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# Statistics in Universities—a Personal View

The Address of the PRESIDENT, Professor H. E. DANIELS, delivered to the
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## 1. INTRODUCTION

IT is a very great honour for a statistician to be elected President of our Society, and one that is not easy to live up to. Past presidents have been highly distinguished men who were leaders in their own area of statistical activity, and in a certain sense they have represented their professional colleagues who were also honoured by their election. Though I would not claim my predecessors' distinction, I must nevertheless regard myself as representing the body of university statisticians, few of whom are likely to share the same opinion on almost any important aspect of our subject, and who would no doubt prefer to speak for themselves. But we do have a common purpose, one that is important to the Society, and I shall try to express at least my own point of view on how that purpose should be fulfilled.

Professor Finney is also a university statistician, but with his great experience of advisory work in many fields he chose to address us last year on how we can make inferences from imperfect data. In doing so he made a substantial contribution to methodology. I shall be less ambitious. I propose to talk about the statistical activities of one kind and another which go on in universities, the most arduous and occasionally the most rewarding of these being the teaching of statistics to students, who also have their imperfections.

In an area where so many disagree, the views I express must inevitably be subjective—some would say biased, since I am a mathematician whose interests lie in the experimental rather than the social sciences. Although I shall frequently wander from my brief I want to speak principally about universities, where I have spent the greater part of my working life, though not all of it, I am glad to say. There will be no tables of numerical information about statistics in universities, as would have been proper in a statistical paper on the subject. I am concerned rather to express opinions based on impressions of a not easily quantifiable kind, something that even a statistician must occasionally be prepared to do.

It seems appropriate to start with a brief historical review of statistical teaching in a rather wider context.

## 2. REPORTS ON THE TEACHING OF STATISTICS

The Society has given its attention on a number of occasions to the teaching of statistics and the training of statisticians. The earliest in my recollection was the paper read to the Society in 1939 by Dr J. Wishart at a time when the subject had passed through a period of major advance and was beginning to establish itself in universities (other than University College, London, where it already had a long history, as had economic statistics in many universities). Immediately after World War II the urgently felt need to train more statisticians led Council to set up a Committee on Teaching of Statistics in Universities and University Colleges. Its report appeared in the *Journal* in 1947, and in 1948 Wishart opened a discussion on it. The report is even now worth reading for its sensible recommendations.

After a slow start there ensued a period of rapid and optimistic growth—even a certain amount of rivalry among universities not to be left behind. The expansion took place primarily within mathematics departments—some departments of economics and agriculture because of their special needs had already had their own specialists for some time. However, rumblings of discontent began to be heard among employers of statisticians at the way the mathematical development of the subject was said to dominate the teaching at the expense of its practical application. These culminated in a Symposium on the Teaching of Statistics held in 1964, opening with a forthright paper by Yates and Healy on "How should we reform the teaching of statistics?" Other excellent papers dealt with the particular requirements of government, economics, business and medicine. The university teachers on the whole put up a spirited defence and there was a useful clearing of the air.

Having completed its report on the university situation in 1947, the Society's committee turned its attention to schools. Its report, published in 1952, concluded that the statistical approach should be an essential part of a liberal education, but that it should be introduced through experimental and other subjects rather than as a separate discipline, for which too few teachers were available. But as the universities began to produce an increasing number of mathematics graduates with statistical training, circumstances changed and Council decided to take another look at the matter. The committee was reconstituted in 1966 and its interim report was presented at a meeting in 1968, together with a somewhat dissident paper by Downton. The ensuing discussion was one of passion and intensity, many of the large audience having travelled long distances to express a strongly held opinion.

The outcome of that meeting was the formation of an Education Study Group, in collaboration with the Mathematical Association and the Institute of Mathematics and its Applications. This now has a separate existence outside the Society as the Committee on Statistical Education. Recently we have collaborated with the Institute of Statisticians in a study of statistics in technical colleges, and the joint report was discussed at a meeting early this year†.

Meanwhile parallel developments were taking place elsewhere. In the U.S.A. in the 1940's the National Research Council and the Institute of Mathematical Statistics both issued reports on broadly similar lines to our own, though with a more mathematical emphasis. The topic has been pursued there with vigour up to the present day. The American Statistical Association and the National Council of Teachers of Mathematics have jointly produced a series of books providing valuable practical material for school use. There has been a remarkably successful experiment by Mosteller and his colleagues in teaching statistics by television. At the international level, the International Statistical Institute is currently organizing a series of Round Table Conferences, the third of which—on teaching statistics at secondary level—has recently issued its recommendations. It pays particular attention to the selection of teaching material suitable for use in developing countries.

## 3. THE ROLE OF THE SOCIETY

On reading through all these reports and discussions one thing becomes clear: it is virtually impossible to say anything new on the subject. I am struck by the way the same ideas are put forward again and again, the same opposing viewpoints discussed, the same recommendations made with slight modifications. Two figures keep

† The discussion at that meeting was published in the *Journal*, **137** (1974), Part 3, pp. 412–427.

reappearing at intervals like stereotypes in a morality play, the practical man and the theoretician, evidently intended to represent the forces of good and evil, in that order. Certainly there have been advances over the last few decades in the amount of statistical teaching, and, I would say, also in its quality. But how much of this is a result of the labours of our committees and how much would have happened anyway? I wonder how many of you remember, as I did not until I reread Wishart's paper, that as far back as 1939 our distinguished president, Lord Stamp, addressed the Mathematical Association on what should be the content of a school course in statistical methods for those interested in a business career. I suppose the war intervened, but had his suggestions been followed up we might have been better off for statisticians in the post-war period.

