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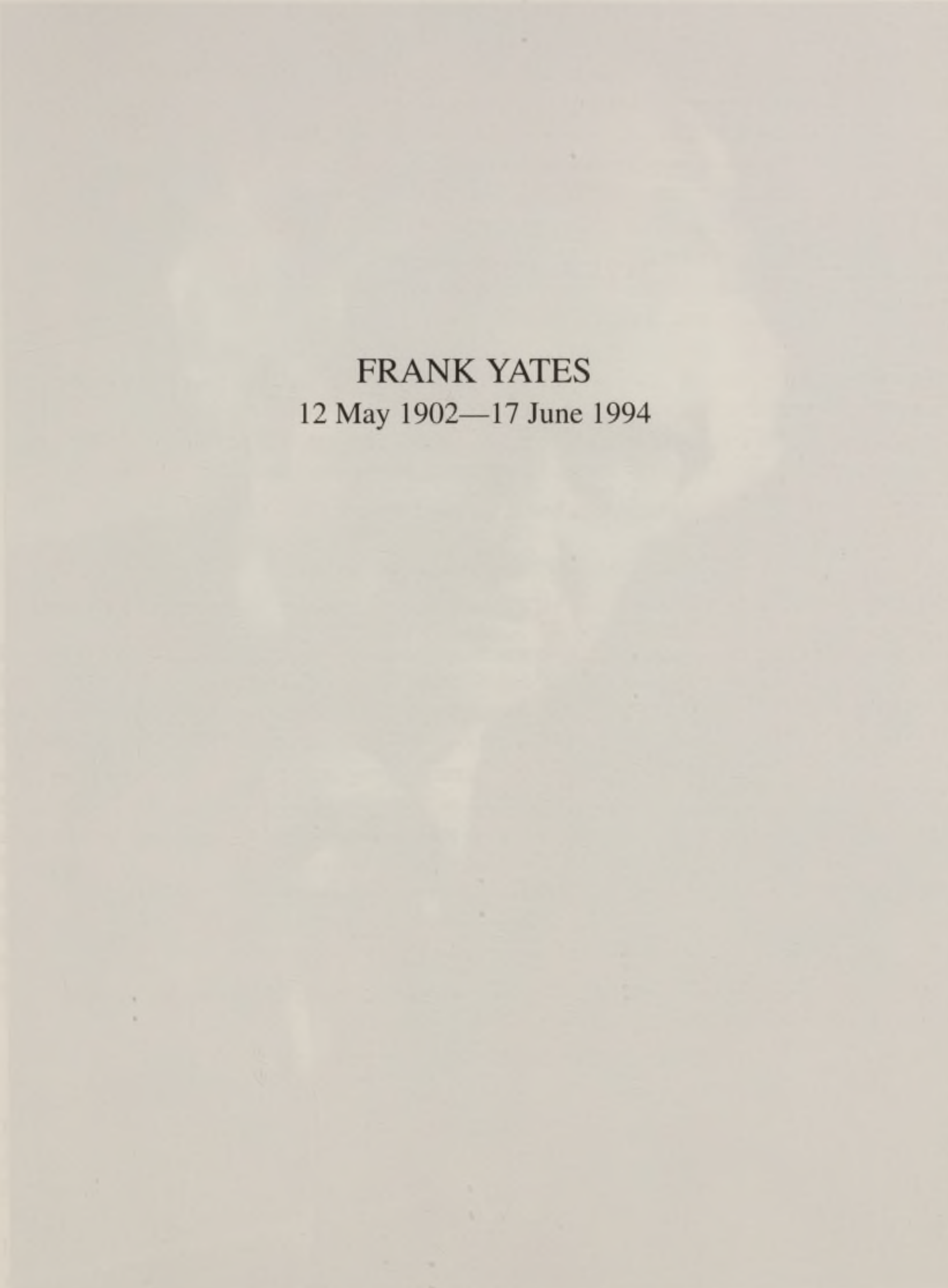

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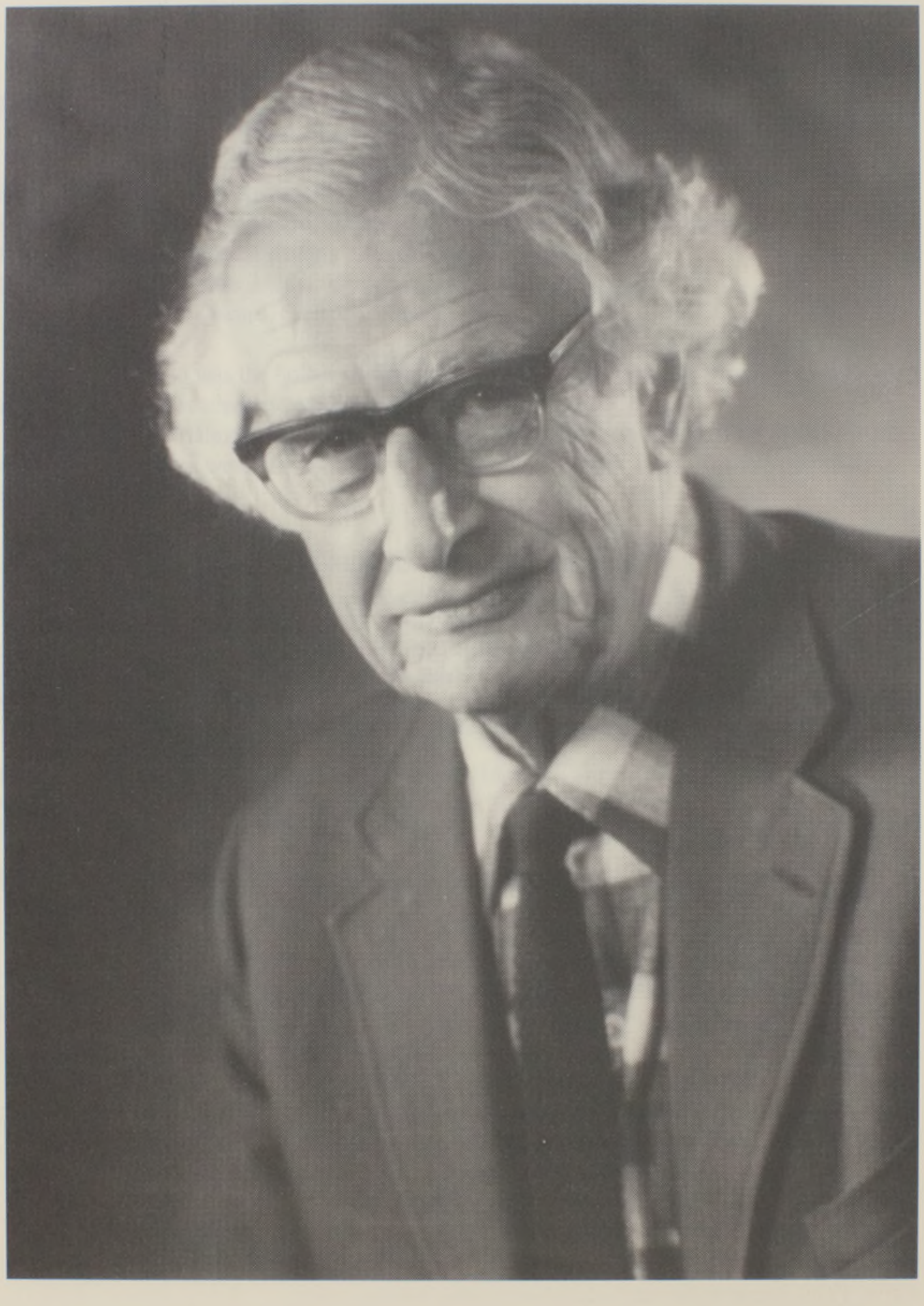

