A symposium sponsored by the John Templeton Foundation



Contact: Mary Ann Meyers, Ph.D., Senior Fellow



What category of causation is taking place in artificial neural networks? Genetic algorithms?

## PURPOSE

Top-down causation refers to the effects on components of organized systems that cannot be fully analyzed in terms of component-level behavior but instead requires reference to the higher-level system itself. A sweeping and fundamental concept, it is not only a philosophical idea but also a key ingredient in the emergence and functioning of complex systems, including life and the human brain. Together with bottom-up causation, top-down causation enables genuine complexity to emerge within specific levels of the hierarchy of complexity and causation. It also links the various levels of the hierarchy in a manner that undermines any simple-minded version of reductionism. A growing literature on complexity and emergence is providing an analysis of how this happens. Nevertheless, there are some who deny that it has any significance, or even reality.

The core issue is volitional agency. The topical focus of the discussion at the Royal Society amongst sixteen scientists and scholars has the potential to link scientific research with progress in philosophical and theological scholarship because of the fundamental importance of causation in daily living and in moral life. Symposium participants will consider the following specific sets of philosophical questions:

- What counts as "top" in top-down causation? What counts as "bottom"? Would "whole-part causation" be a better description? If so, what difference would that make?
- Are there any top-down realities to do the causing? If so, are they properties or substances? If properties, "of what" are they properties? If substances, of what are the substances made/composed?
- What would be required for a supervening or emergent entity to have causal powers? And what would be required for "downward causal" power in particular?
- Where might we get some explanatory (or metaphysical) "cash value" out of employing or hypothesizing top-down causal entities? Gaia? Agents? God? Molecules? Minds?

How would we or could we know that the relevant causal powers are not

(even in principle) reducible to constituent properties of the "bottom" level of reality? If we cannot answer this question, does this rule out top-down causation as empirically useless?

- How could we empirically test for the existence of the relevant causal powers?
  - Is top-down causation a single category, or are there distinguishable different kinds? It has been proposed that there are five different kinds of top-down causation in the hierarchy of complexity, namely: algorithmic topdown causation; top-down causation via non-adaptive information control; top-down causation via adaptive selection; top-down causation via adaptive information control; and intelligent top-down causation. Is this a good classification? Are there other kinds that should be taken into account?

Two key issues in physics are:

- A How can there be room at the bottom for any top-down causation at all?
- .
  - Can non-physical entities have physical effects? If so, how is this possible?

And related to these are a set of subsidiary questions:

- What is the relation of information to causality? What is the nature of information?
- Is quantum theory necessary for top-down causation to be possible?
- How does the environment influence quantum states and outcomes?

From the perspective of chemistry, crucial issues include:

- What distinguishes chemistry from physics? What is chemical identity?
- To what extent does quantum mechanics explain chemical phenomena?
- To what degree are properties of physical entities altered by incorporation in molecules?

Biological issues in this discussion relate to the nature of causation in hierarchically structured networks, as well as to the nature of genetic determinism and evolutionary causation. These include:

- What distinguishes biology from physics and chemistry? What is biological identity?
- What is the ontological status of the structure and relationships in a biological network?
- What is the nature and ontological status of biological information?
- What limits on genetic determinism result from the effects of biological context?

- Is multilevel selection a defensible option?
- Is it the way that evolution works?
- Is "chance" a genuine causal category?

Underlying all of the above questions is the relation of macro levels to micro levels, which remains mysterious. Among the questions confronting us are:

- How is the second law of thermodynamics (a key requirement of physics at the macro level) related to biological development and the growth of information (key biological properties), on the one hand, and the timereversibility of micro physics, on the other?
- Is the macro arrow of time determined by top-down causation, bottom-up, or in some other way?

A central matter at the individual level is how top-down causation relates to the way the individual mind functions and to free will. But because this particular issue was dealt with in depth at an earlier *Humble Approach Initiative* symposium, which led to the volume, *Downward Causation and the Neurobiology of Free Will* (2009) edited by Nancey Murphy, George F.R. Ellis, and Timothy O'Connor, it is not a core focus of the London gathering.

The relation of top-down causation to language is, however, a central part of the discussion, and dealing with it inevitably leads to social issues. At the social level, top-down causation from society to the individual seems rather obvious, and the fact that, as Merlin Donald wrote in *A Mind So Rare* (2001), the "human brain is, quite literally, specifically adapted for functioning in a complex symbolic culture" has been known for a long time. The new point is that in the light of modern neuroscience, this effect is not just from society to the individual, but spans multiple levels and leads to the understanding that individual minds cannot be understood on their own; they can only be understood in relation to the society in which they are embedded. Family life, language, peer pressure, education, and role models are key ways in which this top down causation takes place from society to the brains of individuals.