I am sure that the Society's reports have carried due weight whenever the subject has been discussed. Individuals have also done what they could to improve matters, for example, by their work on G.C.E. boards, or by encouraging the University Grants Committee to support statistics in universities. But could the Society have done more to implement its recommendations? Sir Maurice Kendall doubted it. In seconding the vote of thanks to Dr Yates for his presidential address, in which similar questions were raised, he said, "I think we must draw a distinction between what the Society as such can do and what we can do individually. It is one of the major advantages of a Society such as ours that it includes members of every degree of statistical expertise and every kind of interest in application. This I believe is the source of its vitality. But it carries with it one implication—I will not call it a disadvantage—that we also have a wide spectrum of opinion on every conceivable subject and hence have some difficulty in expressing a collective opinion on any of them." He then went on to mention a few limited objectives which we could aim at.

With all respect, this seems to me too pessimistic a view. The very variety of expertise and interest within the Society gives its considered judgment a weight far beyond that of some homogeneous organization with a narrow interest to defend. I believe the Society should be exerting its influence as the authoritative body to speak on matters within its competence. It should regard it as one of its duties to make representations at the highest level in the expectation that it will be listened to. And when matters of policy are being discussed which involve important statistical considerations, it should be felt natural to seek the counsel of the Royal Statistical Society, in the way that the Royal Society would be consulted on matters of general scientific importance.

## 4. The Pre-university Period

Remarkably little effort has been made to find out why people become statisticians. It may be that psychologists know and have published their findings, but I am not aware of them, so I shall offer my own views for what they are worth, based on a mixture of observation and surmise.

Some people just like playing with figures. This shows at an early age as a passion for collecting engine numbers and other data of an apparently meaningless kind. I would also include memorizing historical dates, and amassing statistical facts of the unrelated sort enumerated in that charming passage from O. Henry which graces the flyleaf of Kendall and Stuart's well-known book.

A love of figures is like the lexicographer's love of words: it is not a rational thing, it is more like an ear for music. I suspect that many young children possess it, that they actually enjoy reciting multiplication tables in defiance of the spirit of modern

mathematics in schools. Some who retain this enthusiasm for figures will take up subjects with a strong factual content, and with the added attraction of a computer they will enter employment involving statistical work where collection and collation of data is the major objective. Others of a more theoretical turn of mind may study economics, adding to their primitive delight in figures a skill in applying techniques of statistical analysis to interpret economic data.

Mathematicians do not normally follow this route. Mathematics at school often produces an understandable antipathy to arithmetic because it seems to supersede it. A liking for numbers becomes an interest in number theory. The interest in statistics comes later through the need to interpret observational and experimental data arising in some other subject.

My own experience was of this kind. I can remember, as it were, the exact moment of conversion. We were to determine the acceleration of gravity, using an apparatus called Atwood's machine whose precise nature now escapes me. The correct value was apparently known to be 32.2 ft per sec$^2$. I managed to get 32.1, which wasn't bad considering the complexity of the equipment. However, I was told to go back and do it again until the result came to 32.2. Needless to say, that didn't take me long, but a sense of outrage led me to think for the first time about experimental errors and how one should allow for them honestly. A year or so later I discovered Fisher's *Statistical Methods for Research Workers* in the local library (I think it was the third edition).

That was a long time ago, and science teaching has no doubt improved since then. But it convinces me that the right way for school children to be introduced to statistics is through collecting and studying real data, and by carrying out artificial sampling experiments, much as described by Dr Yates (1963). By observing for themselves the genesis of a frequency distribution, the properties of sample means and other regularities underlying randomness, children can have the excitement of making discoveries about the real world without having to get a "correct" answer. They will learn that variation is not necessarily synonymous with error, which at school is usually equated with sin.

The concept of randomness is surely a very sophisticated one. It seems to deny the instinctive human need for rational explanations of events. Physicists have for a long time included it as a basic concept in statistical mechanics and quantum theory, but it is easier to accept randomness in this theoretical way than to credit it when you actually see it. It takes a lot of experience to resist the urge to reject apparently outlying observations as "wrong", or to accept points in a plane as being randomly distributed, and the earlier we start acquiring this experience the better.

As things are, most of the current A-level statistics syllabuses are not of a kind to excite much interest, and there is some recent evidence of a drop in the number of candidates. The work of the various committees on teaching statistics in schools is timely, and urgently in need of application. One of the most important requirements is to help the teachers themselves by setting up courses for them on the basic ideas of statistics and how they should be taught.

I have noticed that students who were attracted to statistics at school usually turn out to have had the luck to be taught by an enthusiast. More often, A-level statistics is taken in preference to classical applied mathematics because of an antipathy to the physical sciences. (Or perhaps, as in some girls' schools, there may be no choice.) I have always found this polarization between physics and statistics unfortunate, having myself a keen interest in both. But I am even more concerned at the separation of biology and mathematics at too early a stage at school. It creates an unnecessary

barrier to the biologist's understanding not only of statistics and genetics but also of the allied concepts of information theory and stochastic modelling which are now so important in biology.

## 5. University Teaching

It seems to be agreed, with varying degrees of reluctance, that a suitable place for statistics in a university is in a statistics department attached to a group or "school" of mathematics departments. The teaching need not be exclusively confined to it—econometrics and biometrics are commonly taught in separate departments. Some prefer an alternative scheme by which the statistics department is combined with a Research Council Unit which gives the department a particular flavour and a practical base. But much of the discontent about university teaching of statistics is directed at the way we mathematicians teach it. I sometimes think the difficulties are not fully appreciated.

Take the teaching of statistics to undergraduate mathematicians. There is the sheer lack of time available in a typical English three-year degree course. Students doing a degree in mathematical statistics must learn a lot of basic mathematics. This will occupy much of their first and second year. They will have to take subsidiary subjects which might be one of the physical or biological sciences, or economics. Their statistics courses, if properly taught, will be a time-consuming affair for both students and staff, involving practical work requiring close supervision as well as lectures and tutorials. There is now a requirement, in my own university at least, to allow time for "broader education" courses. We have to strike a balance between all these. It is not easy, but on the whole I think we get it about right.