Frank Yates

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INTRODUCTION

FRANK YATES, one of the greatest statistical scientists of his generation, was born on 12 May 1902, the only son of Percy and Edith Yates of Didsbury, Manchester. He had four younger sisters, two of whom, Dr Edna Oakeshott and Mrs Olive Canton, survive him. Percy Yates was educated at Manchester Grammar School, but, partly for health reasons, left when only 16. He eventually became junior partner in the family seed merchant business in Shudehill, Manchester. The firm, founded in 1826 as a retailer, developed into wholesaling and became a supplier to farmers and market gardeners around Manchester; as Samuel Yates Ltd of Macclesfield, it is still trading. Percy was one of five brothers, of whom Harry, the eldest, was the senior partner; two others emigrated to Australia and New Zealand, establishing similar businesses there, which are still in existence. Edith's father, Frank Wright, ran a corn and seed business (now Frank Wright Ltd) in Ashbourne, Derbyshire; for health reasons, he later took a 200-acre dairy farm on the outskirts of Ashbourne.

FAMILY AND EDUCATION

As far as is known, Frank had no family connexions with any form of scientific activity. He recalled that his father had had leanings towards engineering; his uncle Harry, who was always interested in mathematics, once presented Frank with a long-treasured table of five-figure logarithms.

When Frank was two years old, the family moved to a house in Hale, Cheshire; two years later came a move to a somewhat larger house about a mile from the centre of Manchester, in what was then still open country, surrounded by small farms and market gardens. At the age of five, Frank began to attend the kindergarten of Hale High School. Two years later, he was moved to Wadham House (Hale), a private school, where Mr Edwards, the mathematics master, was a good mathematician who appeared to be truly interested in his subject.

Although Percy had intended that his son should later go to Manchester Grammar School, Mr Edwards recognized his mathematical ability, took great pains with Frank, and changed the course of his life by encouraging him to try for a scholarship to Clifton College.

The Yates family was self-contained, for Percy and Edith were not natural social mixers. Living in the country, with an acre of garden, their children lacked friends of a similar age, but were encouraged to develop an interest in garden care. From an early age Frank became interested in mechanical and electrical engineering, helped by his father who supplied him with a small but well-equipped workshop. Between the ages of 10 and 14, he became a railway enthusiast, and spent much time building a model railway, a taste not shared by his sisters. Short sightedness and the consequent poor performance were possibly the cause for lack of interest in formal sports. Recreation came primarily from family country walks and, until his grandfather's death in about 1910, regular and much enjoyed visits to the farm at Ashbourne.

In about 1912, Percy Yates added stabling to the house, and thereafter, until the outbreak of war in 1914, kept a pony and trap; thus began a practice of family country drives, of a kind that could scarcely have become common until the automobile began to change rural life. Holidays were normally taken at small seaside villages in North Wales or in the country.

In 1916, after success in the Scholarship examination, Frank entered Clifton, where he was taught mathematics by Messrs Bevan, Lewis, and Milne. He retained particular respect for the teaching practice whereby the better scholars were placed at the back of the room studying from their textbooks, while the rest of the class were taught more conventionally. He found this an excellent early training in learning to use textbooks intelligently for himself. Clifton evidently acted with care when appointing teachers of mathematics: W.P. Milne, of whom later in life Frank spoke especially highly, had a long career as Professor of Mathematics in the University of Leeds.

Frank's experience of science teaching was less satisfactory. Despite learning a good amount of physics, he considered chemistry disorderly, and requiring a better memory than he believed himself to have. A thermodynamics course was disastrous because the teacher appeared not to know his subject. Because entry to Oxford or Cambridge required Greek, he spent his first two years on the Classics side. When this requirement was removed, he transferred to the Modern side, where science received greater attention. Yet he was convinced that lack of verbal memory rendered him incompetent at language studies, a belief that scarcely worried him when, 40 years later, he found a need to acquire skill in handling computer languages.

Frank enjoyed Clifton. The senior boys were allowed much freedom, especially those in School House under the Headmaster J.A. King. Frank's incompetence at cricket, a game that he detested, allied with a shortage of playing-field space, secured his exemption from organized sports. With one companion, he was instead permitted to take day-long cycle rides into the surrounding countryside. I note with personal sympathy his recorded comment that athletic prowess never diverted his attention from his true interests in mathematics and engineering!

Around 1912, his father began taking Frank on walking expeditions in the Lake District or among the Welsh mountains, thus nurturing a lifelong love of mountains and countryside, and making him a keen observer of nature and wild life. He never studied any botany or zoology, and in retrospect he has described these interests as purely aesthetic. Rock climbing also became an interest, but only in a mild way and within the U.K. Clifton brought him friendship with Basil Goodfellow, whose home was not far from Frank's. Basil was also a climbing enthusiast but with skills that surpassed Frank's and eventually took him to distinction on Himalayan peaks. Mountaineering annals record that, on 7 July 1924, Goodfellow and Yates traversed all tops of Skye's Cuillin Ridge in 16 hours and 52 minutes, under conditions they recorded as: 'Ridge in mist the whole way and rocks wet throughout'. Thirty years later, by which time he could show good-humoured toleration for those of his associates who were cricket enthusiasts, he had the satisfaction of one of his staff being a member of the successful 1953 Everest expedition.

At the annual examination in December 1920, St John's College, Cambridge awarded a Senior Mathematics Scholarship to 'F. Yates of Clifton'. His intention was that in his second year he would transfer from mathematics to engineering. He wanted to spend the early months of 1921 in gaining practical experience, but his father only succeeded in finding him a temporary place in a small gear-cutting firm in Manchester, which proved uninspiring and failed to give him what he really needed.

As to many boys from similar backgrounds, arrival in Cambridge in October 1921 brought Frank a widening of horizons — new interests in literature, art and in psychology. Cambridge mathematics must then have been very different from what I knew 13 years later. For an undergraduate of scholarship standard, the early terms offered little challenge; by his third year, absence of need had caused some staleness. However, the heavy demands on his time that the engineering course involved, not least the interference with his new enthusiasm for rowing, as well as the economically depressed state of engineering at the time, induced him to complete his degree in mathematics; he graduated with first class honours in 1924. Although he had given little hint of the distinguished career that would eventually be his, he was, and remained, an outstanding mathematician who was almost always able to produce a method that would contribute to elucidation of a knotty practical problem but who had no urge to pursue abstract theory for its own sake.

Pure mathematics as taught at the time gave him no suggestion of any connexion with scientific research, nor did his tutor ever suggest that study of applied science might lead him to a research career. He did, indeed, consider taking up statistics, but not surprisingly found the early chapters of Yule's book so dull that he rejected the idea. The College was prepared to continue his Scholarship. An opportunity arose for research into the transmission of ground waves and their effects on buildings, a topic that, doubtless arising from his naturally practical outlook, had some attraction for him: perhaps wisely, and fortunately for statistical science, he declined.

