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Herbert Fröhlich

A Physicist Ahead of His Time

With a foreword by Fanchon Fröhlich

 Springer

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*This work is dedicated with esteem
and gratitude to
Fanchon Fröhlich,
philosopher and artist—friend for 50 years*

Foreword

It gives me very great pleasure to write a few words of introduction to this biography of my late husband, Herbert Fröhlich.

When my good friend of many years, Gerard Hyland, a former student of Herbert (in fact his last Ph.D. student) shared with me the idea for this book, I was very happy to give him every assistance in piecing together all the available documentation and photographs relating to Herbert's career. It has been a longer journey than expected—books usually are!—but the result is a work that goes far beyond a simple narrative of one man's life. This book touches upon a whole era of physics research in Europe, setting it in the context of the dramatic political and military circumstances of the time. Herbert's experiences, some of which I shared, clearly reveal how science and scientific curiosity are not to be extinguished by mere national enmities; how scientists—then as now—form a mutually self-supporting global community that is often able to overcome the whims of dictators and other political exigencies in their pursuit of scientific progress.

This biography also details the many interactions Herbert and I had with other active scientists and their families. (My strongest memories are of Richard Feynman, S.W. Hayter, Maurice Marois, and Erwin Schrödinger). I am filled with nostalgia as I look at the collected photos, read the anecdotes, and remember not only the many good times described herein, but also the sometimes more difficult ones. For the outsider they will be informative rather than emotive, but still a wonderful record of a decisive period of twentieth-century science and some of the people involved.

I am not a scientist, and my understanding of Herbert's work is not of a technical kind, but rather conceptual, having had the benefit of many discussions with him after our marriage in 1950, particularly when his ideas about a particular problem were still being crystallized—discussions that often included a philosophical dimension. The reception of his work and the respect accorded him by those better qualified than myself to judge its technical merit are ample testimony to its importance. The reader with a basic education in science will learn more in these pages about his many and varied contributions. These reveal that Herbert was—rather like Feynman, some of whose correspondence with my husband is

reproduced in this book—a man of broad interests. He frequently began to address one topic, which, having achieved some new insights and recorded these for publication, he would then drop in order to move on to another more challenging problem. The subtitle of this biography “A Physicist Ahead of His Time” resonates with my impression that he frequently left the jigsaw unfinished, but in a form that allowed others to come along and complete it at a later date.

I thank Gerard for undertaking this biography, and for the marvellous book that has resulted, in which I trust the reader will find enjoyment and inspiration.

December 2014

Fanchon Fröhlich

Acknowledgments

It is a pleasure to fulsomely acknowledge the unstinting help I have received over very many years from Fröhlich's widow, Fanchon, in the course of my documentation of her late husband's life and work, for providing me with valuable information and insights into his life and work, and for making available the photographs included in this biography. I am also indebted to former members of Fröhlich's department in Liverpool for sharing their reminiscences with me—in particular, the late Dr. Brian Holland, the late Dr. Ronald Huby, Dr. Harry Newns, Dr. Charles Terreaux—and to other former colleagues elsewhere, especially Dr. Jiri Pokorný (Prague), Prof. Dr. Fritz Popp (Neuss), and Prof. Geoffrey Sewell (London).

The genealogical assistance of Barbara Staudacher (Rexingen), and the archival assistance of Adrian Allen (former Librarian of Liverpool University), Alan Franklin (Manx National Heritage), Joanna McManus (Royal Society Librarian), Dr. Jagdish Mehra (Professor of Science and Humanities at the University of Houston), Angelika Mundorff (Museum Fürstenfeldbruck), Dr. Gerhard Neumeier (Stadtarchiv, Fürstenfeldbruck), and Josephine Zilberkweit (Liverpool) is gratefully acknowledged. In addition, I wish to thank Helen Ireland, Peter Larkin, and Geoffrey Lewis (Warwick University Library), Prof. John Dainton, F.R.S. and Dr. Peter Rowlands (University of Liverpool), Dr. Brian Pollard (University of Bristol), and especially Dr. Laurence Caves (Southam), Dr. Mario Micallef (University of Warwick) and Anthony Teeluck (Hook) for their assistance in various ways.