Because the computer metaphor is dominant in most current discussions of neuroscience, it is important to consider the issue of top-down causation in digital computer systems, where the causal nature of the lower physical levels is particularly transparent. Issues include:

- What is the ontological nature of computer programs?
- How is the hierarchical nature of software related to that of hardware?

#### What category of causation is taking place in artificial neural networks? Genetic algorithms?

These difficult and compelling questions are being posed in a venue closely intertwined with the history of science. The Royal Society was founded 350 years ago when an "invisible college" of natural philosophers met at Gresham College to hear a lecture on astronomy by the young Christopher Wren. Their decision to found an organization for promoting the still new and controversial "experimental learning" has contributed profoundly to the advancement of knowledge throughout the world.

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Is quantum theory necessary for top-down causation to be possible?

# APPROACH

The symposium is part of the Templeton Foundation's *Humble Approach Initiative*. The goal of the initiative is to bring about the discovery of new spiritual information by furthering high-quality scientific research. The "humble approach" is inherently interdisciplinary, sensitive to nuance, and biased in favor of building linkages and connections. It assumes an openness to new ideas and a willingness to experiment. Placing high value upon patience and perseverance, it retains a sense of wondering expectation because it recognizes, in Loren Eisley's haunting phrase, "a constant emergent novelty in nature that does not lie totally behind us, or we would not be where we are." A fundamental principle of the Foundation, in the words of its founder, is that "humility is a gateway to greater understanding and open[s] the doors to progress" in all endeavors. Sir John Templeton believed that in their quest to comprehend foundational realities, scientists, philosophers, and theologians have much to learn about and from one another. The humble approach is intended as a corrective to parochialism. It encourages discovery and seeks to accelerate its pace.

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# CHAIR



To what degree are properties of physical entities altered by incorporation in molecules? George F. R. Ellis, professor of applied mathematics emeritus at the University of Cape Town (UCT), is as widely respected for his anti-apartheid Quaker activism as for his contributions to cosmology. Born in Johannesburg, South Africa, and educated in Natal and at UCT, where he received his baccalaureate degree with distinction, he earned his Ph.D. in applied mathematics and theoretical physics at Cambridge University in 1964. He became a research fellow at Peterhouse College, Cambridge, and then was a university lecturer in applied mathematics and theoretical physics before joining the UCT faculty as a full professor in 1974. Dr. Ellis also served as a professor of cosmic physics at the International School of Advanced Studies in Trieste, Italy, for five years and has been a visiting professor at the University of Chicago, the University of Hamburg, Boston University, the University of Texas at Austin, and the University of Alberta. He is currently G. C. McVittie Visiting Professor of Astronomy at Queen Mary, University of London, and lectures throughout the world. His scientific work on the mathematical foundations of general relativity and cosmology is recognized for its depth, originality, and wit. He studies fundamental questions like the geometrical structure of the universe and has not been afraid to challenge conventional assumptions about how our universe began and is built. In his alternative model to the violent Big Bang, the Whimper model, all starts with Quaker gentleness. In the bleak South Africa of the 1970's and 1980's, he used knowledge both as a weapon and a shield against violence and injustice. During the past several decades, he has been deeply involved in race relations, housing policy, and the future of the scientific enterprise of his country. Dr. Ellis, a fellow of the Royal Society, has served as president of the Royal Society of South Africa (RSSA) and of the International Society of General Relativity and Gravitation. He is a fellow of the Royal Astronomical Society, the Institute of Mathematics and its Applications, the RSSA, UCT, and the Third World Academy of Sciences. Winner of the 2004 Templeton Prize, his many other awards include the Herschel Medal of the Royal Society of South Africa, the Claude Harris Leon Foundation Achievement Award, the Gold Medal of the South African Association for the Advancement of Science, the Star of South Africa Medal, which was presented to him in 1999 by President Nelson Mandela, the National Science and Technology Forum Award for lifetime contributions to cosmology, the Academy of Science of South Africa Sciencefor-Society Gold Medal, and the Order of Mapungubwe, which was conferred on him by South African President Thabo Mbeki in 2006. Dr. Ellis holds honorary degrees from Haverford College, the University of Natal, Queen Mary (London University), and the University of Cape Town. He serves as co-editor-in-chief of the international Journal of General Relativity and Gravitation. Co-author with Stephen W. Hawking of The Large