In his second and third years he took up rowing. Although Lady Margaret performance on the river was then at a low ebb, he was a member of the First Boat that had the rare distinction of making an over-bump on the first night of the 1924 Lent Races. He found the hard physical exercise beneficial, and his 1924 commemorative oar always ornamented his home. Cambridge roofs offered opportunities for indulging his favourite form of physical activity. A newspaper photograph records his roped descent from the roof of his College Chapel in order to remove a surplice that others (or possibly Frank himself) had placed around a statue in a niche 130 ft above the ground. He may indeed have been the unidentified 'Frank' whom Whipplesnaith (1937) thanked for cooperation!

In 1938, Frank neatly completed his formal academic qualifications by the award of the Cambridge Sc.D. I remember him telling me that the examiners remarked on the collection of publications that he had submitted as being 'less weighty' than was usual: the number of uncut pages suggested to him that 'weight' might indeed have been a test applied! In 1982, he received his final academic distinction: the University of London conferred on Dr Frank Yates the Degree of Doctor of Science *honoris causa* in recognition of his 'Unique contribution to mathematically designed, computer assisted statistical programmes for scientific experiments, censuses and surveys'. The Public Orator introduced him as 'the *doyen* of the British corps of those statisticians who have devoted their mathematical expertise to the design and the consequential interpretation of scientific experiments'.

Beginning a career

After graduation, Frank took a post as Scholarship Mathematics Master at Malvern College. He did not have the temperament for a life of school mastering, and soon became disenchanted with the stresses of inculcating what he would see as obvious mathematical arguments into minds that lacked motivation for studying them. After two and a half years, he decided against continuing. In 1927, without much consideration but led by a fascination with maps, and after spending a few weeks studying triangulation, he joined the Gold Coast (now Ghana) Geodetic Survey as a research officer and mathematical adviser. Here he had to learn Gaussian least squares, then a standard procedure for surveyors (though scarcely well understood by them) but something a Cambridge degree would not have brought to his notice. He also soon developed the concern for efficient, well-organized, and accurate computation that was to characterize so much of his later scientific activity. Already by 1929 he was showing his potential by publishing three monographs to aid the local application of least squares in connexion with triangulation and traverses.

West African life gave to a conventionally educated young Englishman a taste of a very different world. In 1931, the Gold Coast, although possibly no longer the 'White Man's Grave' of earlier days, was still an unhealthy place in which to live. Despite his fine physique, ill health led Frank to reject an opportunity of transfer to East Africa and to seek a post at home. Chance took a hand in starting him on an unexpectedly different career. As he wrote to me in 1982: 'One of the deciding factors was my first impression of Ron Fisher – in this I was not deceived'.

In 1929, Frank had married Margaret Marsden of Manchester. Their one child was stillborn, and the marriage was dissolved in 1933. He subsequently married Pauline, daughter of Vladimir Shoubersky. They became owners of a house with a large rambling garden at Whipsnade, and Frank's naturally inquiring mind led him into statistical problems of concern to the Zoological Society (113, 134, 135)*. Pauline died in 1976; he later married Ruth Hunt, his invaluable secretary and friend for the previous 30 years, who survives him after giving him superb care during his last years.

Rothamsted

In 1931, fortune smiled on Frank Yates. On his first home leave, at the suggestion of the oft-maligned Cambridge University Appointments Board and despite lacking all formal study of statistics, he had inquired about possible jobs with R.A. Fisher (later Sir Ronald), then at the height of his powers as an original thinker on statistical principles and practice (Box 1978). Fisher appeared to ignore this inquiry, but began to send him reprints of a succession of

*Numbers in this form refer to entries in the bibliography on the accompanying microfiche.

papers that must have seemed to Frank incomprehensibly esoteric. During his second leave he wrote again to Fisher; to his surprise, he was invited to lunch in Harpenden with the somewhat unconventional young Fisher family. After informal interview, and a week in which Fisher 'chewed over' his publications on geodetic survey (1929, 1931), he was offered the post of assistant statistician at Rothamsted Experimental Station in succession to Dr J. Wishart. Frank immediately accepted appointment from 31 August 1931, at a salary of £360 per annum, with the understanding that he could use half his time for his own research.

There is no record of exactly how Frank interpreted the advice from his new employer that he should spend the summer 'reading up what one may call the biometrical side of statistics'; at that time, he knew nothing even of Fisher's *Statistical Methods for Research Workers*. Fisher's letter to him placed special emphasis on 'the analysis of variance, as this is the method which everyone who comes here wants to learn, and on which the sooner you are an authority the better'. Because Fisher was about to spend several weeks in the U.S.A., Frank took up his new post somewhat earlier than 31 August. Soon after Fisher's return, Frank chanced to meet him as they both came out of the building; a few minutes of talk was followed by Fisher saying (102) 'I am afraid I have forgotten your name!'

In 1933, Fisher became Galton Professor of Eugenics at University College, London; Frank immediately succeeded him as head of the small but growing Rothamsted Department of Statistics, a post he was to hold until retirement in 1968. Although Fisher and Yates were close colleagues for only two years, they became fast friends in a collaboration that lasted 30 years. Fisher had already established firm foundations for the principles of statistical science, in the design and analysis of experiments and for other applications. Now Frank began to exhibit a remarkable genius for matching designs to special research needs in agriculture (Cochran *et al.* 1970); a practical problem set before him might stimulate an innovative approach, possibly involving a new class of designs whose properties he would rapidly explore, so systematically developing an armoury of types of design that could be deployed for the benefit of research in all branches of experimental science. From the start, he considered himself fortunate not to have been trained in the then fashionable branches of statistics, but his Gold Coast exposure to the calculations for classical least squares soon paid great dividends. He rapidly followed Fisher in ardent advocacy of factorial design (13). He never weakened in his insistence upon the logical importance of proper randomization, but he undertook thorough critical studies of the merits claimed for systematic selection in design (25) and in sampling (49).

Frank's seminal publication on experimental design, known to all associated with Rothamsted as 'TC35' and for long the standard source of information on non-trivial factorial design, appeared only six years after his induction into statistical science. It very quickly began to affect the planning of agricultural field experiments throughout Britain, and soon its influence was world-wide. Few modern statisticians know that TC35, now unfortunately out of print, contained the first use of asterisks to indicate levels of statistical significance. Notwithstanding the merits of this neat symbolism in pointing the eye to features of potential interest, Frank must later have regretted its possible encouragement of the excesses of significance testing that he would so often condemn! Arthur Bunting recalls a lecture by a visitor to Rothamsted who talked at length about the significance testing of every interaction in his 2^{10} experiment. Naturally chance could explain many of the significant differences that the speaker claimed; at the end, Frank remarked dryly that 'it was all too often forgotten that the important thing about a difference was not its significance but its size'.

He soon explored many other adaptations of combinatorial structures to practical experimentation on fertilizer needs of crops, and on comparative testing of other factors affecting crop production. His mastery of least squares enabled him to present the first comprehensive accounts of the nature of *orthogonality* in design (3, 24). He systematically extended Fisher's important technique of confounding for the control of experimental error. He seemed to acquire an instinctive ability for writing sets of useful orthogonal contrasts in the analysis of variance for each new design that he devised. This skill, stimulated by ideas from survey adjustment using sets of connected triangles, aided his introduction of the complex incomplete block designs which are among his greatest contributions to experimental practice. The speed with which he would glance at a new factorial scheme and unhesitatingly write down quantities such as fractional losses of information or efficiency factors could seem uncanny to those who saw him at work.

