrogen atoms but as two benzene rings having one side - or two carbon atoms - in common. Bragg demonstrated the value of this hypothesis by the experimental determination of the form and dimensions of the unit-cell, the infinite repetition of which builds up the crystal - of a number of benzene and naphthalene derivatives and it has since been successfully applied by others to compounds of such extreme complexity as the proteins.

3.10 DIRECTOR OF THE ROYAL INSTITUTION

The Royal Institution of Great Britain, most famous of all scientific foundations, of which it has been well said "that it combines the characteristics of an academy, a college, a research institution and a club" was founded in the year 1799 by that extraordinary individual Count Rumford (born plain Benjamin Thompson, at the little town of Rumford, in the State of Massachusetts).

Exiled from his native land because of his active partisanship of the British cause in the American War of Independence, knighted by King George III for his services in military administration, created a Count of the Holy Roman Empire by Karl Theodor, Elector of the State of Bavaria, in recognisition of the social and military reforms which he effected; soldier, administrator, scientist, inventor and social reformer; Rumford founded the Institution "for the promotion of science and the diffusion and extension of useful knowledge."

Well has it served those worthy aims. From within its laboratories in Albermarle Street, Piccadilly, under the direction of a succession of famous scientists, there has come a succession of famous discoveries. In its lecturetheatre these same men and many others of scientific fame have expounded the most recent advances in their special field of knowledge.

Its first director, Humphrey Davy - famous for adding sodium, potassium, chlorine and iodine to the list of chemical elements and for his invention of the miner's saftey-lamp - by his enthusiasm and eloquence, drew to his audience not only the few engaged in serious scientific pursuits, but also the many to whom is discosurse merely offered intellectual entertainment. His successor, Michael Faraday, greatest of experimental scientists, rose to that dignity and fame from the humble level of Davy's laboratory assistant; as an expositor of science he rivalled his former master.

Daring Faraday's regime the finances of the Institution, hitherto always precarious, were greatly improved by a benefaction by John Fuller, a wealthy - and, it is said eccentric - Member of Parliament. This enabled the managers to create two "Fullerian" Professorships, one in Chemistry, the other in Physiology; to these a third, in Natural Philosophy was subsequently added. Faraday was the first "Fullerian" Professor of Chemistry.

John Tyndall, who followed Faraday, made important contributions to our knowledge of Radiant Heat, of Light and of Sound. He, like his predecessors, combined the faculty of speaking well with that of writing well. His books on Sound, Light and Heat still repay reading by students of Physics.

Next in succession came Sir James Dewar, well-known for his success in liquefying hydrogen gas for the first time and for invention of the Dewar vacuum flask, better known by its commercial title of "Thermos". Dewar died in 1923 after holding office for 46 years.

The task of choosing a successor was probably not a difficult one. Bragg was clearly marked as the right man. He had all the essential qualities demanded of the occupant of this distinguished office in full measure: the ability to originate, prosecute or direct fundamental research; the gift of simple yet inspiring oratory; a personality richly endowed with dignity of bearing, sincerity of speech and charm of manner.

He was elected to the combined offices of Director of the Royal Institution, Resident Professor and Fullerian Professor of Chemistry. To these was added a new responsibility - Director of the Davy-Faraday Research Laboratories, the construction, equipment and maintenance of which was made possible by an endowment which the Institution received from Dr. Wdwig Mond. This fund also permits the financing of a limited number of independent research workers.

Bragg brought with him for inclusion in this band of coworkers, two members of his University College staff, Messrs. Muller and Shearer, both already experienced in the technique of X-ray crystal analysis. These two, especially, gave valuable assistance in the design and construction of new and more powerful equipment, which included, for example, two high-power X-ray generating tubes, one of 5 k.w., the other of 50 k.w.

These and other improvements permitted a reduction in the time required for the observations to a fraction of what it had previously been.

An active school of research in X-ray crystal analysis soon came into being. In its members are included such well-known names in British science as J.D. Bernal, W.T. Astbury, Kathleen Lonsdale, and many others who have made important contributions to this new branch of science.

While the steady flow of publications describing the results of these researches amply fulfilled the primary purpose of Count Rumford's foundation, the "promotion of science", it did not supplant or prevent the fulfilment of its secondary objective, "the diffusion and extension of knowledge." Increase in membership and in the numbers attending lectures necessitated extensive alterations and additions to the Lecture Theatre, Library and reading room of the Institution. The Friday evening discourses initiated in Faraday's time received fresh accession of popularity largely because of the attraction exerted by Bragg's own lectures and demonstrations.

When conversaziones were held, to which large numbers were invited, Lady Bragg was, as formerly in Adelaide days, an active assistant to her husband in explaining exhibits and experiments to visitors.

On this wifely occupation her sister (Miss Todd, makes the following comment: "He and I would listed with great enjoyment to my sister explaining experiments to her friends and he would smile at me with delight and understanding." I once said to her, "How can you dare to do this, especially with Will listening, when you really don't know a thing about it?" "Well, darling," she would reply, "they understand what I tell them far better than when will explains."

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This very human gift for entertaining and interesting people was a great help to my brother-in-law all through his career. They were a much-loved pair in the university town of Leeds and, when at the Royal Institution in London, my sister made an excellent hostess. She still, at the Friday night receptions, would explain the experiments, and I used to think that the more inexact she was, the more the group round her would enjoy themselves."

Bragg's first successful course of "Christmas Lectures to Children" in the 'World of Sound" was followed by several others: "Old Trades and New Knowledge" - designed to demonstrate "the way in which new knowledge is continually changing the old crafts"; "Concerning the Nature of Things" (a modern version of "De rerum Natural' written by the Roman poet Sureties 2000 years ago, devoted not to his object of "freeing mankind from fear of the supernatural" but merely to an explanation of their physical properties in terms of their atomic structure; and the "Universe of Light," the theme and scope of which is well indicated in its opening sentence "Light brings us news of the Universe."

When the Second World War broke out in 1939, Bragg at the age of 76, was not too old to serve the nation as Chairman of the Advisory Committee to the British Government on Food Policy.

A letter which he wrote to the London Times shows no diminution of his power of clear and vigorous expression. His last public activity would appear to have been the organisation of a series of broadcasts by the British Broadcasting Corporation in collaboration with the Science Committee of the British Council - of which Bragg was Chairman - entitled "Science lifts the veil". I quote from the preface to the published edition of these tasks:-

> "The late Sir William Bragg .. was deeply interested in the series. He believed enthusiastically in the great role that broadcasting must have in the stimulation of public interest in and the understanding of science. He proposed the theme for the series, sketched the topics and gave the opening talk himself . He introduced ten of the speakers, including his own son, Sir Lawrence Bragg, and his last public words were spoken in his discussion with Professor J.D. Bernal on 'The Problem of the origin of Life.'"

This most interesting discussion is too long to quote in its entirety. But in order to put these last words spoken by Bragg in public on record here, as well as for their intrinsic interest, I reproduce the last few questions asked and the answers given.

The discussion has turned upon the structure of protein molecules - a problem Bernal had been foremost in attacking by the method of X-ray analysis - and especially of the nature of a virus, probably the lowest thing to which the quality of life can be assigned.

Bragg asks: But if one protein or virus must always come from another how did the first one get there? How did it all start?

Bernal answers: That's what we have to find out. One big step towards it is getting the structure of virus and protein molecules. it's really the problem of the original life.

Bragg: That is just it. What do you mean by life? All the time you have been talking of a virus as alive at one moment and being a crystal at another. How can that be?

(It is now Bernal's turn to put the question) . He asks: Well! What do

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Bragg asks: But if one protein or virus must always come from another how did the first one get there? How did it all start?

Bernal answers: That's what we have to find out. One big step towards it is getting the structure of virus and protein molecules. it's really the problem of the original life.

Bragg: That is just it. What do you mean by life? All the time you have been talking of a virus as alive at one moment and being a crystal at another. How can that be?

(It is now Bernal Is turn to put the question) . He asks: Well! What do you mean by "life"?

Bragg replies: When I was young it seemed quite simple. A thing was alive if it moved and grew and reproduced its like. Crystals did not move or reproduce. They did grow; not like a living thing by taking outside materials into themselves but simply by adding more on the outside like piling stones on a pyramid. Now your viruses don't move. They can't grow by taking material inside themselves because they have not got any insides, but they do seem to reproduce. Are they alive or (are they) not?

Bernal: I would prefer not to say.

Bragg: Why not?

Bernal: Because my colleague Dr. Pirie who had done so much of his work on viruses and has written a cutting essay on the meaninglessness of the term "life" would never let me hear the end of it.

Bragg: But you must have some idea of your own.

Bernal: I have; but it's no question of definition.

3.11 BRAGG 'S RELIGION

Brief reference has already been made to a painful episode in Bragg's early life due to a revolt of conscience against those clauses in the Apostles creed which condemn all unbelievers to an eternity of existence in everlasting fire. A quotation from his autobiographical notes shows how deeply his mind was shaken in the struggle to free itself from the chains of beliefs, fastened upon him in early childhood. "It really was a terrible year," he says. "For many years the Bible was a repelling book which I shrank from reading."

This early experience lends a special interest to the discussion of his views on religion when matured by experience and based upon his independent judgment.

In 1941 he was invited by the University of Durham to deliver one of the annual Riddell Memorial Lectures - a foundation which honours the memory of the Scottish religious poet, Henry Scott Riddell.

The title he gave to his address was "Science and Faith"; its keynote is an endeavour so to interpret the meanings of these two words as to make compatible one with the other.

Defining "Science" in the first place as a "collection of observables of Nature" he proceeds to elaborate this definition by pointing out that to make the vast body of knowledge included in it comprehensible, the scientist must "endeavour to find (in it) correlations, rules and laws. He must reduce his observations to order, because he then finds indications of the most hopeful lines of further advance.

"He could not grasp what he has already got unless he did what he could to codify it. He therefore makes hypotheses." (Here, by the way, is apparent contradiction to Newton's much quoted declaration "Hypotheses non fingo".) "But it is to be observed," he goes on to say, "that all such hypotheses are tentative and are to be amended as knowledge grows." He is insistent also that a clear distinction must be made between "science", so defined, and "the applications of science" and that the reproaches made against science for the evil uses of some of its applications are misdirected.

Again and again he returns to emphasise the provisional character of scientific hypotheses and takes pains to illustrate this character by reference to the amendment which Einstein made in Newton's Law of Gravitation and to the remarkable alternations which have taken place in our views as to the nature of light.

Seeking now a definition of "Faith" he quotes St. Paul: "Faith is the substance of things hoped for, the evidence of things not seen." But while giving praise to this as "a sentence obviously full of earnestness and meaning" he acknowledges that it may mean different things to different people, for he goes on to say "When we look into the definition we find that we way not take it word for word without stripping it of all meaning." My own interpretation," he adds, "is that St. Paul's faith was a hypothesis so firmly held and trusted that he would and did stake his life upon it. But he is describing a hypothesis which, like any other, exists to be tried by experiment. That need not trouble any follower of the rule of Christ because Christianity is again and again defined as an experimental religion."

we see here that his aim is to justify Faith in the realm of religion on the same ground as he would justify it in the context of science, viz., in justification by results. It is at least a generous attempt to find a basis for the reconciliation of the two great modes of interpreting human thought and existence. But does it not ignore the existence of the deeper philosophical antithesis in their outlook, the scientific seeking always to make a picture of the world from which subjective and anthropomorphic aspects have been eliminated; the religious based on a presumption of intelligibility, meaning and purpose in the world which is relative to man's existence and nature.

Irreconcilably opposed as these view-points may appear to be - and the history of the conflict of science and religion bears tragic testimony to the violence of human feeling engendered by this antagonism - we can all agree with Bragg that in the community of civilised educated humanity today, there is on either side a trend towards a less dogmatic assertion of doctrines which previously have been held as incontrovertible and absolute.

Bragg relates as an illustration of such a change in dogmatic theology the following experience of his childhood days.

> "When I was a very small boy the maid in our house took my cousin and myself one Sunday to a service in the Independent Chapel of our town. We were a Church household and my grandmother, who was in charge of us, was much disturbed. in the evening she set us down to be questioned. She went through the item of the Apostles Creed. Did we believe in the Communion of the Saints? Did we believe in the forgiveness of sins? Did we believe in the Resurrection of the Body? And so on. Quite overawed we meekly answered "yes" to each question in turn. Finally, my grandmother closed the prayer-book, saying that she thought we must be all right. We had come to no harm."

"Surely," is his comment, "such an incident would be far more unusual now."

Religion," says Professor Andrade in his obituary, "was a strong influence in Bragg's life." In a particular sense of this word like Faith, of marry meanings - the greater Oxford dictionary gives fifteen of the first and six of the second - this is doubtless true. Although Bragg has nowhere to my knowledge explicitly defined that sense we get some clues to it both from his comments of his early experiences and from other writings or utterances.

In the concluding paragraph of his "World of Sound" he contrasts Religion with Science: "in all our lives, in all we work and strive for it is of first importance to know as much as we can about what we are doing, to learn from the experience of others and, not stopping at that to find out more for ourselves so that our work may be the best of which we are capable. That is what Science stands for. It is only half the battle, I know. There is also the great driving force which we know under the name of religion. From religion comes a man's purpose, from science his power to achieve it. Sometimes people ask if religion and science are not opposed to one another. They are: in the sense that thumb and fingers are opposed to one another. It is an opposition by means of which anything can be grasped."

Here, again, the identification of religion with the motivating agent in human activity is broad enough to include not only the thousand and one "religions" which mankind professes today but a multitude of other spiritual agencies, not usually so classified.

It need not be doubted, however, that Bragg had Christianity chiefly in mind: a Christianity devoid both of theological dogma and of submission to any specific authority of man, church or book - he declined, much though it hurt him to refuse the request of a friend, to read the lessons at the open air services held by the Vicar of Leeds, saying "it would be a vindication in public of something he could not believe because it could not be proved."

As to what is specifically implied in Christianity his own Words are these: "If a man is drawn towards honour and courage and endurance; justice, mercy and charity let him follow the way of Christ and find out for himself that it leads him the way he should go."

3.12 HONOR AND OBITUARY

The scientific importance of Bragg's work was recognised in the bestowal of many honours and awards by scientific societies and foundations. Election to fellowship of the Royal Society of London followed soon upon his earliest researches on alpha rays and X-rays; he became a member of its Council in 1911, vice-president during the years 1920, 1921 and again during 1923, 1924, 1925. He held the Presidency from 1935 to 1940. The Society's Rumford Medal was awarded to him in 1916 for his contributions to the science of radiation, and the Copley Medal in 1930. He was President of the British Association in 1928.

In 1915 the Nobel prize for Physics - an award of the monetary value of about £10,000 made without respect to nationality, sex, or creed - was shared with his son in recognition of their joint creation of the new sciences of X-ray spectrometry and crystal analysis.

Knighthood in 1928 came in recognition of his service to the National cause as well as his scientific eminence. The supreme Civil honour of the order of Merit was bestowed in 1931. Concerning this last Miss Todd relates the following incident. A train traveller reading of the award in his morning paper remarked to his companion: "I see that Sir William Bragg has got an O.M." To which the other rejoined: "Oh! Really. Does he drive it himself?"

Of many personal tributes paid to him during his life and after his death I will reproduce two only here.

The first is in the form of two elegant verses taken from the dedication of Professor Andrade's little book on "Engines" (the record of a course of Christmas lectures to juveniles at the Royal Institution):

"You by a twofold excellence
Raised to deserved eminence
Not only Nature can compel
Her enigmatic oracle
To breathe to you but can convey't
Clear to the uninitiate
Three times yourself at Christmas tide
Have charmed us, as the children's guide
In ice and snow's fantastic frond
And close compacted diamond
Have shown the wonders that abound
And wandered through the 'World of Sound
And have most curiously displayed
How Science guides the hand of Trade."

I quote one other tribute from the distinguished American physicist, Dr. Albert Hull, late Assistant-Director of the G.E. Co's. Research Laboratory, and personal friend of the writer. He writes to me as follows:-

"I am very glad to learn that you are writing the life of Sir William Bragg for whom I have a great affection. Your memory about his lecture in Schenectady is accurate. I recorded it in a paper which I wrote some time ago of which I am enclosing a copy and should be very much pleased to have you quote it or use it in any way you wish. "The reference to Bragg is in a paper by Hull entitled "Outlook for the Physicist in industry'; it runs: 'In 1914 Sir William Bragg came to our laboratory and described in his delightful manner his pioneer work on X-ray Crystal Analysis. At the end of his lecture I inquired whether he had determined the structure of iron which was of interest for the light it might throw on magnetism. He said 'No, We have tried it but we haven't succeeded.' The next day I began working on X-ray crystal analysis. To a physicist the statement 'I have tried and failed' is a stronger challenge than any amount of advice. "

Bragg died peacefully after a very short illness on March 12, 1942. Although his physical strength had been declining for some time previously he remained mentally active and sufficiently interested to take part in a discussion on a point relating to the reflection of X-rays by crystals only a few months before he died.

A Memorial Service held in Westminster Abbey was attended by a great concourse comprising not only personal friends and associates but representatives of the King, Government Departments and all the leading Scientific Societies. The service was conducted by the Archbishop of Canterbury and the Dean of Westminster. His body by the wish of the family was interred in the grounds of the Church at the village of Chiddingford in Surrey where he had a country cottage.

Long before he died Bragg's work had won world-wide renown. He belongs for all time to the company of those whose fame raises them far above all distinctions of nationality, race or creed. Yet perhaps it is still permissible for us in Australia to feel a special pride in the fact that his experimental genius first bore fruit on Australian soil.

The plea so often urged that our geographical remoteness from the centres of creative science in the older continents of Europe and America is a handicap to young men who aim at a career in scientific research work finds no more support from his judgment than from his performance.

On the contrary - as he once told me - he looked upon his own stay in Australia as a factor in his subsequent success and wished that many other of England's young scientists could enjoy the same advantage.

His first experimental result (that all alpha-rays coming from the same radioactive element have a definite range) may seem unimportant in comparison with the extensive and important developments which have resulted from the discovery that a crystal reflects X-rays according to a definite law. Yet it too may be regarded as the starting point of a chain of discoveries culminating in one of portentous significance for the future of mankind.

For it was on this fact that Rutherford was able to discriminate between rays emanating from the radioactove sources and such as resulted from internal atomic energy released by their impact; from this first artificially induced atomic explosion a sequence of others culminated with the discovery of the nuclear fission of uranium, the motive agency in the atomic bomb.

Logically, therefore, the origin of the present international world situation may be followed back to the day when in a small basement-room of the University of Adelaide, William Henry Bragg first obtained the evidence that rays from radium travelled through air into which they emerged just ”thus far and no further.”