Scale Structure of Space Time (1973), which quickly became a standard reference work, he has published more than three hundred scientific papers and eight other major books. His latest studies are (with John Wainwright) *The Dynamical Systems Approach to Cosmology* (1996), (with Nancey Murphy) *On the Moral Nature of the Universe: Theology, Cosmology, and Ethics* (1996), (with Peter Coles) *Is the Universe Open or Closed? The Density of Matter in the Universe* (1997), and (with Roy Maartens and Malcolm MacCallum) *Relativistic Cosmology* (forthcoming from Cambridge University Press in 2010) in addition to three edited volumes, *The Far-Future Universe: Eschatology from a Cosmic Perspective* (2002), (with Nancey Murphy and Timothy O'Connor) *Downward Causation and the Neurobiology of Free Will* (2009), and (with Jeff Murugan and Amanda Weltmann) *The Nature of Space and Time: Reflections on Quantum Gravity*, which will be published by Cambridge University Press later this year.

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#### Gary R. Berntson

Grady Booch Jeremy N. Butterfield Jerome A. Feldman Luc Jaeger Claus Kiefer Barry Loewer Alan C. Love Peter Menzies Denis Noble Timothy O'Connor Samir Okasha David Papineau Geraint Rees Eric R. Scerri Gary R. Berntson, a founding father of the field of social neuroscience, is a professor at The Ohio State University with appointments in the departments of psychology, pediatrics, and psychiatry. He studies the functional organization of brain mechanisms underlying behavioral and affective processes, with a special emphasis on social cognition. A graduate of the University of Minnesota, where he earned his undergraduate degree and took a Ph.D. in psychobiology and the life sciences in 1971, he held a National Science Foundation (NSF) postdoctoral fellowship at Minnesota and subsequently a NSF and United States Public Health Service postdoctoral fellowship at Rockefeller University. Dr. Berntson joined the Ohio State psychology faculty as an assistant professor in 1973 and was appointed a full professor in 1982. The next year he was named a professor of pediatrics and, in 1988, a professor of psychiatry. From 1984 to 1995, he also was an affiliate scientist at the Yerkes Regional Primate Research Center at Emory University. He has been a visiting professor at the University of Chicago. His research is supported by the National Institute of Mental Health, the National Institute of Child Health and Human Development, the National Institutes of Health, the National Science Foundation, the National Heart, Blood, and Lung Institute, the March of Dimes, the Ohio Heart Association, the University of Chicago, and the John Templeton Foundation. A fellow of the American Psychological Society, the International Organization for Psychophysiology, and the American Association for the Advancement of Science, Dr. Berntson has received distinguished teaching awards from Ohio State and special recognition for his scholarship from the Ohio House of Representatives. He is the president-elect of the Society for Psychophysiological Research. The co-editor of the Social Neuroscience Book Series for MIT Press, he currently serves on the editorial board of the International Journal of Psychophysiology. He is the co-author of more than two hundred scientific papers and the co-author of five books, including (with J.T. Cacioppo and L.G. Tassinay) Handbook of Psychophysiology (2nd and 3rd editions), (with J.T. Cacioppo et alia) Foundations in Social Neuroscience, (with J.T. Cacioppo) Essays in Social Neuroscience, (with J.T. Cacioppo) Social Neuroscience, and, most recently, (with J.T. Cacioppo) the two-volume Handbook of *Neuroscience for the Behavioral Sciences*, which was published last year by John Wiley & Sons.