His insistence on well-organized computation, with provision for thorough checking, was evident in TC35. He would not subject his readers to a barrage of algebraic formulae: in words typical of his practical outlook, he wrote '...and where it has been necessary to introduce them particular attention has been paid to writing them in the form required by the computer (in 1937, the 'computer' was a human assistant) and also in a form exhibiting their structure, so that they are easily remembered'. Especially simple and powerful was his method of computing the contrasts needed for single degrees of freedom in 2^n designs and easily generalizable to p^n ; often termed the Yates Algorithm, this trick was a vital aid in the development of fast Fourier transforms. Asked by David Cox how he came to devise so ingenious a procedure, Frank gave the characteristic answer 'Well, it's absolutely obvious isn't it?'. Equally valuable to him when beginning to handle a new set of data was his skill in rapidly scanning pages of data and immediately spotting anomalous entries that might be errors of transcription or clues to unexpected features of an experiment. This skill undoubtedly aided him years later when planning data input to electronic computers.

Collaboration with Fisher continued. One of its finest fruits was *Statistical Tables for Biological, Agricultural and Medical Research.* This superbly formatted and printed volume, published in 1936 at a price suited to every pocket, contained all standard tables (ranging from significance testing and experimental design to miscellaneous mathematical computations), that any practitioner of biological statistics could require. Setting a standard of presentation that has never been equalled, it was soon regarded as indispensable. It was influential in putting important new techniques of statistical science within reach of those who were restricted to use of mechanical calculators. By 1963, it reached the sixth of successively augmented and improved editions. In the 1980s, in association with Professor Henry Bennett of Adelaide, Frank did much to prepare material for a seventh edition. Foolish advisers convinced publishers that statisticians no longer had need of a book of tables. Certainly, every PC user can now have software that in a flash will give, perhaps to ten digit accuracy, the probability associated with a stated value of t or χ^2 or F: Frank knew well that such apparent numerical exactness may be unjustifiable, and can even detract from wise interpretation of data. This death of a favourite book was a major sorrow of his last years.

Seeing a need for experiments that could simultaneously compare large numbers of unstructured treatments, Frank was inspired to map the set of treatments on to the combina-torial elements of a confounded factorial design. This imaginative introduction of pseudo-factors enabled him to devise new types of incomplete block designs (18, 19, 21). Although at first regarded as ingenious curiosities, these *lattice designs* have become valuable to plant breeders and others.

Based upon an idea that he once stated to have come to him in the bath, they were further major contributions to design. Their importance would have been appreciated earlier if Rothamsted had had any responsibility for testing new varieties of crops. Methods for the recovery of inter-block information (26, 33), initially severely taxing a reader's comprehension, have further increased precision; today, these can be seen as a natural development from proper randomization and the analysis of variance, yet they were a pioneering contribution to the modern interpretation of experimental results. Although he never followed Fisher into the increasing complexities of statistical genetics, his early ideas on varietal selection and its consequences for genetic advance were fertile sources for future research by many people and for the development of national variety improvement programmes (34,56).

Rothamsted was pre-eminently a research centre for crop-husbandry, plant nutrition and the use of fertilizers. Most early work on experimental design had been inspired by the need to refine and make more precise comparisons among fertilizer treatments that differed in chemical content or in time and method of application. The institute annually undertook large numbers of field experiments, some on its own farm and some at remote sites; many were simple in structure and lasting for only a single crop season, but a few were complicated by involving a succession of years as part of the problem under study. A system, doubtless initiated by Fisher but much developed during Frank's time, was that plans for every new experiment had to be discussed in the Field Plots Committee, a body consisting of senior members of staff from the main disciplines of the Station. Frank played a major part in the Committee's deliberations, always with an experienced eye on the practicability and logical adequacy of what was proposed. The special demands of chemists, soil physicists, agronomists, and pathologists must have done much to mature his outlook on experimentation and to stimulate his inventive mind to produce new ingenuities of design. All these scientists learnt the merits of discussing the design of a new experiment with Frank or one of his assistants well in advance of asking the Committee to allocate resources of land or farm staff. The extent to which his deep understanding of agricultural research was recognized by his colleagues is evidenced by the fact that, from 1954–1968, Frank himself was the very active chairman of the Committee. By now, his agricultural horizons had so broadened that he and E.M. Crowther (Head of the Chemistry Department) were from time to time the architects of new programmes of research in crop husbandry. Indeed, from 1958–1968, Frank was Deputy Director of Rothamsted, an amazing recognition of the qualities of a man who had never had formal training in any of the biological disciplines whose policies he now had a hand in guiding.

Almost invariably, results from any long series of related experiments will display some degree of discrepancy. Frank realized the importance of devising valid procedures for combining such evidence, with due regard for the different types of inter-site, inter-year, and other sources of extraneous variability. An early paper (22) illustrates the problems on one set of good data. There are lessons in it for those, epidemiologists and others, who today regard what is now termed *metanalysis* as an ill-defined but near-miraculous instrument for combining quantitative evidence from different sources.

Practice and Management

One important aspect of farming practice has always been the rotation of crops, the use of the same land in successive seasons for different crop species, possibly with different fertilizer and management requirements. The understanding of rotations is complicated by the need to assess productivity in any one year, in relation to benefits from fertilizer residues and manurial value of vegetable residues from previous years. Another bequest of Fisher to Rothamsted was the initiation of experiments to compare alternative crop rotations, each intended to continue for several years. The inevitable demands from agricultural scientists that changes be made, or that new problems be brought under examination, directed Frank's attention to a complex of logical issues and the combinatorial questions that they introduced. He contributed to developing general methods of statistical analysis for these experiments, as well as to acceptable ways of modifying cropping sequences in response to changing knowledge and needs. In a series of papers (51, 68, 74, 82, 83), he advanced general understanding and established the principles of statistical interpretation of results. Because of changes in agricultural interests, the subject now attracts less attention, but a framework exists that might one day prove of unexpected value in some entirely different field of research.

His ability to adapt to changes in the questions asked of scientists was called into play again in one of his last major tasks at Rothamsted. About 1967, by then recognized as a leading agricultural scientist, he led the Plots Committee in planning and implementing radical changes in two of Rothamsted's classical experiments that are monuments to the initiatives of Lawes and Gilbert in the mid-nineteenth century; in this context, any change must have needed to be defended against charges of vandalism, but Frank was concerned that, without desecration, they should continue relevant to modern problems.

In the 1920s, combinatorial algebra aroused little interest among mathematicians; it appeared to have little use except to gamblers, and all important formulae were assumed to have been discovered by the great algebraists of the previous century! The work of Fisher and Yates on factorial design had close connexions with the theory of finite groups; this, and research such as the enumeration that demonstrated the non-existence of 6×6 Graeco–Latin squares (10), began to change the outlook. New applications of these researches (such as in coding theory) have operated to make 'combinatorics' now a very live topic for even the most abstract mathematicians.

If well executed, an experiment designed according to Fisherian principles will usually have a pattern of symmetry that makes analysis for estimation of experimental error a relatively simple analysis of variance procedure. This property is a prime consequence of orthogonality. Alas, accidents happen! An experiment may be laid out faultily, rabbits or floods may destroy several plots, vital yield records may be accidentally lost; statistical sleight of hand cannot then restore missing information. If belief that the losses occurred randomly can be sustained, the remaining yield records may repay attempts at interpretation. Frank saw this as a problem of impaired orthogonality, and his earlier experience of geodetic survey showed him that Gaussian least squares could provide the key. He recognized that the method of 'fitting constants' could so systematize the arithmetic as to make it practicable even with purely mechanical calculators. Before the days of computers, the general calculations could be excessively laborious, involving manipulation of large matrices.