Chapter 4

THE APPOINTMENT OF W.H. BRAGG, F.R.S. TO THE UNIVERSITY OF ADELAIDE

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4.1 INTRODUCTION

Two of the more important figures in 20th century science have been William Henry Bragg (1) and his elder son William Lawrence Bragg (2). Less fully studied and understood are the formative years of W.H. Bragg's academic and research career, which were spent in Australia, where, in addition, W.L. Bragg was born, raised and educated. W.H. Bragg was appointed Elder Professor of Mathematics and Experimental Physics in the

University of Adelaide late in 1885; at the age of 23 years and very soon after he graduated from the Cambridge Mathematical Tripos. It may be conceded that such a young man needed time to mature and to learn the ways of the academic world, but nevertheless it seems curious that his first 17 years in Australia should have involved little more than wide social popularity, a passion for golf and painting in water-colours, 'bicycle tours and picnics during the long lazy summer vacations by the sea' , a flirtation with X-rays, and generally 'a pleasant and useful life as a popular teacher and good friend in the Adelaide community (3).

In her illuminating and charming portrait of her father, Bragg's only daughter, Mrs. G.M. Caroe, notes three unusual features of her father's life and career, two in the form of questions: "Why did he come to research so late?"; the uniqueness of father and son sharing work which brought them a joint Nobel Prize; and 'How did a man so retiring, so completely without personal ambition, become such a public figure?'(4).

Previous assessments of the early Adelaide years invite re-examination, and are shown in the present essay to be inadequate; the notable features enumerated by Mrs. Caroe deserve further exploration. In addition, the study of Australian science, then largely confined to the three universities at Sydney, Melbourne and Adelaide, offers additional perspectives on Australian history, on scientific life at the periphery of the English colonial empire, and on the world-wide impact of Cambridge science. The events surrounding both Horace Lamb's tenure of, and resignation from the Adelaide Mathematics Professorship and W.H. Bragg's succession to the augmented chair, as well as Bragg's exceedingly strenuous first,two years there, all illuminate these themes.

4.2 ADELAIDE UNIVERSITY

The colony of South Australia was founded late in 1836, when the first boat-loads of new settlers arrived from England - religious and political dissenters who sought escape from the established religion and class structure of their homeland. It was an agricultural economy from the beginning, but in the 1840s copper was discovered north of Adelaide, and mine owners joined the pastoralists, politicians and businessmen in Adelaide's newly emerging gentry and ruling classes. By the 1870s the transcontinental telegraph line had connected the eastern capitals of Australia, through Adelaide, with Darwin and Europe; Adelaide had 30,000 inhabitants, piped water and gas lighting, and attractive public buildings built from the warm local stone (5).

The University of Adelaide was founded in unusual circumstances. In February 1872 the Baptist, Congregational and Presbyterian Churches decided to establish Union College, primarily to train young men for the Christian ministry. The College soon found it necessary to seek funds to expand its facilities and activities, and the copper magnate Walter Watson Hughes agreed to give £20,000. This princely contribution caused the officers of the College to rethink their plans. In what has been described as 'a splendid act of self-abnegation' they decided to offer the funds for the establishment of a university. The province was less than forty years old; it was imaginative as well as disinterested to think in terms of a university for Adelaide (6). Meetings, discussions and negotiations went ahead under a University Association, and after a lengthy parliamentary debate the required legislation received the Governor's assent on 6 November 1874. On the same day the pastoralist Thomas Elder gave a further £20,000. Hughes's deed of gift specified that his money was to be used to endow two professorships, one in classics and comparative philology and literature, the other in English language and literature, and mental and mral philosophy. The new Council decided to use Elder's gift to appoint two further professors, in pure and applied mathematics and in natural science, the latter including geology and chemistry.

Like the existing universities in Sydney and Melbourne, Adelaide was anxious to recruit the best possible people to its foundation chairs, which characteristically required a broad range of scholarship. It was March 1876 before teaching could begin.

4.3 HORACE LAMB

The foundation Professor of Pure and Applied Mathematics was Horace Lamb, Second Wrangler in the Cambridge Mathematical Tripos of 1872 and Fellow and Lecturer in Mathematics of Trinity College, Cambridge. Lamb had married in 1875 and had therefore been required to resign his college fellowship (7). One of his earlier schoolmasters, by then a clergyman in South Australia, persuaded him to apply for the Adelaide post, to which he was duly appointed. Nothing could be taken for granted in setting up a new institution so far from 'ham' (8); on 20 March 1876 Lamb wrote to the Registrar of the University to report that 'there will be little choice in the matter of chalk as Williams [a local stationer] has no such thing in his shops' (9).

Lamb's formal responsibilities were confined to pure and applied mathematics, but from the beginning and purely of his own volition he instituted and gave courses in natural philosophy at all three levels of the B.A. and B.Sc. degrees (10). Furthermore, in so far as the limitations of apparatus and space would allow, Lamb also held regular laboratory classes for the natural philosophy students.

Initially conditions were difficult, as the embryonic university moved from one set of inadequate, rented quarters to another. In September of his second year Lamb wrote to George Stokes, offering himself (unsuccessfully) for the Sydney mathematics chair, Stokes being on the selection committee (11). Furthermore, when the University reviewed the duties and salaries of its professors early in 1879, the Vice-Chancellor reported to the University Council that 'Professor Lamb agreed with the proposal made to him with this exception that he should not be required to accept the title and duties of Professor of Natural Philosophy in addition to that of Professor of Mathematics if his salary was to be the same as those of Professors Tate and Kelly, as his work would then be much increased' (12).

Despite these difficulties, however, Lamb became a beloved teacher, popular public lecturer and respected member of Adelaide society (13); he carried a large teaching and examining load, saw six of his children born there, and wrote and published the first edition of his famous hyrodynamics text (14).

In December 1883 Lamb wrote to the Registrar as follows (15):

> Sir,
>
> I wish respectfully to ask the Council whether they would be disposed to grant me a year's leave of absence at the end of the next academical year [late 1884]. I shall then have been nine years in the service of the University, during which time I have undertaken duties which do not fall strictly within the scope of my professorship. I think I may fairly urge in support of my request that the change would give me opportunities, of rendering myself more capable of discharging these as well as my other duties with efficiency and advantage to the University.
>
> I am. . . '

This may now sound a rather straightforward request, but it contained the seeds of a long and sometimes distressing debate. First, there were no formal provisions for leave of absence. Second, Lamb was very reluctant personally to arrange for his teaching to be continued during his absence, despite two requests from the Council to do so (16). Third, the Council did not acknowledge the relevance of Lamb's other 'duties' (his physics teaching) to his application (17), although they did discuss the question with him as a separate matter; and finally they appear to have had a suspicion that the reasons for the request were? altogether or ... mainly of a personal and private character' (18).

Correspondence travelled back and forth between Lamb and the Council, but by January 1885 still no decision had been made. In February Lamb wrote a long letter to the Registrar regarding his physics teaching, at the end of which he begged leave 'to suggest that the Council should formally establish a separate Lectureship on Experimental Physics'. As I have no wish to create any unnecessary difficulties', he continued, 'I am willing ... to accept this for the present, as an honorary appointment, from year to year' (19). The Council agreed, and finally also acceded to Lamb's request for leave of absence, although by the time of his departure in mid?1885 there was little doubt as to his underlying motive. With the aid of his old Trinity College colleague, Henry Taylor, Lamb had earlier applied for the chair of pure mathematics at Owens College, Manchester, the Council of which, on 19 June, has resolved to elect him 'subject to the receipt of satisfactory testimonials from Adelaide and to the result of an interview to be held with him on his return from Adelaide' (20).

Despite their protracted nature, these difficult negotiations left no permanent scars and Lamb and the University parted amicably (21). Indeed, Lamb subsequently acted for the University in the United Kingdom on numerous occasions, notably in the selection of his successor and as the University Library's buying agent for many years (22).

As far as the University Council was concerned the principal impediment to granting Lamb's request was the difficulty of providing for his teaching to be continued during his absence. It finally agreed only after Professor Rennie (chemistry) had expressed his willingness to undertake Lamb's duties (23), and subject to the passage of the following addition to Statute 2 - of the Professors and Lectures (24):

'2A. The Council way at its discretion grant to any Professor or Lecturer or any officer of the University leave of absence for any time not exceeding one year on such Professor or Lecturer or other officer providing a substitute, to be approved by the Council, to act in his stead during such leave of absence.'

Thus was a study-leave provision written into the University's legislation, the first such provision in Australia (25). It remains a generous but essential feature of Australian academic life.

As subsequent events were to show, the University also determined that if, as it suspected, a replacement for Lamb would soon be required, then it would seek a professor for a combined chair of mathematics and physics.

4.4 W.H. BRAGG'S BOYHOOD AND YOUTH

William Bragg's early life was extremely tough and testing. He did not remember his mother well, for she died in 1869 when he was barely seven years old (26). His father lived on but is almost totally absent from Bragg's later autobiographical notes. W.H.B. (27) grew into manhood with almost no remembered parental love or guidance. His boyhood was totally dominated, as was the rest of the Bragg family, by his Uncle William, with whom he went to live at Market Harborough in Leicestershire later in 1869. Here 'there were no parties for children; we never went to other people's houses, and no children came to ours. I think my uncle was too "particular" ... He used to lecture us terribly, talking by the hour, and I suspect he was not to be shaken in his opinions by any one' (28).

School offered some outlet. The old grammar school had been re-opened, also in 1869, in 'a quaint structure raised on wooden pillars'. The new master, Wood, 'was an able man, I believe, ... and I got on quickly enough' (29). In 1873, at the age of eleven, W.H.B. went up for the Oxford Junior Local Examinations at Leicester and was the youngest boy in England to get through, although he failed in Church history and Greek. An aptitude for mathematics and modern languages rather than the subjects of the old classical syllabus was already becoming apparent (30).

The few organized school ball-games were 'a great delight', and there were some happy times with his cousin Fanny, who also lived with Uncle William. otherwise, whatever enjoyment, satisfaction and contentment the young W.H.B. found in life were discovered primarily within himself. He was already a solitary child: "I liked peace and was content to be alone with books or jobs of any sort' (31). But he was not, I suggest, without personal ambition; his tough childhood had made him self-reliant, quietly self-confident and self-content. These characteristics would sustain him for the rest of his life, and they would be immediately advantageous at King William's Gollege, on the Isle of Man, where he spent his youth.

'In 1875 my father came to Harborough and demanded me; he wanted to send me to school at King William's College ...', where his brother-in-law was a master. 'I think he became alarmed lest he should lose me altogether' (32). There are but few accounts of the college in the second half of the 19th century (33), and these do not paint an attractive picture. King William's had improved from the unhappy state described by Wilson, but it was no better than many other English public schools, where the conditions, as viewed by the present author from a considerable distance in position and time, can only be described as barbaric. The physical conditions could be extremely harsh, the social and psychological conditions no better. Cruelty among the boys, including the fagging system, was extraordinary, engendered no doubt to a significant degree by the fearful beatings that masters meted out to their pupils. If sexual imbalance and repression were endemic, then the sexual inhibitions of the masters were certainly unhelpful. And the fanatical religious revivals that swept numerous schools surely added to the unrest and confusion which the boys must have felt.

Regarding the 'religious storm' that swept the college in his final year, W.H.B. much later devoted two emotion-filled pages of his brief autobiography to this time, and it clearly affected him profoundly. The headmaster did not then resolve his difficulties; nor later, it seems, did the escablished church. W.H.B. finally settled for a scientific-intellectual humanism of his own making (34).

W.H.B. survived and eventually prospered in this environment by adhering strictly to the rules of the college, by applying himself diligently to his studies, by enjoying to the full the sporting, social and recreational opportunities that the school increasingly provided, and by submerging almost totally the emotions he had already learnt to hide. As he said of the school religious revival: 'the storm passed in time, by sheer exhaustion, and the fortunate distraction of other things, work and play' (35).

W.H.B. found much satisfaction in his school work, especially the mathematics with the Rev. D.D. Jenkins, 'a good fellow, keen, and a good teacher' (36). The ultimate academic goal for school and boys alike was a scholarship to one of the Oxford or Cambridge colleges (37). W.H.B.'s surviving school reports testify to his exceptional mathematical ability and achievements (38). In 1880 he won, as His Excellency the Lieut.-Governor's Prize for Mathematics in the Sixth Form, the two volumes of Maxwell's *Treatise on Electricity and Magnetism*; a formidable gift indeed

(39). His scientific interests also extended beyong mathematics; in 1879 he won the college's Byrom Geology Prize (40).

Outside the classroom, W.H.B. was a praepositor (prefect) in the years 1879 to 1881, and Head of the School in 1880-81. He was secretary of the Chess Association, an active member of the Literary and Debating Society, a fair cricketer, wanting 'freedcm and spirit in his play' (41), and a tennis and fives player. But it was the annual theatricals with the Histrionics Society that W.H.B. enjoyed most. It was 'great fun, the best event of the year', he remembered. 'We made scenery, collected costumes, rehearsed at times when we might have been doing lessons, and generally broke away from the ordinary run' (42). He was Bassanio in the *Merchant of Venice* and Claudio in *Much Ado About Nothing*, but it was in farce, behind a theatrical mask, that W.H.B. let himself go as at no other time. The *Barrovian reporter* was lyrical about his performance: 'the whole life of the piece was Bragg, as Susan, the maid of all work. From his first word "Lawks" to the end he kept the audience in continual fits of laughter' (43).

In the Easter week of 1880 examinations were held at Trinity College, Cambridge, for election to College Scholarships and Exhibitions. emph-The Cambridge University Reporter of 13 April announced that Bragg had been awarded a Minor Scholarship, valued at 175 per year. The King William's College headmaster, Joshua Hughes-Games, described it as 'the highest honour open to a school-boy; and he has won one at an unusually early age, and against unusually strong competition' (44). Three other entrants had beaten him to the more lucrative Foundation Scholarships.

Because of his youth (17 years old) and on the advice of both Trinity College (45) and Hughes-Gaines (46), W.H.B. returned to King William's College for a further year. He participated successfully and enjoyably in almost every available school activity, but his academic work stagnated, so that when he went up again to try for an improved Trinity scholarship he did not do as well as in 1880. The 'effective cause for my stagnation was the wave of religious experience that swept over the upper classes of the school during that year' , he remembered (47).

4.5 CAMBRIDGE

Bragg recalled that 'I went up to Cambridge in 1881, taking the rather unusual course of beginning work there in the Long [vacation]' (48). Three Australians entered Trinity College that year, two of whom W.H.B. was to become particularly aware of: William Sheppard, born in Sydney and educated in Brisbane (49), and Sydney Talbot Smith from Adelaide, whom he met on the lacrosse field. W.H.B.'s tutor was H.M. Taylor, a friend of Horace Lamb. He was allocated rooms in Whewell Court (50). In that first long vacation W.H.B. 'tried to get through an exam that would excuse me the Littlego, and I failed in Latin' (51); he had to take it in November after all. He passed Part I in the Second Class and Part II in the First; further proof, if any were needed, that mathematics was his strength (52). During this period 'it was lonely ... and I had no companions'. Furthermore, 'I could not afford, or thought I could not afford, to join the Union or the Boating Club' (53). His carefulness and reserve held him back.

When classes began he was accepted by Routh, who is remembered as the greatest of all the Cambridge Mathematical Tripos tutors. W.H.B.'s acceptance is indicative of his own awareness of the Cambridge scene and of Routh's early appreciation of his abilities. In the College examinations of 1882 W.H.B, was awarded a freshmen mathematics prize and his minor Scholarship was coverted into a Foundation Scholarship (54). His success gave him 'a standing in the College. I had the right then to join the Trinity Tennis Club without election, and to wear the strawberry and cream blazer; which was a source of pride. I sat in the scholars' seat in chapel. . . '

(55). In 1883 he again won a College mathematics prize.

The next year, 1884, brought the examinations for Parts I and II of the Mathematical Tripos. The details are less important, but it should be noted more generally that the Tripos of the 1880s not only encompassed such Newtonian subjects as statics, dynamics, hydrostatics, optics, gravitational theory and astronomy, but also heat and electricity and magnetism. It had, in fact, a very applied mathematics flavour, providing a wide general education in the subject and fitting its graduates for a range of subsequent studies (56). By the time of the examinations W.H.B. was anxious and weary, but all this was forgotten in the elation with which he greeted the result - 3rd Wrangler: 'I was fairly lifted up into a new world. I had a new confidence; I was extraordinarily happy.' He could still feel the joy of it 43 years later (57).

During the autumn of 1884 W.H.B. worked for Part III of the Tripos, as it then was. When he later applied for the Adelaide Chair, the first reference he supplied was from Mr. Glazebrook, and its contents are most interesting in the present discussion (58):

> Cavendish Laboratory, Cambridge,
>
> Dec. 1, 1885.
>
> Mr. W.H. Bragg of Trinity College attended several courses of my lectures while preparing for the Mathematical Tripos and since that time he has worked under my suggestions at the Cavendish Laboratory while studying practical physics. In his preparation for the third part of the Mathematical Tripos I supervised his reading as University Lecturer in the branch he was taking up. I have also examined him in various College Examinations. I have thus had ample opportunity of becoming acquainted with Mr. Bragg's powers and I have no hesitation in recommending him most strongly to the Electors for the

> Professorship of Mathematics and Physics at Adelaide as being extremely well qualified to discharge the duties of the post and likely in every way to give satisfaction.
>
> R.T. Glazebook, M.A., F.R.S.
> Fellow and Assistant Tutor of Trinity College,
> Demonstrator of Physics
> and University Lecturer in Mathematics.

The branch of mathematics for which Glazebrook was particularly responsible was entitled 'Advanced Physics' in the *Cambridge University Reporter*, and involved the subjects of waves and sound, higher geometrical optics and the theory of light. This short, simple letter clearly throws considerable new light on the progress of W.H.B.'s career. We may note particularly both the waves and sound topic, a precursor to similar lectures to physics and music students in Adelaide, to later studies of the acoustic problems of the new Elder Hall at the University of Adelaide (59), and subsequently to extensive asdic and soundranging experiments by W.H.B. and W.L.B. during the appalling conflict of 1914-18 (60); and also the theory of light, something W.H.B. must have remembered when, during his own research work in Adelaide suggesting the material nature of X-rays and y-ray (61), others stressed their similarity to light. Bragg's interests had already swung towards what we now call physics.

With the conclusion of the Part III examinations and the award of his First in the winter of 1884/85, W.H.B. was confronted with the question of his future. In more normal circumstances a Fellowship at Trinity College would have beckoned, but in 1884 his 'chances did not look well, because in 1883 the 2nd, 3rd, 4th and 5th wranglers were all Trinity men, and in my year the lst (Sheppard), 2nd (Workman), 3rd (myself) and 5th (Cassie) were all Trinity men'. Had he had independent means, he could have contemplated leisurely study 'amongst books and people in Cambridge'

(62). He was offered a commission by a publisher to solve all the problems in Smith's *Conics*; but he 'had other things to do' (63). These 'things' involved work in the Cavendish Laboratory. It had been 'Maxwell's view of the function of the laboratory that it should be a place to which men who had taken the Mathematical Tripos could come, and, after a short training in making accurate measurements, begin a piece of original research' (64). This scheme continued during Lord Rayleigh's professorship and in the early years of J.J. Thomson's tenure of the Cavendish chair, to which he had been appointed in December 1884. Thomson was himself a notable product of the scheme (65).

