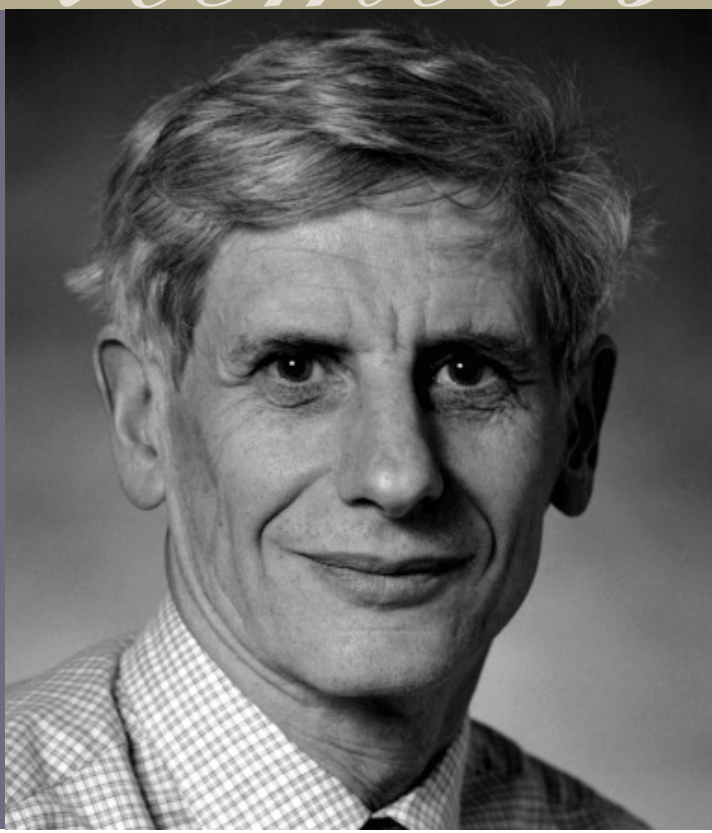
David J. Thouless

1934–2019

BIOGRAPHICAL *Memoirs*



A Biographical Memoir by Michael Thouless

NATIONAL ACADEMY OF SCIENCES

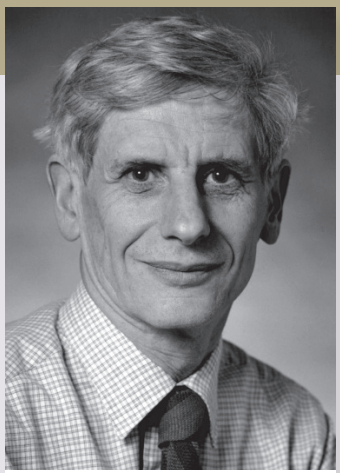
DAVID JAMES **THOULESS**

September 21, 1934–April 6, 2019

Elected to the NAS, 1995

David James Thouless was a theoretical physicist who was awarded the 2016 Nobel Prize in physics for his work on topological phase changes and topological phases of materials.

The Thouless family has its roots in Norwich and neighboring villages in Norfolk. David's paternal grandfather, Henry James Thouless, was the company secretary of Barnard, Bishop & Barnards, an iron-manufacturing company based in Norwich, and also had a passion for natural history. He collected insects (a leafhopper bug was named after him), and his collection is still held by the Natural History Gallery at the Norwich Castle Museum and Art Gallery. David's paternal grandmother Maud (née Harper) was from Devon.

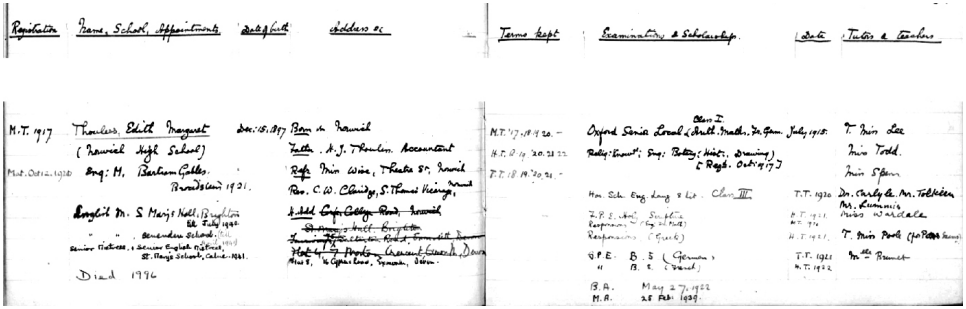


Photography by Mary Levin/ University of Washington 1995.

By Michael Thouless

David's father, Robert Henry Thouless, grew up in Norwich with his sisters Sybil and Margaret. Robert was the first in his immediate family to go to university, but his younger sister Margaret was admitted to Oxford in the fall of 1917, being in the last cohort of women who had to take their finals without having matriculated as members of the University. After taking her finals in the Trinity Term of 1920 (with J. R. R. Tolkein as one of her tutors), she returned to Oxford in the Michaelmas Term and spent a further four terms taking the additional examinations required for a degree. She graduated with a B.A. in 1922.

Robert Thouless entered Corpus Christi College, Cambridge, as a sizar in 1912 to read natural sciences, and graduated in 1915 with a starred first. After graduating, Robert served as an officer in the Royal Engineer Signal Service, first in England, and then saw action on the Salonika front. After the war, he returned to Cambridge to work on a Ph.D. under the psychologist William Rivers, and earned his degree in 1923 with a thesis[1] entitled the "Nature of Religious Experience and its Significance for Thought."



A copy of the academic record of David's aunt Margaret kept in the library of St, Anne's College, Oxford, kindly provided by the librarian in 2021.

One of Robert's friends during this time was Lawrence Bragg — his diaries[2] record a sailing trip in 1921 with Bragg and George Thomson. After his PhD, he was hired by the University of Manchester as a lecturer, which is where he met his wife Priscilla, but then moved to the University of Glasgow as a lecturer in psychology in 1925. It was there that Robert made an important contribution to the psychology of vision, known as "phenomenal regression," about how the brain corrects for perspective and illumination.[3] It was also during this period that he presented a series of popular lectures through the novel medium of radio on the topic of dishonest argument. These lectures became the basis of his best-known work, "Straight and Crooked Thinking," which was first published in 1930,[4] becoming particularly timely with the propaganda of the 1930s and 1940s. This book was so well known that, like the author, David would frequently have been asked whether he was related to Robert Thouless when growing up. Indeed, David gave the impression of still feeling in the shadow of his father, even as his own career was taking off.

David was born in Bearsden, near Glasgow in Scotland, on September 21, 1934. Four years later, Robert moved back to Cambridge, and his interests in parapsychology became a prominent theme of his research. He was president of the Society for Psychical Research from 1942–44, a position that had also been held by physicists such as Oliver Lodge and Lord Rayleigh (both the Nobel Prize winner and, later, the son as well), other well-known chemists and biologists, and a prime minister. As part of his research, Robert explored the concepts of extrasensory perception and life after death. His war-time knowledge of codes led him to devise what was, at the time, a famous experiment whereby he would try to transmit the key to a coded text after death. Although the code

was not broken in his lifetime, he didn't make a connection with the living in the period immediately after his death, and the code was broken by the use of a laptop computer a decade later, ending the experiment.[5]

David's mother was Ella Grafton (née Gorton); as an adult she was known as Priscilla. She came from a family of clergymen. Her grandfather, John Gorton, was an archdeacon of Madras (now Chennai, India), and her eldest brother, Neville Gorton, was appointed Bishop of Coventry in 1943, having a major influence on rebuilding the bombed cathedral after the war. There were senior military officers in her family as well. Hastings Ismay was related through marriage to a cousin, and a paternal uncle was a brigadier-general who was the British representative on the Inter-Allied Military Commission in Hungary after World War I.

David's maternal grandfather was Charles Vincent Gorton, and his maternal grandmother was Isabell Mary (née Clegg). Charles Gorton was a Foundation Scholar at Hertford College, Oxford, and was the Rector of Poulton-le-Sands in Lancashire from 1889-1909. Here, he helped establish the Morecambe Music Festival. This became one of the premier choral events in England, and led to a deep friendship with the composer Edward Elgar. Canon Gorton provided theological advice for some of Elgar's compositions, and in 1909, when his health had deteriorated to such an extent that he had to resign his living, he took his entire family to live in Hereford near Elgar. Elgar moved back to London at the beginning of 1912, and Canon Gorton drowned in the River Wye at the bottom of his garden in August of that year.[6]

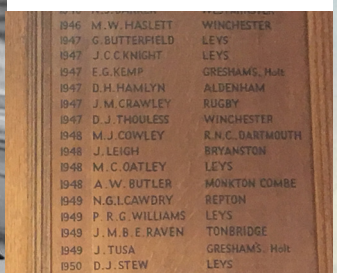
After the death of her father, David's mother, Priscilla, moved with her family back north, earning a scholarship to Manchester University, where she she earned a B.A. and an M.A. in English. She continued as a lecturer in English there until she gave birth to David's elder sister, Susan in 1925. After having to resign her lecturer position because of the birth of a child, Priscilla went on to write a monograph on twentieth-century poetic drama in 1934,[7] but, otherwise, her professional activities outside the home from that point on were limited to volunteer roles at local schools.

