John T. Lewis (1932-2004)

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1 Introduction

The passing of John Trevor Lewis on the 21st of January 2004 was a great loss to the international mathematical physics and applied mathematics communities. An extraordinary scientist and exceptional friend, he is missed by those that knew him or his science.

We begin this tribute with a biography in Section 2 before describing some of his many scientific achievements in Section 3. We finish with John's indelible scientific legacy: his bibliography. We are indebted to many of his friends, students, collaborators and colleagues for helping us in this task.

2 Biography

John Trevor Lewis was born in Swansea, Wales, on the 15th of April 1932 to Tegwyn and Trevor, a ship-broker. One of his teachers in primary school was Thomas George Thomas, who became a member of the British Parliament and, as Lord Tonypandy, speaker of the House of Commons. John was always amused in Dublin when turning on the BBC in the morning to hear his old teacher call out in a Welsh accent the ritual cry of: "Order! Order!".

His secondary education began at Cardiff High School, which he attended between 1942 and 1948. He spoke highly of one of his mathematics teachers there, Arthur Davies. Arthur was the father of Brian Davies, with whom John would later write a fundamental paper on quantum measurement. Tragically, John's mother died while he was still young. After the Second World War his family moved to Belfast where he attended the Royal Belfast Academical Institution from 1948 to 1949.

His third level education was at Queen's University Belfast, where he was an undergraduate from 1949 to 1952 and a postgraduate from 1952 to 1955. He won a Foundation Entrance Scholarship in 1949, the William Blair Morton Prize in 1952 and a Foundation Scholarship in 1955. He was awarded a B.Sc. (First Class Honours) App. Maths. in 1952 and a Ph.D. in Applied Mathematics in 1955. At Queen's John met Maureen MacEntee, an organic chemist. They were married in September 1959.

John's doctoral supervisor was the late Sir David R. Bates FRS, with whom he worked during the first two years of his postgraduate studies. In the final year he primarily worked with a young Alexander Dalgarno, who is now the Phillips Professor of Astronomy at Harvard University.

After completing his Ph.D., John moved to Oxford University where he was a post-doctoral researcher from 1955 to 1956 under the supervision of the theoretical chemist Charles A. Coulson FRS, then the Rouse Ball Professor of Mathematics. He spent 1957 to 1959 as a Research Lecturer at Christ Church, Oxford, and a University Junior Lecturer in Mathematics.

In 1959 he moved to Brasenose College, Oxford, where he was the Hulme Lecturer in Mathematics for 1959 and 1960 and Official Fellow (Tutorial) from 1960 to 1972. He served as Dean of Brasenose College from 1964 to 1967. In 1966 he became a University Lecturer in Mathematics at Oxford; a position he would hold until 1972. It was at Oxford, John and Maureen had their four children: Caitríona, Michael, Róisín and Ciarán.

John spend a year on sabbatical from Oxford in 1969 as a Member of the School of Mathematics at the Princeton Institute for Advanced Study and 1970 as a Visiting Scientist at Rockefeller University. In 1972 John moved to Dublin, Ireland to take up a Senior Professorship in the School of Theoretical Physics at the Dublin Institute for Advanced Studies (DIAS), on the retirement of the relativist John L. Synge. His letter of appointment was signed by the Irish Republic's first Taoiseach (prime minister) Éamon De Valera. He would stay at DIAS until his retirement in 2002, but was on sabbatical from 2001 setting up the Communications Network Research Institute (CNRI) at the Dublin Institute of Technology with a prestigious Principal Investigator award from Science Foundation Ireland.