As we have seen, W.H.B. had a genuine interest in the physical sciences. He was an ideal candidate for the conversion course from mathematician to experimental scientist; indeed, he had already embarked upon it. He studied in the Cavendish for nearly the whole of 1885. All of this makes his later statement, 'I had never done any [physics], nor worked at the Cavendish except for a couple of terms' (66), hard to understand. Appointed to a joint mathematics and physics chair in Adelaide, Bragg for a number of years referred to himself as Professor of Mathematics only, despite his increasing personal dedication to physics (67). The primacy of the Mathematical Tripos and of mathematics in his own education no doubt shaped his view, as too his modesty (68), although his old Trinity and Adelaide colleague Sydney Talbot Smith saw it a little differently: 'Well, we know how clever men can delight to exaggerate their own shortcomings. As Bragg always humorously told the story, he just bought some books on physics, studied them on the voyage, and ... was only about two jumps ahead of his students' (69).

His acquaintance with J.J. Thomson was also central to W.H.B.'s future. In 1882 Thomson had been elected to an Assistant Lectureship in mathematics at Trinity College, where he also resided, in the Great Court; the paths of the two young men must have crossed often. We know J.J. played the card game whist, and got his exercise by taking walks on a very regular basis. He was also a sports enthusiast (70). W.H.B. was a whist player, and had played the game with his brother Jack when Jack was seriously ill at King William's College. W.H.B. also recalled that, at Cambridge, 'every afternoon I played a game ... or went for a walk' (71). In 1885 W.H.B. too had rooms in the Great Court at Trinity, a reflection of his new status. These occasions are conjectural, but there is one other certain avenue of intimate contact between W.H.B. and J.J. in addition to that at the Cavendish; namely tennis. W.H.B. later recalled, "I knew him [J.J.] pretty well at that time [the end of 1885]; he and Carey Wilberforce and I used to play tennis regularly together (72).

If, throughout much of his time at Cambridge, W.H.B. knew little of matters outside his own line of work and was 'very much shut in on myself, unventuresome, shy and ignorant', then in the year after his graduation university life was 'spacious and beautiful', Cambridge ' a lovely place ' and Trinity 'something to be very proud to belong to' (73).

4.6 APPOINTMENT TO ADELAIDE

Horace Lamb's appointment as Professor of Pure Mathematics in the Owens College, Manchester, was formally confirmed on Friday, 2 October 1885 (74). According to a plan previously drafted between Lamb, the University of Adelaide and the Agent-General for South Australia in London, Sir Arthur Blyth, arrangements for the appointment of a successor were implemented immediately. On Monday, 5 October, Blyth wrote to J.J. Thomson at Cambridge, asking him 'to aid the University in the selection of a successor to Professor Lamb', and 'to name the newspapers in which you think the advertisement should appear' (75). Thomson agreed, and with Lamb and Blyth formed the Board of Selection, with full authority to make the appointment without further reference to Adelaide. Such an untrammeled procedure was not universal in Australian universities at the time,

but it is a vivid illustration of the reliance they placed upon Oxbridge professors and graduates for many decades. There was one notable Australian applicant for the position, William Sutherland, M.A. (Melbourne), B.Sc. (London), who later because an outstanding theoretical chemical physicist (76); he had to send his application to London (77).

The conditions, as set out in the advertisement, were as follows (78):

> 'The University of Adelaide
>
> Elder Professor of Mathematics and Experimental Physics.
>
> The Council invite applications for the above Professorship. Salary £800 per annum. The appointment will be for a term of five years, subject to renewal at the discretion of the Council. Salary will date from lst March, 1886 and the Professor will be expected to enter on his duties on that date. An allowance will be made for travelling expenses. Applications, with testimonials, should reach Sir Arthur Blyth ... not later than lst December 1885.'

The circumstances surrounding W.H.B.'s last-minute application for the position are well known. Walking along King's Parade one morning to attend a lecture by Thomson at the Cavendish, Bragg was joined by the lecturer, who asked if Sheppard, the Senior Wrangler in his year, was going in for the post; a logical question as Sheppard was an Australian. W.H.B. thought not; and he then 'asked J.J. whether I might have any chance, and he said that he thought I might'. W.H.B. was astonished at the whole episode: 'it had never occurred to me that anyone so young might be eligible'. Also the 'salary seemed too big for such untried people' (79). His naivety very nearly cost him the appointment that was to shape the course of his future life.

'The total number of candidates is twenty three', the Agent-General reported to the Registrar of the University of Adelaide, 'but one of these has sent in an informal application which cannot be entertained' (80). J.E.A. Steggall, Second Wrangler in 1878 and First Smith's Prizeman, was the applicant concerned. He would surely have been a strong candidate, but he declined to pursue his provisional application (81). Even without Steggall the field was an impressive one: 15 Cambridge graduates, of whom 14 were Wranglers and two Smith's Prizemen, two Oxford graduates, two London, one Trinity College, Dublin, and two whose background I have been unable to trace. Thomson and Lamb met Blyth to discuss the applications and decided to draw up a short list for interview in London. It consisted of J.F. Adair, 7th Wrangler in 1878, W.H. Bragg, and C. Graham, 3rd Wrangler in 1878 and Second Smith's Prizeman. We may wonder why the only Senior Wrangler and First Smith's Prizeman on the list was not invited to attend. The reason is probably contained in the following extract from W.H.B.'s autobiographical notes (82):

> 'By the way, I forgot to say ... that the electors could have sent out a Senior Wrangler of great ability, but he was not safe with the bottle. They thought, however, that they had better consult an Adelaide man who happened to be in London, and he was in favour of the young man who so far had kept off the drink. The Adelaide man was my future father-in-law [Sir Charles Todd].'

Lamb reported to the Chancellor of the University of Adelaide that 'By far the ablest man in the list was excluded ... on personal grounds' (83). When the electors met in London on Thursday, 17 December, Adair was absent owing to illness and the interviews were short. The Board had two additional references for W.H.B.; his College tutor, Taylor, thought him 'a sound and careful mathematician', and Routh certified that 'he has great mathematical talent'. That evening, at Market Harborough, a telegram broke the exciting news. In the dark of nightfall Uncle William broke down and wept.

The next day Lamb hastened to give the Adelaide Chancellor 'some account of the manner in which we have discharged our stewardship' (84). He reported:

> '... Yesterday the interviews were held and - after some slight hesitation between two of the candidates - we unanimously recommend ... Mr. Bragg of Trinity College, Cambridge... It is evident that his math abilities are of the highest, and he has also worked at Physics in the Cavendish Laboratory under my coadjutor in the appointment, who says that his work is very good. I was up at Cambridge a week before our last meeting and ... Mr. Bragg bears a high reputation in every way... As far as I can judge, the only possible source of misgiving as to the propriety of our choice is Mr. Bragg's youth, he is only 23. Personally, I do not think much of this. I cannot but remember that I was myself not much older when I went to Adelaide...

I can testify also that Prof. J.J. Thomson took great care and trouble in this matter, and showed the greatest anxiety to come to a fair decision.

With kind regards I am my dear Chief Justice Yours very sincerely, Horace Lamb.

'P.S. The most curious incident in the award was a letter from Lord Carnarvon (Viceroy of Ireland) arguing that there might be a danger that 'justice to Ireland' would not be done unless some Irish Math^{n} of repute were put on the Board to look after the interests of Irish candidates. Sir A. Blyth sent a very dignified reply.'

Two years later J.J. Thomson confided to his old friend Richard Threlfall, by then Professor of Physics at Sydney University, regarding a further application from Adair for a Demonstratorship (85):

'I do not think he has a very extensive knowledge of the book-work of Physics but he is a good Mathematician (in fact he very nearly got Bragg's appointment) ... he is a gentleman, but an Irish one, and this is my chief doubt as Sir Arthur Blyth told me Irishmen were very unpopular in Australia.'

Graham too was an Irishman, as was Thomas Lyle, another applicant for the Adelaide Chair. Lyle had the added apparent disadvantage of having completed his studies at Trinity College, Dublin, although he was soon to follow Bragg to Australia as Professor of Natural Philosophy at the University of Melbourne. It is perhaps not surprising that late in 1885 the Earl of Carnarvon and Lord Lieutenant of Ireland had written to the Agent-General for South Australia supporting claims by Trinity College, Dublin, that 'Irish Candidates for Educational posts have been frequently overlooked by the Colonial authorities ... in mathematics especially ... as these appointments are practically in the hands of Cambridge men' (86). Blyth replied that his instructions from Adelaide did not permit him to accede to the request, but promised to forward the correspondence to Adelaide for further consideration. He also pointed out that Irish candidates had been successful in previous professional appointments. Blyth was sensitive to local prejudices. South Australians were predominantly English and Welsh and very strongly non-conformist. There was a lower proportion of both Irish immigrants and Roman Catholics in Adelaide than in other Australian capital cities, and those Irish men and women who had emigrated were predominantly working class and unskilled, sometimes uncouth and generally disliked (87).

The choice of W.H.B. was a bold one, and we may wonder if it was an equally daring decision of W.H.B. to accept; but the answer is probably no. Australia was a well-known and integral part of the British Empire, and service in the colonies was a well-trodden path for capable Englishmen. The Cambridge colleges of the time had a surprisingly large number of Australian undergraduates drawn principally from the newly emerging upper class. Sheppard and Talbot Smith have already been mentioned, and many of the prominent Adelaide families were also represented: Barker, Barr-Smith, O'Halloran-Giles, Fowler, Robin, Ibbotson and Murray (88). Although W.H.B. apparently knew none of them well, even he cannot have failed to recognize an Australian presence in Cambridge. In addition, the position was a professorship, where he could be his own master, with a 'magnificent' salary, and all the adventure of going abroad to a new country. As for the dual nature of the appointment, it was common for the young Australian universities to ask their professors to cover more than one discipline, and joint lectureships in mathematics and physics were widespread until the 1920s. W.H.B. probably viewed the duality of the Adelaide chair with much less trepidation than has previously been suggested; the mathematics surely held no terrors, and he was clearly far better prepared for the physics than was earlier understood. Only the extent of the demand on his time and physical stamina lay menacingly hidden.

Preparations for W.H.B.'s departure proceeded apace: 'the next three weeks was a grand time' (89). During 1885 his father had died, an event quite unrecorded in his autobiographical notes; and the day before he sailed his aunt and Uncle William came to London with the news that his brother Jack had just died. At the King William College 1882 Prize Day, Jack had been singled out for special attention for having obtained full marks for all the sixth-form mathematics papers set (90), but his very promising career had finally succumbed to a constantly recurring illness. Many years later, in 1915, W.H.B. would lose another gifted young man tragically close to his heart (91). Yet neither of the present tragedies could dull his elation: 'next day [14 January 18861 they saw me off at Tilbury, and there I was away on the great adventure, thrilled by it' (92).

4.7 FIRST TWO YEARS IN ADELAIDE

The boat trip to Australia on the *Rome* was an exciting, relaxing and fascinating journey for the young professor. He read some of Deschanel's *Electricity and magnetism* on the way (93). The long journey provided a useful transition from the cold and damp of the northern mid-winter to the torrid southern summer in the heat and openness of the Adelaide plain. W. H. B. was landed by tender at Glenelg, where, only 50 years before, the first settlers of the new Colony had also come ashore. Next day Dr. Alfred Lendon called for W.H.B. and took him on his rounds in his horse-drawn Victoria. That first day was one of the most important of W.H.B.'s 23 years in Australia, the people he met symbolic of his new life. First there was Lendon himself, who became a close personal friend and with whom W.H.B. boarded during his early years in Adelaide. He was to become one of Adelaide's leading medical identities and to hold numerous medical and academic posts (94). He would be best man at W. H. B.'s wedding three years later, and W.H.B. would be godfather to Lendon's elder son.

During that first day they also called at Dr. Way's and were refreshed with green figs; 'lovely I thought' (95). The Hon. Samuel Way Ll.D. was the Chief Justice of South Australia and Chancellor of the University. His home, Montefiore in North Adelaide, was one of the city's best-known houses; it had a magnificent garden and large hothouses, and Way used it extensively for entertaining, for which it was renowned. It also contained Way's outstanding personal library of more than 14,000 volumes and his magnificent art collection. Way was a staunch Methodist. He represented better than anyone else in the colony the academic and social milieu into which W.H.B. was soon to be accepted (96).

Finally the two newly acquainted young bachelors trotted down the hill, across the Morphett Street Bridge over the River Torrens lake, and soon arrived at the neat clump of observatory Buildings in the West Parklands. The ample two-storeyed home of Charles Todd, Government Astronomer, Postmaster-General and Superintendent of Telegraphs, looked out over West Terrace. Here they had been invited for supper, and here W.H.B. met the Todd family for the first time. Charles Todd was famous throughout the country as the architect and builder of the Trans-continental Overland Telegraph Line, one of the epic achievements of Australian history (97). He was genial and friendly, possessed of an overbountiful fund of humour which reveled in puns, spoonerisms and riddles. He was an accomplished astronomer and physical scientist, one of the very few in the colony. W.H.B. would find pleasure in his company and conversation; together they would pioneer radio in Australia in the 1890s (98). Alice Todd, his wife, impressed W.H.B. at once (99). She too has a memorial associated with the overland Telegraph; for during construction in 1871, the sub-overseer W.W. Mills had discovered a large spring of water in his section of the line and had named it Alice Springs, in honour of the Superintendent's wife.

What W.H.B. does not immediately mention, but what we can surely guess caught his eye, were the other members of the Todd family. The two sons Charles Edward and Hedley Lawrence were in their middle twenties, beginning medical and business careers respectively. In later years

W.H.B. would be consulted by Dr. Charles on the medical uses of the new X-rays, and by Hedley on the electrification of the city. But most of all there were the four daughters: Lizzie, Maude, Gwen (16 years old) and Lorna. Their irresponsible chatter delighted W.H.B. most. It was a revelation to a young man taught to weigh every word he uttered and, until that day, almost totally deprived of female companionship and affection. They nicknamed him 'The Fressor', and he blossomed under the cheerful and inconsequential atmosphere they created (100).

W.H.B. and the third daughter, Gwendoline, courted, married and built their subsequent lives together, and their relationship will repay further study, for this particular family was to be quite unique in all the history of science. W.H.B. supplied the solidity and the direction of their lives. Gwendoline the social and family environment. He depended on her for all the womanly qualities that his earlier life had lacked. The large, emotional plaque that he placed in the entrance hall of The Royal Institution after his wife died is evocative testimony to his affection and gratitude. Its text speaks of Davy and Faraday but its symbols are a child surrounded by birds in flight. She gave him their children, and she lifted his spirits to the sky (101). William Bragg had arrived in Adelaide.

When W.H.B. entered the University he found an institution still struggling to establish itself. A recent account by Blainey of the University of Melbourne also applied to Adelaide at this time (102):

'The basic weakness of the university was neither shortage of money nor conservatism of thought, but rather a shortage of students who wanted to study and who could afford to study. The university capped the pyramid of education, but the base of that pyramid was weak.'

W.H.B. was responsible for all the pure and applied mathematics and all the physics and practical physics teaching, and for much of the secondary-school public examining in these subjects as well. There is no precise information on his university teaching load in 1886; fortunately, in that first year there were no third-year mathematics students. As for examinations, by the end of his first year Bragg had set and marked 29 major examination papers: 7 in March just after his arrival (2 university supplementary mathematics papers and 5 Matriculation exams), 10 mathematics and physics papers for B.A. and B.Sc. students at the end of the academic year in November, and 3 exams for the South Australian Scholarship and 9 papers for the Junior and Matriculation public examinations in December. One can readily picture the long evening hours W.H.B. spent pouring over Horace Lamb's syllabuses and previous examination papers in an endeavour to acquaint himself with the requirements of such a wide range of courses (103).

In addition there were 48 evening lectures to be given to a class of ten students in advanced mathematics; men and women who were employed during the day and who sought to further their education in the evenings. Adelaide had but one government secondary school at this time, the Advanced School for Girls. Secondary education was otherwise the sole preserve of private and denominational establishments and therefore available only to those families that could afford the fees; and in South Australia the 1880s were a time of depression and widespread unemployment. As if all this were not enough, W.H.B. also gave lectures to second-year music students on acoustics, a course in which he took particular delight. It was no doubt based on his studies with Glazebrook and he filled his lectures with demonstrations and analogies. Of all the lectures he gave in Adelaide that first year, he kept only these notes; they are still among his papers in the archives of The Royal Institution (104).

During 1886 W.H.B. wrote to the Council of the University on three occasions: first to ask for lengths of rubber tubing for the Physical Laboratory, second to point out that 'in the mathematical lecture room there are no desks or tables on which students may take notes during lecture[s] ', and third to request the purchase of 17 books for the Library (105). Later that same year he had returned only 6 of the 47 texts he had earlier borrowed from that same library; preparation for lectures and other very basic matters of teaching filled his days. In October he was elected Dean (and Chairman) of the Professorial Board.

Nor were recreational activities neglected. The game of lacrosse was introduced in South Australia in 1885, and in the winter of 1886 W.H.B. joined his old Cambridge team-mate, Talbot Smith in the Adelaide team. *The Adelaide Observer* newspaper reported that W.H.B. rapidly established himself as 'without doubt, the finest all-round player we have' (106). In future years he would be the central figure in the expansion of the competition (107). In the summer there were games of tennis on the university court and elsewhere (108).

In October of his first year in Adelaide, Professor Bragg took the male lead in a comic drama in two acts entitled 'The Jacobite' (109). It was presented in the Torrens Park Theatre, a magnificent auditorium built by Robert and Joanna Barr-Smith at their massive home at Mitcham, in the Adelaide foothills. Barr-Smith had large pastoral holdings, and his company, Elder Smith & Co., pioneered much of the pastoral settlement of South Australia. His philanthropy became legendary, the University not the least of his beneficiaries. Mr. & Mrs. Barr-Smith were lavish and charming hosts, and the theatre, with its intricate plaster work, oval windows, fully equipped stage and seating for 200 people, became the venue for countless entertainments (110). W.H.B.'s participation in at least one of these is a reminder of his love of theatricals, and indication of his immediate acceptance into the highest level of Adelaide society, and a crucial pointer to his future fame. Seventeen years later BarrSmith would provide the money with which W.H.B. purchased his first radium sample and thereby began his extraordinary research career (111).

In January 1887, during the long summer vacation, W.H.B. visited Melbourne and Sydney; young, moneyed and energetic, he was keen to explore his vast new homeland. He travelled 500 miles by train to Melbourne, where he was able to use Routh's letter of introduction to Professor Nanson (112), and then by boat to Sydney, where Richard Threlfall welcomed him (113). Two months earlier, and after several years of discussion, a preliminary meeting of an Australasian Association for the Advancement of Science (A.A.A.S.) had been held in Sydney, of which W.H.B. was no doubt anxious to hear a first-hand report. In the years ahead, the regular meetings of the A.A.A.S. would provide him with invaluable opportunities for professional and personal development (114).

