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DEPARTMENT OF EDUCATION, N.S.W.

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REF. NO. _____

Dear Lewis,

You may like to have a copy of this for the Departments' files.

Yours sincerely,

H. Lewis

THE FIRST HUNDRED YEARS OF MATHEMATICS

I. S. Turner

I.

October 13, 1852:

"Went to a lecture at 10 with Mr Pell who amused as well as instructed, think I shall like him...."

This statement, Mr Chancellor, Ladies and Gentlemen, is an entry from the diary of W. C. Windeyer (later Mr Justice Windeyer and Chancellor of the University in 1895), one of the students in the first Mathematics class held in the University of Sydney. For it I am indebted to the writer's grandson, Mr W. J. V. Windeyer.

Unfortunately the diary does not give us any personal account of Professor Pell, the first Professor of Mathematics in the University, nor does it give us any details of those early lectures in Mathematics. But it does fix for us the date of the first lecture in Mathematics, and by a happy chance we are meeting on the exact centenary of that lecture. True, Mr Pell had met the class of twenty-four students the day before, October 12, 1852, but on that occasion he merely outlined to them what they would be doing; he did not give them a lecture.

This evening our purpose is to commemorate the centenary of mathematical work in this University and to trace its development through its first century. So this meeting is a kind of epilogue to the splendid ceremonies with which in August the University as a whole commemorated the centenary. It is the result of co-operation between the Mathematical Association of New South Wales and the Department of Mathematics in the University.

We may be sure that the founders of the University of Sydney a hundred years ago were men of vision and wisdom. But they displayed these qualities nowhere more strikingly than in the qualifications they prescribed for their first professors, including the Professor of Mathematics. The first Provost and Vice-Provost of the University, in association with the Colonial Secretary, wrote to the Selection Committee in England:

> We consider it most important that the Classical and Mathematical Professors should bring with them the prestige or high academic distinction at one of the universities of Oxford or Cambridge. And we hope we

> shall not inconveniently fetter your choice by confining it to first-class men at either University in Classics, and the first ten wranglers in Mathematics at the University of Cambridge. We also think it important that the gentlemen should be Masters of Arts of not more than six years' standing, and that there should have been no material interruption to the pursuit of their academical studies up to the time of their appointment by you.

Throughout the first century of its history the Mathematics Department of the University of Sydney has been staffed in a manner which has more than fulfilled the expressed wishes of the writers of that letter. The connexion with Cambridge has been preserved not only without interruption throughout the period, but also with a measure of distinction which could not but satisfy the highest aspirations of the founding fathers. Not only has every Professor of Mathematics in the University been a young first-class graduate of Cambridge University, but so have been also all the permanent lecturers and a good proportion of the temporary and part-time lecturers who have served in the Department since 1852. In particular, the association with St John's College, Cambridge, has been very close since four of the five full professors and many of the lecturers have been Johnians.

It will be convenient to survey the development of the Department in four periods, each corresponding to the tenure of office of the four heads of the Mathematics Department during its first century. The first period, 1852-1877, covers the work of Professor Pell; the second period, 1877-1902, that of Professor Gurney; the third period, 1903-1935, that of Professor Carslaw; the fourth period, 1935-1952, that of Professors Room and Bullen.

Before discussing Pell's work it may be of interest to interpolate the names of the very first aspirants to become teachers of Mathematics in this University. It had been originally planned to open the University, or at any rate a University College, in 1851, and to that end applications were called for the position of Lecturer in Mathematics. Five persons applied for the position, namely:

> The Reverend H. Carmichael, M.A. (St Andrews), who was brought to Sydney by Dr Dunmore Lang to teach in the Australian College;
>
> The Reverend T. Aitken, M.A. (Glasgow), Headmaster of the Normal Institution, Elizabeth Street, Sydney;
>
> The Reverend T. Makinson, M.A. (Cantab.), a teacher in St Mary's Seminary;

The Reverend H. Porter, B.A. (Cantab.);
Mr J. M. O'Brien.

Incidentally the schools mentioned were the principal secondary schools in the colony at that time.

The Selection Committee reported that Porter, Makinson and a new candidate, Kempster Knapp, were, in that order, the most suitable candidates.

But that project was abandoned. If any of these gentlemen did apply in the next year for the Professorship of Mathematics they certainly had not the quality to challenge Pell.

Morris Birkbeck Pell was, as his second Christian name suggests, a descendant of the Birkbeck who founded the first Mechanics Institute in England, later to become Birkbeck College, University of London. He was born in Albion, Illinois, U.S.A., went to England during his later adolescence and entered St John's College, Cambridge, as a sizar in 1845. He graduated Senior Wrangler in 1849, was elected to a Fellowship at John's which he relinquished on marriage (as was the custom in those days).

He was evidently an adventurous young man for he responded to the call for staff for the proposed new University in Sydney, and among twenty-six applicants was chosen for the first Chair of Mathematics and Natural Philosophy in the University. The selectors were Sir John Herschel, Sir George Airey, the Astronomer Royal, Professor Maldon of University College, London, and Henry Denison, formerly Fellow of All Souls' College, Oxford.