Childhood (1934–52)

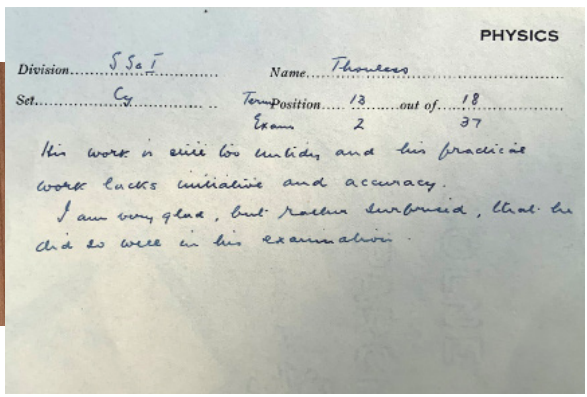
David spent his first two years in Bearsden, and then his father had a year-long sabbatical at Cambridge, before returning to Cambridge permanently in 1938. David started school a year later, just as World War II began in Europe, and moved to St. Faith's School in 1941. In his autobiographical notes, David reminisced about the important role his

father played in his early education, developing an interest in arithmetic, maps, and chess teaching him how to use base-2 arithmetic to win at the game of Nim, and how to sail, and generally filling in the gaps in his education that resulted from many of the better teachers being off fighting in the war. David taught himself the basics of Latin during a longer-than-usual absence from school from a childhood illness. David also noted that a frequent visitor to the family home in Cambridge during his childhood was the philosopher Ludwig Wittgenstein.[8]

In the summer of 1947, David took the scholarship examination for Winchester College. Despite the fact that he did not know the Greek normally expected for someone at that time, he did well enough in Latin and in the other exams to gain the top scholarship (out of twelve in his year). He started at Winchester in September 1947. Although he was initially directed to the Classics side, he moved over to the Science side of the school in his second year.



1946	M.W.HASLETT	WINCHESTER
1947	G.BUTTERFIELD	LEYS
1947	J.C.C.KNIGHT	LEYS
1947	E.G.KEMP	GRESHAMS, Holt
1947	D.H.HAMLYN	ALDENHAM
1947	J.M.CRAWLEY	RUGBY
1947	D.J.THOULESS	WINCHESTER
1948	M.J.COWLEY	R.N.C., DARTMOUTH
1948	J.LEIGH	BRYANSTON
1948	M.C.OATLEY	LEYS
1948	A.W.BUTLER	MONKTON COMBE
1949	N.G.I.CAWDRY	REPTON
1949	P.R.G.WILLIAMS	LEYS
1949	J.M.B.E.RAVEN	TONBRIDGE
1949	J.TUSA	GRESHAM'S, Holt
1950	D.J.STEW	LEYS



PHYSICS

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Exam 2 37

His work is still too untidy, and his practical work lacks initiative and accuracy.

I am very glad, but rather surprised, that he did so well in his examination.

Clockwise from left: David at the age of 4 (by Ramsey & Muspratt), the Honours Board at St. Faith's with a list of scholarships won by "Old Fidelians;" (including his life-long friend John Crawley), and a physics report from Winchester.

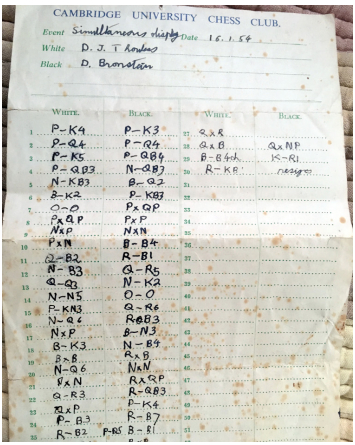
At Winchester, David's school reports often followed traditional British pedagogy in their attempts to ensure that a future Nobel Prize winner developed an inner self-confidence without external nurturing. For example, a physics report says: "His work is still too untidy, and his practical work lacks initiative and accuracy. I am very glad, but rather surprised, that he did so well in his examination." He relates in his memoirs that he was

beaten in the competition for the senior mathematical prize in his penultimate year at Winchester by Nigel Daw (who became a professor of ophthalmology and visual science at Yale University), and shared the prize in his senior year with Andrew McLachlan (FRS), a year junior to him.

Undergraduate Education (1952-1955)

David initially applied to his father's college, but succumbed to the conventional wisdom that Trinity College is the only place for a budding mathematician. In the end, he failed to get a scholarship to Trinity but was awarded one at Trinity Hall, where he was very happy. National Service was still expected of young British men at that time, but Trinity Hall allowed David to defer it, and he matriculated in October 1952 to read for the Natural Sciences Tripos. He took mathematics (taught by Douglas Hartree), along with physics and physical/inorganic chemistry, and metallurgy in his second year, for Part I. He took physics for Part II, attending lectures by Abdus Salam on quantum mechanics and by Herman Bondi on general relativity, and graduated with a First in 1955.

His tutor at Trinity Hall was the historian and theologian Owen Chadwick, and he was supervised in mathematics by Shaun Wylie, who had worked at Bletchley Park with Alan Turing. He was an active participant in the activities of the College Chapel. It was probably at Trinity Hall where he became somewhat "High Church" in his Anglicanism. The author has early memories of a crucifix by David's bed, and of being taken to Little St Mary's in Cambridge with its incense and candles every Sunday. Although David regularly attended church until quite late in life, outwardly, at least, his religious side appeared to decrease as he got older, especially in the 1980s after moving to the United States. While an undergraduate, David developed a close friendship with Karen Spärck Jones, who went on to develop the basic concept underlying most computer search engines, and her future husband, Roger Needham, who became head of the Computer Laboratory at Cambridge. David took a sailing trip with them on the Norfolk Broads in the summer of 1955 and a road trip the following year to France and Spain, visiting the caves in Lascaux before access became restricted.



CAMBRIDGE UNIVERSITY CHESS CLUB.

Event Simultaneous display Date 16.1.54

White D. J. Thouless

Black D. Bronstein

	White.	Black.		White.	Black.
1	P–K4	P–K3	27	Q x R	
2	P–Q4	P–Q4	28	Q x B	Q x NP
3	P–K5	P–QB4	29	B–B4ch	K–R1
4	P–QB3	N–QB3	30	R–KR1	resigns
5	N–KB3	B–Q2	31		
6	B–K2	P–KB3	32		
7	O–O	P x QP	33		
8	P x QP	P x P	34		
9	N x P	N x N	35		
10	P x N	B–B4	36		
11	Q–B2	R–B1	37		
12	N–B3	Q–R5	38		
13	Q–Q3	N–K2	39		
14	N–N5	O–O	40		
15	P–KN3	Q–R6	41		
16	N–Q6	R x B3	42		
17	N x P	B–N3	43		
18	B–K3	N–B5	44		
19	B x B	R x B	45		
20	N–Q6	N x N	46		
21	B x N	R x QP	47		
22	Q–R3	R–QB3	48		
23	R x P	P–K4	49		
24	P–B3	R–B7	50		
25	R–B2	P–R5 B–B1	51		

David Thouless (seated on the left) playing David Bronstein (right) at the Cambridge University Chess Club on January 16, 1954. On the right is David's record of the match. (It looks like David immediately saw Bronstein's error of P-Q5 at move 25, and was so excited that he forgot to record it before entering his own move of B-B1 in the wrong column. It wasn't until move 28 that he corrected things.) (Photo credit or source.)

One particular anecdote from David's undergraduate years is worth telling. David never mentioned it to his family, and the author first heard about it as a young adult from his grandfather while playing chess one day, with a comment that it was the first occasion that he, Robert, had been asked if he was related to David! As an undergraduate, David played chess with the University Chess Club. In January 1954, David Bronstein visited Cambridge from Hastings, where he had just shared first place with Hugh Alexander, the cryptanalyst and two-time British chess champion, accompanied by another Russian chess grandmaster Vladimir Alatortsev. Bronstein had narrowly lost the World Chess Championship to Mihhail Botvinnik in 1951 (they drew twelve games each, but Botvinnik kept the title as current world champion). In Cambridge, Bronstein played a simultaneous match against twenty-five University Chess Club members. Alatortsev played a further seventeen. Bronstein won nineteen of his games, drew five, and lost to David Thouless.[9]

Graduate Research at Cambridge (1955–56)

After graduation, David expected to have to serve in the military, because he didn't want to do the alternative of military research. But when the new Cavendish Professor, Neville Mott, called David into his office to ask what he was doing next and why he hadn't

applied to do a Ph.D., he learned that National Service could be deferred if he continued with scientific research of any kind. He therefore started looking for funding to begin his studies in 1956. Although Mott warned him that the long-term prospects for theorists were poor, he wasn't enthusiastic about solid-state physics. Salam rejected him because his group was full. However, Hans Bethe was on sabbatical at Cambridge from Cornell in 1955-1956, with plans to change his area of research from particle theory to nuclear physics[10] and a particular goal for the year of understanding Brueckner's perturbation theory. Bethe wanted to work with some students while at Cambridge, so Mott suggested that he work with both David and a research student from Trinity College, Jeffrey Goldstone, for the year.

During his year with Bethe, David went to visit Rudolf Peierls in Birmingham, and met Keith Brueckner while the latter was visiting Cambridge. It was the application of Brueckner's theory to nuclear interactions, as further developed by Goldstone[11] under Bethe's direction, that eventually led to David's Ph.D. Although required coursework is not a feature of the Cambridge Ph.D., David took the opportunities offered by the environment to attend a number of courses. These included Bethe's course on field theory and elementary particles and a course on advanced quantum mechanics by Paul Dirac. This latter class provided a first introduction to topological quantum numbers that would become so important to David's career. He also attended what he described as incomprehensible seminars in which no one asked questions. (Later in life he expressed his philosophy on giving scientific talks to the author, perhaps partly in jest: everyone in the room should be able to follow the first third, only the experts should be able to understand the second third, and no one should be able to understand the last third, so you can show how clever you are!)