We cannot teach maturity of outlook, only time and experience can produce that. It is not surprising that fresh graduates are sometimes naive and muddleheaded under the strain of their first interview (I can still remember mine!). They will be all right after a year or so, and their employer, having taken the risk, can take the credit for undoing the damage he thinks we have done to them.

Undergraduate degrees in mathematical statistics of the kind I have described are a relatively recent development. Should we concentrate on the more traditional postgraduate M.Sc. or Diploma course which grew out of the original Cambridge Diploma pioneered by Wishart? Such courses have proliferated in recent years. The extra year allows more time to learn provided the student starts with some preliminary background of statistics or probability theory. There is also the valuable experience of undertaking a practical project on a real problem. But with the present level of starting salaries it looks as if students are becoming increasingly reluctant to spend a fourth year on a grant. The trend will probably continue, though the Civil Service cadet scheme and similar arrangements will always maintain a limited flow of postgraduate M.Sc. students.

A recent Social Science Research Council report on the training of mathematicians (McLone, 1973) finds that a substantial proportion of the mathematics graduates in the survey would have preferred to have studied statistics as part of their undergraduate course, and that employers agreed with this preference. I am confirmed in my view that we must continue with the undergraduate degree, though the balance of specialization may need some adjustment. However, we could be more imaginative in the type of course offered. At Birmingham our students are required to take one of a number of subjects where they can see statistics in action, as it were. In this we have enjoyed the valuable co-operation of friends in other departments. In particular

Dr John Waterhouse has introduced our students to the organizational and data-collecting side of medical statistics, something quite different from the analysis and design aspects which they meet in their normal statistics course. A welcome result has been that some students discover their real statistical fulfilment in such work, and often the less mathematically able students have done unexpectedly well. Should we not offer combined degrees in applied statistics with other departments? We already have at Birmingham a successful course combining mathematics, economics and statistics, but I have something less theoretical in mind. It is possible that other universities already have such courses, but I am not aware of them

## 6. The University Attitude

Universities are not the only establishments offering advanced training in statistics. For specifically vocational purposes the courses offered by polytechnics and colleges of technology may well be superior, particularly the sandwich type with an intercalating period in industry. But the universities have a different role to play, and in spite of pressures to the contrary I believe the distinction should be preserved.

There is, or should be, a characteristically university attitude to teaching and learning a subject. It involves an open-minded and sceptical approach to the received wisdom of the textbooks, a certain disrespect for authority, on the part of both teacher and student. I do not say that teaching in polytechnics and other institutions of higher education may not often have this quality, or that university teaching always does (far from it!). But when it interferes with the smooth flow of instruction it is the universities that have a duty to put up with it.

It is remarkable how much unquestioned dogma goes on being printed and taught, I suspect largely out of inertia. I was led to ponder on this after reading Yates and Healy's disturbing account of candidates' ignorance of basic techniques used at Rothamsted. They concluded: "Even the *t*-test could be a source of confusion."

In my experience the *t*-test is indeed a source of confusion, but it is the better students who are confused. The run-of-the-mill student easily remembers the routine for comparing the means of two independent samples, with its assumptions of equal variances and normality. He may even start with an *F*-test on the sample variances, oblivious of the fact that, with samples small enough to need a *t*-test, only the grossest differences of variance will be revealed.

The good student has already noticed this. He will ask what happens if the assumption is not true, as we cannot really check it. So one goes on to discuss the robustness of the *t*-test, the therapeutic effects of transformations, and so on. One might also remark that many years ago Welch and others showed that the test statistic using individual estimates of variance is much less sensitive to unequal variances and has simple approximate significance levels. In that case, he will ask, why do you go on teaching Student's *t*-test? And I have said nothing of non-normality, which was discussed in a similar context recently by Professor Welch (1970).

I think the *t*-test is still worth teaching, with suitable reservations, oddly enough because of its remarkable theoretical properties when the assumptions are satisfied. One must also discuss alternative non-parametric tests because if the samples are really small the situation must be coped with somehow. But if an experiment cannot produce more than about ten degrees of freedom for error it isn't much of an experiment; if it can, the normal significance levels won't be all that wrong anyway.

Another important feature of a university department is its autonomy with regard to how and what it teaches. It is not tied to some externally imposed syllabus and can

therefore experiment in its approach. Standards of teaching and examining are maintained by the system of external examiners, but the tradition is one of tolerance of different patterns of teaching.

I remember being asked by a visiting American professor, "Has the Bayesian revolution reached England yet?" I knew what he really meant and confirmed that it had not only reached England but Wales and Scotland too. I am not myself a Bayesian except in a very limited sense, but though I don't exactly welcome the infiltration I would not oppose it even in my own department. It is only by trying out different approaches that the subject evolves—without variation there can be no evolution.

We have become set in our ways of presenting the subject to students. Indeed there now seems to be more disposition to try out new approaches in schools than in universities. With the advent of computers and terminals we can redesign our practical teaching to be more flexible and realistic, though we should be careful not to jettison desk computation altogether—I believe that no one appreciates the full meaning of orthogonalization until he has had to solve a set of least-squares equations by pivotal condensation on a desk machine! But we should be willing to experiment in a more fundamental way.

In a thoughtful paper, A. Birnbaum (1971) recently questioned the way textbooks all follow very much the same pattern, each assuming the correctness of its own prescribed techniques for analysing data, though they may differ in their basic approach to inference. He contrasts what he calls the "abstract methodological literature", comprising accounts of competing theories and methods of inference, with the "applied methodological literature" which ought to consist of critical comparison and discussion of the results of applying different methods of inference, including informal data analysis, to the *same* case study material. At present the second of these hardly exists. He proposes that statistics students should collaborate with students in other disciplines in seminar-type discussions of the results of analysing live data in different ways, including presumably the imperfect sort of data described to us by Professor Finney last year.