His practical appreciation of the problems of undertaking statistical arithmetic led him to a further manner of handling situations in which one experiment suffered several isolated plot losses. He devised simple iterative least-squares routines that estimated a value for each missing yield, with the inclusion of these the standard analysis of variance could be used (4, 16, 28). He never fulfilled the dream of successive Rothamsted farm managers, the invention of statistical analysis for experiments that were planned but never actually executed, so that every single plot yield was missing!

Under Frank's leadership, the Rothamsted Statistics Department developed from solely a service role in the Station into being a major centre for research in statistics and computing, in addition to being a national resource for statistical consultation and data analysis. In Brian Church's words, the growth was, a product of Frank's 'energy, determination, persistence, and earthiness', this last characteristic relating to his insistence on work that would contribute to the improvement of agriculture rather than merely extend formal theory. During the years of fundamental innovations, he always saw experimental design to be, as Oscar Kempthorne has written '...a subject that must grow through stimulation by the needs of the experimental sciences'. Technically. Frank was himself a remarkably effective mathematician when need arose, but he continued impatient with those who spent time on new mathematical theory that was not stimulated by a true scientific need. As he remarked many years later, in his presidential address to the Royal Statistical Society, he saw 'no reason why we should tolerate the theoretical branches of the subject becoming pathological' (119).

A great scholar contributes to the advancement of knowledge by his own discoveries and writings, and at least equally by personal influence on his younger colleagues and assistants. This comment applies to Frank Yates with much the same force as it did to his own scientific mentor, Ronald Fisher. We who worked for him have known him both patient and impatient, when refusing to accept work that fell below the standards of penetrating analysis and clear exposition that his perfectionist temperament demanded; we have also had the benefits of his tolerance of youthful brashness and naiveté, and his determination to pass on the skill in wise data handling that he himself never ceased learning. His practice with new staff members was to give them immediate responsibility: a few days after I joined his staff, he left me to run the Department while he went to spend a leave climbing Lofoten peaks! He was always concerned that his staff should gain direct practical experience of Rothamsted objectives. He regarded it as good for a young mathematician to dirty his hands by direct participation in digging field samples of potatoes or cutting wheat on small sample rectangles. George Jolly recalls helping conduct an experiment that '...involved cutting grass samples from the plots, and, for plots grazed by sheep, weighing the animals in the late morning once the dew had dried from their fleeces'. Such manual labours have given many of us an appreciation of the real problems of performing good experiments that could never have come from lecture courses or text books.

By contrast with all the bureaucratic paper pushing and entrepreneurial skill required today of any scientist who heads a department, Frank regarded administration and staff management as something that should be kept simple. When appointing staff, he was fortunate to be operating in a period that demanded little formality. He could appoint a new assistant on the basis of a short chat and a rapid assessment of personality and potential. He would pay little attention to paper qualifications; if he could convince himself that gaining this degree had not destroyed all power of independent thought, he might even decide to tolerate a Ph.D.! The rare event of wishing to dispose of an unwanted member of staff posed greater difficulty. Frank once told a senior colleague that a certain doctor had retained his job for weeks longer than was desirable because he was never there to be dismissed.

In his address at the Memorial Service, Michael Healy said 'FY's method of managing his department was a remarkable one, in that it was totally invisible. There were almost no rules, apart from that which insisted that no scientific paper left the department without being read, and usually greatly improved, by him. Some scientific leaders get their names on to anything emanating from their staffs; FY would never have done that, even though he had a lot better right to do so than most'. This one firm rule has resulted in some who have moved from Rothamsted to academic posts being later criticized by him for permitting someone from a different department of the university to publish a paper containing gross statistical errors in a biological journal that he chanced to have seen! He was always outstandingly generous in offering new ideas to his young associates, whom he would then encourage to develop and publish them under their own names. I have often been credited with originating the useful device of fractional replication of factorial experiments. In reality, I did no more than elaborate formal algebra from an idea that Frank threw at me in a brief discussion of how we might plan an experiment to study the consequences of plant loss on crop yield. Published correspondence with Fisher (Bennett 1990) indicates that in 1952 both men were concerned with the establishment of a convention that might govern the manner in which a scientific paper should express joint authorship or acknowledge the help of others; sadly, this exercise was never completed.

Frank never formally engaged in teaching statistics, although in 1935, apparently, he gave thought to applying for a Readership in Statistics at Oxford. His Rothamsted years involved him in guiding and supervising Ph.D. students attached to his Department, although he was disposed to regard acquiring this degree as more of an obstacle to scientific understanding than as an asset. With students, as with the training of new members of his own staff, he saw the need for deep immersion in practical problems and for leaving them to resolve these for themselves. As one of them has written to me 'He had a knack of giving you the sketchiest of instructions and making you feel you could solve the problem; when faced with it, you were able to sort it out'. Natural to him, as it had been to Fisher, was the Socratic method of posing searching questions and being prepared to spend much time in discussing successive steps towards an answer. This process, as well as his dealings with statisticians elsewhere, led him to form very strong opinions about how university teaching of statistics ought to be organized (107, 110). Thus in one publication he criticized an examination question based upon a problem of medical research by describing as deplorable '...the implication that it is no part of the duty of the statistician to question the premises and procedure put forward by the clinician'. Although he wrote with little appreciation of the constraints that operate within a university, his ideas contained much wisdom and deserve more attention than they have received.

Much of Frank's consultative help to colleagues from other disciplines had the nature of one-to-one teaching. He and his staff were always available to discuss questions of design and analysis relating to any aspect of Rothamsted's diverse programme. In his time, no treatises on how to be a statistical consultant had yet been written: he was content simply to be one. At times, the manner of this tall handsome man might terrify the enquirer, and conversation conducted while he chewed his pipe could be difficult, but several of his contemporary heads of Rothamsted departments still remark on his inherently kind helpfulness. He knew well the stimulus for useful new statistical methodology that might come from a consultative session. With one or two Rothamsted scientists, notably E.M. Crowther and D.J. Watson, his relations amounted to close collaboration in the conduct and planning of research. Others who were less at ease in speaking his language would invariably find him cooperative, either in personal attention to a question or by asking one of his young assistants to handle a problem, an allocation of responsibility that he rightly saw as valuable education for them.

Some moved from Frank's immediate circle to senior academic positions (W.G. Cochran the first, but also O. Kempthorne and M.J.R. Healy, to name only a few). I hope that we have passed to our students some of Frank's insistence on integrity in handling and interpreting data, conciseness, and clarity in everything written for publication. For reasons that are obscure, a young graduate in mathematics or science may begin a research career with negligible understanding of how to write a few coherent paragraphs describing and summarizing a piece of work that he has completed. With any such member of his staff, Frank would labour for hours in critical reading of successive drafts, and in face-to-face discussion of how to improve them. This process was often painful for the recipient, but it brought results! Few will have acquired his remarkable facility for scanning a long list of data, seeing immediately the few values that are noteworthy or differing from the general trend, and rapidly suggesting an analytical process that would extract the main features. His respect for data and their origin was such that he would never regard their statistical analysis as a mere routine 'fitting of a linear model': always, the analysis had to be logically based upon the nature of the data acquisition, the design of any experiment, and the practical implications for agricultural or other questions under study.