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Gary R. Berntson

Internationally recognized for his innovative work in software architecture, software engineering, and collaborative development environments, Grady Booch is the chief scientist for software engineering at IBM's Thomas J. Watson Research Center. He formerly served for more than two decades as chief scientist of the Rational Software Corporation, from its founding until its acquisition by IBM in 2003. A graduate of the United States Air Force Academy, Mr. Booch earned a master's degree in electrical engineering from the University of California, Santa Barbara, in 1979. After service with the U.S. Air Force as a computer scientist, he joined Rational in 1981 where he created the Booch method of software development, originating the term and the practice of objectoriented analysis and design. He subsequently developed (with Ivar Jacobson and James Rumbaugh) the Unified Modeling Language, which is used throughout the software industry to develop complex software-intensive systems in every imaginable domain. Mr. Booch has also served as an architect and architectural mentor for numerous such systems around the world. An IBM fellow, he is also a fellow of the Association for Computing Machinery, the Institute of Electrical and Electronic Engineers (IEEE), and the World Technology Network and serves on the boards of the International Association of Softwear Architects, the Computer History Museum, and the Iliff School of Theology, a Methodist seminary associated with the University of Denver. He lectures and consults extensively. A member of the editorial board of IEEE Software, a journal for which he writes a regular column, he is the author of more than two hundred articles on software engineering. Mr. Booch is also the author or co-author of seven books, including (with Ivar Jacobson and James Rumbaugh) The Unified Modeling Language Reference Manual (2nd Edition, 2004) and (with Ivar Jacobson and James Rumbaugh) The Unified Modeling Language User Guide (2nd Edition, 2005) and, most recently, Object-Oriented Analysis and Design and Application, which was published by Addison-Wesley in 2007.

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Gary R. Berntson Grady Booch Jeremy N. Butterfield Jerome A. Feldman Luc Jaeger Claus Kiefer Barry Loewer Alan C. Love Peter Menzies Denis Noble Timothy O'Connor Samir Okasha David Papineau Geraint Rees Eric R. Scerri Jeremy N. Butterfield is a philosopher noted for his work on philosophical aspects of modern physics, particularly quantum theory and relativity theory, and of classical mechanics. A senior research fellow at Trinity College, Cambridge, where he took first class honors in philosophy and also studied mathematics, he went on to earn a Ph.D. in philosophy from Cambridge University in 1984. He was appointed to the philosophy faculty as a lecturer and was promoted to reader in the philosophy of physics in 1997. He was also a fellow of Jesus College. Dr. Butterfield moved on to Oxford University as a senior research fellow at All Souls College in 1998 and returned to Cambridge in his present position in 2006. He has been a visiting assistant professor and a visiting fellow in philosophy at Princeton University, a visiting professor at the University of Pittsburgh, and a visiting senior researcher at the University of Sydney. His work has been supported by a British Academy-Leverhulme Trust Senior Research Fellowship, and he has been awarded a fellowship at the Center for Advanced Study in the Behavioral Sciences at Stanford. A fellow of the British Academy, he has served as president of the British Society for the Philosophy of Science and next year will be president-elect of the Mind Association. He previously served on the governing board of the Philosophy of Science Association and presently serves on the executive committee of the British Philosophical Association and the advisory board of the John Templeton Foundation. Formerly editor of Studies in History and Philosophy of Modern Physics, he currently serves on the editorial boards of the Cambridge University Press series Studies in Induction, Probability and Decision Theory, the Oxford University Press series Studies in the Philosophy of Science, Studies in the History and Philosophy of Modern Physics, the British Journal for Philosophy of Science, Theoria, and the European Journal for Philosophy of Science. In addition to some seventy articles published in academic journals and volumes of collected works, he has edited seven books, including: Language, Mind and Logic (1986), (with Gordon Belot and Mark Hogarth) Spacetime (1996), (with Constantine Pagonis) From Physics to Philosophy (1999), The Arguments of Time (1999), (with Tomasz Placek) Non-Locality and Modality (2002), (with Hans Halvorson) Quantum Entanglements: Selected Papers of Rob Clifton, and, most recently, (with John Earman) the two-volume Handbook of Philosophy of Physics, which was published by North Holland in 2007.