To those of us who have to cope with the system as it is, such a proposal may seem utopian, but I think we could go some way in that direction. Courses in comparative inference already exist and could be modified to include practical work of this kind, though time is a severely limiting factor. The situation is rather similar to that existing in the field of forecasting, where various rival prediction techniques have been put forward, each with some theoretical support. It has seemed natural to try out different methods on the same time series data, and many studies of this kind have been made. I find it an attractive idea to do the same thing with methods of inference.

In this connection one of the most heartening events of the past year to me was the Society's joint meeting with the British Psychological Society, when papers were read on "The measurement of belief" by P. Suppes and "Assessing uncertainty" by A. Tversky. It was not so much the content of the papers as the feeling that our discussions on inference were at last moving out of an age of faith and religious wars into an age of reason and experiment. It is surely vital for the two subjects to combine forces in trying to find out how people actually make inferences and decisions, as distinct from how we think they ought to, which is also important.

## 7. ADVISORY WORK

Central to a statistics department is its advisory work which gives life to its teaching and research activities and is really what the subject is all about. The image

of a university statistician as someone out of touch with real problems can be absurdly wrong. His experience may well be a good deal wider than that of some of his critics. But he cannot be expert at everything, and it is important to recruit staff with a broad balance of interests, from practical data analysis to theoretical statistics and probability.

It also helps if they have had experience outside universities. Thirty years ago most university statisticians had spent the war period in government establishments working on research or industrial problems. It is a pity that so many new staff nowadays miss the experience of working as statisticians outside the university, which should ideally be the final apprenticeship for a university post. I had the good fortune to start my career in 1935 at the Wool Industries Research Association where B. H. Wilsdon was enthusiastically trying to convince sceptical Yorkshire industrialists of the benefits of statistical quality control and properly designed industrial experiments. He has never received adequate recognition for his pioneering work. A period at the Ministry of Aircraft Production brought me in touch with quite a different range of problems. It also taught me the value of having professional administrators to relieve one of the kind of irrelevant burden that wastes so much academic time in universities.

The gap in experience is to some extent bridged by staff obtaining consultancies with outside organizations. However, part-time activity of this kind often means that the individual has to give up some of his teaching and other university responsibilities, which then have to be borne by the rest of the staff. I feel it necessary to mention such a mundane fact because it is likely to be forgotten when universities are encouraged to interact with the outside world, the implicit assumption being that university staff have time on their hands. But the benefits to statisticians of such consultancies are considerable, and I think there is a case for taking them into account as well as student numbers in the allocation of staff resources to university departments.

Another useful practice which has been encouraged for some time is secondment of university statisticians to government departments. If this is done on a year's leave of absence a temporary replacement can be appointed and the university does not suffer too much. More recently a similar scheme has been advocated by Sir Hermann Bondi for interchange of staff over a longer period of two or three years between universities and research establishments in government and industry. Affiliation of local research organizations to universities has long been a valuable way of interchanging research and teaching activities, my own department's association with the National Vegetable Research Station at Wellesbourne being a typical example. All these devices are important ways of broadening experience and they should be exploited.

It is noticeable that as basic statistical techniques become part of the stock-in-trade of various subjects, other departments inevitably start to appoint their own statisticians who then deal with the more standard kind of query. Individual researchers also begin to feel competent enough to use statistical methods on their own. There is a real danger in this because, as we all know, there are no routine statistical problems, only routine statisticians. The availability of computer packages has also encouraged some rather horrifying do-it-yourself statistical analysis.

Nevertheless, having developed a battery of useful techniques we cannot really complain if people want to use them. I think we sometimes act like overanxious parents. Mistakes will be made, damage may even be done, but we should not underestimate the ability of our colleagues to use their intelligence and common sense. What we have to do is to indicate our willingness to give advice whenever they seek it, and to encourage them to seek it early.

For a long time now, university statisticians have been freely devoting much time and energy to helping their colleagues in this way—not to mention their colleagues' Ph.D. students—without any compensating relief of teaching duties. Unlike normal research, such help does not usually result in publication, most people being content with an acknowledgement or an appendix. I am happy to report that Birmingham University has now recognized the situation by allowing the statistics department an extra member of staff specifically to help organize an adequate statistical advisory service for the university. Perhaps other universities will be encouraged to adopt a similar enlightened attitude.

## 8. RESEARCH STUDENTS

Unlike in other more traditional subjects, postgraduate work in statistics usually terminates at the M.Sc. or Diploma level, most of our students being anxious to apply their knowledge to a real job of work as soon as possible. We are fortunate in this because in some of the older scientific subjects a Ph.D. has become more or less obligatory for many posts. I hope statistics never reaches that state in Britain, but the situation needs watching.

The concept of "training for research" which underlies the Ph.D. system, and the Research Councils' support for it, is a curious one. It surely cannot mean training people to have original ideas—that is impossible. It can only mean training them in the use of techniques and equipment (in our case a computer), and perhaps passing on a few hints on how to organize their thinking. It has little to do with the university's requirement that the thesis shall contain original work by the candidate. Original work in the context of a statistics department means an advance in statistical theory, however trivial. Unless the student has outstanding research ability, his supervisor has somehow to produce a theoretical problem which is not too difficult and then lay a trail of clues for the next two years. I cannot see how this benefits anyone, least of all the average student who often loses what capability he ever had for independent thought. It also tends to produce the kind of published paper we could do without.

On the other hand, an ingenious application of known statistical techniques to a practical problem might be much more worth while and rewarding, yet an examiner may reject the thesis because it contains nothing "new". One way round the difficulty is to arrange that for the average student the Ph.D. is registered jointly between the statistics department and some other department providing the practical problem. To that department the application *is* original. Of course there has to be evidence of more than just an unimaginative use of routine methods, and there is always the question of how much was contributed by the supervisor, but given an oral examination the problem is not insuperable.