David wrote two papers while at Cambridge. The first[12] was apparently prompted by Bethe's concerns about a 1955 paper by Keith Brueckner. The second,[13] related to work by Bethe that had also been prompted by Brueckner's work, was submitted in the summer and revised in the fall, after he had moved to Cornell. He also got some early computational experience programming on EDSAC 1 before leaving Cambridge, which was published in a paper written after he had moved to Cornell.[14]

Cornell (1956–58)

When Bethe returned to Cornell at the end of his sabbatical, David had to make a decision about where to continue his graduate work. The two choices were moving to Birmingham to work with Peierls, or going to Cornell with Bethe. His old mathematics

supervisor at Trinity Hall, Shaun Wylie, encouraged him to go to the United States. He also learned that Peierls's son was going to Cornell, so, he decided to go to there. He got a research assistantship from Cornell, and the Fulbright Foundation paid for his passage to New York City on the *Queen Elizabeth* and for the train ride to Ithaca.

At Cornell, David shared an office with Ron Peierls and two other foreign theory students. One was Mumtaz Zaidi, a Pakistani who came from Delhi. He went on to be a professor at the University of Nebraska-Lincoln, before moving to the University of Merida, where he hosted David in 1971. The other was Hong-Yee Chiu, from Shanghai, via Taiwan. He went on to a long career at NASA, and is credited with coining the term *quasar.* According to David's memoirs, these two provided him with an education during the 1956 Suez Crisis on aspects of British history and colonialism that had been left out of the standard curriculum he had been brought up on.

Lectures at Cornell included a solid-state physics sequence by Al Overhauser, a course on statistical mechanics by Ed Salpeter, and one on stochastic processes by Mark Kac. Kac served on David's Ph.D. committee, and was responsible for a definition that provided some guidance to David's perspective on mathematical physics: the difference between a mathematician and a physicist is that a physicist is interested in simple properties of complicated systems, but a mathematician is interested in complicated properties of simple systems! Seminars that David remembered attending at Cornell included talks by Buckminster Fuller, Leon Cooper, Phil Anderson, and Charlie Townes.

During the Christmas break, David joined a road trip to Florida for foreign students in the back of two trucks that was organized by Lee Klaer, a Presbyterian minister and the Cornell student pastor who was known for his activism for racial and social justice. The truck trips were co-organized by his wife, Betty, and took groups of students across the United States and to Europe, the Middle East, and Central America. These trips were part of Cornell's student-outreach efforts, which also included weekly dinners for foreign students in the Klaer home. The Florida trip gave David a firsthand view of segregation, another aspect of education missing from his formal curriculum. It was on this journey that he fell in love with Margaret Scrase, an English undergraduate who was studying Plant Sciences at Cornell. They became engaged on Easter Sunday, April 21, 1957.[15]

During the academic year, David wrote a short paper on statistical mechanics,[16] identifying a missing term in some work by Takeo Matsubara. This prompted an admonition from Bethe to avoid statistical mechanics as a sterile subject.[17] During this year, David

also developed a deeper appreciation for perturbation theory after being given a copy of an unclassified Atomic Energy Commission report on the subject[18] written by Bryce DeWitt. (This copy was still in David's files when he left his University of Washington office for the last time in August 2016.) That same spring, a conversation with Rudolf Peierls, who was visiting his son, further helped shape his understanding of perturbation theory and its application to Breuckner's theory, which became central to his eventual thesis.

David did not see much of his advisor, as Bethe was often away consulting and serving on government committees. While he found that talking once a month was more than sufficient to provide adequate guidance, they never co-authored a paper.

At the beginning of the summer in 1957, Ron Peierls drove David and Margaret (in a car jointly owned by Ron and David) to meet David's future mother-in-law who was visiting her sister and mother in Connecticut. Margaret then returned to England for the summer, and David went to a conference on nuclear structure at the University of Pittsburgh, also attended by Rudolf Peierls, Hans Bethe, and Jeffrey Goldstone. David returned to Ithaca by plane, which was his first experience flying, in a trip that took seven hours—slightly longer than it would have done by car.

David had arranged to take a summer job as a research assistant under David Judd in the Theory Group at the Radiation Laboratory in Berkeley. He joined a group of Cornell undergraduates in a couple of cars for the first of what would be many drives across the country. The summer appears to have been very productive and enjoyable. In his memoirs, David mentions a weekend trip to Big Sur that included future Nobel Prize winner Roy Glauber as well as Władysław Świątecki and Chuck Zemach. In the major paper associated with his Ph.D. thesis[19] he acknowledges that part of the work was started while at the Radiation Laboratory, and acknowledges discussions with Świątecki, among others. At the end of the summer, David met Ron Peierls and Hong-Yee Chiu in West Yellowstone. From there, they explored Grand Teton National Park and Rocky Mountain National Park, visiting the cosmic ray station on Mount Evans. They then "gate-crashed" an American Physical Society (APS) meeting in Boulder, visited a friend in Los Alamos, and drove non-stop back to Ithaca.

In his second year at Cornell, David moved out of the graduate dorms and into an apartment with Ron Peierls and fellow theory student Marvin Litvak. During the Christmas break, he went to Chicago with Margaret to visit her second cousin Joseph C.

Boyce. Boyce was a physicist who was then dean of the Graduate School at the Illinois Institute of Technology, and arranged for David to visit Argonne National Laboratory and the University of Chicago, where he met Dick Dalitz and Valentine Telegdi.

David spent that second year at Cornell developing the thoughts that he had been pursuing since his summer in Berkeley, with some additional insight gained from a paper by Victor Galitskii and Alexander Migdal.[20] He passed his Ph.D. exam, and arranged for a postdoc back at the Radiation Laboratory in Berkeley to start in the fall. He wrapped up his Ph.D. studies in June by submitting the major paper[19] that described his thesis for publication in the *Physical Review*. Then only a couple of weeks later, Margaret and he travelled back to England on the *Queen Mary*. They got married on July 26, 1958, in Stoughton, in the West Sussex Downs, to where Margaret's parents had recently moved. The church they got married in, St. Mary's, was built just before the Norman Conquest, and it always amused David that the vicar who married them, the Rev. Philip H. Francis, had written a book proposing that the sun is a temperate body providing warmth to the earth without being hot![21]

The couple's honeymoon in France established the tradition of family holidays that David and his family would maintain throughout his career (with one notable exception in 1975): they were always tied to physics. Margaret and David travelled down the Loire River in France by car and spent the middle week of their trip at the summer school in Les Houches, founded by Cécile Morette DeWitt. David gave three lectures at a session on many-body theory, attended by such notables as Keith Brueckner, David Pines, Victor Emery, Philip Nozières, and Cyrano de Domincis. Throughout the years of their marriage, David and Margaret celebrated a number of wedding anniversaries at Les Houches, including their golden anniversary in 2008. (Their silver wedding anniversary in 1983 was celebrated in Aspen—another common location for summers that combined physics with hikes in the mountains.) The return trip to England via Paris included making use of the air ferry service between Le Touquet and Lydd.

Berkeley (1958–59)

For their return trip to the United States, David and Margaret were supposed to catch a Cornell charter flight from Brussels to New York at Heathrow Airport. Unfortunately, the plane ignored the scheduled stop in London, so they eventually made their way to Shannon Airport in Ireland and caught a flight to New York, and then on to Ithaca where they picked up a car they had bought earlier in the summer, before driving across the country to Berkeley.

While Margaret finished her undergraduate studies at Berkeley, David basically worked on his own, with only a requirement to file quarterly progress reports. During the fall, he finished a second major paper from his Ph.D. research.[22] He also had discussions with Alfred Glassgold and Kenneth Watson that led to a refinement of his earlier work on statistical mechanics.[23] He started thinking about the Bardeen–Cooper–Schrieffer (BCS) theory of superconductivity, writing a paper on the strong-coupling limit.[24] He got comments from Ben Mottelson on this paper, and also went down to the UCB campus to talk to Charles Kittel about it. Although this latter conversation wasn't particularly helpful, it allowed him to meet Pierre De Gennes, with whom he would later share the Wolf Prize (1990), and Michael Tinkham, who gave him guidance on the experimental literature. He also started what he regarded as a more substantial piece of work combining statistical mechanics (ignoring Bethe's admonition against the area) and the perturbation theory he had learned from both Bethe and Goldstone with BCS theory. This was eventually written up[25] in early 1960 after he had moved to Birmingham. Another project he started in Berkeley was on the stability of the Hartree-Fock theory, but this was also not written up until he was in Birmingham, after he began to see more of its significance.[26]

In May 1959, David took his first flight on a jet, travelling to the East Coast to attend the APS meeting in Washington, D.C. On this trip he visited Nicolaas Hugenholtz at the Princeton Institute for Advanced Study, Rudolf Peierls, who was on sabbatical at Columbia University. He then visited Ithaca, before returning to Berkeley and spending the summer teaching his first class—a summer course on atomic physics using Max Born's book as the textbook.

Birmingham (1959–61)

David had obtained educational deferments to British National Service thanks to his educational pursuits, but he became increasingly concerned about a provision stating that a male British citizen was liable for military service up to the age of 36, if he was living abroad by the time he turned 26. Although this provision was dropped and would not have affected him, he decided he needed to return to the United Kingdom and agreed to work with Peierls in Birmingham as a postdoc, supported on an ICI Fellowship.

David and Margaret traveled by train from Berkeley to New York. They then stayed with Margaret's aunt in Connecticut, and David made a side trip to Brown University to talk to Leon Cooper. In New York, David and Margaret met up with David's father, who had been visiting North Carolina. They then all took the Statendam back to Southampton.

Mark Kac happened to be a fellow passenger on this same voyage, and it was on this trip that David learned from Kac about the Aharanov-Bohm effect, which was to become important in his later work. They were met in Southampton by Margaret's parents and given the Jowett Javelin that they had borrowed for their honeymoon trip a year earlier. It was a car with many temperamental quirks that broke down on the trip to Birmingham and needed significant engine repairs, but it provided transportation for the family until being replaced by the first of two Bedford Dormobile vans, just before David moved to Birmingham for the second time.