When his work began in 1852 Pell found a University with twenty-four students, all of whom were required to take Mathematics for three years. When he retired in 1877 there were still only fifty-eight students in the University, and they all had to take Mathematics for at least two years.

The mathematical background of Pell's first students was not such as to offer him any challenge: for matriculation, the requirements were the four rules of Arithmetic, Algebra to simple equations in one unknown, the first book of Euclid. The reason for this low standard was the lack of suitable secondary schools in the colony.

From that start he planned to get students who sought

a pass degree in three years to the stage where they would understand the harder rules of Arithmetic, Algebra to quadratics, and the first four books of Euclid - work at about the level of the school Intermediate Certificate examination in Mathematics I and II in 1952.

Pell offered more difficult work for the abler students who took scholarship examinations in the first, fourth and seventh terms of their course, and for candidates reading for a degree in honours. In these more advanced courses he had an opportunity to display his considerable talent for teaching. For these lectures, owing to lack of textbooks, he had to prepare his own lecture notes on the differential and integral calculus, probabilities, etc., and distribute them to the students. During the first period of its history twenty students were awarded first-class honours in Mathematics.

One of his practices in examining has some interest.

> To candidates for honours at the B.A. degree he was wont to give on each of two successive days a paper with which they began at half past nine in the morning, and which they were at liberty to struggle with till the shades of evening compelled them to retire - a cold collation being allowed to any whose spirit might be willing, but whose flesh was weak.

However, as I said, there was little challenge in this work for one of Pell's ability, but it would seem to have left him with opportunities for doing original work. This he did in small measure, though in a branch of mathematics - actuarial mathematics - which he had not studied before. He became associated, as consultant, with a leading assurance company, and wrote several papers over a number of years on actuarial subjects. He drafted the first table of premium rates for endowment assurances and constructed what is believed to be the first life table based on Australian experience. Three or four such papers and a few public addresses represent his total direct contribution to mathematics. Otherwise, his time was spent in work related to the development of the new university, to service on public commissions - the most notable being the first Hunter River Flood Prevention Commission (as Chairman), and the Water and Sewerage Commission (as member) - as a witness before the Commission on Education in 1856 and, as mentioned before, as consulting actuary. He also became a member of the New South Wales Bar in 1863, though there is no evidence that he practised as a barrister.

In 1863 he met with a serious accident resulting in an

injury to his spine from which he suffered progressively until it forced his retirement in 1877 and led to his death in 1879 in his early fifties.

An important precedent, which his successors have willingly continued, was set by Pell - namely, his intense interest in and contribution to the development of secondary education and the improved place of mathematics in secondary schools.

In evidence before the Commission just referred to, Pell revealed that at the time (1856), in the 202 schools in the colony arithmetic was taught in all, but algebra and geometry were taught in only seven. Less than 400 pupils out of about 4,700 had any knowledge of 'higher' mathematics (elementary algebra and geometry) and less than 1,000 pupils could work sums involving the compound rules in arithmetic. He urged the Commission to recommend the establishment of a secondary school of the English grammar school type, maintained out of taxation, free from any major religious influence, with a staff appointed by the Government, and an elected body of trustees. No doubt this is the reason why in the Sydney Grammar School soon thereafter to be founded on this pattern the professor of Mathematics became, and is to this day, ex officio a trustee of the school. He also advocated that a system of scholarships should be instituted.

In 1867 the Junior and Senior Public examinations were introduced, and they continued until the changes in secondary education initiated by Peter Board early in the twentieth century led to their replacement by the Intermediate and Leaving Certificate examinations conducted by the Department of Education. Up till 1867 all students had taken mathematics as a compulsory subject at the University. Some election of subjects became possible with the introduction of the Junior and Senior, but mathematics continued to be a compulsory University subject, at least in the first two years of the course, until after the establishment of the Faculty of Science in 1882.

As a final word about this first period let us recall the simple standard of work required for the first degree examination in Mathematics in 1855, and contrast it with the following subjects required for the B.A. degree in 1876, Pell's last year: Conic Sections, Differential and Integral Calculus, Dynamics, Algebra - Higher Part, Trigonometry. Unfortunately the examination papers for this year are not available for comparison with the first degree papers.

II.

The second professor of Mathematics, Theodore Thomas Gurney, satisfied on appointment the high standard that had been set by the committee who selected his predecessor, Pell. He came of a mathematical family, both his father and grandfather having been students before him at St John's College, Cambridge, and both wranglers. On entering John's from school he was awarded an Entrance Scholarship in Mathematics to which was quickly added a Foundation Scholarship of his College and, later, the coveted University Bell Scholarship for Mathematics. He graduated in 1873 as third wrangler, immediately became a Fellow of the College and remained on in John's as tutor until he married. He came to Australia in 1877.