A related idea which at first sight seems attractive is to use research students directly on contracts with industry or other organizations. I know that some statistics departments do this, but although one can see its advantages I am on the whole against the practice. There is often pressure to produce some sort of answer by a given date, and a temptation to use standard routines to do so. The essence of university research is the freedom to follow interesting paths which may not look immediately fruitful. I am not at all arguing that departments should not accept contracts, only that routine investigations should be carried out by research assistants financed by the contract, not by research students. The same objection does not of course apply to the use of contracts for M.Sc. project work, which has no pretension to originality.

Contracts can be of great benefit in drawing the attention of staff to new lines of research, and good research problems for students often arise out of them. The organization providing the contract also benefits from the expertise of highly trained staff at a relatively low cost. But we have to be a little careful that the department does not become too closely integrated with a particular organization however well intentioned, especially at a time when universities are short of funds and likely to remain so.

Having said one unpopular thing I might as well say another. I believe, perhaps against the present fashion, that in collaborative work of this kind the statistician should retain his identity and not claim to be what he is not. We are being increasingly urged to adopt a "systems" approach to industrial problems, particularly in the field of optimization and control. It is certainly right for the statistician to understand the whole background of his problem and to work closely and harmoniously with those in charge of the operation. But the manager and the statistician have their own expertise and perform essentially different functions. Professor Benjamin recently put the point well, though he was speaking of the relationship between statisticians and administrators in the Civil Service (Benjamin, 1972). He referred to the tradition in the Central Government Statistical Service of establishing "an interface of mutual respect" between statisticians and administrators, each being conversant with the nature of the other's work but leaving to each the ultimate exercise of his function. To me this mutual respect is a vital ingredient in a creative relationship between the statistician and his client, and it implies knowing when not to intrude.

## 9. Mathematics and Statistics

Statistics is not mathematics, not even applied mathematics. It concerns the acquisition, interpretation and exploitation of data, and this may include some shrewd non-mathematical guesswork. Applied probability theory is, strictly speaking, mathematics, but the desire to test a probability model against observations and to use it for prediction can make the semantic distinction unprofitable. On the other hand, pure probability theory is a rapidly growing area of pure mathematics studied by enthusiasts who would be just as happy if it had no applications at all.

There is also mathematical statistics—what F. J. Anscombe once called "that grotesque subject", referring to the archetypal American form. At its worst it has produced vast numbers of tests, procedures and asymptotic results which have little relation to reality. For that one must to some extent blame the Ph.D. system and the pressure to publish, and also a tendency to use statistics as an excuse for mathematics. But at its best it has enriched the subject with penetrating insights and unexpected discoveries.

Should all these be situated within the same department? Theoretically each department is free to teach what it likes, but because of staff limitations, we have each to delineate our own boundaries for the subject, without being too rigid about it. In my view a reasonable balance comprises applied probability, theoretical and practical statistics, statistical computing, and the optimization procedures usually associated with operational research.

I have my doubts about pure probability theory. By including it we have a neat organization of stochastic subjects under one roof, and we have the possibility of cross fertilization. But pure probability theory seems to be on its way to becoming a distinct species which can no longer interbreed with its nearest relatives. Although there is still a substantial area of common interest, I think I would now prefer it to be placed

where it belongs, in pure mathematics, though the two departments should collaborate where possible in research and teaching. It is all a matter of relative priorities—given a substantial increase in staff a statistics department might well accommodate one or two pure probabilists without upsetting the balance.

Statistics needs good mathematicians with the right outlook to develop its technique and its basic ideas. We shall only attract them if we stress the mathematical interest of the subject as well as its practical usefulness. Most of the major concepts of statistical theory have the intuitive appeal and generality of good mathematics. They could only have been developed by mathematicians, but of a particular sort with a feeling for what matters in practice. Sir Ronald Fisher was such a person, though his mathematics was not of the currently fashionable kind. Nor was he always consistent. He admonished his readers for requiring unbiasedness in estimation because of its lack of invariance, yet he invented $k$-statistics, whose defining property is unbiasedness. Like most of the things he did there was a practical purpose behind it, but he developed the combinatorial theory far beyond its usefulness, surely because he enjoyed doing the mathematics, and why not?

Decision theory and mathematical programming have drawn on algebraic and analytic techniques not normally associated with classical applied mathematics, and this has been a source of attraction for research students looking for a new field. But statistics has also gained much in recent years from mathematical ideas originating in physics and engineering, particularly in the area of time series analysis and control theory, and the benefit has been mutual. One of my own interests has been to draw the attention of statisticians to the powerful approximation methods used by physicists for their own purposes, and I think there is more to be done. For example, it might pay us to look at the Padé approximant method which has recently been applied with great success to the study of critical phenomena in physics, and has already had repercussions in pure mathematics and computing.

Sometimes an idea has been pursued overenthusiastically but in the end it finds its true level of usefulness. The smoothing of spectral or probability density estimates is a case in point. Starting from the simple ideas of P. J. Daniell and M. S. Bartlett a major area of research rapidly developed in which much ingenuity was expended in designing smoothing weight functions, or "windows", according to various criteria of optimality. I myself contributed what I hoped would be the definitive word on the subject (Daniels, 1962) but nobody paid much attention, rightly as I now think, though the idea had some merit. After a while it became evident that when you tried out these techniques on actual data they usually all gave much the same answer if you chose the bandwidth right. In the awkward cases one could use J. W. Tukey's prewhitening device before smoothing. (In fact, many of the ideas in this area which have survived are the result of Tukey's sound practical intuition.)

Looking back on all this I feel that the minimum mean-square principle tended to dominate everything else including common sense. Whereas a negative estimate of variance would normally be regarded with horror, the possibility of negative estimates of density was often brushed aside as a small price to pay for minimizing the mean-square error over the whole range. I would now regard non-negativity as a primary requirement of any smoothed density estimate. And, if I may salvage a little from my 1962 paper, the Gaussian window not only satisfies this requirement but it has an important *local* minimum mean-square property as well!