His first year in Adelaide may have been full of activity, but the second year, 1887, was the one in which W.H.B. experienced the full impact of his new responsibilities. In July he recorded the details of his weekly teaching commitments (see Table 1) (115). There were 28 weeks in the academic year and W.H.B. therefore spent 672 contact hours with his students in that year, 168 of them in the evenings. Even by the standards of the day this was an extraordinary teaching load, made all the more remarkable by the fact that he did not have a single academic colleague to assist with student difficulties or the 21 university examinations involved, and only one part-time laboratory assistant to help build, prepare and supervise the lecture demonstrations and laboratory experiments. It is said that W.H.B. was an unimpressive lecturer to start with, being too careful and too mathematical (116). That he later became renowned as a lecturer without peer may owe something to the level of practice he had in Adelaide during his early years there.

This incredible commitment in no way reduced that to his other duties. In March W.H.B. set and marked five mathematics, one natural philosophy and one English history Matriculation examination, and in November another five mathematics and two physics public examination papers (117). On 27 July 1887, W.H.B. wrote to the Council of the University (118):

> 'I beg respectfully to call your attention to the large increase in the duties which devolve upon me as Professor of Mathematics, and to my need of assistance to enable me to fulfill them satisfactorily.... Next year at least one new class must be started in accordance with the University regulations.
>
> 'These lectures are so many that I cannot make them fit in with the lectures of the other professors...[and] not only is there no time to get all these lectures in, but the strain of so much teaching is very heavy: to do so at all well is beyond the strength of one man....
>
> 'I would rather suggest that when it is possible an assistant lecturer in mathematics be appointed...

			Hours per week
B.A.			
	1st year	mathematics	2
		physics	2
	2nd year	mathematics	2
	3rd year	mathematics	2
B.Sc.			
	lst year	same as lst year B.A.	
	2nd year	mathematics (extra)	1
		physics	2
		practical physics	2
	3rd year	physics	2
		practical physics	2
Mus.B.			
	Acoustics		1
Evening classes			
	mathematics		2
	physics		2
	practical physics		2
		total	24
Additional in 1888			
	honours in 3rd year mathematics		2

Table 4.1: W.H. Bragg's teaching commitments, at the University of Adelaide for the academic year 1887 (note 115)

The matter was referred to the Education Committee, which recommended in August that, 'for the sake of the students as well as Professor Bragg, it is desirable that help should be given him next year if the funds will permit' (119). In December W.H.B. wrote to the Chancellor urging that the recommendation be carried out. He proposed that a salary of £300 a year be offered, £100 from the Evening Class Fund and £100 from the University chest; ' the other £100 I will provide myself for the first two years, if the Council will then relieve me of that duty' (120). It was a generous and astute offer.

There were six excellent applicants when the position was advertised shortly afterwards. The Education Committee discussed them fully in January, 'and ultimately Professor Bragg, who was about to start for Tasmania, was desired *en route* to see one candidate in Melbourne, and one in Tasmania; and to report which of the two he considered the better fitted for the lectureship, the Committee to recommend the gentleman so selected to the Council for appointment' (121). W.H.B. Was going to Tasmania to join Gwen and Charlie Todd, who had gone over for a holiday; and from Hobart he wrote to the Registrar of the University to report (122):

> 'I have chosen Chapman as assistant lecturer: he knew a great deal more than the other man, was energetic and strong in appearance, whilst the other was of the scholastic, weak-eyed type. I think Chapman will do very well. By the way he is an oarsman [and] has rowed 6 for Trinity against Ormond. Will you please send him a Calendar as soon as it comes out?'

Robert Chapman, M.A. and B.C.E. from, the University of Melbourne, thus began a lifelong commitment to tertiary education in South Australia (123). We may wonder about some of these stated selection criteria, as we earlier questioned some aspects of the procedures associated with W.H.B.'s own appointment, but in each case the result was quite exceptional; Bragg and Chapman were to become two of the University of Adelaide's most dedicated servants and most illustrious scholars.

W.H.B. had his assistant. Furthermore, when he proposed to Gwen in Tasmania she accepted, subject to approval. Charlie telegraphed their parents and the answer came back: 'say everything kind to both' (124). For W.H.B. going to Australia had indeed become 'like sunshine and fresh invigorating air' (125).

4.8 ACKNOWLEDGEMENTS

The research, of which this paper is the first substantial result, has benefited from the generous assistance of many people whom I am unable to mention individually but to whom. I wish to express my gratitude. These include library and other institutional staff as well as individual people in Adelaide, London, Cambridge, Castletown (Isle of Man), Market Harborough and Melbourne. I am indebted to the various institutions noted throughout the paper for permission to use and to quote from material in their care. Most particularly I wish to thank the Bragg and Adrian families for their generous assistance, Professor Rod. Home for much guidance and encouragement, Mrs. Margaret Gibbs for painstaking research work, and the Australian Research Grants Scheme for financial assistance.

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4.9 NOTES

(1) E.N. daC. Andrade, 'William Henry Bragg 1862-1942' , *Obit. Not. Fell. R. Soc. Lond.* **4** (1942-4), p. 289.

(2) Sir David Phillips, 'William Lawrence Bragg', *Biog. Mem. Fell. R. Soc. Lond.* **25** (1979), 75-143.

(3) Andrade, *op.cit.* p. 280.

(4) G.M. Caroe, *William Henry Bragg 1862-1942: Man and Scientist* (Cambridge University Press, 1978), pp. 2-3.

(5) The most widely respected historian of the early years of South Australia is D. Pike, *Paradise of Dissent* (London, Longmans, 1975); a shorter and more general work is R.M. Gibbs, *A History of South Australia* (Adelaide, Southern Heritage, 1984).

(6) W.G.K. Duncan & R.A. Leonard, *The University of Adelaide 1874-1974* (Adelaide, Rigby, 1973), Chapter 1.

(7) R.T. Glazebrook, 'Sir Horace Lamb, 1849-1934' , *Obit. Not. Fell. R. Soc. Lond.* **1** (1935), 375-392.

(8) Many Australian families for generations referred to the United Kingdom as 'home'.

(9) University of Adelaide Archives (U.A.A.), series 169 (1876) Letter Lamb to Barlow (Registrar), 20 March.

(10) U.A.A. series 169 (1885). Draft letter Lamb to Registrar, 20 February, in which Lamb notes that 'the teaching of Experimental Physics was undertaken by me *proprio motu*, without any suggestion from the Council'. Following patterns set at the University of London, Adelaide, from the beginning, sought powers to award science degrees and to confer degrees on women. After some delay, Royal Letters Patent were granted in 1881 giving the University everything it sought and making it a pioneer in both respects: Duncan & Leonard, *op.cit.* p.14.

(11) University Library Cambridge, Stokes' correspondence (add. MS 7656).

Letter Lamb to Stokes, 13 September 1876 (L12).

(12) U.A.A. series 18 (1879). Council Minutes, vol. II, p. 89 (March meeting).

(13) R.B. Potts, 'Lamb, Sir Horace (1849-1934)', *Australian Dictionary of Biography*, vol. 5 (Melbourne University Press, 1974), p.55.

(14) H. Lamb, *Treatise on the Mathematical Theory of the Motion of Fluids* (Cambridge University Press, 1897).

(15) U.A.A., series 169 (1883). Letter Lamb to Registrar, 19 December.

(16) U.A.A., series 1 (1884). Letter Book no. 8. Letters Tyas (Registrar) to Lamb, 11 January and 21 April. The University was acutely short of funds during this period and Lamb was apparently unwilling to pay the necessary costs himself.

(17) U.A.A., series 169 (1885). Letter (draft) Lamb to Registrar, 20 February.

(18) U.A.A., series 169 (1884). Letter Lamb to Registrar, 28 March, denying this motive.

(19) Note 17, p. 6.

(20) University of Manchester: minutes of meeting of Council of Owens College, 19 June 1885.

(21) In his letter of resignation addressed to the Chancellor of the University of Adelaide from The Owens College, Manchester (6 October 1885), Lamb says: 'In thus severing my official connection with the Adelaide University ... I do so with many feelings of regret, and I shall always cherish most pleasant memories of the years spent in its service' (U.A.A., series 169, 1885).

(22) There are numerous references in U.A.A. regarding Lamb's work for the University Library.

(23) U.A.A., series 1 (1886), Letter Book no. 10. Letter Tyas (Registrar) to Lamb, 29 March. Rennie received remuneration for his additional services for the quarter ending 31 December 1885; Lamb's successor was required

to arrive in time for the start of the next academic year (March 1886).

(24) *Adelaide University Calendar* (1886), p.62.

(25) Similar but less generous provisions were introduced at the University of Sydney in 1895 and at the University of Melbourne in 1898.

(26) The few memories that remained Bragg lovingly recalled later: W.H. Bragg, untitled autobiographical notes (*ca* 1927, with additions *ca* 1937): The Royal Institution Archives (R.I.A.), Bragg papers, 14E/l, p.4. These notes are concerned almost exclusively with Bragg's boyhood, youth and arrival in Australia.

(27) It is necessary to use some form of unambiguous abbreviations to distinguish between William Henry Bragg and William Lawrence Bragg. With their consent, I have chosen to use those adopted by the family over many years; namely W.H.B. and W.L.B.; cf. Caroe, *op.cit.*

(28) W.H.B. autobiography, op. cit. p.10.

(29) *Ibid.* p.9.

(30) *Ibid.* The certificate that W.H.B. received remains in the Bragg family papers, now in the care of Lady Adrian, Pembroke College, Cambridge.

(31) *Ibid.* p.12.

(32) *Ibid.* p.13

(33) J.M. Wilson, *James M. Wilson: An Autobiography* (London, Sidgwick & Jackson, 1932); J. Gathorne-Hardy, *The Public School Phenomenon 597-1977* (Harmondsworth, Penguin, 1979); W.H.B. autobiography, *op.cit.* It should be added that King William's College is now a vastly different institution from that depicted in these works.

(34) The present paper is not the place to expand upon and document the conclusions. However, even a brief reading of the references given in (33) gives credance to these views.

(35) W.H.B. autobiography, *op.cit.*. p.18.

(36) *Ibid.* p.14.

(37) The early entrance hall of the College is lined with dark wooden honour boards which record in Old English script the names and distinctions of previous scholars at Oxford, Cambridge and the military acadamies. The College magazine, *The Barrovian* (named after one of the school's founders, Bishop Barrow), included regular accounts of Oxford and Cambridge life.

(38) Most of W.H.B.'s Terminal Reports from King William's College are preserved in his personal papers, now in the care of Lady Adrian, Pembroke College, Cambridge.

(39) *The Barrovian* no. 3 (second series) p. 126 (September 1880).

(40) H.S. Christopher, *King William's College Register 1833-1904* (Glasgow, Maclehose, 1905), p. 348.

(41) *The Barrovian* no. 3 (second series), p. 126 (September 1880).

(42) W.H.B. autobiography, *op.cit.*. p.14.

(43) *The Barrovian* no. 1, second series (April 1880) p.13.

(44) Letter Joshua Hughes-Games to R.J. Bragg (W.H.B.'s father), 14 May 1880, in Bragg family papers, *op.cit.*

(45) W.H.B. autobiography, *op.cit.* p.15.

(46) Note 44.

(47) W.H.B. autobiography, *op.cit.* p.16.

(48) *Ibid.* p.18.

(49) *Trinity College Admission Book* 1850-, Trinity College Library, Cambridge. W.W.R. Ball & J.A. Venn, *Admissions to Trinity College, Cambridge* (London, Macmillan, 1913), p.647.

(50) *Trinity College Room Rents* 1871-1897 (Trinity College Library, Cambridge).

(51) W.H.B. autobiography, *op.cit.* p.19.

(52) Part I of the Previous Examination involved biblical and Latin and Greek studies, Part II Euclid and some arithmetic and elementary algebra:

Cambridge University Reporter, 19 November 1881, p. 151, and 16 December 1881, pp. 206-212.

(53) Note 51.

(54) *Cambridge University Reporter*, 25 April 1882, pp. 497-498.

(55) Note 51.

(56) D.B. Wilson, 'Experimentalists among the mathematicians: physics in the Cambridge Natural Science Tripos, 1851-1900'. *Hist. Stud. Phys. Sci.* **12**, 2 (1982), 325-371.

(57) W.H.B. autobiography, *op.cit.* p.20.

(58) U.A.A., series 200, docket No.5/1886. This docket contains Bragg's letter of application for the Adelaide post, his three references from Routh, Glazebook and Taylor, and a list of applicants.

(59) See, for example, minutes of the Board of Musical Studies and related correspondence, University of Adelaide archives, series 129,

(60) See, for example, W.D. Hackmann, 'Underwater acoustics and the Royal Navy, 1893-1930'm *Ann. Sci.* **36** (1979), 255-276; W.L. Bragg, A.H. Dowson & H.H. Hemming, *Artillery Survey in the First World War* (London, Field Survey Association, 1971), chapter 4.

(61) R.H. Stuewer, 'William H. Bragg's corpuscular theory of X-rays and -rays', *Br. J. Hist. Sci.* **5**, 19 (1971), 258-281; B.R. Wheaton, *The Tiger and the Shark: Empirical Roots of Wave-particle Dualism* (Cambridge University Press, 1983).

(62) W.H.B. autobiography, *op.cit.* p.22.

(63) *Ibid.* p.20.

(64) J.J. Thomson, *Recollections and Reflections* (London, Bell, 1936), p.95.

(65) *Ibid.*

(66) W.H.B. autobiography, *op.cit.* p.30.

(67) In correspondence and in the annual *Adelaide University Calendar* until 1899.

(68) Caroe, *op.cit.*

(69) S. Talbot Smith 'Memories of Sir Wm. Bragg' , *The Mail* (newspaper) (Adelaide, 4 April 1942), p.7.

(70) Lord Rayleigh, emphThe Life of Sir J.J. Thomson O.M. (Cambridge University Press, 1942).

(71) W.H.B. autobiography, *op.cit.* pp. 24, 19.

(72) *Ibid.* p.21. 'Carey' Wilberforce would appear to be L.R. Wilberforce, Trinity College and Cavendish physics student during Bragg's years there, and later Professor Physics at Liverpool; se J.A. Venn, emphAlumni Cantabrigienses, vol. VI, pt. II (Cambridge University Press, 1940).

(73) W.H.B. autobiography, *op.cit.* p.21.

(74) U.A.A., series 169 (1885). Letter Agent-General to Tyas (Registrar), 29 September enclosing Letter Lamb to Agent-General regarding Manchester appointment. Lamb sent a telegraph to Tyas on 3 October 1885, confirming his appointment and resignation.

(75) *Ibid.* Letter Agent-General to Thomson, 5 October.

(76) W.A. Osborne, emphWilliam Sutherland: A Biography (Melbourne, Lothian, 1920).

(77) U.A.A., series 169 (1885). Letter Sutherland to Registrar, 3 October.

(78) See, for example, *Cambridge University Reporter* (13 October 1885), p.47. The advertisement also appeared in *The Times, Nature, Oxford University Gazette, The Athenaeun; The Academy* - U.A.A., series 169 (1885); copy of letter Agent-General to London advertising agent, 7 October.

(79) W.H.B. autobiography, *op.cit.* pp. 21-22.

(80) U.A.A., series 200, docket no. 3/1886. Letter Agent-General to Tyas (Registrar), 4 December.

(81) South Australian Archives, State Library of S.A., Adelaide, series GRG 55/7. Letter Agent-General to Steggall, 5 December 1885.

(82) W.H.B. autobiography, *op.cit.*/p.30.

(83) U.A.A., series 280, envelope 162 (various dates). Personal letter Lamb on Hon. S.J. Way, 18 December 1885.

(84) *Ibid.*

(85) University Library Cambridge, J.J. Thomson correspondence (add. MS 7654). Letter Thomson to Threlfall, 7 August 1887 (T19).

(86) U.A.A., series 200, docket no. 2/1886. Letter Agent-General to Tyas (Registrar), with 3 enclosures, 2 December.

(87) See, for example, C. Nance, 'The Irish in South Australia during the colony's first four decades', *J. Hist. Soc. S. Aust.* no. 5 (1978), 6673; D.L. Hilliard, 'The city of churches: some aspects of religion in Adelaide about 1900', *ibid.* no. 8 (1981), 3-30.

(88) D. van Dissel, *The Adelaide gentry 1880-1915* (University of Melbourne, M.A. Thesis, 1973).

(89) W.H.B. autobiography, *op.cit.* p.23.

(90) *The Barrovian* no. 11, second series (October 1882) p.291.

(91) His own second son, Robert Charles Bragg, during World War I.

(92) W.H.B. autobiography, *op.cit.* p.24.

(93) *Ibid.* p.29-30.

(94) Unattributed obituary, 'Alfred Austin Lendon, M.D.' *Proc. S. Aust. Brch. R. Geogr. Soc. Aust.* **36** (1934/5), 20-21.

(95) W.H.B. autobiography, *op.cit.* p.31.

(96) H.T. Burgess (ed.), *The Cyclopedia of South Australia*, Vol.I. (Adelaide, Cyclopedia Co., 1907), pp. 245-247.

(97) F. Clune, *Overland Telegraph* (Sydney, Angus and Robertson, 1955).

(98) J.R. Ross, *A History of Radio in South Australia 1897-1977* (Adelaide, author, 1978).

(99) W.H.B. autobiography, *op.cit.* p.31.

(100) Caroe, *op.cit.* pp.33-34.

(101) The plaque was designed and executed by Ernest Gillick, A.R.A.; it

was exhibited at the Royal Academy in 1934 (1934 R.A. Exhibition Catalogue), and in 1935 Gillick was awarded the Silver Medal of the Royal Society of British Sculptors for this work (private communication). The interpretation given here of the allegorical representation is mine; no record of the sculptor's interpretation appears to have survived.

(102) G. Blaney, *A Centenary History of the University of Melbourne* (Melbourne University Press, 1957), p.24.

(103) Details such as these have been gleaned primarily from the annual *Adelaide University Calendar*.

(104) R.I.A. Bragg papers, 31A.

(105) U.A.A., series 200, docket nos. 171/1886F 447/1886, 506/1186 respectively.

(106) *The Adelaide Observer*, 30 April 1887, p.18.

(107) J.G. Jenkin, 'William Bragg and lacrosse in Adelaide', *Aust. Physicist* 17, 5 (1980), 75-78.

(108) J.G. Jenkin, 'William Bragg in Adelaide: tennis too', *Aust. Physcist*, 18, 4 (1981), 69-70.

(109) South Australian Collections, State Library of S.A., Adelaide, Box SC46, Programme for Torrens Park Theatre, 21 October 1886.

(110) J. Brown & B. Mullins, *Town Life in Pioneer South Australia* (Adelaide, Rigby, 1980). pp. 174-186.

(111) W.H. Bragg, *Studies in Radioactivity* (London, Macmillan 1912), p.5.

(112) Letter Routh to Bragg, 22 December 1885, in Bragg family papers, now in the care of Lady Adrian, Pembroke College, Cambridge. E.J. Nanson was Professor of mathematics there.