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Luc Jaeger Claus Kiefer Barry Loewer Alan C. Love Peter Menzies Denis Noble Timothy O'Connor Samir Okasha David Papineau Geraint Rees Eric R. Scerri A professor emeritus of computer science and electrical engineering at the University of California, Berkeley, Jerome A. Feldman is a researcher at Berkeley's International Computer Science Institute (ICSI). His early work on compilers and associative programming languages is cited as one of the foundations of relational databases. He was also one of the initiators of the connectionist approach to artificial intelligence and cognitive science. For more than two decades, he has worked on the neural theory of language. A graduate of the University of Rochester, where he received an undergraduate degree in physics with distinction, he earned a master's degree in mathematics at the University of Pittsburgh and a Ph.D. in mathematics and computer science at Carnegie-Mellon University in 1964. He joined the computer science faculty of Stanford University as an assistant professor in 1966 after serving on the research staff of the Massachusetts Institute of Technology Lincoln Laboratory. For four years he also served as associate director of Stanford's Artificial Intelligence Laboratory. Returning to Rochester in 1974 as professor and founding chair of the university's computer science department, he was named Jerome H. Dessauer Professor in 1981. Seven years later, he accepted a professorship of computer science and electrical engineering at Berkeley, a position he held until his retirement in 2008. In 1988, he also was appointed founding director of Berkeley's ICSI, a post he held for eleven years. In addition, Dr. Feldman has served as director of the cognitive science program at Berkeley and currently serves on the scientific commission of the Open University of Catalonia. He has been a Fulbright lecturer at Hebrew University in Jerusalem. A charter fellow of the American Association for Artificial Intelligence, he is also a fellow of the German Center for Artificial Intelligence and of the American Association for the Advancement of Science. He is the recipient of a Research Leadership Award from Berkeley as well as a Berkeley citation and holds an honorary doctoral degree from the University of Rochester. The author or co-author of some 170 scientific papers or chapters in volumes of collected works, he is also the author of From Molecule to Metaphor: A Neural Theory of Language (MIT Press, 2006), a book in which he integrates current insights from many disciplines to construct a theory of language and thought that treats language not as an abstract symbol system but as a human biological ability that can be studied as a function of the brain.

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#### Luc Jaeger

Claus Kiefer Barry Loewer Alan C. Love Peter Menzies Denis Noble Timothy O'Connor Samir Okasha David Papineau Geraint Rees Eric R. Scerri Luc Jaeger is an associate professor of chemistry and biochemistry at the University of California, Santa Barbara (UCSB). His research is focused on the development of new methodologies and materials with potential biomedical applications in the emerging fields of RNA nanobiotechnology and RNA synthetic biology. It involves an effort to decipher the logic of RNA self-assembly and to unravel how complex RNA molecules evolved. He is attempting to characterize self-autonomous folding and assembly properties of various RNA structural features found in the ribosome with the aim of, one, differentiating RNA regions that contribute to the overall assembly of the ribosome in the absence of proteins and, two, defining new RNA structural and assembly principles for three-dimensional modeling of RNA. A graduate of the University Louis Pasteur (ULP) in Strasbourg, Dr. Jaeger went on to earn a master's degree in chemistry and biology there and then a Ph.D. in structural biochemistry and biophysics at ULP in 1993 under the supervision of Eric Westhof and François Michel. He was awarded a postdoctoral research fellowship from NASA to work with Gerald Joyce at the Scripps Research Institute in La Jolla, California, and, in 1995, returned to France as a research scientist at the Institut de Biologie Moléculaire et Cellulaire in Strasbourg. He joined the faculty of UCSB in 2002 and was promoted to his present position in 2008. Dr. Jaeger has held a ULP-NIBH (National Institute of Bioscience and Human Technology and Information Services) grant for work in Japan and is the recipient of a UCSB Junior Faculty Research Incentive Award. His current research is supported by the National Institutes of Health. A member of the advisory board of the Journal of Molecular Recognition, he is the author or co-author of more than fifty papers published in scientific journals.

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Gary R. Berntson

Professor of theoretical physics at the University of Cologne, Claus Kiefer does research on quantum gravity and the foundations of quantum theory as well as studying black holes and more general cosmological questions. He was educated at the University of Vienna and at the University of Heidelberg, where he completed his undergraduate work and went on to take a Ph.D. in physics summa cum laude in 1988. After postdoctoral research at the University of Zurich, he joined the physics faculty of the University of Freiburg as a lecturer in 1993. He was named to his present position in 2001. Dr. Kiefer previously chaired the Committee on Gravitation and Relativity of the German Physical Society and currently serves on the advisory boards of the Annalen der Physik and Classical and Quantum Gravity. Last year, his essay, "Does Time Exist in Quantum Gravity?," was awarded second prize by the Foundational Questions Institute, an organization supporting research and the dissemination of research findings in physics and cosmology that is funded by the John Templeton Foundation. The author or co-author of more than 150 papers published in scientific journals or as chapters in volumes of collected works, Dr. Kiefer is the co-editor of three books, (with Friedrich H. Hehl and Ralph J.K. Metzler) Black Holes: Theory and Observation (1998), (with Philippe Blanchard, Domenico Giulini, Erich Joos, and Ion-Olimpiu Stamatescu) Decoherence: Theoretical, Experimental, and Conceptual Problems (2000), and (with Domenico Giulini and Claus Lämmerzahl) Quantum Gravity: From Theory to Experimental Search (2003). He is also the co-author (with Erich Joos, H. Dieter Zeh, Domenico Giulini, Joachim Kupsch, and Ion-Olimpiu Stamatescu) of Decoherence and the Appearance of a Classical World in Quantum Theory (2003) and the author of four other books, Quantum Gravity (2004 and 2007) in addition to three titles in German, Quantentheorie (2002 and 2004), Gravitation (2003), and, most recently, Der Quantenkosmos, which was published by Fischer in 2008 and, in a new edition, last year.