John's time at Oxford saw the birth of rigorous Mathematical Physics. Until that point, except in exceptional cases, a mathematically rigorous approach to much of Theoretical Physics was not felt necessary or worthwhile. Although rigorous Mathematical Physics was unfashionable in Coulson's Oxford, this method of dealing with physical ideas appealed to John. He argued that deep understanding of underlying mathematical structure provided new physical insight. Modern thinking would surely support this point of view. From then on, this was his way of understanding. When asked to explain why, he would answer: "you have to ask my psychoanalyst". Although this reply was not supposed to be taken seriously, it accurately described his compulsion for finding the most mathematically concise and economic explanations for complex physical phenomena.

In the spring of 1969, John met Mark Kac at Oxford. After John completed his sabbatical at at the Institute for Advanced Study in Princeton, New Jersey, Kac invited John to Rockefeller University, New York. His interaction with Kac strongly influenced his research interests. It was Kac who introduced him to George W. (Bill) Ford, with whom he would collaborate for over twenty years.

In 1971 he met André Verbeure and although they collaborated on only one paper much later, they became close in their support of the international Mathematical Physics community, particularly through the International Association of Mathematical Physics (IAMP), whose Executive John was a member of from 1982 to 1989.

One of his first acts as a Director of DIAS was to introduce an open access policy to its facilities, enabling scientists from all over Ireland to further their research. In 1988, the Government had more or less decided to close DIAS. There are many people who can claim a share in reversing this decision but the rôle John played was certainly significant.

During the 1980's John was a frequent visitor to Warwick, serving on the Advisory Board to the Mathematics Research Centre from 1980 to 1982. His former student John Rawnsley was appointed there at the same time as David Evans, both of whom had earlier been scholars at DIAS. He also developed close relations with the University of Groningen through Marinus Winnink and Nico Hugenholtz. This provided a sequence of outstanding scholars for DIAS.

John had strong links with the University of Wales. He was influential in bringing the Congress of the International Association of Mathematical Physics to Swansea in 1988, which helped Swansea's reputation as a serious centre for Mathematical Physics. He served as Vice-Chairman of the scientific organizing committee. He was an Honorary Professor at Swansea from 1992 to 1995 and at Cardiff from 1998 until his death.

In July 1997 he returned to Swansea for a conference in honour of his 65th birthday at which many of his collaborators and students congregated. His last visit to Wales was in November 2002 when he was the principal speaker with Vaughan Jones at the London Mathematical Society Regional Meeting in Gregynog.

John had great sympathy for scientists, in particular mathematical physicists, from Eastern Europe. In spite of visa problems, the first research trip, or one of the first trips, to the West for a considerable number of scientists from the former Eastern block was to DIAS. It was particularly beneficial for colleagues in Poland and the former USSR. On the invitation from the Steklov Mathematics Institute, John visited Moscow and Kiev as a Guest of the Soviet Academy of Sciences in 1989. This visit strengthened the links between DIAS and the Moscow State University, through Vadim Malyshev, the Steklov Institute, Moscow, through Alexandre Holevo, the Institute for Problems of Information Transmission, Moscow, through Yevgenii Pechersky, Yuri Suhov and Nikita Vvedenskaya, the Institute of Electronic Machinery, through Vyacheslav Belavkin, the Joint Institute for Nuclear Research, Dubna, through Valentin Zagrebnov and Vycheslav Priezzhev, and the Institute of Mathematics, Kiev, through Dmitri Petrina and Vladimir Skrypnik.

Beyond his research, John was heavily involved in Irish academic life. In 1971, he co-founded the Irish branch of the Pugwash Conferences on Science and World Affairs. He was a member of the Executive of the Irish Federation of University Teachers (IFUT) from 1984 to 1988 and its president from 1985 to 1987. John was elected to the Royal Irish Academy in 1977. He was a member of its council from 1985 to 1989 and from 1997 to 1999, and Senior Vice President from 1999 to 2001. Although his position at DIAS was free of teaching duties, for 24 years he offered statistical mechanics and probability theory courses to undergraduates at Trinity College Dublin and University College Dublin. The close relationship with Trinity was marked by an Honorary Professorship in 1999.