Lodging for David and Margaret in a university flat was found in Selly Oak by Genia Peierls, who seemed to organize all aspects of life for members of the Department of Mathematical Physics. For example, even after Peierls moved to Oxford, a strong childhood memory for the author (who was born in November 1959, less than two months after David and Margaret had moved into the flat) were stops in Boars Hill for lunch on any road trip to destinations in the South of England, and a general feeling of being observed, and advice being given on one's behalf.

During the spring of 1960, David was informed by Peierls that Churchill College in Cambridge was looking for teaching fellows. He decided to apply and was interviewed by novelist and civil servant Sir Charles Snow and by the first Master of Churchill College, Sir John Cockcroft. David would later remark that he felt that the influence of Snow and his book *The Masters* had perhaps made Churchill less experimental in its early days than one might have hoped for in a new Cambridge college. He was offered a fellowship to commence in October 1961; the college had admitted its first students in October 1960, leaving some ambiguity as to whether David should be considered a Founding Fellow of Churchill or not. In the spring, he also taught a graduate-level class to a group of fifteen faculty, postdocs, and students on the quantum mechanics of many-body systems, with an eye to writing a monograph on the subject.

In June 1960, David attended the *International Congress on Many-Particle Problems* in Utrecht, where he presented some work27 that he was doing with G. E. (Gerry) Brown, who had been, until that summer, a professor at Birmingham. He also met Phillip W. Anderson, with whom he had communicated earlier about the work Anderson presented at the conference.28 Anderson would become an important friend, mentor, and colleague for the next half century. It was probably at this conference that they learned they would both be at Churchill College for the 1961–62 academic year.

Gerry Brown moved to the Nordic Institute for Theoretical Physics (NORDITA) in Copenhagen in the summer of 1960, and arranged for David to visit what is now the Niels Bohr Institute, at the University of Copenhagen. David, Margaret, and Michael all moved there for the summer, taking the Jowett Javelin by ferry from Harwich to the Hook of Holland, and driving to Copenhagen via Germany. Later in his life, David often referred to the welcome contrast that Copenhagen made to the dreary and still war-damaged Birmingham, commenting after David Lodge's 1975 novel *Changing Places* was published[29] that the book seemed to describe the Birmingham of 1960, making the contrast to the Berkeley of 1968 even more dramatic. David's stay in Denmark was very productive, as he completed a manuscript for his textbook based on the class he had just taught in Birmingham,[30] as well as two papers.[31,32] The family returned to England by crossing the Øresund from Helsingør to Helsinborg, driving up the coast to Rjukan in Norway, and then taking ferries back to Jutland and from Esberg to Harwich.

One of the papers David wrote in Denmark was coauthored with John Valatin (a Reader in Birmingham, who had also visited Denmark over the summer). This was the first co-authored paper that Davd wrote. Back in Birmingham, he finished up a second paper he had started with Valatin in Denmark,[33] and also wrote up a paper started with Gerry Brown earlier in 1960.[34] Another joint paper, written with a visiting research student from Cambridge and submitted in December 1960 (only a few days before his second son, Christopher, was born in Cambridge), was less successful. There seems to have been one mistake corrected in proof, but, more seriously, shortly after David had moved to Cambridge, a first-year research student called Brian Josephson came to his office to tell him that one of the equations in the paper was sufficiently wrong that the arguments were invalid, and the paper had to be retracted.[35]

The whole family returned to NORDITA and Copenhagen for the summer of 1961. This time they travelled via Stockholm to Åbo University in Turku to visit Karl-Gustav Fogel, a co-founder of NORDITA. Fogel was then dean of the School of Mathematics and Natural Sciences (eventually becoming rector), and had got to know David at Cornell in 1957–58, when he was on leave from Åbo.

Lecturer in Cambridge (1961–65)

David and Margaret bought their first home—a small terraced house on Derby Street in Newnham—for the move to Cambridge. It had two bedrooms upstairs, a front door that entered directly into the living room, a dining room, and a kitchen at the back, with a very small walled garden. When they moved in, the only toilet was in the back, next to

the coal shed, but there was space in the bathroom to add one inside the house. Bikes, dustbins, and bags of coal had to be brought through the living room from the front street to the back of the house.

In addition to being the first Director of Studies for Physics at Churchill College, David had also been appointed as an Assistant Lecturer in the Department of Applied Mathematics and Theoretical Physics (DAMPT). In this role, he lectured to mathematics students and to students in the Natural Sciences mathematics sequence. In this latter class was eighteen-year-old J. M. (Mike) Kosterlitz, with whom David was to share the Nobel Prize fifty-five years later.

During that first year in Cambridge, David finished and wrote up the paper with Peierls that he had started in Birmingham.[36] This seems to have involved a fair amount of discussion between them, captured in some of the published letters of Peierls.[37] He also had many discussions with Phil Anderson. These resulted in only one publication that year, which was not particularly well cited,[38] but it led to a much more significant paper, written just before David moved to Birmingham in 1965, related to interactions that Anderson had had with Conyers Herring and others.[39] Perhaps more importantly though, this first year at Cambridge with Anderson led to a lifelong friendship, maintained through Anderson's visits to the UK and David's visits to the U.S. The resulting discussions through the next twenty years or so often triggered some very significant pieces of work.

The last six months of 1962 were spent in New York. The journey across the Atlantic was the last David made by ocean liner; the family travelled on the SS *Ryndam* from Southampton to Canada, with the voyage providing some of the earliest memories for David's sons. The month of September was spent in Ithaca, but the rest of the time was spent at the University of Rochester. During this period, David's association with Gerry Brown (who was visiting the Massachusetts Institute of Technology), continued, resulting in a second joint paper between them.[40] This was the last co-authored paper David wrote until 1970. In addition, he spent two days a month consulting for Bell Labs in Murray Hill, New Jersey, which allowed him to continue his discussions with Phil Anderson and the other condensed-matter theorists there.

The family returned to the UK to spend the Christmas of 1962 in Stoughton with Margaret's parents, and to pick up the Jowett Javelin that had been left there six months earlier. That winter was the coldest for 200 years, and the huge snowfall over the

Christmas period left the hedgerows covered during the drive back to Cambridge for the start of term in January 1963.

In Cambridge, it looked like the DAMPT and Cavendish faculty might be moving to different buildings, so David applied for a position as a lecturer in the Cavendish, which would start in the Michaelmas Term of 1964. Meanwhile, Peierls had moved from Birmingham to Oxford. A. H. R. (Tony) Skyrme had been recruited back from the University of Malaysia to replace Peierls as head of the Mathematical Physics department at the University of Birmingham. In addition, Stanley Mandelstam, who had replaced Gerry Brown as the second professor of mathematical physics in 1960, had returned to Berkeley in 1963 as a faculty member. Just after David had accepted the Cavendish position, he was approached by two members of the Birmingham search committee to ask if he would accept the second chair if offered it. The decision to pursue the position wasn't made until after the summer.

The summer of 1964 was spent in Chalk River, Ontario, with the whole family flying across the Atlantic to Montreal and living in Deep River. Interactions in Chalk River included discussions with Erich Vogt, a lifelong friend David had met when Eric was a visitor in Birmingham. Two papers came out of David's time at Chalk River, although they were not written up until the following year.[41,42]

Towards the end of 1964, David decided to consider the chair at Birmingham, and was offered it starting in October 1965. In March 1965, David attended a conference on many-body problems in Akademgorodok, about twenty miles south of the center of Novosibirsk in the Soviet Union. There he met many of the top Soviet physicists, including Alexei Abrikosov and Vitaly Ginzburg, and was introduced to cross-country skiing. On his way back to the UK, he spent two days in Moscow, visiting the Landau Institute and Moscow State University, hosted by Lev Pitaevskii and Abrikosov. A couple of months after this trip, he saw Ginzburg and the Landau Institute director Isaak Khalatnikov wandering around the Cambridge market place during a break from a relativity conference, and invited them both back to 12 Derby Street for dinner, along with a Cambridge colleague R. J. Tayler, who had translated one of Ginzburg's books. (According to Margaret,[43] Khalatnikov's wife, Valentina, was also at the dinner in Derby Street—Khalatnikov being a high enough official that his wife could travel to the West with him.)

Birmingham—The Early Years (1965–68)

In September 1965, Christopher started primary school at Newnham Croft, and Michael moved up to the first year of the infants. A few weeks later, they had to start the process again at a new school in Birmingham, as David took up his chair at the beginning of the university year. The entire family, including Pansy the cat (whom David had got as a kitten from the Cambridge Botanical Gardens about a year earlier, and who was part of the family for all the Birmingham years), moved to Birmingham. A professorial salary meant that the family could afford a new house just being built on the Bournville estate, at the entrance to the Manor Park. Both toilets were inside the house, and it had central heating for warmth, so there was no need for fireplaces or coal! The house, however, was still a hole in the ground in 1965, so the family rented a nearby house for a year until it was finished. The neighborhood was between the suburbs of Selly Oak and Northfield, a short bus ride along the Bristol Road to Edgbaston and the University. Several members of the Physics and Mathematical Physics Departments lived in that area, including W. F. (Joe) Vinen and Peter Borcherds. Peter was a lecturer in the Physics Department and the father of future NAS member and 1998 Fields medalist Richard Borcherds, who was a classmate of Michael's at Northfield Manor School. A few years later, Mike Kosterlitz and his family also lived in that part of town. Playdates with Richard and Thomas Canel, son of Physics Department lecturer Eric Canel,[44] also served to provide David's sons with limited exposure to popular culture on TV while growing up, because such an appliance never darkened the doors of any of David's houses during his entire life. (There was a radio-valve wireless that sat in the living room in both Cambridge and Birmingham, next to a record player brought back from the US, which was connected to a transformer and with the speed adjusted to the UK mains frequency.)