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Barry Loewer is a philosopher who does research on the metaphysical foundations of science, philosophy of physics, philosophical logic, and philosophy of mind. Distinguished Professor and chair of philosophy at Rutgers University, he also serves as director of the Rutgers Center for Philosophy and the Sciences. Dr. Loewer earned his baccalaureate degree with honors at Amherst College and a Ph.D. in philosophy from Stanford University in 1975. He had begun his teaching career at the University of South Carolina three years earlier, and he became a full professor in 1986. He was appointed a professor of philosophy at Rutgers in 1989 and named to his present academic position in 2001. Dr. Loewer has been a visiting professor at the University of Michigan, a fellow of the National Humanities Center, and a senior fellow at the Collegium Budapest. His current work is supported by grants from the Australian Research Council/Monash University and Melbourne University. He has given invited lectures at Brown University, Oxford University, and the University of Oslo. He served as philosophy of science editor for the Macmillan Encyclopedia of Philosophy (2006) and currently serves on the editorial boards of Synthese, Nous, and Philosophy Compass. The author of more than forty papers published in scholarly journals, he is also the editor (with Georges Rey), of Meaning in Mind: Fodor and His Critics (1991), (with Carl Gillett) Physicalism and Its Discontents (2001), and Philosophy in 30 Seconds (2009). A collection of his papers, Minding and Saying, is forthcoming from Oxford University Press. Dr. Loewer is writing a new book on laws of nature, chance, causation, and conditionals related to the work of the twentiethcentury American philosopher David Kellogg Lewis.

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An assistant professor of philosophy at the University of Minnesota and member of the Minnesota Center for Philosophy of Science, Alan C. Love focuses on conceptual issues in the biological sciences, especially the concepts of innovation and novelty in the context of evolutionary developmental biology, as well as investigating more general methodological matters in the history and philosophy of science. He also explores questions about evidence and reductive explanation that arise in developmental biology and organismal biology, including studies of the relationship between form and function and historical explanations of fossil record patterns. A graduate of the Massachusetts Institute of Technology, Dr. Love earned a M.A. in philosophy from the University of Pittsburgh and a M.A. in biology from Indiana University then completed a Ph.D. in history and philosophy of science at Pittsburgh. He served for a year as an assistant professor of philosophy at the University of California, Santa Cruz (UCSC), before accepting his present position in 2006. Three years later, Dr. Love was awarded a two-year McKnight Land Grant Professorship at Minnesota. He currently is a co-principle investigator on a Canadian Social Science and Humanities Research Council grant and has previously held grants from the Alexander von Humboldt Foundation and UCSC. One of the founding editors of the online journal Philosophy & Theory in Biology, he is the author of some thirty articles published in academic journals or in volumes of collected works. He is presently researching the role of structured problems in organizing biological inquiry, the significance of pluralism for the metaphysics of science, and Asa Gray's evolving perspective on teleology, natural theology, and variation.