John was a gifted teacher with an enviable ability to get to the core of a subject, stripping it of inessential details, and present it clearly and concisely. He was never satisfied with his presentation and constantly worked at improving his method for giving the students deep insight. He approached his publications in the same way. His writing process was slow and meticulous. He was known on occasion to rewrite the draft of a paper in his clear handwriting seven times.

John did not approve of bandwagons. If he thought that a problem was worth investigating he would work on it whether it was fashionable or not. He was convinced that good work will eventually be appreciated. This view is vindicated by many ongoing citations of his work.

In the early '90s, John was genuinely worried about unemployment amongst gifted young mathematicians. He decided to set up a group in applied probability and move to working in that area. He was convinced that this would be intellectually and technically challenging, while ensuring good employment opportunities for students and postdocs. On his visits to Moscow, John was impressed by how Dobrushin's mathematical laboratory in the Institute for Problems of Information Transmission operated. Researchers there spent half their time on practical problems directly applicable in telecommunications and the other half on basic research. He knew that he could make this work in Dublin. The opportunity came in 1996 after he had an original insight on how to characterize Internet traffic using Large Deviation Theory. He persuaded the Computer Laboratory in Cambridge and the Swedish telecom operator Telia to join him in a three-year research contract funded by the European Commission. The technology developed during the project was to prove sufficiently successful to warrant John co-founding a company, Corvil, to exploit the intellectual property. After Corvil received seed capital and a high-powered management team were recruited, John returned to scientific research. He bid successfully for a prestigious Principal Investigator award from Science Foundation Ireland. In 2001 he and his team established the Communication Networks Research Institute (CNRI) in the Dublin Institute of Technology to continue his work in fundamental modeling of computer networks.

At Oxford John supervised fifteen successful doctoral candidates. Another two started in Oxford and finished at Trinity College Dublin, as DIAS is not a degree awarding institution. With N. M. Hugenholtz, he co-supervised two students at the University of Groningen. An additional five would graduate from Trinity College Dublin, while one would graduate from Dublin City University. Many of his students have become well known academics in their own right. At John's 65^{th} birthday celebration at Swansea John said that he always felt that he was a self-taught mathematician and, on meeting his ex-students again, he had come to realize they too were self-taught.

June 2005 saw the Dublin Institute of Technology host a four day memorial conference in John's honour, generously funded by Science Foundation Ireland and organized by Marguerite Carter, Tony Dorlas, Ken Duffy and Brendan Goldsmith. With over forty international speakers, the wide range of plenary speakers was testament to his diverse research interests: Jennifer Chayes (Microsoft Research), David Evans (Cardiff University), George W. Ford (University of Michigan), Arthur Jaffe (Harvard University), Frank Kelly (University of Cambridge), Christopher King (Northeastern University), Derek McAuley (Intel Research), Cathleen Morawetz (Courant Institute), Neil O'Connell (University College Cork), Raymond Russell (Corvil), André Verbeure (Katholieke Universiteit Leuven) and Marc Yor (Université Paris VI).

John's impressive scientific work is a monument to our memory of him. His friends and collaborators will recall him for his ability, enthusiasm, insight, encouragement and eagerness to help. Many mathematicians would not have considered academic life without John's influence. While considering John's contribution to science, we should not forget the contributions that he made to many of our lives. An old friend of John's from his time at Oxford put it well when he said: "John was a lovely man and a perfect fit to my ideal of an academic: a man of great learning, lightly worn, and no conceit of himself".

3 Research highlights

John's scientific career is difficult to summarize, not only because it is long and distinguished, but also because its subject matter is so varied. André Verbeure encapsulated it with: "...mathematical research, for him a house with many rooms. During his career John has visited many rooms". His obituary in the Irish Times on the 19^{th} of February 2004 was entitled "Theoretical physicist who revolutionized telecommunication". This seemed appropriate for those who knew him during the '90s, but led Simon Altmann to write in the Brazen Nose[1]: "A surprising line to commemorate a man who for many of us had been the most pure of applied mathematicians". John made significant contributions to theoretical chemistry, quantum measurement, quantum stochastic processes, the Ising model, boson condensation and telecommunications. Here we briefly describe some of John's major scientific achievements.