(113) *South Australian Register* (newspaper), Adelaide, 4 January 1887, p.5; letter Bragg to wife, 5 January 1890, in Bragg family papers, *op.cit.*

(114) For the foundation of A.A.A.S. see H.C. Russel, President's Address, *Rep. Australas. Ass. Advmt. Sci.* (Sydney, A.A.A.S., 1888), pp.1-21; for the

importance of A.A.A.S. to Bragg see R.W. Home. 'The problem of intellectual isolation in scientific life: W.H. Bragg and the Australian scientific community 1886-1909', *Hist. Records Aust. Sci.* **6**, 1 (1984), 19-30.

(115) U.A.A., series 200, docket no. 290/1887. Letter: Bragg to University Council, 27 July.

(116) Caroe, *op.cit.* p.31.

(117) Note 103. During 1886-7 there were major changes in the public examination system and the university was also in dispute with Professor Boulger, its usual English History examiner. The final two papers in this subject under the old regulations were set by Professor Rennie (Chemistry) and Professor Bragg.

(118) Note 115.

(119) U.A.A., Report of the Education Committee no. 12/1887, 19 August.

(120) U.A.A., series 200, docket no. 511/1887. Letter Bragg to Chancellor, 9 December.

(121) U.A.A. Report of the Education Committee No. 1/1888, 17 January.

(122) U.A.A., series 200, docket no. 60/1888. Letter Bragg to Tyas (Registrar) , 1 February. Trinity and Ormond are two of the colleges attached to the University of Melbourne.

(123) Unattributed obituary, 'The late Sir Robert Chapman Kt.Bach', *Instn. Engrs. Aust.* **14** (1942), 101-103. This article refers to Chapman as having had 'a few months experience . . . on railway construction in Victoria', the only evidence I have found of a widely told story that Bragg first spoke to Chapman regarding the Adelaide post on the Ballarat railway station.

(124) Caroe, *op.cit.* p.34.

(125) W.H.B. autobiography, *op.cit.*, p.31.

Chapter 5

ADELAIDE GRADUATES IN PHYSICS

5.1 ADELAIDE GRADUATES IN PHYSICS (EXCLUDING MATHS PHYSICS & MAWSON)

SURNAME	OTHER NAMES	DEGREES	CONF
ABBOTT	WILLIAM PETER	B.SC(HONS)	1979
AHMED	NUBASHAR	PH.D	1978
AITCHISON	CORDON JAMES	B.SC(HONS) M.SC PH.D	1940 1945 1957
ALDERSEY	ALGERNON LUMLEY HAYDON	B.Sc	1950
ALLAN	PHILLIP THOMAS	B.SC(HONS)	1976
ALLEN	JAMES BERNARD	B.Sc	1891
ALLEN	WILLIAM DOUGLAS	B.SC(HONS)	1935
AMIES	BRIAN WALTER	B.SC(HONS)	1973
ANDERSON	SYLVIA HILDA	B.Sc M.Sc	1950 1954
ANDREWS	MURRAY WILLIAM	B.SC(HONS)	1950
ANGLEY	RONALD JAMES	B.SC(HONS) M.SC	1952 1954
ANGWIN	HUGH THOMAS MOFFITT	B.Sc	1910
ANTCLIFFE	GAULT ANDERSON	B.SC(HONS) PH.D	1961 1966
ARGALL	PHILIP STEPHEN	B.SC(HONS)	1985
ASENSTORFER	JOHN ANTHONY	B.SC(HONS)	1980
ATRENS	ANDREJS	B.SC(HONS)	1970
AUSTIN	WAYNE DEAN	B.SC(HONS)	1979
AYLMORE	LANCE ARTHUR GRAHAM	B.SC(HONS) PH.D	1957 1961

BACK	PHILLIP JAMES	B.SC(HONS)	1973
BAGOT	CHARLES HERVEY	B.SC(HONS) M.SC	1958 1961
BAHR	JOHN LESLIE	B.SC(HOHS) PH.D	1966 1970
BAILES	MATTHEW	B.SC(HONS)	1985
BALL	SUSAN MARGARET	B.SC(HONS) PH.D	1976 1982
BARNDEN	LEIGHTON REGINALD	B.SC(HONS) PH.D	1966 1972
BARTLETT	BRIAN MERVYN	B.Sc	1949
BARTUSEK	KAREL	B.SC(HONS) PH.D	1964 1971
BASEDOW	ROBERT WILLIAM	B.SC(HONS)	1971
BASTIAN	ALAN CHARLTON	M.SC	19618
BAYLY	L41LLIAPI REY14OLDS	B.SC	1898
BEARE	THOMAS HUDSON	B.A	1887
BEATTIE	ALLAN GEOFFREY	B.SC(HONS)	1975
BEBEE	DAVID JOHN	B.SC(HONS)	1973
BEDNARZ	BERNARD	B.SC(HONS) PH.D	1973 1978
BENNET	ARTHUR DAVID	B.SC(HONS)	1972
BERESFORD	ANTHONY CHARLES	B.SC(HONS) PH.D	1966 1974
BEVAN	ARTHUR REGINALD	M.Sc	1960
BIBBO	GIOVANNI	PH.D	1978
BIRKS	LAWRENCE	B.SC	1894
BLACKBURN	TREVOR ROBERT	B.SC(HONS)	1965
BLAKE	ALASTAIR JOSEPH	B.SC(HONS) PH.D	1963 1967
BLESING	ROBERT GRAHAM	B.SC(HONS) PH.D	1967 1974
BLIGHT	JOHN MALCOLM	B.SC	1950
BOAS	ISAAC HERBERT	B.SC	1899
BOHM	ROBERT ROMAN	B.SC(HONS) PH.D	1969 1975
BOSHER	VICTOR JAMES MARCEL	B.SC(HONS) M.SC	1948 1949
BOSWELL	RODERICK WILLIAM	B.SC(HONS)	1966
BOSWORTH	RICHARD CHARLES LESLIE	B.SC(HONS) M.SC D.SC	1910 1931 1930
BOUNDY	WILLIAM STEVENSON	B.SC M.SC	1950 1969
BOWER	ANTHONY RICHARD DAVID	B.SC(HONS)	1969
BOYD	ASHLEY JAMES	B.SC(HONS)	1961
BRAGG	WILLIAM HENRY	M.A	1888
BRENNAN	MAXWELL HOWARD	PH.D	1964
BRIDGES	GARETH EDWARD	B.SC(HONS)	1983
BRIDGES	ROBERT DEAN	B.SC(HONS)	1972
BRIGGS	BASIL HUGH	PH.D	1963
BRIMBLE	GORDON STUART	B.SC(HONS)	1975
BRISSENDEN	ROGER JAMES VERGE	B.SC(HONS)	1985
BROMWICH	DAVID WILLIAM	B.SC(HONS)	l975
BROSE	HENRY HERMAN LEOPOLD	B.SC D.SC	1910 1931
BROWN	ROGER NORMAN	B.SC(HONS) PH.D	1953 1959
BROWN	MARY HOME	B.SC	1902
BROWN	JAMES WATSON	B.SC	1892
BROWN	DENIS HACKETT	B. SC(HONS) M.SC	1961 1964

BROWN	NICHOLAS	B.SC(HONS) PH.D	1968 1973
BROWN	MALCOLM STEWART	M.SC	1970
BRUCE	TIMOTHY EDMUND GREGORY	B.SC (HONS)	1985
BUNNEY	BRONTE ROWLAND	B.SC(HONS)	1952
BURDON	ROY STANLEY	B.SC(HONS) D.SC	1916 1935
BURFORD	PETER JAMES	B.SC(HONS)	1967
BURLEY	SIMON PETER	B.SC(HONS) PH.D	1960 1965
BURNELL	REGINALD GEORGE	B.A	1905
BUSELLI	GIACHINO	B.SC(HONS) PH.D	1967 1972
BUTEMENT	WILLIAM ALAN STEWART	D.SC	1961
BUTLER	STUART THOMAS	B.SC(HONS) M.SC	1947 1948
BUTTERFIELD	ANTHONY WILLIAM	B.SC(HONS) PH. D	1965 1970
BYRNE	PAUL KEVIN	B.SC(HONS)	1973
CAMERON	ROBERT ANDREW	B.SC(HONS)	1980
CAMERON	MICHAEL THOMAS	B.SC(HONS)	1979
CAMPBELL	JOHN ARTHUR	B.SC M.SC	1961 1964
CAMPBELL	ROBERT DEAN	B.SC(HONS) PH.D	1963 1969
CAMPBELL	ALLEN PETER	B.SC(HONS)	1962
CAMPBELL	LAURENCE	B.SC(HONS)	1975
CANNY	NICHOLAS JOSEPH	B.SC(HONS)	1949
CARRICK	IAN GALBRAITH	B.SC(HONS)	1972
CARVER	JOHN HENRY	PH.D	1965
CASSIDY	ROBYN ANNE	B.SC(HONS)	1979
CATCHPOOLE	JOHN ROGER	B.SC(HONS) M.SC	1953 1964
CATFORD	WILTON NEIL	B.SC(HONS)	1977
CAVENETT	BRIAN CLIFFORD	B.SC(HONS) PH.D	1961 1965
CAWTHRON	EDWARD ROBERT	B.SC(HONS)	1964
CHAMBERLAIN	MALCOLM TREVOR	B.SC(HONS)	1970
CHAPMAN	ROBERT WILLIAM	M. A	1889
CHAPPLE	ALFRED	B.SC	1894
CHAPPLE	PHOEBE	B.SC	1898
CHAPPLE	FREDERICK JOHN	B.SC	1891
CHARTRES	BRUCE AYLWIN	B.SC(HONS) M.SC	1951 1953
CIAMPA	DOMINIC	B.SC(HONS)	1985
CLANCY	MICHAEL CHARLES	B.SC(HONS) PH.D	1967 1972
CLARK	EDWARD VINCENT	B.SC	1895
CLENDINNEN	IAN JEFFREY	B.SC(HONS)	1952
CLOSE	RONALD WILKINSON	B.SC(HONS)	1929
COCKS	TERRY DOUGLAS	B.SC(HONS)	1971
COLMAN	PETER MALCOLM	B.SC(HONS) PH.D	1966 1970
COLVILLE	JOHN STUART	B.SC(HONS) M.SC	1950 1956
COMLEY	CHARLES HERBERT	B.SC	1910
COOKE	WILLIAM ERNEST	M.A	1889
CORANI	CLAIRE	B.SC(HONS)	1983
CORBIN	HUGH BURTON	B. SC	1892

COTTRELL	PETER LEDSAM	B.SC(HONS)	1974
COVENTRY	CAMERON HILDER	B.SC	1900
COWLEY	JOHN MAXWELL	B.SC(HONS) M.SC D.SC	1943 1945 1957
COX	DAVID WILLIAM	B.SC(HONS)	1936
CRAIG	RONALD LEEDSMAN	B.SC(HONS)	1976
CREASER	ROGER PHILLIP	B.SC(HONS)	1965
CROMPTON	ROBERT WOODHOUSE	B.SC(HONS) PH.D	1949 1954
CROUCH	STEPHEN JOHN	B.SC(HONS)	1970
CROUCH	PHILLIP CHARLES	B.SC(HONS) PH.D	1973 1981
CROUCHLEY	JIM	M.SC	1945
CROWLEY	MARY ESTELLE	B.SC	1951
CUNDY	SUSAN MARY	B.SC(HONS)	1972
CUNNINGHAM	ROBERT JOHN	B.Sc.	1972
CUTTEN	DEAN ROBERT	B.SC(HONS) PH.D	1964 1969
DALE	ALAN GEORGE	B.SC(HONS)	1970
DANCER	ROBERT FREDERICK	B.SC(HONS)	1971
DARWIN	LISLE JULIUS	B.A	1905
DAVEY	ROYCE CHRISTOPHER	B.SC(HONS)	1971
DAVIES	IAN MALCOLM	B.SC(HONS)	1965
DAVIES	RODNEY DEANE	B.SC(HONS) M.Sc	1951 1953
DAVIS	LESLEY ANNE	B.SC(HONS) PH.D	l972 1982
DAVIS	RONALD LINDSAY	B.SC(HONS)	1964
DAW	FRANCIS ALAN	B.SC	1945
DAWSON	BRUCE ROBERT	B.SC(HONS)	1981
DELAND	RAYMOND JAMES	B.SC(HONS)	1949
DENBY	ERNEST FRANK	B.SC(HONS)	1952
DENNIS	EDWIN	B.SC(HONS) M.SC	1951 1967
DENNISON	PAUL ANTHONY	PH.D	1968
DENTON	ROBIN ERIC	B.SC(HONS) PH.D	1967 1973
DICKSOIN	RONALD STANLEY	B.SC(HONS) PH.D	1959 1963
DINGLE	RODERICK EDWARD	B.SC(HONS) PH.D	1964 1970
DOBNEY	PHILLIP THOMAS	B.SC(HONS) PH.D	1962 1970
DODWELL	GEORGE FREDERICK	B.A	1905
DONALDSON	ARTHUR	B.A	1881
DOOLETTE	ASHLEY GRANT	B.SC(HONS)	1978
DOOLETTE	DENNIS PHILLIP	B.SC(HONS)	1969
DORNWELL	EDITH EMILY	B.SC	1885
DOUGHTY	CHRISTOPHER JOHN	B.SC(HONS)	1970
DOWLING	DEAN ROBERT	B.SC	1962
DOYLE	ELIZABETH MARGARET	B.SC(HONS) PH.D	1964 1969
DREW	JCHN FRANCIS	B.SC(HONS)	1964
DUFFIELD	WALTER GEOFFREY	B.SC D.SC	1900 1908
DUNCAN	ROBERT ALLEN	B.SC(HONS) D.SC	1952 1965
DURANCE	GEOFFREY	B.SC(HONS)	1965
DURDIN	JOHN MACGREGOR	B.SC(HONS)	1970

EDGAR	ROBERT STEEL	M.SC	1945
EDWARDS	PHILIP GLEN	B.SC	1958
EDWARDS	MICHAEL FRANCIS	B.SC(HONS)	1981
EDWARDS	PHILLIP GREGORY	B.SC(HONS)	1984
EDWARDS	PAUL JULIAN	PH.D	1965
EKERS	RONALD DAVID	B.SC(HONS)	1963
ELFORD	MALCOLM THOMAS	B.SC(HONS) PH.D	1954 1958
ELFORD	WILLIAM GRAHAM	B.SC(HONS) PH.D	1949 1955
ELLIS	BRIAN DAVID	B.SC(HONS)	1951
ELTON	STEPHEN DENNIS	B.SC(HONS)	1985
ERICSON	LEON GORDON	B.SC(HONS) PH.D	1956 1959
EY	CHRISTOPHER MAURICE	B.SC(HONS)	1974
FABIAN	WERNER	B.SC(HONS) PH.D	1967 1972
FARMER	ANTHONY JOHN DOUGLAS	B.SC(HONS) PH.D	1966 1970
FARR	CLINTON COLERIDGE	B.SC D.Sc	1888 1902
FAZZALARI	NICHOLA LORENZO	B.SC(HONS)	1974
FELGATE	DAVID GORDON	B.SC(HONS) PH.D	1965 1970
FERGUSSON	IAN CHARLES STEWART	B.SC(HONS) PH.D	1968 1973
FIEBIG	MERRILYN JOY	B.SC(HONS)	1984
FIELD	DONALD WILLIAM	B.SC(HONS) PH.D	1968 1973
FLETCHER	JOHN	PH. D	1966
FONG	LIAN HERN	B.SC(HONS) PH.D	1962 1968
FORD	JOHN MACKAY	B.SC(HONS)	1965
FRANCIS	ROBERT JOHN	B.SC(HONS)	1960
FREUND	JOHN TERENCE	B.SC(HONS)	1969
FRY	ROBERT MASON	B.SC(HONS)	1949
FULLER	GEORGE RAYNER	B.SC(HONS)	1924
FULLGRABE	KYM ANTHONY	B.SC(HONS)	1977
FURNESS	IAN WARREN	B.SC(HONS)	1979
GAFFNEY	ROBERT DENIS	B.SC(HONS)	1973
GAMBLING	DAVID JOHN	B.SC(HONS) M.SC PH.D	1964 1967 197I
GARDNER	JAMES LAURIE	B.SC(HONS) PH.D	1968 1971
GARDNER	KEVIN JOHN	B.SC(HONS)	1980
GARTRELL	GRANT	B.SC(HONS) PH.D	1965 1972
GEMMELL	DONALD STEWART	B.SC(HONS)	1956
GEORGE	BARBARA KAY	B.SC(HONS)	1958
GEORGE	PETER LESLIE	M.SC	1969
GERHARDY	PETER RONALD	B.SC(HONS) PH.D	1977 1984
GERLACH	RODNEY VERNON	B.SC(HONS)	1968
GIBBERD	WILLIAM OBED	B.SC M.SC	1939 1945
GIBBS	STUART GEOFFREY	B.SC(HONS)	1971
GIBSON	STEPHEN THOMAS	B.SC(HONS) PH.D	1979 1984
GIES	HANS PETER FREIDRICH	B.SC(HONS) PH.D	1974 1980
GIGNEY	DAVID ALBERT MORRIS	B.SC(HONS) PH.D	1972 1981
GLASSON	JOSEPH LESLIE	B.SC(HONS) D.SC	1908 1912

GOLLEY	MALCOLM GEORGE	B.SC(HONS) PH.D	1963 1971
GOODEN	JOHN STANLEY	B.SC(HONS) M.SC	1941 1945
GOODEN	JOHN ERNEST ALFRED	B.SC	1955 1958
GOODWIN	GEOFFREY LEONARD	B.SC(HONS) M.SC	1952 1959
GOODWIN	ROBERT DOUGLAS	B.SC(HONS) PH.D	1968 1973
GOONAN	PAMELA JOY	B.SC(HONS)	1974
GOUGH	PAUL LANCELOT	B.SC(HONS) PH.D	1965 1972
GOYDER	ALEXANDER WOODROFFE	B.SC	1889
GRADY	BETTY GRACE	B.SC(HONS)	1964
GRAHAM	LANCE ARTHUR	B.SC(HONS)	1957
GRANT	COLIN KERR	B.SC	1931
GRANT	KERR	B.SC	1911
GREGORY	ALAN GOWER	PH.D	1967
GREVINS	JURIS	B.SC(HONS)	1969
GRIERSMITH	DAVID	B.SC(HONS)	1975
GRIFFIN	DONALD WARD	PH.D	1966
GRIMBELL	GORDON STUART	B.SC(HONS)	1975
GROTH	MICHAEL JOHN	B.SC(HONS)	1970
GROVES	JAMES MARK	B.SC(HONS)	1984
GUBBAY	JACOB SAMUEL	PH.D	1970
GUINAND	ANDREW PAUL	B.SC	1932
GUM	COLIN STANLEY	B.SC(HONS) M.SC	1949 1951
GURR	GRAHAM EDWARD	B.SC(HONS) PH.D	1957 1962
HADDAD	GERALD NEIL	B.SC(HONS) PH.D	1963 1968
HALE	ROBERT PALMER	B.SC(HONS) M.SC	1956 1966
HALL	BARBARA ISABELLE HERBERT	B.SC(HONS) PH.D	1953 1956
HAMILTON	DAVID JAMES	B.SC(HONS)	1975
HANSBERRY	MARY ESTELLE	B.SC	1951
HARRIES	JOHN ROBATHAN	B.SC(HONS) PH.D	1964 1969
HARRIS	BRIAN ALEC	B.SC(HONS)	1979
HARRIS	ROBERT WAYNE	B.SC(HONS)	1969
HART	DENNIS NEIL	B.SC(HONS)	1972
HARWOOD	KEITH	B.SC(HONS) PH.D	1967 1976
HASLAM	JOSEPH AUBURN	B.SC	1892
HAYCRAFT	EDITH FLORENCE	B.SC	1890
HAYTHORPE	ALAN DAVID	B.SC(HONS)	1979
HEADING	KEITH EDWARD GEORGE	B.SC	1930
HENNESSY	MICHAEL JOSEPH	B.SC(HONS)	1981
HERRAMAN	RICHARD ANTON	B.SC(HONS)	1971
HIRSCH	ERNEST HERMANN	M.SC	1965
HOBBS	TREVOR IAN	B.SC(HONS) PH.D	1974 1980
HOCKING	WAYNE KEITH	B.SC(HONS) PH.D	1977 1981
HOLDEN	EDWARD WHEEWELL	B.SC	1905
HOLMES	NIGEL ERIC	B.SC(HONS) PH.D	1970 1975
HOLMES	JOHN WINSPERE	M.SC	1955