However, in Australia he did not fulfil the promise which his undergraduate performances had foreshadowed. In fact after occupying the Chair of Mathematics in this University for twenty-five years he had done no original work, and his lack of creative enterprise in mathematics led the local authorities, when seeking his successor, to write in these terms to Sir Joseph Larmor, a member of the Selection Committee:

> There is very considerable activity in all other branches of Science here (i.e., at Sydney), but research in mathematical matters is absolutely non-existent. The present professor, Gurney of your College, has held the Chair for 25 years. Mentally equipped with every gift except ambition, he has, as you know, never published a line...
>
> (Quoted from a letter in the library of St John's College, Cambridge, kindly sent to me by the Librarian of the College.)

Since the size of the University was still very small during much of Gurney's time pressure of teaching duties could not be advanced as a reason for his inactivity. As part compensation, he did take some active part in the life of the young University. He was a member of Senate and of University committees; with his wife he was very active in the work and negotiations which led to the founding of the Women's College; and with Professor Warren of Engineering he took a leading part in organizing a University musical society.

By all accounts he was a very shy man and perhaps

this shyness led him to live in a place remote from the University, for the Gurneys lived in a beautiful large stone house, now known as Dalwood Home, on French's Forest Road, Seaforth. How he got from there to the University in those days I do not know. During term time he lived in rooms in the city. Near Dalwood Home is a street named Gurney Crescent, so Gurney would seem to have the distinction, unique so far as I know among Australian mathematicians, of having a street named for him.

The information about Gurney is mainly anecdotal. He was said to have been a good lecturer who took some pains to use teaching aids in applied mathematics or natural philosophy as it was then called, and some of these aids are still thought to be in the University, though I could not track them down. Evidently for all his shyness he had some interest in the general education of his students, as this story will illustrate. Sitting at table during a lecture to the honours class of three students one day in 1902, he looked up at one of them and said, "Tivey, have you read the Decameron?" "No, sir." "Well, you should do so; I'll bring my copy along for you to read." And he did so, the edition being the unexpurgated edition which until very recently has been regarded by the authorities as too strong meat for the modern undergraduate!

Also, he was invited on one occasion to give evidence at a coroner's inquest. In the great fire at Anthony Hordern's emporium, July 10, 1901, a young man was trapped 120 feet from the ground and had to jump, with fatal result. Professor Gurney was asked to explain to the coroner the victim's chances of survival if better rescue means had been available - i.e., better than some sort of sheet held about two feet from the ground. Gurney's evidence, printed in the Sydney Morning Herald of July 26, 1901, was to the effect that the probability of survival under those conditions was very small - surely as striking an example of mathematics applied to a real life (or should I say a real death?) situation as we could wish for!

Although Gurney failed to do research work in mathematics he did not neglect either the development or the teaching of the subject in the University. A comparison of the courses in mathematics offered in 1876, Pell's last year, with those offered in 1902, Gurney's last year, shows considerable growth in content and difficulty.

In that year the Department of Mathematics was providing lecture courses for students in the faculties of Arts, Science and Engineering. There were separate lecture courses in the Faculty of Arts in first, second and third years: in each of first and second years there were courses at three

standards, A, B, C. The B and C courses formed the pass course and were examined in December; the A course was an honours course examined in March. This arrangement of examining the honours course separately in March was continued till 1935. The courses in Science and Engineering were selections from those offered in Arts.

The pass work was examined by three papers in each of first and second years and by four papers in third year: the honours work by four papers in each of first and third year and by five papers in second year.

The first question in the first year Trigonometry paper for 1902 interested me:

Question: What is the thing denoted by π in Trigonometry? Is it an angle or a number?

What answer was required, I wonder?

During this second period twenty-six students graduated with first-class honours in Mathematics.

Some indication of the type of work done by 1902 can be conveyed to members of this audience by the mention of a few of the textbooks set down for study by students in the third year - Todhunter's books on Algebra, Conics, Calculus, Spherical Trigonometry; Charles Smith's Algebra and his Solid Geometry; Edward's Differential and Integral Calculus - a mine of information but not presented rigorously by modern standards - Murray's Differential Equations; Besant's Dynamics; Routh's Analytical Statics; Godfray's Astronomy.

There was still no adequate State-wide secondary education even in 1902 though the establishment of a few State high schools in city and country and the introduction of the Junior and Senior Public Examinations had widened the range of school studies in mathematics, so that entrants to the University came better prepared to undertake more advanced work.

But during this period there was a steady increase in the number of students attending the University - 81 in 1881, 397 in 1891, 244 in 1901. The high enrolment in 1891 included students awarded scholarships by the Department of Education. The overall increase made necessary both an increase in staff and a differentiation of courses. The first lecturer in Mathematics in the University, H. E. Barff, later Registrar of the University, was appointed for one year in 1880. He was succeeded in turn by H. L. P. Elles of Trinity (1881), F. J. Horner of John's (1881-1886), R. G. Goggs of Christ's, Acting

Professor during Gurney's absence abroad in 1884 and Evening Lecturer in 1885.

