Identifying an Intractable Scientific Problem

Sandia researcher Sorin Istrail and the Ising model, developed by Ernst Ising in 1926 as part of his PhD dissertation.

Some scientific problems simply cannot be solved. One such problem was identified in 2000 by computational biologist Sorin Istrail at Sandia National Laboratories, who proved that the solution of the much-studied Ising model cannot be extended to three dimensions (3D). The original model, developed by Ernst Ising in 1926 as part of his Ph.D. dissertation, often is used to describe wide-ranging changes in state, from flocking birds to unison freezing of water molecules. Ising conceived of the model in one dimension; later, Nobel laureate Lars Onsager extended it to two dimensions. But the world's top mathematical physicists failed to provide the exact solution for the 3D Ising model; its properties can be determined numerically with high accuracy, but not exactly, not for any lattice, and not in terms of elementary equations. Istrail explained why, using a method called computational intractability, which identifies problems that cannot be solved in humanly feasible time. Approximately 6,000 such problems are known among all areas of science.

Scientific Impact: The work eliminated scientific uncertainty about the exactness of the 3D Ising model, thus ensuring that scientists would not waste time trying to solve the unsolvable. Fundamental problems in physics hinge on whether such models are fully understood.

Social Impact: Because most real-world problems occur in 3D, this work effectively eliminated the possibility that the Ising Model will ever have a direct social impact. But indirectly, this work has saved money by encouraging the direction of scientific efforts toward other, more fruitful areas.

Reference: "Statistical Mechanics, Three-Dimensionality and NP-completeness: Universality of Intractability for the Partition Function of the Ising Model Across Non-Planar Lattices," *Proceedings of the 31st ACM Annual Symposium on the Theory of Computing* (STOC 2000), May 21-23, 2000, Portland, Oregon. ACM Press 2000.