I also wish to acknowledge the assistance of the Department of Special Collections of the Bodleian Library, Oxford, in making available material from the archives of the Society for the Protection of Science and Learning, and to thank its successor organization, the Council for Assisting Refugee Academics (CARA), for permission to reproduce some of the material in this book.

Liberal use has been made of unpublished interviews with Fröhlich, recorded by Profs. Haken and Wagner in Stuttgart, during the 1980s, which Fröhlich made

available to me to supplement those recorded by myself in Liverpool around the same time.

The collaboration during the 1970s with Prof. George Rowlands, a fellow member of the Department of Physics at the University of Warwick, and with Prof. Fred Cummings of the University of California at Riverside in extending some aspects of Fröhlich's work on superfluid He⁴ is remembered with pleasure.

It is a particular pleasure to thank my old friend and former colleague Claudio Ronchi for encouraging me to approach *Springer Verlag*, and to gratefully acknowledge the invaluable editorial assistance of Dr. Angela Lahee (Springer Verlag, Heidelberg) and of Charles Rayappan and Gajalakshmi Sundaram (Scientific Publishing Services, Chennai, India).

Finally, I wish to sincerely thank my wife, Mercedes, for her help with proof-reading, the compilation of the index, and general word-processing matters.

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Herbert Fröhlich—a drawing by his wife Fanchon, 1973

Chronology

Cited references in square brackets correspond with those in the *Complete Bibliography of H. Fröhlich* at the end of this book. Particularly important works are identified by parenthetical numbers in **bold** type; asterisked references denote his most influential works.

- 1905:** Herbert Fröhlich born in Rexingen (Württemberg) on Saturday, 9 December.
- 1907: The Fröhlich family moves to Munich.
- 1911–1915: Herbert attends Primary School in Munich.
- 1915–1921: Attends the Municipal High School of Commerce in Munich, after which he moves to Reutlingen to spend 6 months at the Technical College for the Textile Industry.
- 1927: **age 21:** Takes his *Abitur* at the *Oberrealschule* in Magdeburg; enters the Ludwig-Maximilian University, Munich, to study experimental physics.
- 1928: Enrols for a doctorate in experimental physics under W. Wien; Wien dies, Fröhlich changes to theoretical physics, and starts attending lectures by Sommerfeld.
- 1929: Enters the Theoretical Physics Institute under Sommerfeld.
- 1930: **age 25:** Awarded D. Phil. (*Magna cum Laude*) for a thesis on the Photoelectric Effect in metals, which is published in *Annalen der Physik* as [F1].
- 1930–1931: Research Fellow in Munich, where he is the first to apply ‘second quantization’ to electrons in solids [F2].
- 1931: Moves to Freiburg im Breisgau (Württemberg) as Research Fellow, to introduce modern physics in Gustav Mie’s Physical Institute.
- 1932: *Privatdozent* in Freiburg from December.
- 1933: *Habilitationsschrift* published as [F7]. *Privatdozent* appointment confirmed by the State of Württemberg early in the year, but is terminated by the Nazis in April.