The Rothamsted environment proved ideal for Frank. By nature a very hard worker, he drove himself and all who worked with him to ever increasing effort. Yet his early upbringing gave him something of the outlook of a country gentleman; he walked the Rothamsted estate with dogs to assist his shooting of rabbits and pheasants, dogs whose growls scared many a visitor to his office. In his early days, he even indulged his personal interest in the biology that he had never been taught: in his garden at Stackyard, he set up a colony of about 50 rats that he bred carefully and with which he conducted experiments on animal intelligence. Although he satisfied himself that wild rats manifested much more intelligence than the albino laboratory rat, he seems never to have tried to analyse and interpret the notebooks containing his experimental records. In the 1950s he became involved in the affairs of the Zoological Society of London. The late Lord Zuckerman, with whom he had worked so closely on wartime operational research, had the task of reorganizing the Society's structure so as to preserve the Zoo in the face of financial difficulties; Frank's life-long interest in wildlife encouraged him to use his skill in interpreting data, notably records of numbers of admissions to the Zoo and of associated trends in revenue, in order to advise on rationalization of policies.

THE MIDDLE YEARS

In the dark days of 1939–40, food supplies for Britain were gravely menaced by submarines. Home production was a vital issue. Frank noted that a key question was the balance between imports of food and imports of fertilizers, yet there existed no comprehensive quantitative assessment that might form a basis for policy. From early in the century, very large numbers of field experiments had been conducted to study responses of major crops to fertilizer application, not only in Britain but also in many countries of western Europe that have similar patterns of cropping. The Rothamsted library owned long series of reports of agricultural research from countries of this region. From among many sections of Rothamsted staff, Frank hastily recruited helpers whom he set to abstracting from every relevant report (about 5000 experiments conducted since 1900) estimates of the yield increase associated with stated quantities of each of the three major fertilizer elements, N, P, and K.

Relatively few of these experiments had been conducted in a period when they could benefit from the post-1925 Fisherian revolution in design, with proper randomization and replication.

The practical problem was urgent, and the abstracting procedure was crude, with no scope for critical judgment on the validity or precision of individual experiments. Frank's major contribution now was to synthesize the collected information into estimates of fertilizer response curves applicable to different crops. The resulting report (35) told a coherent story, consistent with existing views of experts on soils and plant nutrition. As soon as he had completed a first version of a report, Frank sent copies to the Ministry of Agriculture. He used to enjoy telling how weeks elapsed before its receipt was acknowledged, and then only with a mild rebuke for his extravagant wastage of paper by failing to duplicate on both sides of each page! The report was a true scientific metanalysis, though Frank would never have used so pretentious a name. It pointed clearly to a potential for appreciably increasing home food production if moderate imports of phosphate and potash were to continue and to be wisely used (especially for potatoes and sugar beet). This view soon became a central component of a rational policy on imports and rationing, as operated by the Ministry's Fertilizer Control.

A year later, under similar stimulation from problems of imports, the food requirements of dairy cattle were discussed (37) in the light of evidence from published reports of excellent experiments on commercial farms in Denmark. These did much to clarify the effects of variation in protein intake on milk production and on changes in live weight. Because of the consequential government policy, these two papers almost certainly helped to reduce deaths among seamen, yet the home population continued to be adequately fed.

His early wartime activities led Frank increasingly into efforts to combine quantitative information from different sources which, under the exigencies of the time, commonly involved seeking to extract usable information from non-experimental data. His friendship with Solly Zuckerman drew him into studies of the effects of aerial bombing in the U.K. and the use of records of bomb damage at home and around the Mediterranean for predicting the damage and casualties to be expected from alternative Allied bombing policies during the coming invasion of Europe (Zuckerman 1978). His analyses of casualties and physical damage in relation to bomb size and distances from points of burst were pioneering studies of a logical character that years later would become familiar in industry under the name of 'operational research' (50).

With the honorary rank of Wing Commander, and a uniform that sometimes caused a little kindly mirth among his senior agricultural colleagues, he made many trips to Sicily and other theatres of war in order to see problems on the spot, and to return home with highly secret data for analysis and interpretation. Had the Zuckerman and Yates evaluation of the vital effects of bombing critical communication nodes been accepted earlier, the eventual policy of massive destruction of German cities might have been judged unnecessary.

From his earliest years at Rothamsted, when he was asked to investigate the possibility of improving the pre-harvest forecasting of crop yields, by weighing samples taken while the crops were still growing in the field, Frank had been attracted to a wide range of problems of estimation by sampling. He had special concern for the ease with which bias could enter unless rules for sample selection are carefully defined and observed (8, 12). His experience with experimental design showed him the importance of random selection of a sample, the correspondence between blocking and stratification, and the value of analysis of variance in studying efficiency (14, 17, 20).

He applied the ideas developed in connexion with crop-forecasting to large scale estimation of Britain's resources of standing timber in 1937, the Forestry Commission had begun a Census of Woodlands, with estimation of yields of timber per acre being supplemented by eye estimation on sample plots. Wartime timber needs caused Frank to be urgently requested to help in completing estimation from the 1937 survey. He had already seen data indicating that estimation of volumes by eye was leading to serious underestimation relative to actual measurement of the sample plots. By disregarding eye estimates, and making use of information on areas obtained in a survey made in 1923, he was able to respond to the emergency by rapidly synthesizing an estimate of the total national stock.

Further important sampling projects concerned the study of densities of insect pests by sampling among growing plants or in the soil (36). During years of agricultural depression, much farmland had reverted from arable cropping to rough grazing. Wartime needs resulted in this land now being ploughed for food crops. A characteristic of old temperate grassland is infestation by insect pests that relish any opportunity to feed upon seedlings of newly sown grain or root crops. Frank devised a simple, though operationally laborious, scheme for estimating population densities of the most troublesome of these pests, the wireworm (mostly *Agriotes* spp.), by counting larvae in sets of small cores of soil from a field, and using the estimates to assist precautions in the choice and management of the first crop taken after ploughing old grass.

At this time, little was known about how farmers actually used fertilizers, or even whether the strictly calculated rations were reaching the crops for which they were intended. After a struggle against the resistance of the Agricultural Research Council, Frank was allowed to initiate a series of 'Surveys of Fertilizer Practice', involving visits and questionnaires to a random sample of farmers. At first, these surveys covered only selected counties or other compact areas, but the programme steadily grew and produced a succession of valuable reports that continued to be a foundation for policy makers and agricultural advisers even when peace again made fertilizer imports possible. This work presaged his later concentration of interest on the principles and practice of sample survey (38).

POST-WAR DEVELOPMENT

After 1945, external demands on Frank increased. During the 1960s, he was enabled to increase staff to about 60, so as to operate the National Agricultural Research Statistical Service that he set up in 1947. He always endeavoured to recruit people whom he saw as potentially useful to his current developments, without undue regard to their exact paper qualifications. Healy (1982), regretting that the lesson of value in diversity '...has not been put to use in other areas of statistical applications', noted that at one time Frank's four senior staff members were in origin a mathematician, an engineer, a geographer, and a veterinarian! A short but important paper (69) from this period was that in which he related the size of a planned experimental programme to the benefits expected from it.