In 1886 A. Newham, another Johnian, was appointed Assistant Lecturer in Mathematics to take the evening classes and E. M. Moors, M.A., F.I.A., of Melbourne and Cambridge, was appointed Assistant Lecturer in 1887: Newham retired in 1915, Moors in 1918. Gurney, Newham and Moors were the members of staff till Gurney's retirement in 1902.

Newham and Moors will be remembered by many in this audience. By all accounts they were both fine lecturers.

Moors was an actuary who was consultant to assurance companies. His published papers are all devoted to actuarial subjects. He has earned the gratitude of many in this audience through his pioneering work connected with State superannuation in New South Wales. His concept of "units of contribution", which forms the basis of this scheme, was, I understand, quite new in actuarial mathematics. He had more than a passing interest in astronomy, and arranged for a six-inch telescope to be set up in the middle of the Quadrangle housed in a hut for observatory.

Gurney's failure to do research in mathematics meant that the Department of Mathematics had not acquired (or earned) a reputation abroad by the end of its first half-century.

But his very inactivity had this value that it made the University authorities aware that they should seek a successor who not only had done brilliantly in mathematical studies during his period of training at the University, but had already shown his capacity for creative work in mathematics.

III.

So the Department entered the third period of its history (1903-1935) with the appointment in 1903 of a Scot, Horatio Scott Carslaw, known well and affectionately to a good many in this audience. Before coming to Sydney Carslaw had had a wide training in mathematics. He entered Emmanuel College, Cambridge, as a graduate of Glasgow and was in due course placed fourth wrangler in mathematics in 1894. He was elected a Fellow of Emmanuel College and pursued his studies abroad in Italy and Germany. Returning to Scotland he was appointed Lecturer in Mathematics in the University of Glasgow, and also - what became of the greatest significance for New South Wales - an inspector of mathematics in secondary

schools in the adjoining counties. Thus he came to Sydney with a fine record of research and well equipped to continue his researches, with experience in lecturing at the University level, and with an understanding and appreciation of mathematics in the schools. Throughout his long career at the University Professor Carslaw continued to combine successfully these three functions - research, lecturing, interest in developments in school mathematics and in secondary education generally.

In due course as a result of Professor Carslaw's personal researches, by the publication of his treatises on advanced mathematical subjects, especially on Fourier's Series, and by the quality of the work which some of the graduates from his department began to do, the reputation of the Department of Mathematics achieved world recognition.

During the earlier part of his professorship the mathematics staff of the University consisted of Carslaw, Moors and Newham.

It was fortunate that a munificent bequest by Thomas Barker in 1853 began to make available travelling scholarships in mathematics shortly after Carslaw came to Sydney: for thus a succession of able students already well prepared in this University was given the opportunity to pursue their mathematical studies abroad. All of these Barker Scholars except one went on to further study at Cambridge, though Carslaw did not insist on them all going to Emmanuel. Thus was kept alive the close association between the Mathematics Department and the University of Cambridge to which I have already referred. The exception, by the way, was Professor Simmonds of the University of Queensland, who went to Columbia. Professor Carslaw's kindness, encouragement and help to these students when going abroad is one of the cherished memories of each of them.

The two first Barker graduate scholars were E. M. Wellish (1907) and R. J. Lyons (1908) who, after gaining experience elsewhere, returned to the staff of the University in 1915 and 1914 respectively. H. H. Thorne, the Barker Scholar for 1914, whose son R. C. Thorne was also the Barker Graduate Scholar in 1950, joined them in 1920 after experience in aircraft design at Farnborough during the first World War and as lecturer in mathematics at the Sydney Technical College. The four of them, Carslaw, Wellish, Lyons, Thorne, formed the permanent staff of the department till Professor Carslaw's retirement early in 1935. Each of them served the University for over thirty years.

The majority of us in this hall have occasion to know of the work of these four men through their University teaching and especially through the prominent part they played in the development of school mathematics in this State. As Chairman and/or members of the Syllabus Committees, and as Examiners in Mathematics in the Public Examinations, their names became a household word among students and teachers of mathematics. The mathematics syllabuses which were prepared from time to time under their leadership reflected changes in the teaching of the subject which were reported at intervals in the important reports of our parent Mathematical Association. Teachers of mathematics in this State have always responded well to these changes in curricula; that they have done so is in large measure due to the able and tactful way in which the Chief Examiners in Mathematics have conducted the negotiations. Perhaps the most lively memories which many of us retain relate to Professor Carslaw's masterly handling of the meetings of the Mathematical Association at which the school examination papers were discussed each year.

I am sure their former colleagues in the Department of Mathematics, as well as the students and teachers present who had the privilege of knowing them, would wish me to make special mention of the work of Professor Wellish and Mr Lyons so recently gone from our midst, who made unique contributions to the Department of Mathematics and through it to the University for more than thirty years each. I shall do it at this point since the greater part of their service was given in Professor Carslaw's time.