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Gary R. Berntson

A pioneer in the development of systems biology as well as a noted philosopher of biology, Denis Noble held the Burdon Sanderson Chair of Cardiovascular Physiology at Oxford University for twenty years. He is now professor emeritus and co-director of computational physiology at Oxford. His research is focused on using computer models of biological organs and systems to interpret function from the molecular to whole body levels. He constructed the first computer model of a heart cell, a feat reported in two articles published in Nature in 1960, and with international collaborators, he subsequently used supercomputers to create the first virtual organ, the virtual heart. Dr. Noble was educated at the Emanuel School and at University College London (UCL), where he took first class honors and went on to earn a Ph.D. in physiology in 1961. He served as an assistant lecturer at UCL for two years before accepting appointments at Oxford as a fellow and tutor at Balliol College and as university lecturer in physiology. He was named Burdon Sanderson Professor of Cardiovascular Physiology in 1984 when he also became a Balliol professorial fellow. Upon his retirement in 2004, he was elected an emeritus fellow of Balliol. Dr. Noble, who has been a visiting scientist and visiting professor of the Medical Research Council of Canada, as well as a visiting professor at Johns Hopkins University and an adjunct professor at Xi'an Jiaotong University in China, is currently a visiting professor at Osaka University in Japan. He has delivered numerous invited lectures throughout the world. As the former secretary general of the International Union of Physiological Sciences (IUPS), he played a major role in launching the Physiome Project, a global effort to use computer simulations to create the quantitative physiological models necessary to interpret the human genome. He now serves as president of the IUPS. A fellow of the Royal Society, he is a member of the Academia Europaea, an honorary fellow of the Royal College of Physicians (RCP), an honorary foreign member of the Acadèmie Royale de Médecine de Belgique (ARMP), and an honorary member of the American Physiological Society, the Physiological Society (UK and Ireland), and the Physiological Society of Japan. Dr. Noble is the recipient of Zoological Society's scientific medal, the British Heart Foundation's gold medal and prize, Oxford's professional distinction award, the Pierre Rijlant Prize given by the ARMP, the RCP's Baly Award, the Pavlov Medal of the Russian Academy of Sciences, the UK Physiological Society's Hodgkin-Huxley-Katz Prize, the MacKenzie Prize of the British Cardiac Society, and the medal of merit awarded by the European Union-International Society for Heart Research. In 1998, he was made a Commander of the British Empire by Queen Elizabeth II. He holds honorary degrees from Sheffield University, the University of Bordeaux, and Warwick University. Currently chief editor of Progress in Biology and Molecular Biology and of Faculty of 1000: Physiology,

he also serves on the editorial board of Transactions on Computational Systems Biology and as advisor to the board of the Journal of Experimental Physiology. The author or coauthor of some 350 papers published in scientific journals, he is the co-editor (with C.A.R. Boyd) of The Logic of Life (1993) and (with J.D. Vincent) of The Ethics of Life (1997) as well as the author of eight other books, including The Initiation of the Heartbeat (1975 and 1979) and, most recently, The Music of Life, which was published in 2006 by Oxford University Press. Subsequently translated into Italian, Spanish, French, Korean, Chinese, and Japanese, the widely-praised study challenges reductionist dogma by presenting the genome as a database from which the organism can select in order to call upon an elegant modularity of gene expression in response to environmental and physiological conditions.

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### PARTICIPANTS

Gary R. Berntson Grady Booch Jeremy N. Butterfield Jerome A. Feldman Luc Jaeger Claus Kiefer Barry Loewer Alan C. Love Peter Menzies Denis Noble Timothy O'Connor Samir Okasha David Papineau Geraint Rees Eric R. Scerri Timothy O'Connor, professor and chair of philosophy and a member of the Cognitive Sciences Program at Indiana University, is a philosopher of mind and of religion. Much of his writing centers on two topics: the nature of human action (including the challenges to belief in human freedom and moral responsibility that arise from advances in neuroscience and social and clinical psychology) and concepts of emergence that may have application to complex systems and to the conscious mind in particular. An honors graduate of the University of Illinois at Chicago, where he earned an undergraduate degree with distinction in philosophy as well as an M.A. in philosophy, he went on to study at Cornell University, where he was a Susan Linn Sage Fellow and received a Ph.D. in philosophy in 1992. After post-doctoral research at the University of Notre Dame, he joined the Indiana philosophy faculty in 1993 as an assistant professor. Dr. O'Connor spent a year at the University of St. Andrews as a Gifford Research Fellow and was named to his present position in 2005. In addition to research fellowships awarded by Indiana, he also has been the recipient of a fellowship given by the Pew Scholars Program. He has won several awards for teaching excellence. Dr. O'Connor formerly served on the executive committee of the Society of Christian Philosophers and currently serves as a member of the board of advisors of the John Templeton Foundation. The author of some fifty papers published in scholarly journals, he is the editor of Agents, Causes, and Events: Essays on Indeterminism and Free Will (1995) and the co-editor (with David Robb) of Philosophy of Mind: Contemporary Readings (2003), (with George F.R. Ellis and Nancey Murphy) Downward Causation and the Neurobiology of Free Will (2009), and, most recently, of two volumes published earlier this year: (with Constantine Sandis) A Companion to the Philosophy of Action (Wiley-Blackwell) and (with Antonella Corradini) Emergence in Science and Philosophy (Routledge Press). He is also the author of Persons and Causes: The Metaphysics of Free Will (2000) and Theism and Ultimate Explanation: The Necessary Shape of Contingency (2008), which sketches an account of how we are able to know non-empirical facts concerning what is possible and what is necessary, argues that such facts play an essential role in constraining our scientific theorizing concerning the world, and then refurbishes and defends Leibniz's argument that classical theism provides the best explanation for the ultimate empirical fact of existence itself.