[1] A publication of the Brasenose College Society, Oxford.

3.1 Perturbation theory

In the final year of his graduate studies John worked with Alex Dalgarno on the use of variational methods in quantum mechanical perturbation theory. Emerging from their studies was a procedure for the evaluation of infinite summations of matrix elements which is widely applicable. It has come to be known as the Dalgarno-Lewis sum rule or method. They also explored the structure of the series representation of atomic interactions in inverse powers of the interatomic distance and demonstrated that the series were unique and asymptotically divergent.

3.2 Quantum measurement theory

This important work with Brian Davies was stimulated by a series of lectures of George W. Mackey in Oxford, stretching over three terms in 1966/67. During the second term Mackey concentrated on his approach to the foundations of quantum mechanics, which combined von Neumann's account of measurement with the theory of group representations. This inspired John and Brian to start a collaboration that lasted until John left Oxford, and which influenced the work of both for years afterwards. In order to provide a mathematical framework for the process of making repeated measurements in a quantum system they proposed a mathematical definition of an instrument that generalized the concepts of observables and operations. This definition made it possible to develop notions of joint and conditional probabilities without the commutation conditions needed in the approach via observables. One crucial notion was that of repeatability, which they showed had been implicitly assumed in most of the axiomatic treatments of quantum mechanics, but whose abandonment led to a considerably more flexible approach to measurement theory. It turned out that this new theory provided an appropriate way of describing measurements in quantum optics, then a new field, but for which Roy Glauber was awarded a Nobel Prize in 2005. The value of the insights provided by their joint work became widely known long after both had moved on to other subjects.

3.3 How to make a heat bath

This is the title of one of John's papers. Typical of his style, it encapsulates the problem in just a few words. The work was motivated by the Ornstein-Uhlenbeck model and the model of a heat bath proposed by George W. Ford, Mark Kac and Peter Mazur. The basic problem considered is to model dynamical systems where friction or dissipation emerges in the statistical description of a small system. Given the dissipative irreversible dynamics of the small system, how does one construct a reservoir so that after the restriction or projection of the reversible dynamics of the larger system one recovers the dynamics of the small system? John started this programme with his student Lyn Thomas, encapsulated in the Hilbert space setting of Thomas's thesis (1971). Having sat John's M.Sc. class as an undergraduate, in

1975 David Evans came from Oxford to work as a scholar with John at DIAS. David and John wrote a series of papers on dilations of dynamical semigroups, culminating in their 1977 monograph. This collaboration during 1975-77, particularly the monograph, has been influential in subsequent developments of quantum probability.

3.4 Quantum Stochastic Processes

In 1969, John spent a year at the Institute for Advanced Study in Princeton, New Jersey. While there he visited Rockefeller University, New York, where Mark Kac suggested they consider the problem of quantum stochastic processes. After returning to Oxford, John started working on this problem with Lyn Thomas. In New York, Kac had introduced him to George W. Ford, from the University of Michigan, who was visiting Rockefeller at that time. This was the start of a collaboration that lasted for the rest of John's life. Their seminal paper on quantum stochastic processes was published some years later, but in the meantime their collaboration resulted in important work on quantum master equations and rotational Brownian motion. In 1984, Robert O'Connell from Louisiana State University joined the collaboration considering a broad program of research dealing with fluctuation and dissipative phenomena in quantum mechanics. This collaboration, facilitated by annual summer visits by Ford and O'Connell to DIAS, resulted in many publications.

