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OBITUARY

Models, Unification, and Simulations: Margaret C. Morrison (1954–2021)

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The philosophy of science community mourns the loss of Margaret Catherine Morrison, who passed away on January 9, 2021, after a long battle with cancer. Margie, as she was known to all who knew her, was highly regarded for her influential contributions to the philosophy of science, particularly her studies of the role of models and simulations in the natural and social sciences. These contributions made her a world-leading philosopher of science, instrumental in shifting philosophers' attention from the structure of scientific theories to the practice of science. Her sophisticated studies of the function of models in scientific practice drew on detailed knowledge of the theories and experiments of physics as well as the history of physics. In emphasizing the autonomy of scientific models and their interventional character, her insights had some affinity with Cartwright's and Hacking's views on phenomenological laws, entity realism, the instrumentalist interpretation of scientific theories, and the disunity of science. But Morrison's approach was distinguished by the conviction that the existence of unobservable entities cannot be defended independently of the theories that support their evidence, and that scientific practice cannot be adequately understood without examining the reasons for theory unification.

Morrison grew up in the province of Nova Scotia in Eastern Canada. Her interest in the philosophy of science began when she was a student research assistant in the Department of Biophysics at Dalhousie University from 1976 to 1981. She graduated with a B.A. in Philosophy in 1982 and went on to study at the University of Western Ontario, where she received an M.A. in philosophy in 1982 and a Ph.D. in philosophy of science in 1987. She was then Visiting Assistant Professor in Philosophy at Stanford University (1987–1988) and an Assistant Professor at the University of Minnesota in the United States (1987–1989). In 1989, she accepted her position in the Philosophy Department of the University of Toronto, where she received tenure in 1992, was promoted to Full Professor in 1998, and retired in 2019.

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From the beginning, Morrison's work had a broad philosophical focus, targeting debates about scientific realism and critically evaluating approaches to the metaphysics of nature. Her investigation of scientific models and theory unification was complemented by studies in the history of philosophy ranging from Cartesian Science (1989a) to Kant's theory of nature (1989b; 1998a; 2008a) and Whewell's inductivism (1997a; 2000a), which served as a background to her case studies on unification through Maxwell's electromagnetic theory (1990a, b; 2000a) and the Salam-Weinberg theory of electroweak interaction (1994a; 2000a). Based on her detailed knowledge of various physical theories, she raised substantive objections to some of the most widely discussed views of the 1980s about scientific realism, empirical evidence, and the structure of science. Relying on Maxwell's conceptions of the electromagnetic ether and the displacement current, she argued against Friedman's influential view that theory unification is not necessarily based on scientific realism (1990b). Against Hacking's manipulability criterion of entity realism and the related claims about scientific "home truths", she objected that employing unobservable entities as experimental devices to produce an effect cannot be isolated from the theories about them (1990c). A related argument was directed against Cartwright's account of the causal stories that trace back to the capacities of nature which, or so Morrison argued, cannot be isolated (1994a; 1995a). In addition, she investigated the relations between theory construction and the phenomena from Newton to Einstein by examining the complex nature of experimental evidence (1992); and she challenged the 1990s views of the disunity of science espoused by Cartwright and others (1994b; 2000a).

From 1992 to 2005, Morrison was a Research Associate of the Centre for Philosophy of Natural and Social Science (CPNSS) at the London School of Economics where she also met her second husband, the noted philosopher of science Colin Howson (1945–2020). In the academic year 1995/96, she was a Research Fellow at the Wissenschaftskolleg zu Berlin, working on the project "Models as Mediators: The Role of Models in Physics and Economics" (1997b; 1998b) and participating in an interdisciplinary research group of philosophers, physicists, biologists, economists, historians, and urban planners. One outcome of this work was a case study on the transfer of models associated with the ideal gas law from kinetic theory to population genetics (1997c).

The project at the Wissenschaftskolleg eventually resulted in the book *Models as Mediators*, edited with Mary S. Morgan (1999a). It was a great success and the claims articulated in the programmatic introductory essay (1999b) attracted attention far beyond their field. In that essay, Morgan and Morrison argue that models mediate between (often quite abstract) scientific theories and the world. Morrison's own contribution on models as autonomous agents (1999c) emphasizes that models have a life of their own and that the specific features of scientific practice are fundamental to the construction and use of models. The book has been reviewed by prominent philosophers and in leading journals in the history and philosophy of science, physics, social sciences, and economics. The views expressed in it prompted a rethinking of the role of models and theories in the philosophy of science. *Models as Mediators* initiated an influential research program that focused on the detailed analysis of the role and function of scientific models, resolutely distinguishing itself from the views as put forward by the proponents of the syntactic and semantic views of scientific theories about models.