The family moved into the new house in the fall of 1966. In the following summer of 1967, David was invited to teach at the Liperi Summer School in Finland. David, Margaret, and the boys drove in the Bedford Dormobile from Birmingham to Finland and back. One of the more memorable aspects of that trip was that it took place just a few weeks before "Dagen H" (September 3, 1967) in Sweden, the day when the country would switch from driving on the left-hand side of the road to the right-hand side of the road, with all the road signs related to the switch already in place. So, David had to drive on the left-hand side of the road to get onto the ferry (the MS *Winston Churchill*, which had been launched only a few months earlier) in Harwich. Upon arriving at Esbjerg, he had to remember to leave the ferry driving on the right until getting onto a ferry again at Helsingbørg. Leaving that ferry in Helsingbørg, he had to drive on the

left until getting onto the ferry in Stockholm, and then switch to the right again upon arriving in Helsinki. The whole process had to be reversed on the return trip! The journey to Finland involved a stopover to see Gerry Brown, and to talk to people in Copenhagen. Sweden and Finland provided David with the lakes he loved to swim in, and he used them to start teaching his sons how to swim. Before leaving Finland, David visited Åbo University in Turku, where Vogel was now the pro-rector, and the whole family spent the weekend on the Vogels' summer island off Turku, riding out a storm while cut off from the mainland for a day.

David's first few years in Birmingham were not very productive in terms of papers. Before going on sabbatical in 1968, he wrote only one paper other than a few book reviews. This paper was a foray into condensed-matter physics, suggested by Neville Mott, on long-range order in antiferromagnetic systems.[45] He did, however, develop two additional lines of research. One,[46] which he appears to have started thinking about in the summer of 1967 while walking in the Dyrehaven Bakken in Copenhagen (according to his memoirs), was written up in fall 1968 while he was on sabbatical at Cornell. In this paper he tried to explain the small size of the vortex cores in superfluid helium, and he discussed the problem with both Joe Vinen in the Physics Department at Birmingham and Vitaly Ginzburg, who had visited Birmingham in fall 1967.[47] The other paper followed up on his work on using perturbation theory in the theory of superconductivity from his Berkeley days (and also on Ginzburg's work, which he had not known about in 1960), and emerged while teaching a class on phase transitions and critical phenomena. According to David's memoirs, it was a reaction to questions raised by Michael Fisher in a review article. However, this review article doesn't seem to be referenced in the resultant paper,[48] but his discussions with Fisher are acknowledged.

Sabbatical in North America (1968–69)

In the summer of 1968, David began a year-long sabbatical in North America. The family flew to Montreal, and again spent the summer in Deep River, as it had four years earlier. Although he wrote no papers during this visit to Chalk River, David's memoirs indicate that he spent the time deciding that experimental data on neutron scattering from liquid ^{4}He were too unreliable for his goal of using them to provide insight into his theory on vortex cores. The major features of that summer were camping trips in the Canadian wilderness. A local trip to a large lake in Algonquin Provincial Park found him hauling the food up a tree to protect it from the bears, only to spend the night chasing off raccoons—to the great amusement of his children, who incorporated the drama into their play for several years afterwards. At the end of the summer the family caught

a Canadian Pacific train from Chalk River to Calgary, where they rented a car to go camping at Moraine Lake, with a side trip to the Athabasca Glacier, before catching the train back to Chalk River. They then travelled to Ithaca for the fall semester.

At Cornell, David taught an undergraduate class on mathematical methods and interacted with Michael Fisher and K. G. Wilson, while writing up his papers on the critical region for an Ising model with long-range interactions,[48] and on the size of vortices in a superfluid.[46]

After Christmas, the family went skiing in Vermont with Margaret's parents, with a cross-country ski trip at the Trapp Family Lodge, seeing Maria von Trapp when they went to eat. In the New Year, the family moved to Stony Brook, where David spent the winter semester visiting C. N. Yang, and took the family on a spring vacation, going by train to camp in the Everglades, and being joined at the campsite by David's parents, who were visiting the southern part of the U.S.

Although the family had rented a house close to the campus, the atmosphere on campus in the spring of 1969 was such that David did not want his family to visit him there, and it is not obvious that his interactions with people there were particularly productive. However, during a trip to Murray Hill to talk to Phil Anderson and others at Bell Labs he learned about recent work on the Kondo effect (a resistivity minimum in magnetic materials at a temperature above absolute zero) by Anderson and a Cambridge Ph.D. student Gideon Yuval, as well as that of another member of the technical staff at Bell Labs, Donald R. Hamann.[49,50] Anderson and Yuval had been thinking about the problem in terms of an Ising model. According to his memoirs, on the train trip back to Stony Brook, David contemplated this problem and its relationship to the argument in his graduate-school copy of Landau and Lifshitz[51] that long-range order is not possible in a one-dimensional system with short-range interactions. He realized the argument needed to be modified in the case where the interaction between spins went as $1/r^2$. This resulted in a paper written up just before he left Stony Brook that summer.[52] These thoughts on a one-dimensional phase transition to a unmagnetized state, a continuous transition with a discontinuity, eventually evolved into the realization of a new type of phase transition, which became very important over the next few years.

As seems to have been the case so often with David, he got the paper out only a few days before leaving on a long trip. This time, Margaret and David sent Michael and Christopher back to the UK with Margaret's parents. There, they spent the summer in Cambridge with David's parents and in Margaret's parents' recently acquired summer

cottage in the French village of Le Boulvé. Meanwhile, David and Margaret set off across the country in the Lincoln Continental that had served the family during the sabbatical, going via Glacier National Park to Berkeley, and from there to visit Erich Vogt in Vancouver. From Vancouver, they flew to Hawaii and then Fiji, and from there to Sydney, where David saw his sister for the first time since 1953. He also visited the University of Sydney and the Australian National University in Canberra, with a side trip to Adelaide and to Melbourne, where, according to his memoirs, he talked to N. E. Frenkel about his Monte Carlo work on long-range interactions in the Ising model.[53] It would also have been at the University of Sydney where David wrote up his brief foray into special relativity that he had started thinking about two years earlier. He penned a letter to *Nature*[54] criticizing those who dismissed the concept that the existence of particles that travel faster than light would violate free will and providing a thought experiment to make the point. At the end of the summer, he and Margaret flew back to the UK from Sydney by way of Hong Kong.

A Fruitful Decade (1969–78)

The next decade played out against the general economic malaise and unrest in the UK, but it was a remarkably productive time for David, in which various streams of thoughts, some of which had begun in the US, came together. This productivity also corresponds to a period when David wrote co-authored papers again, with the first one since 1963 being on nuclear structure[55] written with a graduate student, but prompted by discussions with Nobel laureate Walter Kohn. From this point on, David wrote more joint papers with colleagues, postdocs, and students than single-author papers. In 1973, he got the first of the prizes he would be awarded over his career, receiving the Maxwell Medal and Prize from the Institute of Physics (IOP). The money that came with this award was credited in family lore as providing the funds for his first electronic calculator, an HP-21, and a 1965 edition of the *Encyclopedia Britannica*.

This fruitful period was initially sparked by a trip to Bristol to recover the Bedford Dormobile (probably still the original one, although it would soon be replaced by an "F"-registered version) from friends who had borrowed it while the family were in the US. David records in his memoirs that while waiting on the University of Bristol campus to collect the car, he bumped into John F. Ziman, who invited him to lunch and told him that two of his postdocs had proved Phil Anderson's 1958 theory on electron localization to be wrong, but that Mott and Anderson refused to accept the theory was wrong when he had raised this point at the Third International Conference on Amorphous and

Liquid Semiconductors at Cambridge in September 1969. Ziman asked David to take a look at the papers, and to see who was correct.

This conversation and request resulted in focused study by David to really understand the details of Anderson's 1958 paper. His verdict was that Anderson's theory of localization was correct, and that the postdocs' attempt to show that localization is not possible was based in an incorrect deduction from their interpretation of a simplified version of the theory presented in the second of two papers written by Ziman on the localization of electrons in ordered and disordered systems.[56] David's analysis also concluded, however, that there were some details missing in Anderson's original analysis that suggested delocalization was actually easier than proposed. His defense of Anderson's theory was published in 1970,[57] and then repeated at the Fourth International Conference on Amorphous and Liquid Semiconductors, held in Ann Arbor, Michigan, in August 1971, at which Mott was, as so often seemed to be the case for that series, the keynote speaker.[58]

The following year saw David's single venture into the experimental side of physics.[59] He had been concerned by statements in the first of Ziman's pair of papers on the localization of electrons[60] that the mobility of an electron in a disordered semiconductor should be given by a solution to the classical percolation problem. So, with graduate student Brian Last, he spent one Saturday in a teaching lab with a voltage source, electrical contacts, graph paper, colloidal graphite paper, a hole-punch for sewing borrowed from Margaret, and a table of random numbers. Punching holes in random locations, they showed that the percolation density fell with the concentration of holes much more rapidly than the conductivity, leaving them to conclude that the mobility of an electron was more relevant to the conductivity of a disordered system than the percolation probability. This work was further elaborated upon in numerical work by David and graduate student John Edwards in which they also showed that localization was probably easier than originally suggested by Anderson.[61] In the appendix to this paper, the authors developed the concept of what would later be called the "Thouless Energy," which measures the sensitivity of conductivity to boundary conditions.[62]

This work seems to have quickly caught quite a lot of attention. In the late summer of 1973, the family (which now included daughter Helen, who had been born in June 1972) traveled in the (new) Dormobile across Germany via the Hook of Holland to Garmisch-Partenkirchen, so David could attend the Fifth International Conference on Amorphous and Liquid Semiconductors in early September, while the rest of the family met up with Margaret's parents in the nearby Austrian Alps for a few days. There seems

to be no record of David's attendance at this conference in the resultant conference proceedings,[63] but there are many references to his recent work with his two graduate students. This line of work was continued by David throughout his remaining time at Birmingham, culminating in one of his most highly cited papers in this particular area, in which he argued that the resistance of a thin wire should increase exponentially, not linearly, with length at very low temperatures.[64] This seems to have been part of a fruitful vein of research that also resulted in a series of papers[65,66,67] written with his postdoc Don Licciardello, who later developed the software that allows for electronic bank transfers. This work in turn was followed up by Anderson and others (including Licciardello) in a highly cited 1979 paper[68] on a scaling theory of localization.