- 1933: Visits London in an unsuccessful attempt to obtain, *via* the Academic Assistance Council (AAC), financial support for a research position in the *UK*—despite an offer from Schrödinger to be his Assistant at Oxford. Joins his parents in Strasbourg, to where they have fled from from Munich to escape the Nazis.
- 1934: Accepts an invitation from Frenkel to go to Leningrad (St. Petersburg) to work as a ‘Foreign Expert’ in A.F. Joffe’s Physico-Technical Institute.
- 1935: **age 30:** Flees Russia to escape Stalin’s purges, and eventually arrives (*via* Vienna) in the *UK* on 30 June to attend a conference in Bristol on the Metallic State; he is awarded a Research Fellowship for 12 months by the AAC in July to work with Mott in Bristol.
- 1936: First book—*Elektronentheorie der Metalle* [F(i)]**—is published by Springer. Obtains a grant from Bristol University.
- 1937: Publishes his first paper on dielectric breakdown [F16]*. Moves to Holland for 6 months with a stipend from the Lorentz Foundation to work in Kramers’ group in Leiden, from where he publishes [F17] dealing with the specific heat of small particles. Returns to Bristol with the promise of financial support from the Electrical Research Association (ERA) to continue work on dielectric breakdown.
- 1938: Collaborates with Heitler and Kemmer [F20] in a vector extension of Yukawa’s meson theory, which predicts a neutral meson.
- 1940: **age 35:** Interned for about 3 months, together with other ‘aliens’ including Heitler and Heinz London. Publishes [F33] (with Nabarro), predicting that monovalent metals should, through an indirect interaction between nuclear spins mediated by conduction electrons, exhibit nuclear ferromagnetism at sufficiently low temperatures—anticipating by 14 years the better-known work of Ruderman and Kittel.
- 1943: Joins the academic staff of Bristol University as a lecturer in Theoretical Physics.
- 1946: Attends the International Conference on Fundamental Particles and Low Temperature Physics in Cambridge.
- 1947: Publishes [F60]*, out of which later evolved ‘hot’ electron physics. Visiting Professor at the Dublin Institute for Advanced Studies, where Schrödinger and Heitler are then based.
- 1948: Leaves Bristol to take up the first Chair of Theoretical Physics at the University of Liverpool on 1st October.
- 1949: Oxford University Press (OUP) publishes his second book—*Theory of Dielectrics* [F(ii)]**.

- 1950: **age 45:** Publication of his work (in collaboration with Pelzer and Zienau) on the properties of slow electrons in polar materials (large polarons) [F72]*. Visiting Professor at Purdue, where he lectures on *Statistical Mechanics*, and tours principal universities in USA and Canada. Identifies the electron-phonon interaction as the basis of superconductivity [F76]**, consistent with which is the contemporaneous discovery of the isotope effect [F77]. Marries Fanchon Aungst (b.1927).
- 1951: Elected Fellow of the Royal Society on 15th March. Invited to speak [F81] in Washington on the occasion of the 50th anniversary of the US National Bureau of Standards (NBS).
- 1952: Publication of his field-theoretical Hamiltonian [F84]*** for electrons and phonons in interaction, marking the start of a new era in solid-state physics. Lectures in Lille (under the auspices of the Foreign Universities Interchange Scheme), Zurich, Rennes, and in Paris, at the conference ‘Rotational Transformations in Solids’ [F82].
- 1953: Visiting Professor at Purdue during the Lent term, where he lectures on *Electrons in Crystals*; lectures in other US Institutions, at the Canadian Research Council, and at the Lorentz-Kamerlingh Onnes Centenary Meeting in Leiden [F85]. Lectures at international theoretical physics conferences in Kyoto and Tokyo [F87, 88] and at a conference on low temperature physics in Houston, USA.
- 1954: Solves his Hamiltonian exactly for a 1-dimensional model of a superconductor, finding, for the first time, an energy spectrum characterised by an essential singularity in the electron-lattice coupling constant and a gap [F89]; presents these results at the 10th Solvay Conference in Bruxelles [F93]. Lectures in Copenhagen, Rennes, ETH Zurich, and at the International Conference on Semiconductors in Amsterdam [F91].
- 1955: **age 50:** Awarded his first honorary degree (D.Sc.) by the University of Rennes, France, in recognition of his contributions to dielectric theory.
- 1956: Lectures at Purdue on the *Polaron* and on the *Many-body Problem*, and in Bruxelles at l’Institut des Hautes Études. Attends the International Conference on Electron Transport in Metals and Solids held at the Canadian National Research Laboratories, Ottawa, in September.
- 1957: Second Edition of *Theory of Dielectrics* published by OUP. Lectures at a number of American universities, at the University of Paris, and at the Dublin Institute for Advanced Studies.
- 1958: Visits the University of Strasbourg under the auspices of the Foreign Universities Interchange Scheme.