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Professor of the philosophy of science at the University of Bristol, Samir Okasha specializes in the philosophy of evolutionary biology and also writes on the philosophy of economics as well as epistemology and metaphysics. He is a graduate of Oxford University, where he studied at Balliol College, took first class honors in philosophy and economics, and received a D.Phil. in philosophy in 1998. He began his teaching career as a lecturer in philosophy at St. Hilda's College, Oxford, and held a postdoctoral research fellowship at the National University of Mexico (NUM), a Jacobsen Research Fellowship at the London School of Economics, and a visiting research fellowship at NUM before being appointed a lecturer in philosophy at the University of York in 2000. He came to Bristol as a lecturer in philosophy in 2003 and was named to his present position in 2006. Dr. Okasha also has been a visiting research fellow at the Australian National University. Recipient of a Phillip Leverhulme Prize for research, he presently holds an Arts and Humanities Research Council grant for work on evolution, cooperation, and rationality. He serves as associate editor of the European Journal for the Philosophy of Science and on the editorial boards of Signos Filosoficas, Philosophy and the Theory of Biology, and Biology and Philosophy. The author of more than sixty papers published in scholarly journals or as chapters in volumes of collected works, Dr. Okasha is the co-editor of two forthcoming books, (with Stephan Hartmann and Herman de Regt) Proceedings of the 1st Conference of the European Philosophy of Science Association (Springer) and (with Kenneth Binmore) Evolution and Rationality (Cambridge University Press). His first book, Philosophy of Science: A Very Short Introduction (2002), an explanation of how scientists think and draw conclusions, has been translated into ten languages. His subsequent and highly-praised study, Evolution and Levels of Selection, which was published by Oxford University Press in 2006, is a philosophical examination of the conceptual framework deployed by multilevel selection theory. It won the 2009 Lakatos Award presented by the London School of Economics for outstanding contributions to the philosophy of science.

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Professor of cognitive neurology and director of the Institute of Cognitive Neuroscience (ICN) at University College London (UCL), Geraint Rees conducts research on the neural mechanisms underlying human consciousness in health and disease. His current work focuses on the neural correlates of particular types of conscious content in an effort to distinguish between conscious and unconscious representations in the human brain. Educated at Gonville and Caius College, Cambridge, where he took first class honors, he went on to study at New College, Oxford, and received a bachelor of medicine degree from Oxford University in 1991. Dr. Rees took further specialized training at the Royal College of Physicians of London, receiving MRCP certification in 1994, and earned a Ph.D. in neurology at UCL in 2000. After two years as a Wellcome Advanced Fellow at the California Institute of Technology where he worked with Christof Koch on computation and neural systems, he continued postdoctoral studies at the ICN and was appointed a clinical lecturer at the UCL's Institute of Neurology in 2002, as well as an honorary specialist registrar in neurology at Charing Cross Hospital. He became a Wellcome Senior Clinical Fellow and senior lecturer at the Institute of Neurology the next year and was named to his present academic position in 2006. Dr. Rees was appointed director of the ICN last year and also serves as an honorary consultant to the National Hospital for Neurology and Neurosurgery. Winner of the Medical Research Society's Young Investigator's Award, the Young Investigator Medal of the Organization for Human Brain Mapping, the Royal Society (TRS) Francis Crick Medal, and the Experimental Psychology Society Prize, he is a fellow of the Royal College of Physicians and of the Academy of Medical Sciences and serves as secretary and treasurer of the Guarantors of Brain. In addition to giving the Francis Crick Lecture at TRS in 2007, he delivered the Donders Lecture at the University of Nijmegen in 2006 and the Royal College of Physicians' Goulstonian Lecture in 2009. His research has been supported by the Wellcome Trust, the Mind-Science Foundation, and TRS. Associate editor of Brain and the author of nearly 150 papers published in scientific journals or in volumes of collected works, he is the co-editor of with Laurent Itti and John Tsotsos of the reference work, Neurology of Attention, which was published by Academic Press in 2005.