In parallel, Morrison continued her studies on theory unification and the dichotomy of unity and disunity in relation to the structure of science, culminating in the publication of her book *Unifying Scientific Theories* (2000a). This book also attracted much attention in the philosophy of science; it was reviewed in leading journals and was shortlisted for the Lakatos Award in 2005. The book explores how exactly the unification process works and what epistemological value should be attached to unified theories. More specifically, Morrison provides a detailed look at several unified theories including Maxwell's electrodynamics, special relativity, and the electroweak theory that is part of the Standard Model of particle physics, as well as Darwin's theory of evolution and Fisher's population genetics. Morrison argues that in each of these cases the ability to unify phenomena was largely dependent on a particular type of mathematical structure that formed the basis of each theory. Moreover, each theory exhibits different characteristics with respect to unification. Morrison ultimately concludes that while mathematics plays an important role in unification there is no single feature common to all unified theories. The book has two important philosophical results. First, contrary to popular belief in the philosophy of science, unification is in many cases decoupled from explanation. Second, a different type of unification was used in each of the cases studied. Accordingly, the unity vs. disunity debate is based on a false dichotomy, and although unification is critical to scientific practice, there is no single philosophical account of unification. All that exists is a variety of approaches to unification.

While Morrison always maintained an interest in scientific models, her intellectual curiosity led her to broaden the scope of her work in the subsequent years. And so she began to think about the relationships between unification, reduction, emergence, and the limits of science (2000b; 2002a; 2008a) and the role of values in science (2008b). She also examined the connection between theoretical principles like spontaneous symmetry breaking and emergent phenomena and argued that new ways of thinking about emergence and fundamentalism are required to account for the behavior of many phenomena in condensed matter physics and other areas of contemporary physics (2006a; 2007a), laying the groundwork for her later work on the renormalization group. In parallel, she published a series of papers on the philosophy of biology (2002b; 2004; 2006a, b) that addressed the historical controversies surrounding Fisher's approach to population genetics. Here she examines their contents as well as unification, explanation, mathematical abstraction in the modelling strategies, and the use of statistical theory. This research culminated in her contribution to the *Handbook of the Philosophy of Biology* (2006c).

Her work on scientific models, written after *Models and Mediators*, is characterized by a focus on more general questions. In particular, she became interested in the relationship between models and theories (2005a, b; 2006c, e; 2007b) and in the relationship between models (or theories) and reality (2001a, b; 2006c; 2008c, d; 2009a). Her main concern was how it is possible for mathematics to apply to empirical reality. She asked how abstract and idealized mathematical models, which often have little relation to the concrete physical world, can shed light on the concrete structure of reality. This question is crucial not only for the philosophy of science but also for economics, policy making, and other fields that rely on mathematical modelling. To investigate the fascinating question of how abstract models relate to reality, she conducted further case studies in physics. In this context, she considered spin (2001b; 2007c) and compared turbulence models with models of the atomic nucleus (2011a). For the latter, she explored the implications of the widespread scientific practice of using different inconsistent models simultaneously, the difficulties of interpreting the information such models provide, and the strategies scientists use to overcome them (such as perspectivism, paraconsistency, or the partial structures approach). Here she argued that coexisting models of the same phenomena either correspond to complementary ways of modelling that do not pose an obstacle to knowledge acquisition (as in the case of turbulence), or they are inconsistent and pose major philosophical problems (as in the case of the nuclear models).

In another philosophical twist, Morrison extended her interest in models into the realm of computer simulation, asking how we can use simulations as a source of reliable information or as a substitute for experimental data (2009b; 2014a). Her book *Reconstructing Reality: Mathematics, Models and Simulations* (2015a) represents the culmination of her many years of work on the topics mentioned in the book title. The book, which has been favorably reviewed in several leading journals, offers a novel approach to thinking about the complex relationship between abstract mathematical representations and the reality we are trying to understand. From a metaphilosophical perspective, *Reconstructing Reality* defends a particularist or even therapeutic position which states that a general philosophical account of models and simulations is not possible. To this end, Morrison argues that all currently available general accounts do not cover all paradigmatic examples of models and simulations in the sciences. Accordingly, Morrison challenges defenders of general philosophical accounts to respond to her critique.