During years when the aftermath of war had left grave doubts about world food supplies, Frank's integrity as a scientist and his innate humanity led him to concern himself with statistical aspects of human nutrition (41, 59). When the United Nations established a Sub-Commission on Statistical Sampling, he was one of the first members. He was soon commissioned to prepare a manual on sampling practice, for use in the World Censuses of Agriculture and Population projected for 1950. The result was *Sampling Methods for Censuses and Surveys*, first published in 1949. This was almost the first comprehensive text in the field; it was immediately valuable and highly influential. In the Sub-Commission, Fisher had always been insistent on the importance of good terminology, and Frank continued in this way by introducing words such as 'frame' that were to become established in the terminology of planned sample survey. Although to some extent it is now superseded by other books written as more systematic treatises, and better suited for academic courses, his book retains the virtue of containing a vast amount of practical wisdom on the conduct of large surveys. The publication of revised editions in 1953, 1960, and 1981, successively introducing more information on the increasing role of the electronic computer, is a tribute to the author's special skills and deep practical understanding. Its discussion of domains of study and of the planning and interpretation of repeated surveys were far ahead of their time, and in the 1990s continue to be valuable references.

His early experience in Africa instilled in him a concern for the problems of overseas aid in statistics. Gavin Ross writes: 'He supported many requests for statistical advice from developing countries, and welcomed overseas visiting workers, as well as sending some of us to provide on the spot advice'. As early as 1950, he was able to persuade the Overseas Development Administration to fund a special unit for this kind of work within his department at Rothamsted. In 1951, the UN Food & Agriculture Organization asked Frank to advise the Indian Council of Agricultural Research on the provision of statistical support for research. I participated in this mission for a full year, with Frank making shorter visits as leader; one such visit allowed him a much enjoyed climbing excursion into Nepal and the Himalayas. Like western Europe in 1939, India had a vast reservoir of under-exploited results from fertilizer experiments. As a first task, he examined fertilizer responses for the major grain crops along the lines adopted for the U.K. in 1941; this was stimulated by analogous problems of national policy, especially the economic question of the potential gains from vast investment in factories for synthesizing nitrogenous fertilizers. Our efforts inevitably suffered some administrative frustrations, but the recommendations in the final report (71, 78, 84) had the effect of inducing India to create a major institute for statistics in agricultural research. This institute has grown with the years; its unique character gives it potential for producing a major help to agricultural research throughout South-East Asia.

Computing and computers

The archives of Rothamsted should still contain large files of pen-and-ink arithmetic from Fisher's earliest work on the classical field experiments, arithmetic that was the inspiration for that great statistical tool, the analysis of variance. Anyone who ever worked close to Frank Yates must have been impressed by his close attention to careful arithmetical analysis. In 1933, Frank inherited and himself adopted the tradition (115) that '...to be a good theoretical statistician one must also compute, and must therefore have the best computing aids'. He himself chose to use the remarkably powerful Millionaire electromechanical calculator that Fisher had managed to acquire, and he ensured that his staff were equipped with the latest models of the electrical machines that bore the long-famous names of Marchant and Monroe. Until electronic technology made such instruments obsolete, he would seldom be far from the slide rule that his early years had taught him to use so effectively and that he found ideal for simple summarizing calculations of standard errors.

His Department's heavy annual requirements for analysing data from field experiments continued to be handled with the aid of a group of 'human computers', mostly local young women who had left school without formal qualification in mathematics or science. In 1931, Fisher had advised him to organize their work that '...when no machine is available, seven-figure logarithm tables used without interpolation to five figures are quite good enough for reducing actual produce to produce per acre'. Frank would have been a firm taskmaster, but surviving correspondence shows his determination that their pay and conditions of work should be good.

Today, to talk about 'the girls' might be unacceptable terminology! In the 1930s, Frank taught the girls to accomplish much by using their desk calculators in accordance with rules that he set out, rules the object of which they were far from comprehending; these systematic rules were precursors of the instructions that constitute a modern computer program. Doubtless the Millionaire was the means by which the computational skills that Frank brought from the Gold Coast were adapted to the needs of agricultural research. His love of engineering must have rejoiced in regular use of this elegant piece of machinery, and even enabled him to be patient in restoring it once when I, thinking to follow his practice, unsuccessfully tried to right a fault by taking a screwdriver to it!

The first edition of the sampling manual introduced ideas on inducing, what was then, standard commercial equipment for handling punched cards, with its sorting and tabulating facilities, to undertake the analyses, error estimations, and tabulations required for a large sample survey. Still earlier, Frank had begun to make good use of edge-punched (Cope-Chat) cards for the recording of survey data; a complicated code of punching facilitated sorting operations that gave statistical clerks at work the appearance of a group of *tricoteuses*. By the 1950s, electronic computers were beginning to make the news. Frank quickly saw the potential that they offered for carrying the computing load of his Department.

His wartime activities in operational research gave him a contact with the National Research Development Corporation, through which, in 1954, he was able to secure an Elliott 401 computer. It must surely have been his already established reputation for well-organized computing that caused P.M.S. Blackett and J.B.S. Haldane to advise the Agricultural Research Council in the following terms "With an electronic computer of their own, both to use and 'play around with', we think that valuable advances may be made in the theory and method of handling this kind of data on electronic machines". Operating with thermionic valves, and its main memory on a magnetic drum, the 401 arrived with a single page of instructions and very little software; input and output rested upon a home-made paper tape reader and a standard electric office typewriter. Frank was delighted by the challenge; he would sit for hours trying to get his program code correctly positioned on the drum, and with eyes fixed on the cathode-ray display that could give him clues about progress.

He led his enthusiastic group of helpers to success in making this primitive machine run general programs (which until 1966 he continued to call 'programmes')for analysing designed experiments and sample surveys: very soon his Department was analysing 4000 or more experiments annually. As was to be expected of him, he insisted on incorporating thorough checks on data during their input. Even before the existence of high-level programming languages, Frank foresaw the need for generality, and for a comprehensiveness that enabled an individual program to undertake the full succession of calculation required for one set of data, rather than having *ad hoc* programs for single tasks (79, 80, 83, 92, 93, 95, 98, 122). His approach to the efficient use of computers and of programming manpower foreshadowed the development of multi-purpose software packages; early on, he recognized the need for portability of software across hardware systems. In exploring the potential value of this new tool, he operated an open-door policy. As Gavin Ross has written 'He allowed his staff freedom to experiment with the use of the computer, and also to take on outside work from a variety of sources, usually without charge. He saw no point in a bureaucracy in which government departments spent all their time billing each other for small sums of money. If it was interesting and not prohibitively time consuming, we did it'.

The 401 had more sophisticated successors, to the effective use of which Frank gave much of his great energy, at a time when statistical science lacked the range of general software available today. From its early days, Frank played an important part in the establishment of the British Computer Society: he gave wise guidance during an early crisis and he was President in 1960–61. At Rothamsted, the impetus and much of the actual labour of translating original ideas into computer code occupied his own time and thought, but aided of course by an able group of colleagues. In retrospect, one may question whether the energies of one outstanding scientist should have been so totally devoted to work that, by 1995 standards, could have been delegated, but one must also ask whether computing for statistical science could conceivably have developed so successfully in other hands.

Healy (1982) has given a clear account of this period that made Rothamsted a leading centre for the software widely needed in agriculture and other branches of biological research. An early success was the general survey program, RGSP, used in processing the Seychelles census of 1977 (Beasley 1982). Frank's insistence on generality had ensured ability to handle records of varied types. He incorporated flexibility at input, range and consistency checking of data input, ease of calculating derived variates, and output of a quality that could include diverse but clear tabulations ready for insertion into a subsequent report. Indeed, RGSP introduced facilities for table manipulation, such as forming a new table of ratios or products from corresponding entries in two other tables, that are of evident value to statisticians but that even today may not always be found in standard software (120, 127). Frank responded to the need for software that would similarly handle the complex factorial and other designs that Rothamsted had pioneered. His Genfac was a concept ahead of its time (116). More adaptable hardware (notably ICT ORION) was becoming available, and more powerful computing algorithms were being devised. His long standing concern for the correct handling of estimation from non-orthogonal data led him to undertake much of the writing for the splendid program FITCON, and by his own enthusiasm to ensure the production of the companion program FITQUAN for use with quantal data (Lewis 1968). Although not his personal products, that same enthusiasm must have been a factor contributing to the subsequent appearance of more powerful packages, especially Genstat and GLIM.