The whole episode illustrates the way research often proceeds in practice, by false starts and conflicting claims rather than by the inexorable advance that would be so

much more convenient for planners and examiners. Universities exist to accommodate this kind of wayward, untidy, but in the end fruitful activity without irrelevant interference.

## 10. CONCLUSION

I have set out my views on statistics in universities—aired my prejudices if you like—knowing that not everyone will agree with them. In doing so I have mostly confined myself to generalities, which is much easier than getting down to awkward details, and I have tried to avoid current controversies on the principle that in a presidential address *de vivis nil nisi bonum*, though I may not have been entirely successful. But I hope the Society will continue its lively debate on how statistics should be treated not only in universities but in other places of education too, because on the way we do this depends ultimately the quality and attitudes of recruits to our profession, and nothing could be more important to the Society than that.

## REFERENCE

BENJAMIN, B. (1972). Teaching statistics and operational research to civil servants. *Amer. Statistician*, **26**, 23–26.

BIRNBAUM, A. (1971). A perspective for strengthening scholarship in statistics. *Amer. Statistician*, **25**, 14–17.

DANIELS, H. E. (1962). The estimation of spectral densities. *J.R. Statist. Soc.* B, **24**, 185–198.

DOWNTON, F. (1968). Statistics at A-level—a reappraisal. *J.R. Statist. Soc.* A, **131**, 500–506.

HOTELLING, H. *et al.* (1948). Report of the IMS Committee on the teaching of statistics. *Ann. Math. Statist.*, **19**, 95–115.

INTERNATIONAL STATISTICAL INSTITUTE. Recommendations of the 2nd Round Table Conference: "Teaching of statistics at the secondary level". Vienna, 1973. *Rev. Int. Statist. Inst.* (to appear).

MCLONE, R. R. (1973). The training of mathematicians. S.S.R.C. Research Report.

NATIONAL RESEARCH COUNCIL (1947). Personnel and training problems created by the recent growth of applied statistics in the United States. Reprint No. 128.

PEARSON, E. S. *et al.* (1952). The teaching of statistics in schools. *J.R. Statist. Soc.* A, **115**, 126–135.

WELCH, B. L. (1970). Statistics—a vocational or a cultural study? *J. R. Statist. Soc.* A, **133**, 531–554.

WETHERILL, G. B. *et al.* (1968). Interim report of the R.S.S. Committee on the Teaching of Statistics in Schools. *J.R. Statist. Soc.* A, **131**, 478–499.

WISHART, J. (1939). Some aspects of the teaching of statistics. *J.R. Statist. Soc.* A, **102**, 532–564.

—— (1948). The teaching of statistics. *J.R. Statist. Soc.* A, **109**, 212–229.

YATES, F. (1963). What is wrong with the teaching of statistics. In *Contributions to Statistics* (C. R. Rao, ed.) Mahalanobis 70th birthday volume. Calcutta: Statistical Publishing Society. (Pergamon Press.)

—— (1968). Theory and practice in statistics. *J.R. Statist. Soc.* A, **131**, 463–477.

YATES, F. and HEALY, M. J. R. (1964). How should we reform the teaching of statistics? Symposium on the teaching of statistics. *J.R. Statist. Soc.* A, **127**, 199–233.

The last President of the Society proposed the vote of thanks as follows:

Professor D. J. FINNEY: Whatever my views might be on the address that we have just heard, my duty as Ex-President would be now to congratulate the President of our Society on the ideas he has put before us and the clarity of his exposition; I should then invite this meeting to accord him a vote of thanks. I am grateful to the Society for its choice of President and to Professor Daniels himself because together they have made it possible for me to perform my duty with honesty, sincerity and pleasure.

I agree with almost every word that the President has said. I believe he has done well to provide us with an up-to-date view of the role of statistics in our universities. It is indeed strange that our Society, despite its deep concern for the development of statistics and for the use of sound statistical practices in all aspects of the life of our community,

should have passed its centenary before giving much attention to the teaching of statistics and the training of statisticians. Since then we have perhaps made up for the earlier neglect. However, we must count ourselves fortunate that, long before that time, there were individuals who not only taught statistics but also thought about the development of teaching programmes. The President has mentioned Dr J. Wishart, to whom both he and I owe a considerable debt; indeed, for a time a substantial proportion of the mathematically trained statisticians in Britain were Wishart products. He has also mentioned the long and distinguished history of statistical training at University College, London. I think that the pioneering spirit shown by the University of Aberdeen, though aimed much more at practice than at theory, deserves to be remembered. After agreement that the teaching of statistical methods "in the opinion of the Senatus, is required for the equipment of advanced students in various branches of Science", Aberdeen appointed a lecturer in 1906. From 1910 to 1939, Dr J. F. Tocher held that post with distinction. The syllabus that Tocher adopted for courses of lectures addressed to scientists about 1912 would not disgrace a course on applied statistics today, though possibly some of the methods that we use for the objectives that he described are a little more sophisticated.

I particularly welcome the emphasis that Professor Daniels places on exposing students to data. I cannot rival his personal discovery of Fisher's book, but I still have the copy that I bought before I began Wishart's course. I well remember the mounting excitement with which I, a pure mathematician taught to despise useful mathematics and almost totally ignorant of biology, spent a vacation struggling with pencil, paper and logarithms, to understand these mysterious analyses by reproducing them. Today I would hesitate to describe *Statistical Methods for Research Workers* as a well-planned text for the systematic enlightenment of students, whether biologists or prospective statisticians. Yet among the scores of books now available, written by teachers for use by teachers, how many share its power to arouse enthusiasm and its rewards for repeated reading?