In 1982 John wrote a paper of distinction with Luigi Accardi and Alberto Frigerio. It is highly cited, primarily because it achieves the correct categorical definition of random variable in quantum probability. The key observation is that a classical random variable X determines an algebra homomorphism through composition with functions f defined on the state space: $f \mapsto f \circ X$. Since quantum theory deals with observables which form noncommutative algebras, they defined a quantum random variable to be a homomorphism between involutive algebras, together with a state on the target algebra which determines expectations. A quantum stochastic process is then a family of such homomorphisms.

3.5 The Ising Model

When John moved from Oxford to Dublin in 1972, he took with him Peter N. M. Sisson, a graduate student who completed his Ph.D. at Trinity College Dublin in 1974. In 1972 Serguei Pirogov had shown that the thermodynamic limit of the Gibbs state in the two dimensional Ising model induced a pure state on the Fermion algebra containing the transfer matrices at all temperatures, so the phase transition was not apparent in this algebraic context. This problem was the basis of joint work between John and Peter. They showed that the phase transition was related to a jump in the index of a certain Fredholm operator, which John and Marinus Winnink later related to non-Fock quasi-free states on the half lattice which were only primary at high temperatures. However, the full lattice in the setting of Pirogov remained tantalizingly open. John returned to this problem later in a second collaboration with David Evans, which took place during 1982 to 1986 when David was at Warwick. They returned to the operator algebra framework for understanding the Ising model. On the Pauli algebra, the state induced by the Gibbs state with periodic or free boundary conditions is pure for high temperatures and impure for low temperatures. The automorphism method initiated by them for relating the Ising model at different temperatures gave a better understanding of Pirogov's puzzle. The method has become a standard tool.

3.6 Brownian motion on a manifold

John made illuminating contributions to the theory of Brownian motion on a submanifold of Euclidean space. He and Michiel van den Berg studied Brownian motion on a hypersurface (of codimension 1), and John then generalized this to Brownian motion on a submanifold of arbitrary codimension. The intuitive idea is that the infinitesimal increment of Brownian motion on a submanifold may be obtained by projecting onto the tangent space (at the point where the Brownian particle currently is) the increment of a Brownian motion in the ambient space. One has to be careful, however, because there are two versions of stochastic calculus, the Itô and the Stratonovich. The simple projection idea described above works only if Stratonovich calculus is used. On translating this into Itô form, one discovers the drift (in the ambient space) needed to keep the particle on the manifold, which proves to be a constant multiple of mean curvature in the normal direction for the case of a hypersurface. John and Michiel concentrated on the Itô version, because it then allowed them to exploit the powerful technology of martingales.

3.7 Do bosons condense?

Although Bose-Einstein condensation was discovered in 1925, there is still no rigorous proof that interacting bosons do condense. One of John's important contributions in this area is the realization that the condensation mechanisms can vary radically in different models. John's interest in Bose-Einstein condensation started with a visit by Mark Kac to Oxford, who introduced him to the problem. Together with Joe Pulè, he started by considering the free Bose gas, including the rotating gas, giving a complete rigorous analysis of the phase transition in the framework of C*-algebras. Kac had also pointed out the inequivalence of ensembles for the Bose gas. John and Joe formalized Kac's ideas by introducing what has now become known as the Kac density. Later on in Dublin they went on to consider the mean-field model in collaboration with Michiel van den Berg and Phillip de Smedt. With van den Berg and others, John found that an external field, as well as an unusual geometry, can drastically alter the nature of the phase transition exhibiting condensation in the lower states rather than just the ground state. This is now of relevance for recent experiments where fragmentation of the condensate has been discovered. John also proposed that condensation into the lower lying states, Girardeau's generalized condensation, is thermodynamically stable and that condensation into the individual states is not.