In 1946 Professor Wellish retired after thirty-one years of devoted service to the University and to the cause of mathematical education in this State. As Chairman, for many years, of Syllabus Committees in Mathematics, as Chief Examiner in Mathematics in the public examinations, as member of the Board of Secondary School Studies and as administrative head of the Department during the difficult war years when Professor Room and Mr Lyons were on secondment to national service, Professor Wellish made a contribution to the work of the Department unique in its history for selfless devotion to duty. In the effort involved in keeping so many threads together the opportunities available for his own work were few indeed. His character and sense of duty were such that he judged the sacrifice worth the while in the interests of mathematical education. But sacrifice it surely was, for Professor Wellish was one of the most brilliant graduates of this University. In 1907 he won the first Barker Scholarship from the University of Sydney. Subsequently at Cambridge, where he worked with Sir J. J. Thomson, he was attracted to the problems which physical science constantly places in the lap of the mathematicians, and

he soon drew considerable attention by the quality of his work, one result of which was the award of the coveted Clerk Maxwell Studentship for research in Physics. These achievements led to his appointment as Assistant Professor of Physics at Yale, 1911-1915. But to our great advantage, he returned to Sydney in 1915 and remained in the Department till 1946, with but one short break for sabbatical leave. He died in 1948 after a very brief period of retirement.

Recently on her retirement from the Board of Secondary School Studies I heard Miss F. Cohen pay a special tribute to the outstanding work on that Board of Professor Wellish and the former Secretary, Mr F. Hutchins.

Mr Lyons served the University for thirty-seven years. He joined the staff in 1914 and his connexion with the University was broken only on his death in November, 1951, though he was due to have retired earlier.

Richard Jenkins Lyons in many ways approached the popular idea of a mathematician: that is of one who was in a certain sense unworldly, who could easily absorb himself in the abstract ideas of mathematics - first analysis and later geometry - who loved a problem and could be sure of giving a most elegant solution to it.

On going abroad in 1908 he enrolled at St John's College, Cambridge, and, like Gurney became a Foundation Scholar of the College. Graduating with first class honours in 1911, he spent a short period in the University of Queensland before returning to his Alma Mater in 1914. Here for years he was known to generations of students for his enthusiasm, for his advanced teaching and for his wide knowledge of and power in analysis. He was known universally and affectionately as Dickie Lyons.

Mr Chancellor, we hear much in these days of the disadvantages of large numbers in the University, especially since this has the effect of making contact between teacher and student so difficult. For that very reason I should like publicly to express my personal gratitude, and I know that I speak for hundreds of others, for the personal interest which members of the staff of the Mathematics Department took in me during my course at the University, and in my subsequent career. It was true of Professor Carslaw that he took the liveliest interest in the problems and welfare of his students. But for me, teacher-student relationships, in the true university sense of association leading to friendship between scholar and teacher, will always be linked with the name of R. J. Lyons. To be ranked as a member of his sailing crew - for he loved sailing

and the sea - to camp with him during vacations and to come under the spell of his devoted Christianity, to listen while his mind sought the great mathematical truths, to learn from him veneration of the great masters of our science, later in 1926 to walk with him almost daily in the late evening in the fields near Cambridge during his year of sabbatical leave, even to come under censure from him for shoddy thinking, these were privileges which he granted to one who came to the University with no record of distinction in mathematics. Certainly he inspired in that person something of the passion for mathematics which he himself had in such measure.

We have yet to give an account of the great progress made in mathematical studies at the University under Professor Carslaw. To do so it will be necessary briefly to recall some landmarks in the history of mathematics during the eighteenth, nineteenth and twentieth centuries. In this way we shall the more easily be able to place in perspective the contributions of Professor Carslaw and his successors in the Mathematics Department during the second half of its first century; and also to appreciate the necessity for the great expansion in the University courses in mathematics which this half-century has seen.

Cantor, the great historian of mathematics, has compressed into four large volumes the story of the growth of mathematics from the beginning of its history to the end of the eighteenth century. It has been estimated that, using similar compression, it would require fourteen or fifteen volumes of equal size to record the growth of mathematics in the nineteenth century alone. Add to this a statement by Professor Room that between the two latest International Congresses in Mathematics in 1936 and 1950 there has come across the face of mathematics a change as profound and fundamental as that produced in a few years during the Newtonian era and it becomes obvious that it is no longer possible for a mathematician to be competent in or to contribute to the whole range of mathematical studies. Gauss did it in the mid-nineteenth century, but Poincaré, who died in 1913, is said to have been the last universalist in mathematics.

Besides seeing the working-out of the consequences of the Newtonian system of mechanics, and the expansion of great branches of mathematics already well established (theory of numbers, analytical mechanics, calculus) the eighteenth century produced new branches of mathematics, among them actuarial mathematics, calculus of variations, finite differences, descriptive geometry, differential geometry. I mention these because some of them evidently attracted Pell's notice: we find

reference in his honours lecture courses to the calculus of variations, and his creative work related to actuarial mathematics and finite differences.