In any general address on statistics today, it is customary to make some reference to the revolution introduced by computers. Professor Daniels's omission of this looks almost a deliberate flouting of fashion. Though I commend his originality, I want to suggest that his presentation calls for some mention of computers, for the problems they create rather than those they solve. Though we can be grateful for the occasional addition of a member of staff to the Department of Statistics as an aid to advisory services in the university, this is a small drop in the bucket of total university needs for statistical help. Some departments are able to appoint their own statisticians, or to include in their own professional staffs people with good experience of special fields of applied statistics (genetics, psychology, economics, engineering, and so on). Nevertheless, if my Department were to provide all the additional statistical consultative service that the University of Edinburgh could use, I am sure I should need at least 20 additional staff members, and I question whether the University of Birmingham would be very different. The demand for service does not exist on this scale at the moment, because other departments know there to be no hope that it will be satisfied: it could rapidly rise to this level if we were enabled to provide qualified help in the planning and analysis of statistical investigations. Some years ago, lack of these facilities meant that investigations were not undertaken or data were very incompletely examined and reported. Today, recourse is had to the university computer. There can be found one or more program packages with alluring titles, SPSS or BMD or many another; without too much pain, the psychologist or sociologist or engineer can learn how to feed data in and how to receive in return large quantities of tabulations and summaries of statistical tests. Quite often all is well, but the name *automatic data processing* itself carries a hint of the dangers: data may be fed uncritically into a program whose nature and purpose are inadequately understood by its user. I am not happy simply to say that the Department of Statistics has no responsibility for the illogical, incomplete or even erroneous analyses that occasionally emerge in this way, yet I do not see what action we can take. I recollect many years ago a colleague from a research institute asking me why I allowed such nonsense to be published from my university as he had recently encountered

in a paper in a biological journal. Despite my declared willingness to be consulted by my university colleagues, in this instance I did not know the author or the journal and had little contact with the department concerned. Within a research institute, rather tighter controls may operate; for practical reasons as well as moral, I should not like to see any censorship of the use of program packages or any requirement that the Department of Statistics be consulted before they are used. Perhaps during his year of office the President can give a little time to the implications of these difficulties.

We have preserved in our universities a diversity of outlooks on statistics, on what shall be taught and on how it shall be taught and on the relation of a Department of Statistics to other parts of the university. In this age of planners, of cost–benefit analysis, and of perpetually seeking a criterion of optimality for objectives that are neither unidimensional nor well defined, doubtless someone will want to enforce on us his own version of the best syllabus, method and form of organization. If everything else in this year's Presidential Address should eventually be forgotten, I hope six words will still be preserved: "without variation there can be no evolution". Others are more fitted than I to discourse on this theme in the wider context of social and political life. I hope that all who come from the universities see it as a principle to be maintained throughout university teaching, and maintained very strongly indeed in the teaching of statistics.

The President has given us a memorable address. I am happy to propose that we accord him a vote of thanks.

Professor G. A. BARNARD: Since the Prime Minister is preoccupied with affairs of State, it falls to me to second the vote of thanks. Insofar as I might be thought to be standing in for him, and insofar as some of my remarks may be interpreted in relation to national policy, perhaps I had better say that Mr Wilson has not seen my text, so he has even less idea of what I am going to say than I have. He can in no sense be held responsible, although I hope he would not disagree strongly with much of my remarks.

The responsibility of standing in, even in this limited sense, for the Prime Minister would weigh heavily on me were it not for the deep pleasure given to me to be able to welcome and congratulate such an old friend as Professor Daniels on his witty and stimulating address and on his inauguration as President.

We have enjoyed well over 30 years of friendly disagreement on a wide variety of topics. Neither of us has ever been able to quite convince the other. We have usually moved in the same direction, but not at a similar rate, nor from the same place. This friendly disagreement is continued this evening but, on this occasion, I immediately concede the debate to him because I was criticized on a previous occasion for the solecism of discussing the actual matter of the President's address at length. So, instead of doing that now, I hope I may be forgiven if I dwell a little on a title near to his—statistics *of* universities, rather than statistics *in* universities.

Statistics of universities have shared in the general improvement which has taken place in our official statistics as a result of the impetus provided by Professor Finney's predecessor —although his predecessor's complaint about last year's Bradshaw might still be echoed in this case because the latest available volume of university statistics relates to 1971.

1971 was the year in which the DES moved over to an individualized record system, fully computerized, which was intended to provide us with all sorts of information about stocks and flows, and which aroused considerable misgivings at the time concerning the risks of undue disclosure of personal information which might ensue. As a result, an elaborate system of safeguards was set up to prevent any such improper disclosure. So effective has this been that no information of any kind, proper or improper, has since been published!

When this hiatus has been overcome I feel confident that my successor as President would join me in the hope that the new volumes will contain, alongside the data relating to institutions on the University Grants Committee's list, data relating to the Open University. In making estimates of the stock of graduate mathematicians, for example,

it seems we shall have in 1980 about 70,000 as compared with about half that number two years ago. Such estimates could be seriously understated if the output of the Open University is not taken into account.

Rapid growth of this kind in the stock of graduate mathematicians and corresponding changes in the stock of graduate statisticians should clearly be giving those of us who are in the universities food for thought. I think that this is a statistic of universities which is relevant to statistics in universities.

I would also like to take issue with some of those who have been taking a simplistic misreading of recent university statistics to suggest that there can be no further university expansion because there is a shortage of student applicants.

It is true that the figures of home applicants through the UCCA for the past three years have shown a very slight, apparently linear trend downwards. However, it must be borne in mind that the size of the relevant cohort has been fluctuating in an unusual manner—just how unusual is a little obscure because the figures of the Government Actuary do not altogether square with those of the Registrar General, so it is not possible to be absolutely certain of the situation. The figures are not affected by the uncertainty affecting those published in the Red Book yesterday, of which the Chancellor of the Exchequer is reported in *The Times* today as saying that their origin lies in the

> "extrapolation from a partially known past through an unknown present to an unknowable future according to theories about the casual relationships between certain economic variables which are hotly disputed by academic economists . . .".