Her particularism also shows up in her most recent work on the heuristics of theory building—a topic that increasingly interested her. Continuing her work on the strategies of unification and on models as autonomous agents, Morrison defended the claim that no logical reconstruction in terms of the syntactic or the semantic view of theories can do justice to the many faces of theory building. In one of her last papers, she explored the top-down and bottom-up strategies of theory building in high-energy physics and the interplay of these strategies with analogical reasoning in population biology (2018a).

In addition to the theories of fundamental physics, Morrison has had a keen interest in the philosophical questions raised by the physics of complex systems. In a series of papers (2012a, b; 2014b; 2015c; 2018b), for example, she discussed the consequences of the renormalization group approach for the debate around questions of reduction and emergence. In her typical style, she carefully examined various case studies (such as phase transitions and superconductivity), paying particular attention to the relationships between the various ontological and explanatory levels involved. This is perhaps best demonstrated in her contribution to the co-edited volume *Why More is Different. Philosophical Issues in Condensed Matter Physics and Complex Systems* (2015b), in which she insists on focusing ontological aspects of emergent phenomena "in order to understand not only the basis for their similarity, but also the stability of their behaviour patterns" (p. 113). This volume grew out of a workshop at the spring meeting of the Philosophy of Physics Division of the German Physical Society (DPG) in March 2012 and is an excellent starting point for anyone interested in the foundational and methodological problems of a part of physics that has not yet received the attention it deserves.

Over the years, Morrison has been an active member of several interdisciplinary research collaborations. Her publications had a profound impact on turning the philosophy of science toward the study of scientific practice. She lectured widely around the world, served on many editorial boards, and received a substantial number of grants and awards. She has also been invited to write articles for several leading handbooks of the philosophy of science (2006e; 2013; 2016). In 2004, she was elected to the Leopoldina, the German National Academy of Sciences, in 2015 to the Royal Society of Canada, and in 2016 to the Académie Internationale de Philosophie des Sciences of Brussels. She has received fellowships from the Social Sciences and Humanities Research Council of Canada, the British Academy, the Connaught Fund, and the Jackman Humanities Institute at the University of Toronto. In 2014, she held a residential fellowship at the Institute for Advanced Study in Durham (UK) and received the Carl Friedrich von Siemens Research Award from the Alexander von Humboldt-Stiftung, which she used to spend one year at the Munich Center for Mathematical Philosophy (MCMP) at LMU Munich. Her close ties to the German academic community are also reflected in her many presentations and conference participations at German universities and research institutions, especially in Berlin, Dortmund, Munich, and Wuppertal. In June 2014, she delivered the prestigious *Carl Friedrich von Weizsäcker Vorlesungen* in Hamburg, sharing her insights on models and simulation with a broader academic audience. Finally, in 2017, she was awarded a Guggenheim Fellowship for her work on the role of mathematical frameworks in explaining the behaviour of complex systems.

Most of Morrison's work addressed the broad topic of how the methods and practices of science associated with mathematics, modelling, unification, and simulation, provide information and knowledge of the world around us. Her work gathers important insights into many specific philosophical problems that arise in the context of models and unification. She illuminated the role of mathematics in the construction and interpretation of models and theories, as well as mathematics as a method for generating understanding of the world itself. With the theme of simulation, she extended her rich conceptual framework and philosophical findings to understanding how contemporary scientific practice reconstructs the world in new and complex ways. Her multifaceted *œvre* shows that this reconstruction is by no means simple. Examining the strengths and weaknesses of computer simulation, she shows how simulations can be used to legitimately push the boundaries of theoretical and empirical knowledge. Margie Morrison's lifework traced the path that modern science has taken, from classical physics, its history and philosophy, to current scientific practice and its thorny philosophical problems. That is, her main goal was not to grapple with or attempt to explain what Eugene Wigner famously referred to as the "unreasonable effectiveness" of mathematics. Rather, she was interested in exploring more deeply the relationships between mathematics and physics, and between physics and the world, from a postmetaphysical standpoint. Her interest in explicating these relationships sprang from an attempt to understand how the abstract nature of mathematics can nonetheless provide concrete information about the world, and how a reconstruction of reality in mathematical terms can help us solve scientific problems. She took it as a given that these relationships remain mysterious, but the mystery need not prevent us from attempting to uncover at least some of their properties.

Beyond her outstanding work as a scholar, Margie was a very lovely person and a most popular member of the worldwide philosophy of science community. She cared deeply about her friends and students and was a fantastic mentor and role model for numerous male and female junior scholars. Always exquisitely dressed, she had a keen interest in fashion and regularly attended fashion shows. She also had many friends in the fashion industry. In the last years of her life, she even thought about combining her various interests and made plans to write about the philosophy of fashion. Due to her untimely death, she did not get to do so.

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