The late years

After Frank's retirement in 1968, he became a Senior Research Fellow at Imperial College, London for about 10 years. Although this did not involve him in formal duties, he spent much time with the statisticians there. In part, with support from the Social Science Research Council, he was continuing development of RGSP. An especially useful outcome was a critical discussion (127) of the facilities appropriate to sample survey software, and of the failure of most packages to supply what the user needs. A criticism of popular software packages, still very relevant in 1995, was that they often output (in his words): '...measures of association that are misleading to the beginner, who is apt to think that because the computer produces them they must be meaningful'. For the first time in his life, he had some involvement with teaching: he helped individual students and occasionally lectured on his current work. He was not an ideal lecturer, for he lacked concern for comprehensive formal presentation and preferred to talk about general ideas.

Meanwhile, his old Department had been divided into two, so separating statistics and computing. He retained a room as an Honorary Scientist in the Rothamsted Computing Department. His residual influence was, perhaps deliberately, slight: he was punctilious in avoiding temptations to intervene in either department on issues of policy or research, but his advice and experience were always available to his younger colleagues. He continued to work on problems that interested him, especially on improvements to RGSP. Brian Church states that, even in 1986, this 'was still the only package capable of reorganizing tables in a way that users actually want, such as combination of adjacent columns, handling missing values etc.'. In all that he did, Frank would have described himself as a statistical scientist, rather than as statistician or biometrician. He was always concerned to get at the scientific content and objective of any problem or set of data on which his advice was sought.

Another major activity during his retirement years was editorial work for the *Journal of Agricultural Science*. Many of his own important papers on experimental design had appeared in that journal in the 1930s; he now played a great part in raising the quality of statistical presentation acceptable to the journal. His care for the manner of presentation of quantitative results made him an ideal choice for this task. His outlook on presentation was a major reason for Sir Harold Jeffreys being able to say, in an address to the British Association in 1953: '...the standard of presentation of results in agriculture is better than in any of the so-called exact sciences; and this is a state of affairs that physicists should cease to tolerate.'

With limited success, Frank tried to stem the tide of research publications that regard a row of asterisks, a correlation coefficient, or the result of a multivariate significance test as indicators of triumph in research or as sufficient summaries of findings from an experiment. As he had written in 1951 (60) '...the occasions, even in research work, in which quantitative data are collected solely with the object of proving or disproving a given hypothesis are relatively rare'.

Until his last three years, he retained good health and would walk with the vigour of a younger man. Sadly, he became increasingly deaf; despite a series of hearing aids, even the friendliest oral communication with him could be a very laboured shouting match, until in his last year he acquired a much improved aid. Although unfortunately he abandoned going to meetings or himself speaking in public, his mental strength was undimmed. Once a conversation was established, he would inveigh as ever against those, biologists or their statistical advisers, who act as though the sole purpose of statistical analysis is to obtain an exact value of P from a significance test! Similarly to be condemned were those software packages that failed to reach his exacting standards of performance and output, whether by encouraging use of methods ill-suited to data or by lack of generality or by careless errors.

His opinions were often dogmatic, leaving him impatient with those whose outlook was different. For example, he could see no use for the theory and use of power functions. Yet in 1972 he proposed an alternative measure of the quality of a significance test, which he called its 'sensitivity'; this involved comparison with a test of a unit Normal deviate as standard, an ingenious and potentially useful idea which seems never to have been taken seriously among statisticians (122). As John Nelder has commented 'He had very strong views on what was acceptable in statistical practice',and this could at times lead him to refuse to consider the possibility that more than one plausible inference could follow from a single data set. Despite his oft displayed impatience with some of the nonsense that gets published under such heads as 'Bayesian techniques' and 'multiple range tests', his condemnation attached particularly to the wastage of effort in bringing clever mathematics to the solving of unreal problems. Even in 1946, in discussion of an early paper on industrial statistics, he could write '...Mr Barnard had raised the question of Bayes's theorem as if this was a heresy which it was dangerous to utter. But in fact in the sequential type of problem there existed a distribution of the means (or other parameters) of the various batches, and it was consequently perfectly reasonable to consider what would happen when this distribution assumed different forms.' (Barnard 1946).

The testing of association in a 2 × 2 contingency table is, historically and conceptually one of the most basic of statistical analyses. Karl Pearson invented the χ^2 test, but was entrapped by a mistake that Fisher had to correct 20 years later. Argument continued, and *Yates's continuity correction* (11) was not universally accepted as an improvement. Fifty years later, at the age of 82, Frank published a definitive paper (141) that should lay the ghosts of the past. Despite his own strong convictions, he enjoyed a good professional argument, but only rarely did he display (25, 31, 111) Fisher's concern for the subtler points of probabilistic philosophy.

The body began to fail, yet the old fire remained. In 1993, he completed 60 years at Rothamsted, a span exceeding that of Lawes and Gilbert, the great founders of the Station. John Gower recalls a meeting with Frank only a few weeks before his death on 17 June 1994. Someone mentioned a plan to have a group photograph of past Heads of Rothamsted statistics; he dismissed the idea with a characteristic snort of disapproval 'I don't agree with any of them!'. On 26 August 1994, a Memorial Service was held at the Church of St Nicholas in Harpenden. Many old friends attended in a spirit of remembering with joy their friendship and affection for Frank. In his address, Michael Healy paid tribute to his scientific achievements and to his outstanding qualities as man, mentor, and colleague. Michael ended 'I remember my friend, my teacher, my boss, my privilege in knowing and working with one of the great men of our time.'

Honours and awards

1938	Sc. D. (Cantab.)
1948	Fellow of the Royal Society
1953	Weldon Memorial Prize (awarded by University of Oxford)
1960	Guy Medal (in gold) of the Royal Statistical Society
1960–61	President of the British Computer Society
1963	Commander of the British Empire
1966	Royal Medal of the Royal Society: 'In recognition of his profound and far reaching contributions to the statistical methods of experimental biology.'
1967–68	President of the Royal Statistical Society
1975	Honorary Member of the Biometric Society
1982	Doctor of Science honoris causa, University of London

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Many old friends and colleagues have generously contributed memories, stories, and details of professional life. Among them, I must mention particularly George Barnard, Vic Barnett (whose disk version of the bibliography saved me many hours of labour), Henry Bennett, Arthur Bunting, Brian Church, David Cox, Irena Gill, John Gower, Michael Healy, Mary Hills, George Jolly, Oscar Kempthorne, John Nelder, Desmond Patterson, Clifford Pearce, Bill Pirie, Donald Preece, Gavin Ross, and Howard Simpson. I have made free use of three previously published biographical notes (Cochran *et al.* 1970; Finney, 1982; Healy, 1982), and further information may still be found in these.

The photograph was taken by the Godfrey Argent Studio, it was received by the Royal Society in 1982. It is reproduced with their permission.

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The complete bibliography appears on the accompanying microfiche. A photocopy is available from the Royal Society library at cost.