Nineteenth century mathematicians not only built rapidly on the foundations laid by their predecessors but also, as I have said, initiated many new branches of mathematics. One of these, non-Euclidean geometry, discovered in the early nineteenth century by Lobetchevsky and Bolyai independently, but known also to Gauss, was one of those "major revolutions in all thought" which someone has said changed our "whole outlook on deductive reasoning". This revolution in thought gave prominence to the postulational method which has become an extremely powerful method in the modern abstract aspects of mathematics. It has especially influenced modern geometers and algebraists. Problems in Science, especially in physical science, have always provided a stimulus to mathematical growth and vigour. The earlier study of vibrations and of other physical problems led to the formulation of differential equations, the solution of which led gradually to the recognition and isolation of a number of special mathematical functions, like Bessel's Function, and to the exploration of their properties. A profitable method of discussing mathematically physical problems on which may be imposed what are called boundary conditions, was developed by Fourier, and many mathematicians who received their training in the later part of the nineteenth century came to examine and to learn to apply this powerful instrument.

Furthermore, rigour came into mathematical argument through the work of Cauchy, Weiertrass and others who founded the branch of mathematics we call analysis.

The twentieth century has seen a tremendous growth in abstraction and generalization in the field of pure mathematics, often through the application of the postulational method; abstract algebra and topology vie with each other for the attention of geometers. In the field of applied mathematics new mathematical methods have been evolved - quantum theory, relativity, wave mechanics - which make possible a more profound mathematical attack on a wider range of physical problems than was heretofore possible. This century has seen also the growth of mathematical statistics and their application in all branches of science, and the renewal of interest in computation which has resulted in the compilation of magnificent tables of a wide variety of mathematical functions, and in the devising of great machines to do the necessary computations.

Reference is made to these nineteenth and twentieth century discoveries and developments - non-Euclidean geometry,

functions arising from physical problems, Fourier's Series, Analysis, Geometry, etc. - because these are the branches of mathematics in one or more of which members of the Department of Mathematics of this University have made their original contributions.

Professor Carslaw made his principal contributions to the theory of Fourier's Series and their application in the mathematical theory of the conduction of heat and in the rigorous formulation of the underlying theory using the methods of Analysis; in the exposition of non-Euclidean geometry; in the development of operational methods in Mathematical Physics; in numerous papers on a wide range of mathematical subjects as far apart as a splendid commemorative account of the discovery of logarithms by Napier and a series of papers on the basis of income tax assessment.

Nor did he hesitate to use his influence in the cause of mathematical education and of secondary and tertiary education generally. Indeed the earliest papers he wrote in Australia bear titles such as "The Teaching of Geometry", "The University and the Schools", "Education in Australia".

For his distinguished contributions he was awarded the degree of Doctor of Science by the University of Cambridge.

Professor Wellish and Mr Thorne were interested in applied mathematics and they contributed, as I have said, to the solution of problems posed by theoretical physics and the new science of aeronautics respectively. Since Professor Carslaw's interests did not include the more modern abstract geometry, he asked Mr Lyons to make a study of geometry during his sabbatical year in 1926. This Lyons did and it is in this field that he made his own elegant contributions.

During the major part of the third period (1903-1934) the mathematics courses were organized in a fairly standard way. There was a pass course in first, second and third years examined in November. The first and second years of this course became a kind of service course for engineers and for students of other faculties who used mathematics only as a tool subject. The first year course became fairly standardized to include Differential and Integral Calculus, some Algebra, Conic Sections and the Elements of Statics and Dynamics. The second year course carried the Calculus further, introduced Differential Equations and extended the work in Mechanics. More variation was introduced into the third year courses, though the basic studies were analytical geometry of three dimensions, differential equations, mechanics. The variants included some consideration of special functions, introductory analysis, differential geometry.

There was a three-year honours course also leading to an honours degree. A separate distinction class was formed in each of the three years, an honours degree being awarded at the end of three years on the cumulative record of the students. The honours course in third year reflected especially the staff's interest in and awareness of developments in mathematics, and there was opportunity to specialize to some extent in either the pure or the applied side. The quality of the work done was such that the better graduates going abroad could expect to do well in the Mathematical Tripos in Cambridge after two years of further study or even to begin research work at once for a Ph.D. degree. During this period 82 students - 28 in Arts, 54 in Science - graduated with first-class honours in mathematics.

Professor Carslaw kept closely in touch with mathematicians overseas, and no doubt exchanged views on what topics were currently being taught in universities in other countries. He had a delightful and stimulating practice of passing on to his classes scraps of information from letters he had received: and it added interest to know that he was in correspondence with Lamb or Forsyth or Whittaker or Hardy or a Continental mathematician whose text we were currently using.

It is just to say that within the limits set by a small staff with heavy lecture load and heavier examining duties, both for schools and university, the quality of mathematics taught in the University was high during this period. Further progress could only be made when staff was increased and the course of study lengthened. These changes have come during the fourth period.

IV.

The fourth period, fortunately still not ended, dates from Professor Carslaw's retirement at the beginning of 1935 and Professor Room's appointment in August, 1935.