I suspect that there is a misprint there! The figures of the Registrar General are much safer than that, but are still a little puzzling.

When we relate these figures of applications to cohort sizes we find that while the proportion of men applying to universities seems not to be rising, but fluctuating a little, the proportion of women applying is continuing to rise at a rate which is most encouraging to those of us who feel that there has been a great waste of talent in our failure to distribute university education equally to members of both sexes.

Bearing in mind that the births in 1964 exceeded 1 million for only the second time since the Second World War—as against, for example, 790,000 in 1955—and that people born in 1964 will be entering tertiary education around 1982, it becomes clear that a 20 per cent increase in demand for places over the next 8–10 years for universities and tertiary education institutions could well prove a conservative estimate.

I make this point, not because I wish to suggest at all that tertiary education should not bear its proper share of the economies which are being forced upon us by world conditions, but because some vice-chancellors—who ought to know better—may have created the impression that economies can be made in this sector without loss. That is not at all true.

Reverting to the stock figures which I mentioned earlier, and also more closely to the topic of the President's address, these should lead us to reconsider the content and form of the courses which are provided in universities—as our President has done tonight. There must surely be less emphasis than in the past on post-graduate training for the Ph.D. of a traditional type—as he has suggested. We must broaden our courses so that our students, in learning to express themselves in mathematical terms, do not lose the capacity to express themselves in lucid prose. As the President has said, this does not imply that we should reduce our efforts in research.

By making this excursion so far from the main theme, I have managed to resist the temptation which naturally arises to argue about the precise interpretation of the so-called assumptions of the $t$-test, the possible snags of prewhitening, or the relationship between biology and mathematics teaching in schools and the dozens of other penetrating remarks and insights which we have been given tonight.

If I may be permitted to catch one possible misunderstanding before it goes down as history, I might remark that the Diploma of Imperial College was being awarded in statistics under the guidance of Professor Hyman Levy many years before the Cambridge Diploma was instituted. However, of course it was the latter, especially its development,

for which Professor Daniels was so largely responsible, which had by far the major influence.

It gives me the warmest pleasure to second the vote of thanks.

The vote of thanks was passed by acclamation.

As a result of the ballot held during the meeting, the following were elected Fellows of the Society:

APPS, Patricia Helen
BOWERS, David
CROFT, George
CUNNINGHAM, John
CUTHBERT, James Rutherford
GLASSER, Jay Howard
HENTSCHKE, Richard Paul
HEWER, Alan Reginald
JONES, Charles Langford
KEMPSON, Robert Eric
LANG, Clive Dennis
LEIGHTON, Monica Hedy
MCCARTNEY, Peter Russell
MARKHAM, John
MULREANY, Philip Vincent
OYEKA, Christopher Chike
PEDERSEN, Jørgen Granfeldt
POLONIECKI, Jan Dominik
REYNOLDS, Catherine Joan
RICHARDSON, William Alan
ROBINSON, Anthony
ROSS-PARKER, Howard Morgan
RUDDOLFER, Stephen Martin
SHAW, Peter
TAN, Khye Chong
TAVARE, Simon
WALKER, Peter Arthur
YOUSEFZADEH, Behrooz
GEORGE, Professor Aleyamma

As a result of the ballot held during the meeting of October, 1974, the following were elected Fellows of the Society:

AKEROYD, Susan Elizabeth
ALAVI, Athar Shafi
BARNATO, Michael
BENNETT, Martyn Christopher
BISHOP, Ian James
BOOTH, Nathaniel Barton
BRACKSTONE, Gordon John
CHAKRABARTY, Biswanath
CLUCAS, Marion
COLEMAN, Michael Joseph
COLOMBO, Richard Alan
CONGDON, Peter Douglas
CRANLEY, Roy
DAVIES, Alan Gareth
DE PAIVA, Antonio Fabiana
DREDGE, Robert
DUCKWORTH, Frank Carter
ESTCOURT, Paul
GODSELL, Robert Frank
GORE, Sheila Macdonald
GOLDIE, Charles Maxwell
GORDON, Osmond George
GREEN, Michael Robert
GREENWOOD, Ruth Nicholl
HABBANTI, Andrew
HANKS, Brian James
HICKEY, Raymond John
HOLMES, Peter
JAMES, John David
JENKINS, Linda Margaret
KMIETOWICZ, Zbigniow Wawrzyniec
LAWAL, Hammed Bayo
LAWS, Elaine Anne
MACDONALD, Marion Joy
MCDONNELL, Joseph
MACMAHON, Kevin Jude
MCNICOL, James William
MOYNIHAN, John Anthony
MURTY, Radhakrishna Bhyravabholta
NARAIN, Prem
NAYIR, Ravesndran P. R.
NICHOLSON, Michael David
OWEN, Delyth Ann
PARKER, Philip Roger
PARRY, Roger
QUIRKE, Barry Anthony John
RANDALL, Robin Brian
RESPEN, Marie-Madeleine
ROGERS, Judith
ROPER, Brian Anthony
RUTTER, Edward Leonard
SHEARRING, Howard Gordon
SHERINGTON, John
SPENCER, Bruce

ST LEGER, Antony Selwyn
STARK, Louis Ien
STRANGE, Glenn
STROGANOV, Eugeny
SUSTS, Antons Bruno
SWIFT-PEDERSEN, Joanne
TERRY, Edward George
TURNER, Philip John
VASSILIOU, Papayotis Christos
WALL, David Anthony
WHICHELOE, Peter John
WHITEHEAD, John Raymond
WOODMAN, Michael James
YAP, Kim-Seong
YASSAEE, Hedayat