The Road to Maxwell's Demon

Conceptual Foundations of Statistical Mechanics

Time asymmetric phenomena are successfully predicted by statistical mechanics. Yet the foundations of this theory are surprisingly shaky. Its explanation for the ease of mixing milk with coffee is incomplete, and even implies that un-mixing them should be just as easy. In this book the authors develop a new conceptual foundation for statistical mechanics that addresses this difficulty. Explaining the notions of macrostates, probability, measurement, memory, and the arrow of time in statistical mechanics, they reach the startling conclusion that Maxwell's Demon, the famous *perpetuum mobile*, is consistent with the fundamental physical laws.

Mathematical treatments are avoided where possible, and instead the authors use novel diagrams to illustrate the text. This is a fascinating book for graduate students and researchers interested in the foundations and philosophy of physics.

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To my wife Tami, and to my children Alma, Avigail, and Shaul – M. H.
For my daughter Marie – may your trajectory, like that of
Maxwell's Demon, evolve through growing
potentialities and increasingly meaningful experiences – O. S.

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Preface

This book is a product of more than decade of joint work during which we have greatly benefited from discussions with many people.

First and foremost, the approach we put forward here has been greatly influenced by David Albert's groundbreaking book from 2000 *Time and Chance*. Albert's way of thinking about Maxwell's Demon has made us realize that the foundations of statistical mechanics are in need of clarification, refinement and sometimes even revision, and this realization has led us to develop many of our ideas that come up in this book. Although we agree with Albert on some important matters – such as the radical idea that Maxwell's Demon is consistent with statistical mechanics – our approach substantially differs from his on a number of issues. However, the need to explain our differing opinions has greatly helped us sharpen our thoughts on the topics we address in this book.

Many conversations with the late Itamar Pitowsky over more than two decades have been extremely valuable to us. Itamar's open mind to new ideas and his constant encouragement throughout our research kept us on the right track.

It is a special pleasure to thank the members of the philosophy of physics group which meets monthly as it has for several years at the Edelstein Centre for the History and Philosophy of Science at the Hebrew University of Jerusalem: in particular we thank Yemima Ben-Menahem, Alon Drori, Daniel Rohrlich, Lev Vaidman, Boaz Tamir, and Simcha Rozen. We received valuable comments from the participants in two series of workshops in which we have presented some of our ideas: New Directions in the Foundations of Physics organized by Jeff Bub, Rob Rynasiewicz and James Mattingly, and the meetings in Sesto, Italy organized by GianCarlo Ghirardi, Nino Zanghi, Shelly Goldstein and Deltef Dürr; and from the participants in two international meetings of

the Bar Hillel Colloquium for the History, Philosophy and Sociology of Science held at the Van Leer Institute in Jerusalem: in 2000, on the subject of foundations of statistical mechanics, and in 2008, on the subject of probability in physics, in honor of Itamar Pitowsky. We have also benefitted from discussions and written exchanges with (in alphabetic order) Frank Arntzenius, Joseph Berkovitz, Jeff Bub, Criag Callender, Shelly Goldstein, Amit Hagar, Carl Hoefer, the late Rolf Landauer, Barry Loewer, Tim Maudlin, Wayne Myrvold and Jos Uffink. We also thank the Cambridge University Press editorial team and especially Lindsay Nightingale for her thorough copy editing.

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