HOLYWELL	KEITH HAROLD	M.SC	1959
HOOPER	ANDREW WESLEY	B.SC(HONS) PH.D	1963 1968
HORSFALL	LAURENCE MICHAEL	B.SC(HONS)	1972
HORTON	BRIAN HENRY	PH.D	1969
HORTON	MALCOLM IAN	B.SC(HONS)	1981
HOUSE	ANTHONY JOHN EDMUND	B.SC(HONS)	1977
HUNT	BARRIE GEORGE	M.SC	1966
HURST	ELINOR MARY	B.SC(HONS)	1976
HUTTON	JENNIFER MYRA	B.SC(HONS) M.SC	1973 1982
HUXLEY	LEONARD GEORGE HOLDEN	PH.D	1950
ILIFFE	MICHAEL ISAAC GLOVER	B.SC(HONS)	1934
ILYAS	MOHAMMED	PH.D	1977
IRVING	ELIZABETH ANNE	M.SC	1954
ISLAM	ANOARA	PH. D	1980
JACOB	PETER GORDON	B.SC(HONS)	1980
JAMES	ALAN TRELEVEN	B.SC(HONS)	1944
JAUNCEY	GEORGE ERIC MACDONNELL	B.SC(HONS) D.SC	1912 1922
JELAVIC	ANNEMARIE	B.SC(HONS)	1971
JENKIN	JOHN GRENFELL	B.SC(HONS)	1961
JENSEN	HANS ERHARD	B.SC(HONS) PH.D	1977 1982
JOLLY	NORMAN WILLIAM	B.SC(HONS)	1901
JONES	ALEXANDER LEWIS	B.SC(HONS)	1983
JONES	NORMAN PHILLIP	B.SC(HONS)	1980
JORY	RODNEY LEONARD	B.SC(HONS)	1960
KALISZEWSKI	ANTONI BOGUMIL	B.SC(HONS)	1975
KAMMER	MONICA VIVIENNE	B.SC(HONS)	1962
KAMPROD	JANICE LEE	B.SC(HONS)	1971
KEATS	REYNOLD GILBERT	B.SC	1948
KEEVES	JOHN PHILIP	B.SC(HONS)	1947
KEMPSER	CHARLES JOHN EDGAR	PH.D	1960
KHAWAJA	EHSAN ELLAHI	PH.D	1975
KIDMAN	BARBARA PHYLLIS	B.SC(HONS) PH.D	1949 1956
KILLEEN	NEIL EDWARD BEAUCHAMP	B.SC(HONS)	1980
KLEEMAN	RICHARD DANIEL	B.SC(HONS) D.SC	1905 1908
KOBELT	ROBERT JOHN	B.SC(HONS)	1974
KOERBER	BRIAN WALTER	B.SC(HONS)	1957
KOHLHAGEN	MYRA AUDREY	B.SC(HONS)	1956
KOVENDY	ANDREW ZOLTAN	B.SC(HONS)	1984
KUHLMANN	JIM DOUGLAS	B.SC(HONS)	1975
KUMAR	VIJAY	PH.D	1970
LAMB	HORACE	M.A	1877
LANG	GRAHAM BRUCE	B.SC(HONS)	1959
LAWRANCE	ROBERT	M.SC PH. D	1958 1965
LE MESSURIER	THOMAS ABRAM	B.SC	1893
LEAN	JUDITH LESLEY	PH.D	1982

LEE	STEPHEN MARK	B.SC(HONS)	1985
LEIGH-JONES	PETER	PH.D	1972
LEWIS	BRIAN MURRAY	B.SC(HONS)	1965
LEWIS	BRENTON RAYMOND	B.SC(HONS) PH.D	1967 1973
LIDDIARD	KEVIN CHARLE	B.SC(HONS) M.SC	1965 1975
LIDDLE	PETER FRANCIS	B.SC(HONS)	1967
LIDDY	DESMOND TERENCE	B.SC(HONS)	1951
LIEBING	DAVID FRANK	B.SC(HONS) PH.D	1977 1984
LILLYWHITE	JOHN WILSON	B.SC	1936
LILLYWHITE	CUTHBERT	B.SC	1899
LIM	KIM CHOO MARGARET	B.SC(HONS)	1985
LIM	HENG WAH	B.SC	1966
LIM	SENG GUAN	B.SC(HONS)	1973
LINDEMANS	WILLEM	B.SC(HONS) PH.D	1971 1982
LINDNER	BERNARD CRAWFORD	B.SC(HONS) PH.D	1969 1974
LIOUTAS	NICK	B.SC(HONS)	1982
LITTLE	ROWLAND EDMUND	M.SC	1966
LOCKEY	GEORGE WILLIAM ALBERT	B.SC(HONS) PH.D	1968 1973
LOHMANN	BIRGIT	B.SC(HONS)	1980
LOKAN	KEITH HENRY	B.SC(HONS)	1955
LOWER	JULIAN CHARLES ANDRE	B.SC(HONS)	1983
LOWKE	JOHN JAMES	B.SC(HONS) PH.D	1956 1963
LUCAS	ROBERT MICHAEL	B.SC(HONS)	1975
MACKENZIE	EUAN CHISHOLM	PH.D	1967
MACKLIN	WILLIAM CHARLES	B.SC(HONS) M.SC	1953 1956
MACK	HANS HAMILTON	B.A	1880
MACLEOD	RODERICK IAN	B.SC(HONS)	1980
MADSEN	JOHN PERCIVAL VISSING	B.SC D.SC	1901 1907
MAHONEY	ALLAN ROBERT	M.SC	1971
MAINSTONE	JOHN SYDNEY	B.SC(HONS) PH.D	1955 1959
MANSBRIDGE	HAROLD EDGAR	B.SC M.SC	1949 1960
MARRIAGE	ALLAN JOHN	M.SC	1965
MARTIN	RODNEY JOHN	B.SC(HONS)	1978
MARTIN	LESLIE HAROLD	D.SC	1967
MARTIN	BYRON THOMAS	B.SC(HONS)	1982
MASSEY	HARRIE STEWART WILSON	D.SC	1974
MATERNE	MYRA AUDREY	B.SC(HONS)	1956
MATHER	KEITH BENSON	M.SC	1944
MATHEWS	JOHN HUGH	B.SC(HONS)	1963
SWENSEN	EVELYN MAIME	B.SC(HONS)	1958
MATTHEWS	BRIAN WESLEY	B.SC(HONS) PH.D	1960 1964
MAYFIELD	JOHN MAXWELL	B.SC	1958
MAY	PETER THOMAS	B.SC(HONS)	1982
MAYNARD	ROBERT KEITH	B.SC(HONS)	1962
MAYNARD	DONALD ARTHUR SCOTT	B.SC	1938

MCAVANEY	BRYANT JOHN	B.SC(HONS) PH.D	1965 1971
MCCARTHY	IAN ELLERY	B.SC(HONS)	1953
MCCOY	DONALD GEORGE	B.SC(HONS) PH.D	1961 1967
MCCRACKEN	KENNETH GORDON	D.SC	1971
MCDONALD	DONALD MALCOLM	B.SC(HONS) PH.D	1973 1982
MCDONNELL	THOMAS PETER	B.SC(HONS) PH.D	1967 1972
MCDONOUGH	MARY-ANNE	B.SC(HONS)	1981
MCGEE	COLIN RAYMOND	B.SC(HONS) M.SC PH.D	1954 1963 1971
MCGRATH H	DAVID NEIL	B.SC(HONS)	1972
MCGREGOR	PETER JOHN	B.SC(HONS)	1977
MCKELVIE	DONALD	B.SC(HONS)	1954
MCLEAN	IAN WEYMOUTH	B.SC(HONS)	1954
MCLEOD	KATHRYN MARY	B.SC	1977
MCPHERSON	ALEXANDER OWEN	B.SC(HONS)	1928
MEDLIN	EDWIN HARRY	B.SC(HONS) PH.D	1951 1956
MEIGHEN	PHILLIP JOHN	B.SC(HONS)	1971
MENA	MENAS ANTONIOS	B.SC(HONS)	1983
MENZIES	NICHOLAS CHARLES	B.SC(HONS)	1984
MERCER	EDGAR HOWARD	B.SC(HONS) D.SC	1937 1960
METCHNIK	VICTOR IVOR	PH.D	1963
MICKAN	ERWIN LAURENCE	B.SC(HONS)	1957
MILES	PERRY AMBROSE	B.SC(HONS) M.SC	1950 1951
MILLAR	GEOFFREY LLOYD	B.SC(HONS)	1976
MILLER	RAYMOND ORLANDO MAURICE	B.A	1905
MILLS	GRAHAM ALAN	B.SC(HONS)	1968
MILTON	BERNARD ERIC	B.SC(HONS) M.SC	1954 1959
MITCHELL	PETER	B.SC(HONS) PH.D	1960 1966
MITCHELL	IAN VAUGHAN	B.SC(HONS)	1960
MITTON	RONALD GLADSTONE	B.SC(HONS) M.SC	1926 1928
MIZON	ERROL ALFRED	B.SC	1948
MORLAND	ANTHONY MICHAEL	B.SC(HONS)	1976
MORROW	RICHARD	B.SC(HONS)	1966
MOYSE	JOHN STOWARD	B.A	1905
MUMME	WILLIAM GUSTAV	M.SC PH.D	1959 1964
MURPHY	DAMIAN JOHN	B.SC(HONS) M.SC	1983 1985
MURRAY	ERIC LIONEL	B.SC(HONS) PH.D	1954 1962
MYSIOR	FRANCES	B.SC	1952
NAGORCKA	BARRY NEWELL	B.SC(HONS)	1970
NANKIVELL	JOSEPH FRANK	B.SC(HONS)	1948
NIELSEN	IAN RONALD	B.SC(HONS)	1972
NIETZ	HERBERT WALTER	B.SC	1921
NILSSON	CARL SIGURD	B.SC(HONS) PH.D	1959 1965
NITSCHTKE	PHILLIP HAIG	B.SC(HONS)	1968
NOGARE	RONALD RAPHAEL DALLE	B.SC	1953
NOWICKI	STANISLAW ZYGMUNT	B.SC(HONS)	1977

NUGENT	KEITH ALEXANDER	B.SC(HONS)	1981
O'BRIEN	CHRIS	B.SC(HONS)	1977
O'BRIEN	RICHARD SEARCEY	B.SC(HONS) PH.D	1968 1974
O'CONNOR	GRAHAM GEOFFREY	B.SC(HONS) PH.D	1965 1974
ODAM	KEITH BRIAN	B.SC(HONS)	1973
OLIPHANT	MICHAEL JOHN	B.SC(HONS)	1960
OLIPHANT	MARCUS LAWRENCE ELWIN	B.SC(HONS) D.SC	1923 1969
OLLINO	RICHARD	B.SC(HONS)	1958
OLSEN	JOHN ERIC	B.SC(HONS)	1972
OPHEL	TREVOR RICHARD	B.SC(HONS)	1955
ORELL	TADZIU DENIS	B.SC(HONS)	1972
PADDICK	ANTHONY WILLIAM	B.SC(HONS)	1961
PAGE	NECIA JOY	B.SC(HONS)	1977
PALMEN	BROR TORBJORN	B.SC(HONS)	1973
PALMER	JOHN EDWARD	B.SC(HONS)	1967
PALMER	IAN DEXTER	B.SC(HONS) PH.D	1965 1971
PANIZZA	MARK PETER	B.SC(HONS) M.SC	1981 1985
PARHAM	RICHARD TREVOR	B.SC(HONS) PH.D	1969 1982
PARKER	MURRAY HAROLD	B.SC(HONS) M.SC	1951 1952
PARKIN	IAN ANDREW	B.SC(HONS) PH.D	1962 1968
PATON	DORA ISABELLE	B.SC	1902
PATON	ALFRED MAURICE	B.SC	1898
PATRICK	ELAINE	B.SC(HONS)	1970
PATTERSON	JOHN RAYDEN	B.SC(HONS)	1963
PATTISON	JOHN EDWARD	M.SC	1972
PFITZNER	JULIAN PAUL	B.SC(HONS)	1965
PHILLIPS	ANDRE MICHAEL	B.SC(HONS)	1983
PHILLIPS	DONALD ANDREW	B.SC(HONS)	1972
PORTLOCK	TREVOR JOHN	B.SC(HONS)	1972
POTTS	RENFREY BURNARD	B.SC	1945
PRESCOTT	JOHN RUSSELL	B.SC(HONS)	1945
PREST	DAVID HARRIS	B.SC(HONS)	1954
PRICE	GEORGINA DAWN	B.SC(HONS)	1984
PRICE	TRAFFORD CONOR	B.SC(HONS)	1958
PRIEST	HERBERT JAMES	B.SC	1902
PROVIS	DESMOND CHRISTOPHER	B.SC(HONS)	1975
RADOSLOVICH	EDWARD WILLIAM	B.SC(HONS) M.SC D.SC	1950 1952 1968
RANCE	GEORGE HOWE	B.SC	1935
RASHLEIGH	DAVID GRAHAM	B.SC(HONS)	1969
RAYNER	JAMES NIGEL	B.SC(HONS)	1976
REID	IAIN MURRAY	B.SC(HONS) PH.D	1979 1985
REIMANN	ARNOLD LUEHRS	B.SC(HONS) D.SC	1922 1935
RICEMAN	MARY STIRLING	B.SC(HONS)	1965
RICEMAN	WILLIAM DAVID	B.SC(HONS) M.SC	1967 1971
ROBERTSON	DAVID STIRLING	B.SC PH.D	1941 1954

ROBERTSON	JAMES GORDON	B.SC(HONS)	1972
ROBIN	PERCY ANSELL	B.A	1880
ROBINSON	PETER JOHN	B.SC(HONS)	1975
ROBINSON	LAURENCE CHARLES	M.SC	1959
ROGERS	PAUL JOHN	B.SC(HONS)	1980
ROPER	JOHN MCEWEN	B.SC(HONS)	1967
ROPER	ROBERT GEORGE	B.SC(HONS) PH.D	1958 1963
ROSSITER	DEAN EDWARD	B.SC(HONS) PH.D	1965 1970
SANDERCOCK	EDWARD ROBERT	B.SC(HONS) PH.D	1960 1968
SANDERS	JOHN VEYSEY	B.SC(HONS)	1947
SCHUBERT	MARK THEODORE	B.SC(HONS) M.SC	1966 1970
SEBESTYEN	MELINDA	B.SC	1986
SEPPELT	BRIAN MAXWELL	B.SC(HONS)	1960
SEXTON	LEO FRANCIS	B.SC(HONS)	1968
SHACKLEFORD	PETER RONALD JAMES	B.SC(HONS) M.SC	1971 1979
SHAW	PETER JOHN RANDALL	B.SC	1949
SHEPLEY	ARTHUR RAYMOND	B.SC	1923
SIGNORIELLO	GIOVANNI BATTISTA	B.SC(HONS)	1978
SIMPSON	MICHAEL KENNETH	B.SC(HONS)	1982
SIMPSON	PENELOPE MARGARET	B.SC	1949
SLEE	WALTER VERNON	B.SC(HONS)	1960
SMEAT0N	STIRLING	B.A	1880
SMITH	ROGER NEVILLE EARL	B.SC(HONS)	1968
SMITH	WILLIAM IRVING BERRY	B.SC(HONS)	1941
SMITH	JOHN WILTON	B.SC(HONS) M.SC	1954 1961
SMITH	DAVID AITCHISON	B.SC(HONS)	1962
SMITH	BARNABY WHITMORE	B.SC(HONS) PH.D	1979 1984
SMITH	JACK EDWIN	B.SC(HONS)	1947
SMITH	HAROLD WHITMORE	B.SC	1906
SMITH	RAYMOND THOMAS	B.SC	1932
SMITH	JULIAN AUGUSTUS ROMAN	B.SC	1892
SPOONER	NIGEL ANTHONY	B.SC(HONS)	1981
SPURR	ROBERT THOMAS	B.SC(HONS)	1949
STAIN	CORBET WRIGHT	B.SC(HONS)	1977
STEPHAN	LESLIE GEORGE	B.SC(HONS)	1979
STEVENSON	DONALD GEORGE	B.SC(HONS) M.SC	1950 1952
STEVENS	PHILIP JOHN	B.SC(HONS)	1973
STEWART	CRAIG GRANT	B.SC(HONS)	1985
STEWART	IAN CHARLES FERGUSSON	B.SC(HONS) PH.D	1968 1973
STIRLING	ANDREW JOHN	B.SC(HONS)	1966
STONE	BRIAN JAMES	B.SC(HONS) PH.D	1960 1968
STORM	JOHN ROBERT	B.SC(HONS)	1984
STUART	NOEL HARRY	B.SC(HONS)	1928
STUBBS	THOMAS JOHN	B.SC(HONS) PH.D	1971 1975
STUCKEY	EDWARD JOSEPH	B.SC	1895

