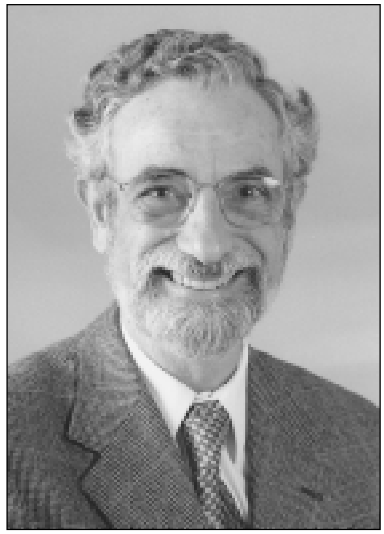
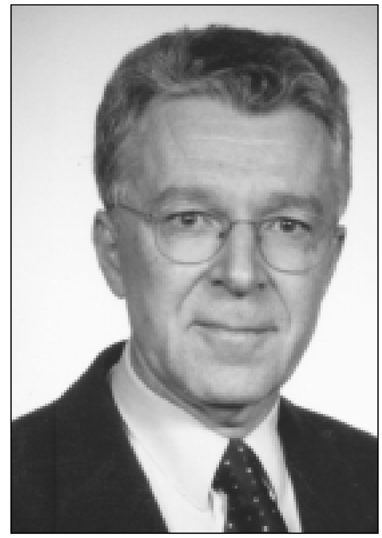
2002 Conant Prize



Elliott Lieb



Jakob Yngvason

The 2002 Levi L. Conant Prize was awarded at the 108th Annual Meeting of the AMS in San Diego in January 2002.

The Conant Prize is awarded annually to recognize the best expository paper published in either the *Notices of the AMS* or the *Bulletin of the AMS* in the preceding five years. Established in 2000, the prize honors the memory of Levi L. Conant (1857–1916), who was a mathematician at Worcester Polytechnic University. The prize carries a cash award of $1,000.

The Conant Prize is awarded by the AMS Council acting on the recommendation of a selection committee. For the 2002 prize, the members of the selection committee were: Brian J. Parshall, Anthony V. Phillips (chair), and Joseph H. Silverman.

The previous recipient of the Conant Prize is Carl Pomerance (2001).

The 2002 Conant Prize was awarded to Elliott H. Lieb and Jakob Yngvason. The text that follows presents the committee's citation, a brief biographical sketch, and the awardees' response upon receiving the prize.

Citation

The Levi L. Conant Prize in 2002 is granted to Elliott H. Lieb and Jakob Yngvason for their appealing and thought-provoking article "A Guide to Entropy and the Second Law of Thermodynamics", *Notices of the AMS* **45**, no. 5 (1998), 571–581.

"This article is intended for readers who, like us, were told that the second law of thermodynamics is one of the major achievements of the nineteenth century...but who were unsatisfied with the 'derivations' of the entropy principle as found in textbooks and in popular writings." Thus do Lieb and Yngvason begin their article. They proceed to take the reader on a tour of the second law of thermodynamics as seen through an axiomatic-mathematical lens, without ever losing the friendly and conversational tone of the start.

Abstractly, there is only a set G and a preorder $<$ on G. Interpreted physically, the elements of G represent states of a system, and the preorder $<$ is required to satisfy certain natural axioms that characterize when one state can "lead to" another state (specifically, when the second is adiabatically accessible from the first, in a precise sense that the authors make clear). The second law of thermodynamics is then formulated in terms of an entropy function on $(G, <)$, that is, a real-valued function S on G that characterizes $<$ and has certain additivity and scaling properties. The authors detail the search for simple, elegant, and mathematically precise axiom systems that allow the construction of an entropy function and, thus, that capture the powerful predictive capabilities of thermodynamics. In doing so, they illuminate a fascinating trail between the "pure" world of mathematical abstraction and the "real" world of physics, chemistry, and engineering.