Collaborations with Anderson continued throughout the Birmingham period, as Anderson had an ongoing position as a visiting professor at Cambridge between 1967 and 1975. Anderson visited Birmingham, and David routinely visited Cambridge during this period because his parents were still living there, and there was at least one visit by the family to Anderson's cottage in Cornwall. Two papers came out of this collaboration. One was written in 1973 on localization.[69] The other, written in 1976[70] during a summer in Aspen, was David's initial foray into spin glasses, with a new solution being presented for the model developed a year earlier by David Sherrington of Imperial College and Scott Kirkpatrick of IBM Yorktown Heights.[71] This paper was followed a year later by another of David's best cited papers, written in collaboration with Jairo R. L. de Almeida, a physicist on sabbatical from Brazil, in which they noted that the Sherrington-Kirkpatrick solution was unstable in the spin-glass phase, and they were able to construct the phase diagram for a non-zero magnetic field.[72]

By far the most significant collaboration that David had while at Birmingham was with Mike Kosterlitz. Mike was involved in these latter discussions on spin glasses and wrote three papers with David on the topic between 1976 and 1980,[73,74,75] with the last two written when David was at Queen's University and at Yale University, respectively. But, of course, it is the Nobel Prize-winning work with Kosterlitz that is of the most interest.

According to David's memoirs, it was in about 1970, while giving a graduate class on superconductivity and superfluidity, that he realized the interaction energy between a pair of vortices in a 2-D superfluid depends logarithmically on the distance between them, in an analogous fashion to the interaction between domain walls in a 1-D Ising model. This suggested that the study of 2-D superfluids might be interesting, but he thought the problem would be too hard for a Ph.D. student. Fortunately, Mike Kosterlitz, who was

then a postdoc with unrestricted funding looking to move away from his background in elementary particle theory, was prompted by Eric Canel to knock on David's door to ask if he had any ideas about a problem he might work on. In 1972, Mike and David published their first paper together in which they coined the concept of topological long-range order as an alternative to the classical perspective of long-range order based on a point-to-point correlation. It had been shown by Peierls forty years earlier that two-dimensional systems with short-range interactions cannot exhibit the classical form of long-range order because the thermal motion of low-energy phonons results in the mean deviation of atoms from their equilibrium spacing increasing logarithmically with the size of a system.[76,77] The perspective presented in this first paper[78] was that topological defects having an energy of interaction that scales logarithmically (such as dislocations with their $1/r$ stress fields in a crystal, and vortices in a superfluid) are bound together in pairs until the temperature is increased to such a level that the entropic term becomes dominant, allowing the defects to unbind and move freely.

A year later, the pair produced a second paper on the topic,[79] in which they proposed a definition of order for two-dimensional systems—topological order—with a phase transition characterized by changes in the response to external perturbations, rather than in terms of changes in positional correlations. It was this paper that was cited by the Nobel Committee in 2016 for a half-share in the Nobel Prize. Initially, neither paper attracted particularly significant attention. Indeed, when the Nobel Prize was awarded, a reviewer of this second paper wrote to David congratulating him and admitting that they had only ranked the paper as being of average significance at the time!

Although the significance of the work was not recognized for a few years after publication, among the predictions it made was an equation relating the critical temperature for the transition to super-fluidity, T_c, to the density, ρ_s, of a super-fluid film just below T_c:

$$k_B T_c = \pi \rho_s \hbar^2 / 2m^2, \qquad (1)$$

where m is the mass of the atoms in the fluid, and $\hbar$ is Planck's constant. This relationship was justified a few years later by Nelson and Kosterlitz[80] and confirmed experimentally by Bishop and Reppy in 1978.[81] From that point on, the significance of the work became increasingly recognized.[82]

Travels (1969–78)

Other than the previously mentioned trip to Garmisch-Partenkirchen in 1973, there are a number of other trips that come to mind from this period. In the early spring of 1970, David volunteered to help his father-in-law sail his motor cruiser down the Rhine from where it was usually kept on the French rivers and canals to the Netherlands, where Michael and Christopher were due to join their grandparents over the Easter holidays on the Dutch canals. Apparently travel in a relatively small matchbox-like vessel competing with the commercial river traffic for space on the Rhine and its locks in poor weather ended up being one of the more terrifying weeks of his life. In the springs of 1971 and 1972, David arranged boating trips much more to his tastes, renting a sailing yacht on the Norfolk Broads for a week and teaching his sons to sail, as he had been taught by his own father, and visiting the locations of the Arthur Ransom stories that he had read to them when they were younger. Unfortunately, the Norfolk Broads were no longer the place of his memories, however, even from 1955. The motor cruisers that now dominated the Broads took the fun out of sailing for him. He did not sail again until after moving to Seattle, when he would occasionally rent a yacht to explore Puget Sound with Margaret and Helen. Also in 1971, David and Margaret were invited to visit Mumtaz Zaidi, his old office mate from Cornell, at the University of Merida. They toured Mexico City and the pyramids of Yucatan, leaving the boys with the Vinens in Birmingham.

In the spring of 1973, David was invited to spend a month or so working at Hebrew University in Jerusalem, and the family planned to go with him for the period of the Easter holidays. A few weeks before they were due to travel, a Libyan civilian airliner was shot down by Israeli fighter planes over the Sinai desert, killing most of the people on board. Needless to say, there was some concern about whether it would be wise to travel to the Middle East with the heightened tension. But a childhood friend who worked for the UK Foreign Office assured David that no one would be ready for a war until at least the fall, so the trip went ahead. The family flew to what was then Lod Airport (less than a year after the massacre there), driving to Jerusalem while occasionally noticing burned-out military vehicles by the side of the road left from a previous war. They lived in a rented apartment in West Jerusalem, and spent the holidays exploring the Old City (with a palpable feeling of tension in the air, especially when the city filled with pilgrims at Easter), Bethlehem, and Masada. They also rented a car, and went on a road trip through the occupied West Bank from Jericho up the Jordan River, passing villages emptied by the fighting six years earlier, and occasionally seeing the no-man's land with its warnings of mines on the west bank of the river. After the rest of the family returned

to England, David stayed on for several weeks at Hebrew University, pulling together his thoughts on electrons in disordered systems and localization in a review article on the subject.[83] Hebron, with the Tomb of the Patriarchs being one other place of Biblical reference that he wanted to see, and, having been told by his Jerusalem landlady that it was too dangerous to take the family there, he went on his own after the family had left.

The summer of 1974 saw another visit to the Physics Department at Cornell, with the family living in a rented house in Cayuga Heights. Other than the Watergate hearings and Nixon's resignation, a major piece of international news that occurred while the family was in Ithaca was the Turkish invasion of Cyprus. This was an important event for David because, as a result of growing up in the war, he was very hostile to any regime he considered to be fascist. On a point of principle, he would not visit any country that had a fascist government—Spain and Portugal were probably the only two countries in Western Europe that he did not visit until much later in his life, long after democracy had been restored. At this time, Greece was under the control of the Junta, which David regarded as a fascist government. Turkey's 1974 invasion caused the Junta to fall, and Greece finally became a country open to him. Visiting Greece must have been a long-held dream of his, for he completely surprised his family (or, at least the author) by leaping at the opportunity and, acting totally out of character, booked a "fly-drive" package holiday for the whole family to visit Athens and the Peloponnese in April 1975, with not a whiff of a physics conference on the horizon.

The Nomadic Years (1978–80)

David's productivity between 1969 and 1978 was played out against serious economic malaise in the UK, with its industrial action, three-day working week, and rolling power cuts. These cuts, following schedules published in the local newspaper, allowed David to show his experimental physics side, charging a car battery while there was power to run a headlight balanced on the living-room bookshelf at night to supplement the candles for reading and doing homework!

The general loss of an atmosphere conducive to doing high-level research at UK universities, unimaginative academic administrators (whose retention policy when David was looking for an excuse to stay in the UK was to say, "If you have a job in North America you should take it."), plus a general feeling that he was always going to be overlooked for the more prestigious chairs in the UK, led David to think about jobs abroad. David seems to have had a rather competitive perspective about being a physicist, referring to several colleagues in his memoirs as "competitors." He had been awarded only one

junior-level prize up to the beginning of this period when he was thinking of moving, but his work at Birmingham was soon to be recognized by two senior awards—election as a Fellow of the Royal Society in 1979, and the award of the Fernand Holweck medal from the IOP and the French Physical Society in 1980.

An additional consideration for deciding whether to move was the fact that the late seventies and early eighties provided a window between Michael and Christopher finishing up at King Edward's School and going to university, and Helen starting her secondary schooling. On the flip side was the fact that in 1974 Margaret had obtained her Ph.D. in virology at Birmingham under Peter Wildy, and now had a job at the East Birmingham Hospital working with Tom Flewett on the rotavirus. This hospital was a forty-minute drive on the other side of Birmingham, so a second car joined the Dormobile, a rather mundane Ford Escort (which ultimately made learning to drive much easier for Michael and Christopher than it might otherwise have been).