STUCKEY	FRANCIS SEAVINGTON	B.SC	1896
SUTTON	DAVID JOHN	B.SC(HONS) PH.D	1949 1954
SWAN	GEOFFREY IAN	B.SC(HONS)	1985
SYMONDS	JOHN LLOYD	B.SC(HONS)	1945
SYMONS	GEOFFREY DAVID	B.SC(HONS)	1960
TAN	KAR FATT	B.SC(HONS)	1971
TAN	SIEW KEE KITTY	B.SC(HONS)	1974
TARRANT	JANICE MARIE	B.SC(HONS)	1984
TAYLOR	REGINALD MORTON	B.SC M.SC	1951 1962
TAYLOR	MALCOLM VICTOR	B.SC(HONS)	1968
TAYLOR	WILLIAM HALDANE	B.SC	1956
TEAGUE	PETER FLETCHER	B.SC(HONS)	1983
TEAGUE	BADEN CHAPMAN	B.SC	1968
TEUBNER	PETER JOHN OSMOND	B.SC(HONS) PH.D	1961 1968
THEILE	DAVID VICTOR	B.SC(HONS)	1971
THOMAS	LINDSAY	B.SC(HONS) PH.D	1963 1968
THOMAS	RICHARD MURISON	B.SC(HONS) PH.D	1967 1972
THOMAS	JOHN ANGUS	B.SC(HONS)	1950
THOMPSON	NORMAN	B.SC	1965
THOMPSON	ARTHUR MELVILLE	B.SC(HONS)	1938
THOMPSON	THOMAS ALEXANDER	B. SC	1896
THORNTON	GREGORY JOHN	B. SC (HONS) PH. D	1976 1985
THUTUPALLI	GOPALA KRISHNA MURTY	PH.D	1977
THYER	ROBERT FRANCIS	B.SC	1932
TINDALL	RONALD GRAHAM	B.SC(HONS)	1957
TODD	CHARLES	M.A	1886
TOMLIN	STANLEY GORDON	PH.D	1960
TONIN	RENZO FRANCIS	B.SC(HONS)	1973
TOOP	ANDREW	B.SC(HONS)	1978
TOOZE	MERVYN JOHN	B.SC	1947
TOROP	LEE WALTER	PH.D	1968
TRELEAVEN	WALTER	B.SC	1893
TRETHEWIE	JOHN VERE	B.SC(HONS) M.SC	1967 1973
TROJANOWSKI	EDWARD	B.SC(HONS)	1970
TROWSE	JAYNE ELIZABETH	B.SC(HONS)	1983
TUCKER	DAVID HAMILTON	B.SC(HONS) PH.D	1967 1976
TUOHY	IAN RONAYNE	B.SC(HONS) PH.D	1968 1972
TURNER	KEVIN JAMES	PH.D	1956
TYSON	ANGUS GORDON	M.SC	1954
URCH	IAN HAROLD	B.SC(HONS) PH.D	1968 1971
VAN DER. ZWAAG	PETER	B.SC(HONS)	1972
VEITCH,	LINDSAY GARFIELD	B.SC	1949
WAGNER	FRANZ WILLIAM	B.SC(HONS)	1928
WAINWRIGHT	EDWARD HALEY	B.SC	1883
WAITE	PETER JOHN	B.SC	1962

WALKER	ALAN	B.SC(HONS)	1977
WALKER	DANIEL	B.SC	1887
WALTER	BRYAN ROBERT	B.SC(HONS) M.SC	1964 1970
WALTON	BRUCE ADRIAN	B.SC	1945
WARD	BRUCE DONALD	B.SC(HONS) PH.D	1972 1976
WARDILL	PAUL	B.SC(HONS)	1982
WARREN-SMITH	DAVID NOEL	M.SC	1980
WATKINS	BRENTON JOHN	B.SC(HONS)	1969
WAUCHOPE	FREDERICK JOHN	B.SC	1930
WAUGH	ELIZABETH ANNE	M.SC	1954
WEBB	RAYLENE JOYCE	B.SC(HONS)	1972
WEBBER	BRIAN JOHN	B.SC(HONS)	1960
WEBSTER	BETTY LOUISE	B.SC(HONS)	1963
WEIGOLD	ERICH	B.SC(HONS)	1959
WEISS	ALAN AUSTIN	B.SC(HONS) PH.D	1951 1955
WELLER	THEO RUDOLPH	B.SC(HONS) M.SC	1968 1972
WESTPHALEN	JOHN ARTHUR	B.SC	1950
WHEATLEY	FREDERICK WILLIAM	B.SC D.SC	1890 1913
WHEATON	RUSSELL NORMAN	B.SC(HONS)	1953
WHILLAS	GEOFFREY FRENCH	B.SC	1946
WHITE	ROY EDWIN	PH.D	1969
WHITINGTON	BERTRAM	B.SC	1899
WIGG	HUGH HIGHAM	B.SC	1964
WIGHT	HUGH HUMPHREY	B.SC(HONS)	1929 1962
WILKSCH	MICHAEL VINCENT	B.SC(HONS)	1964
WILKSCH	PHILIP ANTHONY	B.SC(HONS)	1968
WILLIAMS	GEOFFREY ROY	B.SC(HONS)	1970
WILLIAMS	KEVIN GRAHAM	B.SC(HONS) PH.D	1959 1970
WILLIAMS	KENNETH CHRISTOPHER	BSC(HONS)	1975
WILLIAMSON	GEOFFREY LEA	B.SC(HONS)	1957
WILSON	LUTHER ERNEST CROSBY	B.SC(HONS)	1926
WILTON	JOHN RAYMOND	B.SC(HONS)	1903
WISEMAN	MICHAEL	B.SC(HONS)	1968 1973
WIWATOWSKI	RYSZARD JOSEF	B.SC(HONS)	1974
WOOLDRIDGE	ALAN FRANK	B.SC	1947
WORTHINGTON	CHARLES ROY	B.SC(HONS) PH.D	1951 1956
WORTHLEY	BOYCE WILSON	B.SC(HONS) M.SC	1939 1944
YOUNG	STUART ASHLEIGH	B.SC(HONS) PH.D	1972 1981
ZADOROZNYJ	IVAN	B.SC(HONS)	1969
ZIESING	GEORGE MURRAY	B.SC(HONS) M.SC	1951 1952

5.2 ADELAIDE GRADUATES IN MATHEMATICAL PHYSICS

SURNAME	OTHER NAMES	DEGREES	CONF
AMOS	KENNETH ALBERT	B.SC(HONS) PH.D	1961 1965
ANSTIS	GEOFFREY RICHARD	PH.D	1976
ASENSTORFER	JOHN ANTHONY	B.SC(HONS)	1976
BARKER	ANTHONY ALFRED	B.SC(HONS) M.SC PH.D	1962 1965 1969
BARNES	ALAN JOHN	PH.D	1982
BELL	PETER ALEXANDER	B.SC(HONS) PH.D	1970 1975
BISHOP	ROBERT RAYMOND	B.SC(HONS)	1964
BISHOP	GREGORY RAYMOND	B.SC(HONS)	1972
BISWAS	SAMENANDRA NATH	PH.D	1958
BRACKEN	ANTHONY JOHN	B.SC(HONS) PH. D	1966 1970
BRAY	IGOR	B.SC(HONS)	1983
BREARLEY	MAURICE NORMAN	PH.D	1958
BRIGGS	KEITH MARTIN	B.SC(HONS)	1977
BROADBRIDGE	PHILLIP	B.SC(HONS) PH.D	1976 1983
BROOKE	ANTHONY LACKINGTON	B.SC(HONS)	1965
BROOKER	PETER IAN	B.SC(HONS) PH.D	1966 1970
BULBECK	ALAN RONALD	B.SC(HONS)	1983
BURTMANIS	EGILS	B.SC(HONS)	1964
CAMBRELL	GREGORY KEITH	B.SC(HONS)	1967
CAMPBELL	JOHN ARTHUR	B.SC(HONS)	1962
CANT	ANTHONY	PH.D	1979
CAREY	ALAN LAWRENCE	M.SC	1974
CARTER	COLIN LESLIE	B.SC(HONS)	1965
CHAPPEL	MARK JOHN	B.SC(HONS)	1983
CHUAH	KIM LEONG	B.SC(HONS)	1960
CLAYTON	KYM ROBERT	B.SC(HONS)	1976
CORBETT	JOHN VINCENT	B.SC(HONS)	1961 1966
CULLINAN	MICHAEL CHARLE	B.SC(HONS)	1967
CUNNINGHAM	ANDREW ALLAN	PH.D	1968
DAINIS	ANDREW	B.SC(HONS) PH.D	1963 1968
DAY	ANDREW MORRISON	B.SC(HONS)	1977
DODD	TIM	B.SC(HONS)	1984
DODD	LINDSAY RICHARD	B.SC(HONS) PH.D	1961 1965
DUNNE	GERALD VINCENT	B.SC(HONS)	1985
EDWARDS	STEPHEN ANTHONY	PH.D	1982
EDWARDS	ANDREW FRIEND	B.SC(HONS)	1976
EVANS	JAMES WILLIAM	PH.D	1980
EY	CHRISTOPHER MAURICE	PH.D	1980

FAULKNER	IAN PATRICK	B.SC(HONS)	1969
FRANCEY	JOSEPH LOGAN AYRE	M.SC	1963
FREDERIKSEN	JORGEN SEGERLUND	B.SC(HONS)	1969
GAFFNEY	JANICE MARGARET	B.SC(HONS) PH.D	1969 1975
GERRARD	PETER NORMAN	B.SC(HONS)	1970
GIBBERD	ROBERT WILLIAM	B.SC(HONS) PH.D	1965 1968
GOULD	MARK DAVID	B.SC(HONS) PH.D	1976 1980
GRAY	DOUGLRS ANDREW	B.SC(HONS) PH.D	1969 1974
GREEN	HERBERT SYDNEY	D.SC	1952
GRIGSON	CHRISTOPHER JAMES	B.SC(HONS) PH.D	1966 1971
GRIMM	RAYMOND CLIFFORD	B.SC(HONS)	1966
GRISOGONO	ANNE-MARIE	PH.D	1981
GROBLICKI	ROMAN MACIEJ	B.SC(HONS)	1981
HARRIS	ANDREW STEPHEN	B.SC(HONS)	1973
HARTLEY	DAVID HOLMES	B.SC(HONS)	1985
HASELGROVE	MAXWELL KEITH	B.SC(HONS)	1969
HEADLAND	MICHAEL	B.SC(HONS)	1972
HEWITT	JOHN SINCLAIR	B.SC(HONS)	1971
HILDEBRANDT	JOHN WILLIAM	B.SC(HONS)	1984
HINTON	KERRY JAMES	B.SC(HONS) M.SC	1980 1982
HOSKING	ROGER JOHN	B.SC(HONS)	1962
HOUGH	GERALDINE	B.SC(HONS)	1970
HURST	CHARLES ANGAS	PH.D	1959
IRVINE	ROBERT DAVID	PH.D	1975
IVERSON	GEOFFREY JOHN	B.SC(HONS) PH.D	1965 1969
JAMES	PETER ALAN	B.SC(HONS)	1980
JAMESON	IAIN JOHN	B.SC(HONS)	1985
JARVIS	PETER DAVID	B.SC(HONS) M.SC	1973 1975
JOHNSTON	LINDSAY COLLINGE	PH.D	1967
KERRISK	JOHN MICHAEL	B.SC(HONS)	1966
KLAEBE	KENNETH ERIC	B.SC(HONS)	1961
KLEMM	ANTHONY DESMOND	B.SC(HONS)	1967
KRIPS	HENRY PAUL	B.SC(HONS) PH.D	1966 1973
LEE	GEOK ENG	B.SC(HONS)	1969
LIM	KHAIK LEANG	B.SC(HONS) PH.D	1960 1965
LIM	TECK KAH	B.SC(HONS) PH.D	1965 1969
LOHE	MAX ADOLPH	B.SC(HONS) PH.D	1970 1975
LYSTER	PETER MICHAEL	B.SC(HONS)	1977
MARINOFF	GEORGE MICHAEL	B.SC(HONS)	1969
MCCARTHY	JANE FRANCES	B.SC(HONS)	1984
MCCARTHY	IAN ELLERY	PH.D	1956
MCDOWALL	BARRY PATRICK	B.SC(HONS)	1956
MCFARLANE	ANTHONY RODERIC	B.SC(HONS)	1966
MCLAUGHLIN	IAN LEONARD	B.SC(HONS) PH.D	1961 1966
MCLEOD	NIGEL BRUCE	B.SC(HONS)	1970

MEATHERINGHAM	STEPHEN JOHN	B.SC(HONS)	1984
MERNONE	ANACLETO	B.SC(HONS)	1985
MESSEL	HARRY	PH.D	1952
MILLS	RICHARD GRAHAM JOHN	B.SC(HONS) PH.D	1962 1968
MILNE	GEOFFREY MAXWELL	B.SC(HONS)	1964
MORGAN	FRANCIS HAMILTON	B.SC(HONS) M.SC	1972 1977
MOSIUN	MARTIN EDWARD	B.SC(HONS)	1978
MOUNTFORD	GRAHAM CHARLES	B.SC(HONS) M.SC	1964 1968
MURRRY	STEPHEN BURNIE	B.SC(HONS)	1970
MYSAK	LAWRENCE ALEXANDER	M.SC	1963
NIEUKERKE	KAJ	PH.D	1981
NITSCHKE	IAN ATHOL	B.SC(HONS)	1965
NOGARE	RONALD RAPHAEL DALLE	B.SC(HONS)	1955
0BRIEN	DENNIS MICHAEL	B.SC(HONS) PH.D	1970 1976
PASSMORE	TIMOTHY JAMES	B.SC(HONS)	1977
PELLEN	ROBIN VICTOR	B.SC(HONS)	1968
RANKIN	JOHN ROBERT	PH.D	1978
RAUPACH	MICHAEL ROBIN	B.SC(HONS)	1972
RAWINSKI	EDWARD	B.SC(HONS)	1978
READ	JEFFREY MAXWELL	B.SC(HONS)	1970
REDDECLIFFE	OWEN ANDREW	B.SC(HONS)	1967
REEVES	LEOPOLD HUGH DUNCAN	PH.D	1964
REINFELDS	JURIS	B.SC(HONS) PH.D	1959 1963
SEYMOUR	PATRICK WILLIAM	PH.D	1965
SINCLAIR	DONALD KEITH	B.SC(HONS)	1967
SINHARDY	MAHENDRA NATH	PH.D	1982
SIZER	TOM	B.SC(HONS)	1977
SOBEY	ANTHONY JAMES	B.SC(HONS)	1975
STACEY	ANDREW JAMES	B.SC(HONS)	1981
STELBOVICS	ANDRIS TALIS	B.SC(HONS) PH.D	1970 1975
STORER	ROBIN GEORGE	B.SC(HONS) PH.D	1960 1964
STROUD	WILLIAM JOHN	B.SC(HONS)	1985
SVED	MARTA	B.SC(HONS)	1956
SYMONDS	PHILLIP JEFFREY	B.SC (HONS)	1964
TONG	PEGGY	B.SC(HONS) M.SC	1967 1969
TUCKWELL	HENRY CLAVERING	B.SC(HONS) M.SC	1965 1970
TWISK	SIMON	B.SC(HONS)	1985
VACCARO	SAMUEL ROBERT	PH.D	1980
VNUK	JOSEPH DOMINIC:	B.SC(HONS)	1983
WALSH	ELEANOR WYNN	B.SC(HONS)	1965
WHITE	NEIL JOHN	B.SC(HONS) PH.D	1974 1979
WIGLEY	TOM MICHAEL LAMPE	B.SC(HONS) PH.D	1961 1968
WILKINSON	STEPHEN KIDMAN	B.SC(HONS) M.SC	1982 1983
WILLIAMS	ANTHONY GORDON	B.SC(HONS)	1980
WILMOT	GREG PAUL	B.SC(HONS)	1984

WRIGHT	JILL DIANNE	B.SC(HONS) M.SC	1975 1981
YARDLEY	NEALE	B.SC(HONS)	1980
YEOMANS	FRANK EDWARD	B.SC(HONS) M.SC	1962 1969
YIP	BRANDON	B.SC(HONS)	1983
ZAINUDDIN	HISHAMUDDIN	B.SC(HONS)	1985

5.3 ADELAIDE GRADUATES IN PHYSICS - THE MAWSON INSTITUTE FOR ANTARCTIC RESEARCH

SURNAME	OTHER NAMES	DEGREES	CONF
BASEDOW	ROBERT WILLIAM	PH.D	1978
BOWER	ANTHONY RICHARD DAVID	PH.D	1975
CHAMBERLAIN	MALCOLM TREVOR	PH.D	1978
COCKS	TERRY DOUGLAS	PH.D	1978
FRANCIS	ROBERT JOHN	M.SC	1968
FREUND	JOHN TERENCE	PH.D	1977
HEADLAND	MICHAEL	M.SC	1976
JAMES	MAURICE KEITH	PH.D	1972
KILFOYLE	BRIAN PATRICK	M.SC	1970
SCHAEFFER	ROBERT CARL	PH.D	1970
WILKSCH	PHILIP ANTHONY	PH.D	1976
YUAN FAN FU.	FREDERICK	PH.D	1971

Chapter 6

LIST OF PRIZE WINNERS

Fellow of the Royal Society of London
Fellow of The Australian Academy of Science
1851 Exhibition and Rutherford Scholarships
The Angas Engineering Scholarships
David Sutton Memorial Prize
The John L. Young Scholarship
Philips Prize (Honours Level)
Rhodes Scholarship and
South Australian Scholarship

6.1 FELLOW OF THE ROYAL SOCIETY OF LONDON

BRAGG, William Henry 1907

6.2 FELLOW OF THE AUSTRALIAN ACADEMY OF SCIENCE

GREEN, Herbert Sydney 1954
HUXLEY, Leonard George Holden 1954
HURST, Charles Angas 1972

6.3 1851 EXHIBITION AND RUTHERFORD SCHOLARSHIPS

(Previously known as Science Research Scholarship, Exhibition of 1851 and Royal Commissioners for the Exhibition of 1851.)
KLEEMAN, Richard Daniel 1905
GLASSON, Joseph Leslie 1909
JAUNCEY, George Eric Macdonnel 1912
OLIPHANT, Marcus Lawrence Elwin 1927
BOSWORTH, Richard Charles Leslie 1933
HALL, Barbara Isabelle Herbert 1956
LOHE, Max Adolph 1973
CANT, Anthony 1978

6.4 THE ANGAS ENGINEERING SCHOLARSHIPS

FARR, Clinton Coleridge 1889
BIRKS, Laurence
CHAPPLE, Alfred Equal 1895
CLARK, Edward Vincent 1898
DUFFIELD, Walter Geoffrey 1901

SMITH, Harold Whitemore 1907
ANGWIN, Hugh Thomas Moffit 1911

6.5 DAVID SUTTON MEMORIAL PRIZE

EDWARDS, Phillip Gregory 1983
BAILES, Matthew 1984
SCHOLZ, Timothy Theodore 1985

6.6 THE JOHN L. YOUNG SCHOLARSHIP

GUINAND, Andrew Paul 1933
ALLEN, William Douglas 1935
MERCER, Edgar Howard 1936
SMITH, William Irving Berry 1940
WRIGHT, Jill Dianne 1974

6.7 PHILIPS PRIZE (HONOURS LEVEL)

HARRIES, John Robatban 1963
McAVANEY, Bryant John 1964
COLMAN, Peter Malcolm 1965
LEWIS, Brenton Raymond 1966
URCH, Ian Harald 1967
PARHAM, Richard Trevor 1968
DURDIN, John MacGregor 1969
ROBERTSON, James Gordon
SHACKLEFORD, Peter Ronald James Shared 1970