It is a period in which, as I have said, the world reputation already won for the Department by Professor Carslaw and his colleagues and students has been maintained and even enhanced. The Department has expanded considerably during the post-war years. The present establishment is two professors, seven lecturers and senior lecturers, three teaching fellows, two secretaries, though this establishment is still small when compared with that in the Mathematics Departments, of great universities overseas. At the end of the first century mathematical work in the University has been organized under a "Board of Mathematical Studies" within which two Departments separately administered - the Department of Pure Mathematics

under Professor Room, the Department of Applied Mathematics under Professor Bullen - have already been organized, and a Department of Statistics approved but not yet organized. In making this separation the University has followed the practice of the major universities of the world, and has given recognition, in the centenary year, to the staggering extent of present-day mathematical knowledge which makes inevitable some division of mathematical studies even at the undergraduate level.

T. G. Room, the third Johnian to hold the Chair of Mathematics in the University, graduated B.A. with great distinction in Mathematics at the University of Cambridge in 1923. Awarded a Smith's Prize in 1925, he became a Fellow of St John's 1926-1928, was Lecturer in Mathematics in the University of Liverpool 1925-1928, and returned to Cambridge where he was University Lecturer in Mathematics till his appointment to Sydney. He was a distinguished member of what came to be known as Baker's School of Geometry in Cambridge. He has made his principal original contributions to mathematics in the fields of projective and birational geometry with special emphasis on incidence theorems. He is the author of a large standard work on Determinantal Loci. In recognition of the publication of this distinguished research he was elected to a Fellowship of the Royal Society in 1941, and in the same year he was awarded the Lyle Medal. During the war (1941-1945) he, with R. J. Lyons, was seconded for special service with the Central Bureau. In the post-war years, 1948-1949, he went abroad on sabbatical leave to study and teach in universities in the United States, spending some time in the University of Washington, the University of Tennessee, and the Institute of Advanced Study at Princeton. Like all of his predecessors, he has taken over the responsibility of Chief Examiner in Mathematics in the secondary schools of the State.

Significant developments which have occurred so far during the fourth period are as follows: in 1938, the approval and organization of the first four-year honours course which did not really develop fully till 1946, when the first full Mathematics IV course was offered; in this and subsequent honours courses the opportunity has been taken to introduce a wide range of advanced topics in Pure Mathematics; also in 1938, the introduction of mathematical statistics for pass and honours students, given by the late D. T. Sawkins; in 1946 an increase in the lecture time to six hours for the IIIB class, to be spread over two years for evening students, with the consequent introduction of new courses - computation or foundations of geometry, foundations of analysis, matrix algebra, all of great value to future teachers of mathematics; in 1945, the formulation of a definite curriculum for the pass M.A. degree in mathematics; in 1946 the appointment of a full

Professor of Applied Mathematics; in 1952 the reorganization of the Department as already stated.

The Cambridge tradition in mathematics persists in this fourth period. All the staff of the Department appointed to the end of 1951 are Cambridge men, the Barker Scholars and other graduate scholars of the University taking mathematics have studied in Cambridge. But as the century closes that strong Cambridge influence is tempered by the appointment to the staff of a distinguished graduate of Melbourne and Oxford, Dr Westfold, and by the recent visits to the United States of two other members of the staff, Professor Room and Dr Chong.

On Professor Wellish's retirement in 1946 a full Professorship of Applied Mathematics was established and Professor K. E. Bullen was appointed to the Chair after serving a short period as Lecturer in Applied Mathematics in the University of Melbourne. A graduate of the University of New Zealand and for some time a teacher of mathematics in secondary schools in New Zealand, Professor Bullen became interested in the problems of seismology, no doubt because of the intermittent reminders which his native country gave him that there are regions of great instability in the earth's crust. He studied seismological problems with Dr (later Professor) Harold Jeffreys at Cambridge, a leading authority on the mathematics of the earth's interior. Since Dr Jeffreys was a Fellow of St John's College, Cambridge, it was natural that Professor Bullen should go to John's, giving that college, though all unsuspecting at the time, the right subsequently to claim a fourth professor of mathematics in the University of Sydney among its distinguished alumni.

Professor Bullen's studies, alone and in co-operation with Jeffreys, were responsible for great advances in the mathematical treatment of geophysical and seismological problems. From these studies were developed standard seismological tables used by workers in this field. Shortly after his appointment to Sydney Professor Bullen was awarded first the degree of Doctor of Science in the University of Cambridge, and then the coveted Fellowship of the Royal Society for his distinguished contributions to geophysics. His election meant that both Professors of Mathematics in the University were Fellows of the Royal Society, the only two Fellows of that Society on the staff of the University at the moment.

In keeping with the expansion and changing nature of mathematics studied in universities changes have been introduced in applied mathematics. Vector methods were introduced and used in the solution of problems, topics formerly in the honours courses were placed in corresponding pass courses, allowing for a considerable increase in the work of the honours courses.