The activation barrier to moving seems to have been overcome by the intriguing possibility of David joining his old friend Erich Vogt at the University of British Columbia in Vancouver. For some reason, this fell through. However, once the idea of emigrating to Canada had been broached, David was receptive to an offer from Queen's University in Kingston. In autumn 1977, while Michael was preparing for the Cambridge entrance exams, the whole family had to do the interviews and medical tests required for a Landed Immigrant Visa to Canada. Christopher was studying for A-levels, so David went alone to Kingston in January, leaving Margaret working in Birmingham and looking after Christopher and Helen. (Michael started off his "gap" year in the Boston area that same month, so David saw him a few times either in Canada or in Boston.) David lived in an apartment in the outskirts of Kingston and discovered how isolated it was. Its regional airport had the grand title of "international" because of the short flights across the lake to points in New York. Otherwise, access was by a train ride of several hours to Montreal or Toronto. On the positive side was the easy access to cross-country skiing from David's apartment in the winter, and hiking trails and lakes for canoeing in the spring.

Helen and Margaret flew to Canada in the spring of 1978 for a brief visit, but it was long enough for Helen to be in school for a few weeks, before everyone decided it was not going to work, and they returned to Birmingham. The mixture of isolation and lack of interaction with colleagues, and the lack of a virus laboratory for Margaret, made the move unworkable. So, David left Queen's at the end of the academic year and also returned to live in Birmingham. That summer was their twentieth wedding anniversary,

which they celebrated at the summer school on condensed matter in Les Houches, accompanied by Helen and Christopher.

The fact that David was in a disordered state, and no longer localized, was noticed by Werner Wolf, chair of the Engineering Physics Department at Yale, who recruited him. Yale had the additional attraction of a medical school with a job for Margaret with W. C. (Bill) Summers. The fall of 1978, while Christopher was doing his Oxford entrance exams, was spent with the required interviews and medical tests for a U.S. green card. This was a remarkably efficient process; David was even given a private number to contact the American Embassy in London. The fact that the previous president of Yale, Kingman Brewster, was the U.S. ambassador to the UK at the time was probably not unconnected to the expedited service. The author met Brewster at an event at Churchill College in the Michaelmas Term, and it was clear that the ambassador knew all about David.

In January 1979, the whole family (except for Michael, who was starting his second term at Cambridge), went off to New Haven, living in a rented house in Hamden. Christopher then went on to Australia for his gap year, and the rest of the family settled down to life in New Haven. David had limited interactions with his Yale colleagues but was close to Bell Labs, Rutgers University, and the IBM Research Division in Yorktown Heights. At IBM, he interacted primarily with Scott Kirkpatrick, Praveen Chaudhari, and Rolf Landauer.[84] These interactions led to a series of related papers[85–88] on the conductivity of thin wires, following on from one of the lines of work he had been doing in Birmingham.

Unfortunately, it quickly became apparent that New Haven was not going to provide the sort of safe environment to roam that David wanted Helen to grow up in. He was particularly offended by what he saw as Yale's attitude toward campus safety. As he described it, all members of the Yale community were issued a whistle and instructions that if they saw anyone in danger they were not to help, but to retreat to a place of safety and blow their whistle as hard as possible.

At the beginning of the summer in 1979, David visited NORDITA in Copenhagen, accompanied by Margaret and Helen. There, he wrote up one of his papers on conductivity in thin wires and explored the possibility of moving permanently to Copenhagen. This idea fell through because of a lack of opportunities for Margaret, and because of the question of Danish schooling for Helen. That summer, David, Margaret, and Helen retuned to the U.S. and drove across the country to Aspen for the summer school, where

David wrote another of his Yale papers.[88] Michael joined them later, and they all drove back to New Haven, exploring a new route for David across the Midwest: I-70. Margaret and Helen then returned to Birmingham to their old job and school, and David moved to a cottage near the beach in Branford, where he spent the rest of the 1979–80 academic year alone, visited occasionally from England by family members helping to keep Freddie Laker's "Skytrain" in business.

During that year, David explored various opportunities around the U.S. and finally found a match with the University of Washington in Seattle. Margret was given a job as a research professor at the School of Public Health. On June 12, 1980, as Mount St. Helens was undergoing one of its more major secondary eruptions, David, Margaret, and Helen flew into Seattle to finalize their decision about moving, and to look at places to live. David moved to Seattle for the start of the academic year in September 1980, buying a house just north of the university with a glorious view of Mt. Rainier (weather permitting), the Cascades, and Lake Washington. Margaret and Helen remained in Birmingham during the fall of 1980 to pack things up and get ready to let the Birmingham house. They flew out to Seattle after the end of the school term in December, starting the only stable phase of Helen's primary education for its last few years!

The University of Washington (1980–2003)

Just as David was moving to Seattle, Nobel laureate Klaus von Klitzing and co-workers published their discovery of the integer quantum Hall effect.[89] Shortly afterwards, David was asked by his colleague Hans Dehmelt how the fine-structure constant could be determined to such precision by the quantum Hall effect when relatively little was known about the devices and the theory.[90] Later, this question summarized for David how awareness of the importance of topology and topological quantum numbers was increasing within the physics community. He worked with the three theory postdocs in the department to look at the phenomenon, publishing in 1982 the second paper, the Thouless-Kohmoto-Nightingale-den Nijs (TKNN) paper[91] later cited by the Nobel committee in establishing the concept of topological phases of matter for the second half of the Nobel Prize.

Integer and fractional quantum Hall effects were a major aspect of David's work with students and others during the early 1980s. A lot of this work seems to have involved more deeply integrating the TKNN paper with the topological quantum aspects he was thinking about. For example, in 1983, he examined the motion of particles that satisfy

the Schrödinger equation with a slowly varying potential to examine when the transport is quantized.[92] He also worked with a graduate student and a visitor to UW to develop ideas regarding how the quantized Hall conductance can be written as a topological invariant.[93] Not all of this work in this area was completely successful, however. In 1983, he developed a theory with a different graduate student to explain the fractional quantum Hall effect,[94] presenting it as a contrast to the work that gained R. B. Laughlin a Nobel Prize in 1998. Two years later, David decided that Laughlin's theory was probably correct, and that his was less likely to be correct. As a result, he wrote a single-author paper[95] that has the dramatic closing statement, "I think the time has come to abandon the Tao-Thouless theory," while acknowledging a possible disagreement with his former student about this conclusion.

The last twenty years of David's professional career involved a general evolution in his understanding of topological quantum numbers, and a synthesis of his ideas into a coherent framework into which some of his earlier papers, such as the two cited by the Nobel committee, were incorporated. These thoughts are presented in his 1998 book *Topological Quantum Numbers in Nonrelativistic Physics*,[90] consisting of introductory chapters followed by reprints of what he considered to be the key papers in the evolution of the subject. They include one by Dirac (whose lectures he had attended in Cambridge) from 1931[96] and one by Aharonov and Bohm from 1959[97] (to which he had first been introduced by Mark Kac on the Atlantic crossing back to the UK in that year). Interestingly, the TKNM paper with the UW postdocs does not feature in David's own selection of key papers on the development of topological quantum numbers, although it features as a fundamental reference in a number of them. Of his own work, he calls out his 1973 paper with Kosterlitz, his 1985 paper[93] (described above), and a 1991 paper[98] on multiple Aharonov-Bohm periods written with Yuval Gefen, a regular visitor to UW from the Weizmann Institute.

Although David was very productive in Seattle, the pull of the UK was strong. He was very torn when he was offered a position as a Royal Society professor at Cambridge. Unfortunately, the notion that a spouse might also need a job still seemed to be very alien to the academic establishment in the UK in the early eighties. After all, if one has a job as a professor at Cambridge, what more could one want? UW, on the other hand, played their hand well and gave David permission to split his appointment, with time in Cambridge and time in Seattle, until he could decide what would work best for him and Margaret. David and Helen moved to Cambridge in the fall of 1983. David joined Clare Hall as a Fellow, and Helen started at the Perse School. Margaret got leave from UW

and joined them in December, spending the spring of 1984 working at the Houghton Poultry Research Station. Michael also joined them at this time, spending the majority of 1984 working in Cambridge as a visiting student. David's mother had a major stroke in February, from which she never recovered.

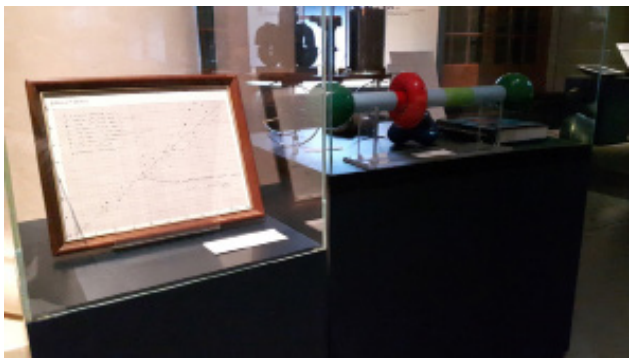
In March 1984, David and Margaret returned to Seattle for the last quarter of the academic year, as required for David by UW, leaving Helen to be looked after by Michael in Cambridge. David and Margaret returned to the UK in the summer. David's father was ninety in July, and his mother died shortly afterwards. After the funeral, David, accompanied by Margaret, Helen, and Michael, went to the Les Houches summer school. David spent his fiftieth birthday in Seattle, returning to the UK upon the death of his father a few days later. Margaret returned to Seattle after the funeral, and David spent the winter and spring working in Cambridge, renting a house from a friend, and looking after Helen. Again, the last quarter of the year was spent teaching at UW.