- 1960: **age 55**: Publishes a novel approach to space-time reflections, predicting 4 new mesons with the same isospin as the *K*-mesons [F107]. Visits Australia as a consultant to the Executive of Australian Commonwealth Scientific and Research Organisation (CSIRO).
- 1961: Gives further lectures in USA and Canada.
- 1962: Visits Hungary (under the auspices of the British Council) at the invitation of the Hungarian Government. Lectures on *Polaron Theory* [F114] at the Scottish Universities Summer School on *Polarons and Excitons* at St. Andrews.
- 1963: Develops further his isobaric spin algebra in [F116]; publishes a new formulation of the electron-phonon interaction in narrow band materials with Machlup and Mitra [F118]. Gauss Visiting Professor in Göttingen (May–July).
- 1964/1965: Visits universities and research laboratories in the USA during the Lent term, and is Visiting Professor at the Technical University of Stuttgart during July, where he lectures on *Solid-state Physics*.
- 1965: **age 60**
- 1966: Elected Chairman of the International Commission of Statistical Mechanics and Thermodynamics of the International Union of Pure and Applied Physics (IUPAP) until 1972. Visits Leiden as Lorentz Professor, and a number of American universities during the autumn, and speaks [F127] at a symposium on Ferroelectricity in Michigan in honour of P.W. Debye.
- 1967: Publishes his first paper [F129] on the connection between micro and macrophysics. Gives the opening address *Quantum Mechanical Concepts in Biology* at the first meeting in the series ‘From Theoretical Physics to Biology’ organised by l’Institut de la Vie, in Versailles.
- 1968: Speaks on *The Connection of Micro and Macrophysics* [F139]* at the International Conference on Statistical Mechanics in Kyoto, where he is Visiting Professor at the Research Institute for Fundamental Physics. Publishes a theory of superconductivity in materials with incomplete inner shells [F131], and presents a model showing how coherent excitations can be established in living systems [F134]**. Visits Italy in April (under the auspices of the Italian Research Council and the British Council), and, during the autumn term, the USA and the University of Alberta, Canada, where he lectures on *The Connection between Microscopic and Macroscopic Physics*, and where he is awarded LL.D (*Hon. causa*).

- 1969: Proceedings [F138]* of the 1967 Versailles conference (*From Theoretical Physics to Biology*) published; gives the Opening Address at the 2nd Versailles meeting on the same topic. Awarded Sc.D (*Hon. causa*) by Trinity College, Dublin, and is Visiting Professor at Stuttgart, where he lectures on *The Connection between Micro and Macrophysics*.
- 1970: **age 65**: Lectures at the Dublin Institute for Advanced Studies during February, and at the University of Stuttgart during July. Broadcasts on German Radio a series of talks [F148] entitled *Theoretische Physik und Biologie* (Theoretical Physics and Biology). Undertakes further visits to the USA and Canada during the autumn term.
- 1971: Visits several European universities during April, July and September, and lectures in Stuttgart on the *Boltzmann Equation*. Attends the 3rd meeting of the series 'From Theoretical Physics to Biology' organised by l'Institut de la Vie; proceedings of the second meeting published [F147].
- 1972: Awarded the *Max Planck Medal* of the German Physical Society (presented *in absentia*, owing to convalescence from surgery, and accepted on his behalf by his wife, in October in Wiesbaden). Predicts a frequency-specific long-range interaction between coherently oscillating systems [F150]*. Speaks at a symposium on Synergetics at Schloss Elmau, Bavaria [F153]. Visits Canada and USA (including La Jolla). Undertakes a Royal Society Study Visit to Japan during December and January 1973, visiting Tokyo and Kyoto (Institute for Fundamental Physics); returns home *via* Bombay (Tata Institute).
- 1973: Retires from the Liverpool Chair, which is marked by the publication of the *Festschrift* 'Cooperative Phenomena'. Becomes *Professor Emeritus* in Liverpool, and is appointed (until 1976) Professor of Solid-state Electronics at the University of Salford, Manchester UK. Publishes [F154] dealing with non-linearly coupled electric polarization and elastic fields, and a major review article [F155]* on the connection of micro and macrophysics.
- 1974: Lectures at the Erice Summer School on Cooperative Effects [F158].
- 1975: **age 70**: Speaks at a colloquium in Berlin to mark the 75th Anniversary of Planck's Quantum Theory [F165]. Gives the opening address at the 5th International Conference on Theoretical Physics and Biology, in Vienna.
- 1976: Gives a Science Faculty Lecture (*Order and Organisation in Physics and Biology*) in Liverpool to celebrate his 70th birthday, and lectures at a symposium on Interdisciplinary Aspects of Modern Physics, in Parma, Italy.
- 1977: Speaks at a Workshop on Synergetics at Schloss Elmau, Bavaria [F172].