Biographical Sketch: Elliott H. Lieb

Elliott H. Lieb was born in Boston, Massachusetts, in 1932. He received his B.Sc. degree from MIT in 1953 and his Ph.D. degree in mathematical physics from the University of Birmingham (UK) in 1956 under the direction of S. F. Edwards. He holds honorary doctorates from Copenhagen University and the École Polytechnique Fédérale de Lausanne. After a Fulbright postdoc in Kyoto, he held positions in Illinois, Cornell, IBM, Sierra Leone, Yeshiva, Northeastern, and MIT. From 1975 he has been a professor in the mathematics and physics departments of Princeton University.

He has received a number of prizes for his work in mathematics and mathematical physics, including the Birkhoff Prize of the AMS and the Society for Industrial and Applied Mathematics, the Rolf Schock Prize in mathematics of the Swedish Academy, the Heinemann Prize in mathematical physics of the American Physical Society, the Boltzmann Prize in statistical mechanics of the International Union of Pure and Applied Physics, and the Max-Planck Medal of the German Physical Society. He is a member of the U.S., Austrian, and Danish Academies of Science, and the American Academy of Arts and Sciences. He served twice as president of the International Association of Mathematical Physics. Invited lectures include the AMS Gibbs Lecture and the Hedrick Lecture of the Mathematical Association of America.

Biographical Sketch: Jakob Yngvason

Jakob Yngvason was born in Reykjavik, Iceland, in 1945. He studied physics at the University of Göttingen, Germany, receiving his Ph.D. there in 1973 under the direction of H. J. Borchers. He was assistant professor at the University of Göttingen from 1973 to 1978, and from 1978 to 1985 he was senior research scientist at the Science Institute of the University of Iceland in Reykjavik. From 1985 to 1996 he was professor of theoretical physics at the University of Iceland. Since 1996 he has been professor of mathematical physics at the University of Vienna, Austria. He is also president of the Erwin Schrödinger Institute for Mathematical Physics in Vienna and vice president of the International Association of Mathematical Physics. He has held visiting positions at many research institutions, including the Universities of Göttingen and Leipzig, Rutgers University, the Institut des Hautes Études Scientifiques in Bures-sur-Yvette, DESY in Hamburg, NORDITA in Copenhagen, and the Max Planck Institute for Physics in Munich.

His main research interests are in quantum field theory and rigorous quantum many-body theory. He was plenary speaker at the 13th International Congress on Mathematical Physics in Paris, 1994. He received the Olafur Danielsson Prize for Mathematics in 1993.

Response from Lieb and Yngvason

This award was a pleasant surprise to us. We had worked for many years to try to formulate the second law of thermodynamics—the law of increasing entropy—in a mathematically precise, yet accessible, way and were not sure to what extent we had succeeded in communicating our enthusiasm for the subject to our colleagues. It is a very much appreciated honor to have our *Notices* article counted as "the best expository paper published in the *Notices* or the *Bulletin* in the preceding five years."

Our article is based on a long and detailed analysis (in *Physics Reports* **310** (1999), 1–96) of one of the most precise laws of physics. It was discovered in the first half of the nineteenth century and by the beginning of the twentieth century had attracted the attention of mathematicians, notably Carathéodory. To this day many schools of thought continue this interest.

The twentieth century, however, tended to see the law as an "easy" consequence and "incomplete expression" of statistical mechanics (Gibbs). This is an overstatement since the "derivation" from statistical mechanics is, after more than a century, still in a rudimentary phase, and because the law itself makes no reference to statistical mechanics. That is to say, the second law could well hold even if the world were made of vortices in a seamless fluid instead of being made of atoms. Statistical mechanics is a beautiful and important subject, but it is essential to understand the second law in its own right if we are ever going to derive it from statistical mechanics. Beginning in the fifties some people (e.g., P. Landsberg, H. Buchdahl, G. Falk and H. Jung, and, most notably, R. Giles) advocated an approach to the law based on an order relation among equilibrium states. We built on this structure. The earlier work introduced a basic new axiom which we call "comparison"; one of our main contributions was to convert this from an axiom to a theorem.

The subject is not, and may never be, finished. Also, the logical structure may have use in other fields, such as economics. We would be delighted if our article motivated other mathematicians to take up the thread.

Our sincere thanks go to Beth Ruskai for urging us to write this article; to the editor, Tony Knapp, for patience and much helpful criticism; and to Sandy Frost for essential help with editing.