Around 1985 John met Monroe Donsker at a conference. Donsker personally explained to John the elements of Large Deviation Theory. This proved to be of great benefit for future research. From one back-of-an-envelope calculation, John quickly realized that this theory could be applied to obtain a much simpler derivation of the formula for the pressure of a mean-field Bose gas. In collaboration with Joe Pulè and Michiel van den Berg, and later also with Tony Dorlas, this was subsequently extended to the Huang-Yang-Luttinger model of a hard sphere gas and more complicated models. It culminated in a complete description of the most general Bose gas model with interaction diagonal in the occupation numbers. For several of these models the Bose-Einstein condensation phenomenon could be analysed.

3.8 Applied probability and telecommunications

In computer networks such as the Internet, machines communicate by transmitting variable sized packets of data that have attached a header indicating where the packet is from and where it wishes to go. As a packet traverses the network it is processed by intermediate machines called routers that choose on which link the packet should next be sent on the path to its destination. As links in the core network are typically fast, backlogs of packets at routers are rare. However, when congestion occurs, incoming packets are lost which leads to inefficiencies. In the 1990s, Large Deviation Theory was used to predict and quantify queueing behaviour at computer network routers, treating packet sizes and inter-arrival times as stochastic processes. The tail of the queue length distribution at a router can be related to the large deviation rate functions of these processes, enabling one to determine the likelihood of extreme queuing congestion.

The practical implementation of this knowledge had previously been to model the input as a Markov chain with many states, fit transition probabilities empirically and then determine the chain's rate function using spectral analysis; a cumbersome calculation that could not be performed in real-time. Drawing an analogy with chemical engineering, where entropy plays the rôle of the rate function, John knew that engineers did not determine a gas's entropy by fitting model parameters, instead they measured it directly. With his applied probability group he developed an approach based on this insight, which is best described in the 1995 IEEE Journal of Selected Areas in Communications paper. It was co-authored by Nick Duffield, Neil O'Connell, Raymond Russell and Fergal Toomey. The principles on which the techniques are founded were to prove sufficiently successful to warrant John co-founding a company, Corvil, to exploit this intellectual property.

3.9 Large deviations

John and his collaborators had used Large Deviation Theory for Bose systems and in queuing theory. In addition he became interested in the work of Charles Pfister on the foundations of large deviations theory in the context of statistical physics. John encouraged Wayne Sullivan to join the project. The result was a series of papers with applications to probability theory, information theory and dimension theory as well as statistical physics. Two fundamental aspects of the theory are exponential tilting and conditioning. In statistical physics these correspond to interaction potentials and conditioning by observables. The large deviation approach provides a natural treatment of equivalence of ensembles, which relates these two aspects. The ideas also suggest a way to define typical sequences in shift spaces and a consequent interpretation of asymptotic equipartition. Typical sequences may also be used to construct generic points. The Hausdorff dimension of the set of generic points of a measure corresponds to the entropy of the measure. The techniques yield results on sets more general than generic-point sets and apply to extended dimension theory concepts.

A Doctoral students

J.T. Lewis had twenty five successful doctoral students. Fifteen graduated from Oxford University: Robin Hudson (1966); C. Martin Edwards (1966); Atu Mensa Taylor (1967); Roger J. Plymen (1967); Lionel S. Wollenberg (1967); Wayne G. Sullivan (1968); Keith C. Hannabuss (1969); Mary Lunn (1969); G. Robert Mordaunt (1970); G. Malcolm King (1971); Lyn C. Thomas (1971); M. Elizabeth Major (1972); Joe Pulè (1972); John Rawnsley (1972); Robert H. Critchley (1974). With N. M. Hugenholtz, John was a co-promoter of two at the University of Groningen: Michiel van den Berg (1981); Hans Maassen (1982). Seven graduated from Trinity College Dublin, though the first two started in Oxford: Peter N. M. Sisson (1974); John A. Ziegler (1974); Raymond Russell (1997); Fergal Toomey (1997); Ken Duffy (2000); Brian McGurk (2001); W. Mark B. Dukes (2001). One graduated from Dublin City University: Cormac Walsh (1999).

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