- 1978: Speaks at the Pennsylvania Conference on Electrical Insulation and Dielectric Phenomena, organised by the National Academy of Science Conference [F175].
- 1979: Elected a Foreign Member of the Stuttgart Max Planck Institute for Solid-state Research. Speaks on *Non-local electrodynamics and the Kemmer Equation* at a symposium to mark Kemmer's retirement from the Edinburgh Chair, and at the *IBM International Workshop on Physical Concepts in Tissue Growth*, in Bad Neuenahr (Rhine-land-Palatinate), Germany [F178].
- 1980: **age 75:** Awarded Honorary Doctorates by the University of Stuttgart (Dr. Rer. Nat.), and by Purdue University (D.Sc.). Lectures in Munich, Alberta, Houston (at a symposium on the Biological Effects of Non-ionising Radiation [F179]) and at the Dublin Institute for Advanced Studies.
- 1981: Lectures in Cologne, at the Dublin Institute for Advanced Studies, and at the international symposium Biomedical Thermology in Strasbourg [F181]. Visits New Delhi, India (under the auspices of the British Council) and there attends the 1st International Seminar on the Living State.
- 1982: Lectures in Erice [F185], Palermo, San Miniato (*NATO Advanced Study Institute on Molecular Models of Photoresponsiveness* [F187]), Stuttgart, and at an International Symposium in Bad Neuenahr.
- 1983: Contributes [F186] to the proceedings of the 1982 Bad Neuenahr Symposium, which he co-edits with F. Kremer, and which is published by Springer under the title *Coherent Excitations in Biological systems* [F(iii)]. Speaks at the International Conference on Non-linear Electrodynamics in Biological Systems, in Loma Linda, California. Visits Moscow.
- 1984: Lectures in Messina, Sicily.
- 1985: **age 80:** International Symposium held at Liverpool to celebrate his 80th birthday. Speaks at the 50th Anniversary of Meson Theory in Kyoto, Japan [F193], and attends the Sixth International Meeting on Ferroelectricity in Kobe.
- 1986: Chairs the European Physical Society Meeting in Überlingen (Baden-Württemberg), Germany.
- 1987: Publication of the *Festschrift* 'Energy Transfer Dynamics' in honour of his 80th birthday in December 1985. Presents *Elementary Remarks on High Temperature Superconductors* at the International Workshop on Novel Mechanisms of Superconductivity in Berkeley [F197]. Speaks in Prague at the International Seminar on the Biophysical Aspects of Cancer. Appears on *UK Granada Television* in a Nuclear Science Documentary. Attends an international conference at the University of Bristol to celebrate the 40th anniversary of the discovery of the π - and V -particles.

- 1988: *Biological Coherence and Response to External Stimuli* [F(iv)] is published by Springer, which he edits and contributes the first chapter. His 1968 paper *Long range coherence and energy storage in biological systems* [F134]** is listed as a ‘most frequently cited work’ by the Institute for Scientific Information (*ISI*). Attends a conference (Meaning and Structure in Biology and Physics: Some Outstanding Questions) in Bermuda, and is Chairman of the last in the series of conferences on Theoretical Physics and Biology organised by l’Institut de la Vie.
- 1989: Awarded D.Sc (*Hon. causa*) by North Eastern Hill University, India. Principal speaker at a symposium on Biophysics in Kiev (May), and at a symposium on Biometrology in Stockholm (June).
- 1990: **age 85**: Attends the First International Conference on the Study of Consciousness within Science, San Francisco, in February, but is too unwell to speak.
- 1991: Dies in the early hours of Wednesday, 23 January, aged 85, in the Royal Liverpool University Hospital, from an infection following an operation there for bowel cancer.