6.8 RHODES SCHOLARSHIP

JOLLY, Norman William 1904

BROSE, Henry Leopold Adolph 1913

MITTON, Ronald Gladstone 1927

WAGNER, Franz William 1928

GUINAND, Andrew Paul 1934

ALLEN, William Douglas 1937

SEPPELT, Brian Maxwell 1961

WILKINSON, Stephen Kidman 1982

6.9 SOUTH AUSTRALIAN SCHOLARSHIP

BEARE, Thomas Hudson 1879

ROBIN, Percy Ansell 1880

DONALDSON, Arthur 1882

COOKE, William Ernest 1883 (Scholarship waived)

Chapter 7

HOLDERS OF NAMED OFFICES IN THE DEPARTMENT OF PHYSICS THE DEPARTMENT OF MATHEMATICAL PHYSICS AND THE MAWSON INSTITUTE FOR ANTARCTIC RESEARCH

7.1 DEPARTMENT OF PHYSICS

7.1.1 HEAD:

BRAGG, William Henry 1886 - 1908

GRANT, Kerr (acting) 1909 - 1910, 1911 - 1948

HUXLEY, Leonard George Holden 1949 - 1959
TOMLIN, Stanley Gordon (acting) 1960
CARVER, John Henry 1961 - 1972
PRESCOTT, John Russell 1973

7.1.2 CHAIRMAN:

PRESCOTT, John Russell 1974 - 1975
CARVER, John Henry 1976 - 1978
ELFORD, William Graham 1979 - 1985
PRESCOTT, John Russell 1986 -

7.1.3 DEPUTY CHAIRMAN:

CARVER, John Henry 1972 - 1975
SUTTON, David John 1976 - 1978
BLAKE, Alistair Joseph 1979 - 1983
THOMAS, Anthony William 1984 -

7.1.4 ELDER PROFESSORS:

BRAGG, William Henry 1886 - 1908
GRANT, Kerr 1926 - 1948
HUXLEY, Leonard George Holden 1949 - 1959
CARVER, John Henry 1961 - 1978
PRESCOTT, John Russell 1983 -

7.1.5 OTHER PROFESSORS:

LYLE, Thomas Rankine (visiting) 1898
GRANT, Kerr (acting) 1909 - 1910, 1911 - 1925

PRIEST, Herbert James (acting) 1909
BRENNAN, Maxwell Howard 1964 - 1966
JACKA, Frederick John ("Cognate") 1965 -
McCRACKEN, Kenneth Gordon 1965 - 1969
PRESCOTT, John Russell 1971 - 1982
THOMAS, Anthony William 1984 -

7.2 DEPARTMENT OF MATHEMATICAL PHYSICS

7.2.1 HEAD:

GREEN, Herbert Sydney 1951 - 1964
HURST, Charles Angas 1965 - 1966
GREEN, Herbert Sydney 1967 - 1968
HURST, Charles Angas 1969 - 1970
GREEN, Herbert Sydney 1971 - 1972
HURST, Charles Angas 1973

7.2.2 CHAIRMAN:

HURST, Charles Angas 1974
GREEN, Herbert Sydney 1975 - 1976
DODD, Lindsay Richard 1976 - 1978
SZEKERES, Peter 1979 - 1980
HURST, Charles Angas 1981 - 1982
GREEN, Herbert Sydney 1983 - 1984
HURST, Charles Angas 1985 - 1986

7.2.3 DEPUTY CHAIRMAN:

GREEN, Herbert Sydney 1974
DODD, Lindsay Richard 1975 - 1976
GREEN, Herbert Sydney 1977
SZEKERES, Peter 1978
HURST, Charles Angas 1979 - 1980
GREEN, Herbert Sydney 1981 - 1982
DODD, Lindsay Richard 1983 - 1984
SZEKERES, Peter 1985 - 1986

7.2.4 PROFESSORS:

GREEN, Herbert Sydney 1951 -
HURST, Charles Angas 1964 -

7.3 MAWSON INSTITUTE FOR ANTARCTIC RESEARCH

7.3.1 DIRECTOR:

JACKA, Frederick John 1965 -

7.3.2 DEPUTY CHAIRMAN:

SEYMOUR, Patrick William 1974 - 1977

Chapter 8

ACADEMIC STAFF

8.1 PHYSICS STAFF

FROM	TO	SURNAME	OTHER NAMES	SENIOR APPOINTMENT
1875	1885	LAMB	HORACE	*LABORATORY HEAD
1886	1909	BRAGG	WILLIAM HENRY	*ELDER PROFESSOR
1888	1907	CHAPMAN	ROBERT WILLIAM	*LECTURER
1895	1927	ROGERS	ARTHUR LIONEL	*LAB ASSISTANT
1898	1898	LYLE	THOMAS RANKINE	*VISITING PROFESSOR
1900	1901	ALLEN	JAMES BERNARD	*LECTURER
1901	1908	MADSEN	JOHN PERCIVAL VISSING	*LECTURER
1904	1906	KLEEMAN	RICHARD DANIEL	*DEMONSTRATOR
1907	1909	PRIEST	HERBERT JAMES	*ACTING PROFESSOR
1908	1909	GLASSON	JOSEPH LESLIE	*ASSISTANT LECTURER
1909	1946	GRANT	KERR	*ELDER PROFESSOR
1918	1919	SCHNEIDER	WALTER HERMAN	*ASSISTANT LECTURER
1918	1923	CLARK	EDWARD VINCENT	*LECTURER
1918	1919	HURST	WALTER WILLIAM	*ASSISTANT LECTURER
1922	1958	BURDON	ROY STANLEY	*READER
1924	1926	HONNOR	JOHN MORTON	*DEMONSTRATOR

1924	1924	NIETZ	HERBERT WALTER	*DEMONSTRATOR
1925	1963	FULLER	GEORGE RAYNER	*SENIOR LECTURER
1925	1927	STUART	NOEL HARRY	*DEMONSTRATOR
1926	1927	OLIPHANT	MARCUS LAWRENCE ELWIN	*DEMONSTRATOR
1927	1928	WAGNER	FRANZ WILLIAM	*ASST DEMONSTRATOR
1927	1928	WAUCHOPE	FREDERICK JOHN	*DEMONSTRATOR
1928	1932	BOSWORTH	RICHARD CHARLES LESLIE	*DEMONSTRATOR
1928	1929	WIGHT	HUGH HUMPHREY	*DEMONSTRATOR
1928	1928	YOUNG	DONALD SCOTT	*TUTORIAL ASSISTANT
1929	1975	ILIFFE	MICHAEL ISAAC GLOVER	*SENIOR LECTURER
1929	1932	THYER	ROBERT FRANCIS	*DEMONSTRATOR
1933	1934	GUINAND	ANDREW PAUL	*JR DEMONSTRATOR
1933	1935	RANCE	GEORGE HOWE	*JR DEMONSTRATOR
1935	1937	ALLEN	WILLIAM DOUGLAS	*JR DEMONSTRATOR
1936	1936	COX	DAVID WILLIAM	*JR DEMONSTRATOR
1936	1938	MERCER	EDGAR HOWARD	*JR DEMONSTRATOR
1937	1938	LILLYWHITE	JOHN WILSON	*JR DEMONSTRATOR
1937	1939	THOMPSON	ARTHUR MELVILLE	*DEMONSTRATOR
1939	1950	BROOKE	WILLIAM CHARLES ROBERT	*LECTURER
1941	1961	AITCHISON	GORDON JAMES	*SENIOR LECTURER
1941	1941	WHILLAS	JEOFFREY FRENCH	*JR DEMONSTRATOR
1943	1945	CROUCHLEY	JIM	*JR DEMONSTRATOR
1943	1945	EDGAR	ROBERT STEEL	*JR DEMONSTRATOR
1943	1946	MATHER	KEITH BENSON	*LECTURER
1944	1545	COWLEY	JOHN MAXWELL	*JR DEMONSTRATOR
1945	1945	SYMONDS	JOHN LLOYD	*RESEARCH ASSISTANT
1945	1948	TOOZE	MERVYN JOHN	*DEMONSTRATOR
1946	1950	WHITINGTON	BERTRAM	*DEMONSTRATOR
1946	1946	PRESCOTT	JOHN RUSSELL	*DEMONSTRATOR
1946	1947	BUTLER	STUART THOMAS	*DEMONSTRATOR
1946	1947	DAW	FRANCIS ALAN	*DEMONSTRATOR
1946	1946	KEEVES	JOHN PHILIP	*DEMONSTRATOR
1946	1948	NANKIVELL	JOSEPH FRANK	*DEMONSTRATOR
1946	1946	SMITH	JACK EDWIN	*DEMONSTRATOR
1946	1948	WALTON	BRUCE ADRIAN	*DEMONSTRATOR

1947	1949	CANNY	NICHOLAS JOSEPH	*DEMONSTRATOR
1947	1960	CROMPTON	ROBERT WOODHOUSE	*SENIOR LECTURER
1947	-	ELFORD	WILLIAM GRAHAM	*READER
1947	1945	FRY	ROBERT MASON	*DEMONSTRATOR
1947	1948	WORTHLEY	BOYCE WILSON	*P/T LECTURER
1948	1950	ZIESING	GEORGE MURRAY	*RESEARCH ASSISTANT
1948	1948	BOSHER	VICTOR JAMES MARCEL	*P/T LECTURER
1946	1948	DELAND	RAYMOND JAMES	*DEMONSTRATOR
1949	1949	BARTLETT	BRIAH MERVYN	*DEMONSTRATOR
1949	1959	HUXLEY	LEONARD GEORGE HOLDEN	*ELDER PROFESSOR
1949	1949	STEVENSON	DONALD GEORGE	WDEMONSTRFITOR
1949	1949	THOMAS	JOHN ANGUS	*DEMONSTRATOR
1949	1949	VEITCH	LINDSAY GARFIELD	*DENONSTRRTOR
1950	1951	DUNCRIN	ROBERT ALLEN	*DEMONSTRATOR
1950	1950	SHAW	PETER JOHN RANDALL	*DEMONSTRATOR
1950	1980	SUTTON	DAVID JOHN	*READER
1950	1981	TOMLIN	STANLEY GORDON	*READER
1951	1951	BLIGHT	JOHN MALCOLM	*DEMONSTRATOR
1951	1951	ALDERSEY	ALGERNON LUMLEY HAYDON	*DEMONSTRATOR
1951	1951	ELLIS	BRIAN DAVID	*DEMONSTRATOR
1951	1951	HALL	BARBARA ISABELLE HERBERT	*DEMONSTRATOR
1951		MEDLIN	EDWIN HARRY	*READER
1952	1953	MCLEAN	IAN WEYMOUTH	*P/T DEMONSTRATOR
1952	1952	NOGARE	RONALD RAPHAEL DALLE	*P/T DEMONSTRATOR
1952	1953	SMITH	JOHN WILTON	*P/T DEMONSTRATOR
1953	1953	HALE	ROBERT PALMER	*P/T DEMONSTRATOR
1954	1955	ERICSON	LEON GORDON	*P/T DEMONSTRATOR
1954	1954	HASLAM	DENISE ALLISON	*P/T DEMONSTRATOR
1955	1955	GUM	COLIN STANLEY	*DEMONSTRATOR
1955	1955	TAYLOR	WILLIAM HALDANE	*P/T DEMONSTRATOR
1956	1956	BAGOT	CHARLES HERVEY	*P/T DEMONSTRATOR
1956	1963	DOWLING	DEAN ROBERT	*DEMONSTRATOR
1956	1958	ROPER	ROBERT GEORGE	*DENONSTRATOR
1957	1961	METCHNIK	VICTOR IVOR	*SR DEMONSTRATOR
1958	1959	MCGEE	COLIN RAYMOND	*DEMONSTRATOR

1959		BEVAN	ARTHUR REGINALD	*SENIOR LECTURER
1959	1967	KEMPSTER	CHARLES JOHN EDGAR	*LECTURER
1959	1969	LAWRANCE	ROBERT	*SENIOR LECTURER
1960		ERICSON	LEON GORDON	*SENIOR LECTURER
1960	1961	WHITE	ROY EDWIN	*DEMONSTRATOR
1961	1971	BASTIAN	ALAN CHARLTON	*DEMONSTRATOR
1961	1978	CARVER	JOHN HENRY	*ELDER PROFESSOR
1962	1962	BELL	ROGER ALISTAIR	*LECTURER
1962	1984	BRIGGS	BASIL HUGH	*READER
1962	1964	CATCHPOOLE	JOHN ROGER	*DEMONSTRATOR
1962	1966	MURRAY	ERIC LIONEL	*LECTURER
1962	1962	SMITH	DAVID AITCHISON	*DEMONSTRATOR
1963	1963	CAMPBELL	ROBERT DEAN	*DEMONSTRATOR
1963	1984	HORTON	BRIAN HENRY	*SENIOR LECTURER
1963	1965	WEIGOLD	ERICH	*LECTURER
1964	1964	BURROWS	KEITH	*LECTURER
1964	1966	BRENNAN	MAXWELL HOWARD	*PROFESSOR
1964	1967	EDWARDS	PAUL JULIAN	*LECTURER
1964	-	GREGORY	ALAN GOWER	*SENIOR LECTURER
1964	1965	MERRY	RAYMOND WAYNE	*DEMONSTRATOR
1964	1964	WILKSCH	MICHAEL VINCENT	*DEMONSTRATOR
1965		JACKA	FREDERICK JOHN	*'COGNATE' PROFESSOR
1965	1966	FLETCHER	JOHN	*LECTURER
1965	1967	LOKAN	KEITH HENRY	*SENIOR LECTURER
1965		MACKENZIE	EUAN CHISHOLM	*SENIOR LECTURER
1965	1969	MCCRACKEN	KENNETH GORDON	*PROFESSOR
1965	1968	WALTER	BRYAN ROBERT	*DEMONSTRATOR
1966	1971	GARTRELL	GRANT	*DEMONSTRATOR
1966	1967	GOUGH	PAUL LANCELOT	*DEMONSTRATOR
1966		MCCOY	DONALD GEORGE	*SENIOR LECTURER
1966	1967	MITCHELL	PETER	*TEMP LECTURER
1967	1973	DENNISON	PAUL ANTHONY	*LECTURER
1967	1967	HADDAD	GERALD NEIL	*TEMP LECTURER
1967		TOROP	LEE WALTER	*SENIOR LECTURER
1968	1971	BARTUSEK	KAREL	*DEMONSTRATOR

1968	1969	NILSSON	CARL SIGURD	*LECTURER
1968		PATTERSON	JOHN RAYDEN	*SENIOR LECTURER
1969	1971	BUCKLEY	RICHARD	*P/T LECTURER
1969	1969	BUTTERFIELD	ANTHONY WILLIAM	*DEMONSTRATOR
1970	1971	DAVISON	PETER JAMES NEIL	*TEMP LECTURER
1970		BLAKE	ALISTAIR JOSEPH	*READER
1970	1971	SMITH	ROGER NEVILLE EARL	*DEMONSTRATOR
1971	1972	FABIAN	WERNER	*DEMONSTRATOR
1971	1974	LEWIS	BRENTON RAYMOND	*TEACHING FELLOW
1971		PRESCOTT	JOHN RUSSELL	*ELDER PROFESSOR
1972	1972	BROWN	NICHOLAS	*DEMONSTRATOR
1972	1974	OBRIEN	RICHARD SEARCEY	*DEMONSTRATOR
1973	1973	BOWER	ANTHONY RICHARD DAVID	*DEMONSTRATOR
1973	1973	BOHM	ROBERT ROMAN	*DEMONSTRATOR
1973	1973	LINDNER	BERNARD CRAWFORD	*DEMONSTRATOR
1974		CLAY	ROGER WILLIAM	*SENIOR LECTURER
1974	1975	FIELD	DONALD WILLIAM	*SR TEACHING FELLOW
1974	1974	HOLMES	NIGEL ERIC	*DEMONSTRATOR
1974	1977	STUBBS	THOMAS JOHN	*SR TEACHING FELLOW
1974		VINCENT	ROBERT ALAN	*READER
1975	1977	BIBBO	GIOVANNI	*TUTOR
1975	1975	CHAMBERLAIN	MALCOLM TREVOR	*TUTOR
1975	1978	LINDEMANS	WILLEM	*TUTOR
1976	1976	ILYAS	MOHAMMED	*TUTOR
1977	1979	GIGNEY	DAVID ALBERT MORRIS	*TUTOR
1978	1979	HOBBS	TREVOR IAN	*TUTOR
1979		ROBERTSON	GILLIAN BARNARD	*P/T DEMONSTRATOR
1979		JOHNSON	EDWIN RICHARD	*P/T DEMONSTRATOR
1979	1979	YOUNG	STUART ASHLEIGH	*TUTOR
1980	1984	THORNTON	GREGORY JOHN	*TUTOR
1980		ROBERTSON	DAVID STIRLING	*P/T DEMONSTRATOR
1980	1982	WILKSCH	PHILLIP ANTHONY	*TUTOR
1981	1981	PARHAM	RICHARD TREVOR	*P/T LECTURER
1981	1984	CRAIG	RONALD LEEDSMAN	*TUTOR
1982		HIRSCH	ERNEST HERMANN	*VIS RESEARCH FELLOW

1983		HOCKING	WAYNE KEITH	*LECTURER
1983		PROTHEROE	RAYMOND JOHN	*P/T LECTURER
1983		HUTTON	JOHN THOMAS	*VIS RESEARCH FELLOW
1983	1983	GRISOGONO	ANNEMARIE	*TUTOR
1983		POLLARD	JUDITH MARY	*P/T LECTURER
1983	1983	CAMPBELL	LAURENCE	*TUTOR
1984		THOMAS	ANTHONY WILLIAM	*PROFESSOR
1985	1988	BRIGGS	KEITH MARTIN	*TUTOR
1985		WARDILL	PAUL	*TUTOR
1985		CREWTHER	RODNEY JAMES	*LECTURER

8.2 MATHEMATICAL PHYSICS STAFF

FROM	TO	SURNAME	OTHER NAMES	SENIOR APPOINTMENT
1951	1953	MESSEL	HARRY	*SENIOR LECTURER
1951	1985	GREEN	HERBERT SYDNEY	*PROFESSOR
1952	1953	BERGMANN	CTTO	*TEMP LECTURER
1954	1955	WARD	JOHN CLIVE	*SENIOR LECTURER
1957		HURST	CHARLES ANGAS	*PROFESSOR
1960	1963	MCCARTHY	IAN ELLERY	*LECTURER
1963	1968	SEYMOUR	PATRICK WILLIAM	*READER
1966	1969	COHEN	HARVEY A.	*TEMP LECTURER
1968		DODD	LINDSAY RICHARD	*READER
1971		SZEKERES	PETER	*SENIOR LECTURER

8.3 MAWSON INSTITUTE STAFF

FROM	TO	SURNAME	OTHER NAMES	SENIOR APPOINTMENT
1965		JACKA	FREDERICK JOHN	*DIRECTOR
1967		CREIGHTON	DONALD FRANCIS	*ENGINEER
1969	1977	SEYMOUR	PATRICK WILLIAM	*READER
1978	1981	REID	IVAN DONALD	*POST DOCTORATE FELLOW