Cartensian tensors, general dynamics to the Hamilton-Jacobi Theorem, Wave Theory, Quantum Theory, Relativity, Elasticity, became subjects of study as part of the necessary technical equipment of those who would have occasion to use modern mathematical methods in solving problems whether in Geophysics, Theoretical Physics, Engineering, and the hosts of specialized fields which now demand mathematical investigation.

A strong bias is given towards training in scientific method and scientific inference, and it is, in my view, greatly to the advantage of future teachers that in the third year pass course they should come to understand the ideas and problems involved in this important aspect of scientific work, especially when it is presented by a scientist who is interested also in the philosophical foundations of his subject.

To date in the fourth period, thirty-one students have graduated with first-class honours in mathematics, making a total of 159 first-class honours graduates in the first century.

Since the reputation of any university department rests principally on the ability and reputation of its staff and on the influence of its distinguished graduates, I should like to give a brief indication of the success of the Mathematics Department measured in terms of these criteria. As I have said, the professors of mathematics appointed during the twentieth century have built for the Department a world reputation. They have been ably supported in their teaching by a team of lecturers, all of whom have studied mathematics abroad with distinction, and have published work to their credit.

The Department of Mathematics has produced other distinguished mathematicians, four of whom have been appointed to Chairs of Mathematics in other universities. Professor Weatherburn of Vector Analysis fame was for many years Professor of Mathematics in the University of Western Australia; Professor E. M. Simmonds is Professor of Mathematics in the University of Queensland; and recently Professors Jaeger and Moran were appointed as the first Professors of Mathematics in the National University. Professor Jaeger holds the Chair of Geophysics, a just tribute to his versatility as an applied mathematician; Professor Moran holds the Chair of Statistics.

The academic record of the students of the Department of Mathematics who have won graduate scholarships for study abroad is a very creditable one. They number among their company three of the four Professors of Mathematics just mentioned, a Fellow of Trinity, a number of senior lecturers in Mathematics, Physics and Engineering subjects in universities, as well as others whose later career did not run to academic pursuits. The

Department may justly take some reflected glory from the success of its graduates in these other spheres of life. Among these graduates are eminent jurists both State and Federal, schoolmasters and schoolmistresses, engineers, physical scientists, actuaries. We mathematicians and teachers of mathematics like to believe that the training these men and women have received in clear thinking and high thinking in their mathematical studies has contributed in no small measure to their later success. But I am not sure that we could get the warrant of educationists to make so firm a claim.

Among honours graduates who became jurists I shall mention three only - Sir Samuel Griffiths, Dr H. V. Evatt and our distinguished Deputy Chancellor, Mr Justice Roper. Among school men and women, Miss Fanny Cohen, member of the Senate and for many years headmistress of Fort Street Girls' High School, and Mr L. C. Robson, Headmaster of Shore, are distinguished representatives.

At least one of the distinguished graduates in mathematics has become prominent in politics, but we have not had, as England has had, a mathematical Prime Minister - yet. However, current speculation suggests that one distinguished graduate of the Department may be approaching that high office - but whether asymptotically or not, who can say?

So much for a brief statement of the outcome and the present state of mathematical teaching in the University at the end of its first century. There is a temptation, which I am reluctant to resist, to speculate a little on developments in the next century of our history. The history of mathematics warns us that it is foolish to try to predict in what directions and how far the creative imagination of mathematicians will lead them in any given period. So I shall not attempt to predict where mathematics will go in the next hundred years. Consolidation there will be as established methods and techniques are applied to a wider range of problems and in more and more diverse fields of study. But of new ideas - who can say?

However, I would feel reasonably confident in predicting the general shape of that future in so far as it concerns the joint task of teachers of mathematics in schools and in the university.

I have already mentioned the fact of the staggering growth of mathematical knowledge. This has a particular relevance for the teaching of mathematics. At the school level we teachers of mathematics will have to examine our syllabuses critically to see what outmoded topics we can discard to make room for newer and more important topics. And the members of

the University Department will have to suggest other topics to us which are vital in the development of mathematical ideas yet simple enough to be understood by school pupils; and in co-operation we shall have to think out easy approaches to the teaching of these topics. The University will have the further responsibility of ensuring that the mathematical courses taken by our future teachers of mathematics includes the study of these topics, whatever they may be. I am convinced that this can be done, but there is not time nor is this the place to develop these ideas further.

And now I must end. In due course I shall present to the University a full account of the work which I have so briefly surveyed this evening. However, I trust, Mr Chancellor, that I have succeeded in showing that this University has reason to be proud of the standing which its Department of Mathematics has won in the mathematical world in the first century of its life. With its two leaders both elected Fellows of the Royal Society in recognition of distinguished creative work in mathematics, with its staff all brilliant mathematicians with overseas as well as local experience and qualified to stimulate the oncoming generation, with its graduates occupying prominent positions in mathematics and allied studies, the Department is starting on its second century of work and influence full of promise for splendid achievements in the future.

If its rate of growth during its first century is maintained during the second century - one can hardly expect this rate to be excelled - I for one should like to be listening in to what my successor in this role will have to say on October 13, 2052.