Having used that year to settle his parents' affairs, Margaret and David sold their Birmingham house in the spring of 1985 and bought a house on Gough Way in Cambridge from John Chadwick (of linear-B fame). This became their UK base for the rest of David's life.

The University of Washington was very patient with David's indecision about which country to settle in, but the Royal Society seemed to be impatient. The final straw came when it gave David the impression that it would require him to ask permission to leave the country, even to attend a talk in Paris. That made the decision about where to live easy, and by the fall of 1986, David was back in Seattle full time, where he stayed until he retired.

In 1990, David was awarded the Wolf Prize, which he shared with Pierre-Gilles de Gennes for their work on phase transitions. However, the following year brought disappointment, when de Gennes was awarded the Nobel Prize as the sole winner. The disappointment was, perhaps, slightly intensified by the fact that David was the obvious person for people to ask why de Gennes had won the Nobel Prize. Other forms of recognition did come: he was awarded the Dirac medal from the IOP in 1993, and shared the Lars Onsager Prize from the American Physical Society with Mike Kosterlitz in 2000. In September 1999, a sixty-fifth birthday celebration was organized by his department to recognize his achievements. It was at that event that he was given the original hand-drawn version of Figure 3 in the 1978 paper of Bishop and Reppy.[81] This was displayed

prominently in his office until it was given to the Nobel Prize Museum in 2016. David retired from the University of Washington in 2003.



The original hand-drawn version of Figure 3 in the 1978 paper of Bishop and Reppy.[81] This was donated to the Nobel museum in 2016.

The Last Years (2003–19)

The two major features of David's retirement were his battle with the challenges of dementia, and the award of the Nobel Prize in 2016. When the Nobel Prize was announced, his family realized they had never had the important conversation with him that no family ever thinks of having with someone developing dementia, "What do you want the world to know about your illness when your name is in all the newspapers of the world for a day, and there is speculation about your health?" Although the family was caught flat-footed at the time of the announcement, this was a conversation that developed in the fall of 2016. His answer was very clear—people should know that dementia is a disease that can affect the most active of minds. It is a disease that is multi-faceted and happens to many people. It is not an illness to be hidden or to be ashamed of, although it is cruel to the sufferers and their families. In that spirit, his illness forms an important part in the closing of this narrative. It is also important to put on the record that he was aware of the Nobel Prize and enjoyed it, because there was uninformed speculation to the contrary at the time that should have no part in the historical record.

As the disease progressed, the form of David's dementia made it harder for him to plan sentences or find the words he wished to use. Often, his strong literary background enabled him to find alternative ways to make his thoughts known, such as by reciting

appropriate lines of poetry, and he would be delighted when his listener picked up the reference. He also maintained a sense of humor until quite late. For example, looking at the Bishop and Reppy graph the night before it was given to the museum, he exclaimed, "For once, the experimentalists got it right." However, he had a sense of intense frustration about his situation, and about the limits of his abilities. There were topics those around him had to be very careful to avoid for fear of distressing him, not least was any reference by name to the U.S. president in the last two years of his life. Conversely, he was very pleased to receive a letter from the outgoing U.S. president when he got back from Stockholm in 2016.

David's retirement was spent travelling with Margaret, often to the various countries in Africa, where Christopher and his family were living. A particular highlight of his travels was in the spring of 2011 when David and Margaret took advantage of the brief window after the fall of the military dictatorship in Egypt to visit that country. In Seattle, David grew vegetables, taking particular pride in his artichokes, canoed on Lake Washington, and hiked in the Cascades. Professionally, he continued giving a few seminars and attended meetings such as the celebration of fifty years of Anderson Localization.[99] He spent the last half of 2008 at the Isaac Newton Institute in Cambridge as part of their program, "Mathematics and Physics of Anderson Localization: 50 Years After," which ran from July to December of that year.[100] Although not obvious to others at the time, both he and Margaret were concerned that something was happening to his mental abilities; he felt he no longer had the intellectual acumen that he used to have, and it was part of the reason he had retired relatively early.

By 2013, the onset of dementia was clear, although without a definitive label. In the summer of that year, he travelled to Copenhagen, a city he had an abiding fondness for, for the last time, visiting Michael who had a visiting position in Denmark, before going to his last conference—a celebration of forty years of the BKT transition in London—of which there exists a brief recording of him giving some remarks.[101]

After an episode where he got lost during one of his late-afternoon wanderings and had to be found by the police, which is a common feature of dementia, Margaret decided they should move back permanently to their house in the UK. On September 12, 2016, David crossed the Atlantic for the last time and returned to the city where he had grown up. Hence, three weeks later, on the morning of Tuesday, October 4, no one in Stockholm knew how to contact him.

That morning, Margaret had gone to the weekly meeting of the Visiting Scholars Society to take a break from providing care, leaving David to be looked after by his not-quite eighteen-year-old granddaughter Rachel. David's son, Christopher was the first to ring Gough Way from South Africa to tell his father about the Nobel Prize. Christopher realized that his father really needed to hear it firsthand from Göran Hansson (Secretary General of the Royal Swedish Academy of Sciences) and eventually found a way to get the Gough Way telephone number to him. The author's conversation with his father a few minutes after Christopher's went roughly as follows:

> *M: "Congratulations; great news about the Nobel Prize."*
>
> *D: "Yes, if it is true."*
>
> *M: "Yes, it is true, listen to the press reports," reading various press releases from the Internet.*
>
> *D: "If Mike and I got the Nobel Prize, then it is good that Duncan got it as well."*

Eventually, Michael commented that he had to get off the phone to take his daughter Emily to school, which elicited the response, "I think a Nobel Prize should be a good excuse to be late for school." A text message to Rachel, who, perhaps, did not fully appreciate what was unfolding under her watch, prompted her to use the Internet to show David the world's reaction. She texted home later, saying he now believed it and was so happy that there were tears in his eyes as he tried to explain his work to her!

Meanwhile, frantic texts to Margaret from her children to return home went unread, because her US pay-as-you-go phone was out of credit. Göran Hansson eventually got through to give David the news officially, and more congratulatory phone calls came in, under the watchful eye of Rachel, who realized that it was all getting a bit stressful for him. Eventually, in the early afternoon, Margaret noticed that her phone indicated a huge number of calls and texts from her children that she could not access, so with some trepidation she went to a mobile-phone store in the center of Cambridge to unlock the messages, which is when she discovered that her husband had just won the Nobel Prize. The next day, David was very pleased to see someone in a Cambridge coffee shop reading one of his books and happily informed the reader that he was the author!

Meanwhile, the rest of the family were trying to negotiate the "Where's today's Nobel Prize winner?" and "Why is the Nobel Prize winner so silent?" comments of the world's

press. Especially cruel was a retweet from a BBC correspondent of the "silver alert" from the Seattle Police Department issued the previous summer when he had gone wandering, with a comment, “This looks like today’s Nobel Prize winner, has anyone seen him?” (Fortunately, David’s daughter-in-law managed to find the person who had posted the tweet and asked them to take it down.)

The fall was spent negotiating with the Nobel Foundation about what David could and could not be expected to do in Stockholm. The Nobel Foundation gave the impression to the family that they hadn’t dealt with this situation before (although one suspects that not to be true), and that they had a very black and white view of dementia, rather than the various shades of grey that David’s condition covered. Yes, he would probably get bored if he was asked to sit too long during the ceremony and might wander off. Yes, if he was sitting in the audience and didn’t enter with the other laureates, he would wonder why he wasn’t with them. No, it was his prize; he should receive it from the King; no one should receive it on his behalf. But why couldn’t he be escorted to the King by a student marshal and then sit in the audience after he received it (which was the final successful solution)? Yes, he might find the banquet too loud and need to get up and sit quietly somewhere, so if protocol really dictates an old man can’t leave the High Table for any reason while the King is seated, then he should sit with his family at another table. (Indeed, at the banquet, Helen did have to take him out for a short break in a quiet room so he could enjoy the rest of the evening.) But why shouldn’t he go to the private dinner at the palace the next day, especially as Queen Sylvia is known for her concern for dementia patients and their careers? (Indeed, she was very friendly and knew how to talk to him.)

In retrospect, the ceremony in Stockholm was like a fireworks show late on a summer evening: a last dazzling display before the darkness. David summoned all his mental energy to enjoy the celebrations and the hospitality, generosity, and graciousness of the scientists of the Swedish Academy and of his physics colleagues, while being excused some of the more arduous chores the Nobel Foundation puts upon the laureates. He even seemed to enjoy the autograph hunters who lay in ambush in Stockholm’s cafés. At the end of the banquet, the author asked him, “So, did you enjoy it in the end?” He replied, “What do you mean, ‘In the end’? I enjoyed it from the beginning.” Even in the last weeks of his life he enjoyed looking through a book of pictures compiled by a daughter-in-law about the events of that week.

It appeared that he had pushed himself to the limit in Stockholm, and he never recovered from the mental exhaustion of that week. The next two years saw his health and mental cognition gradually decline. In October 2018, Margaret moved him to a residential care facility in Cambridge, and he died of pneumonia on April 6, 2019. His funeral was held a week later, and he was buried at Grantchester Church, near the grave of his parents.

After the Nobel Ceremony, December 10, 2016, with his family and John Crawley (a childhood friend from St. Faiths). From the left: Margaret Thouless, Caroline Thouless, Clare Thouless, Robert Thouless, Christopher Thouless, David, John Crawley, Helen Thouless, Rachel Thouless, Peet Sasaki, Yi-Li Wu, Emily Thouless, and Michael Thouless.

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