**Ludwig Boltzmann (1844-1906)**

Ludwig Boltzmann was born in Vienna, Austria. He received his early education from a private tutor at home. In 1863 he entered the University of Vienna, and was awarded his doctorate in 1866. His thesis was on the kinetic theory of gases under the supervision of Josef Stefan. Boltzmann moved to the University of Graz in 1869 where he was appointed chair of the department of theoretical physics. He would move six more times, occupying chairs in mathematics and experimental physics. Boltzmann was one of the most highly regarded scientists, and universities wishing to increase their prestige would lure him to their institutions with high salaries and prestigious posts. Boltzmann himself was subject to mood swings and he joked that this was due to his being born on the night between Shrove Tuesday and Ash Wednesday (or between Carnival and Lent). Traveling and relocating would temporarily provide relief from his depression. He married Henriette von Aigentler in 1876. They had three daughters and two sons.

Boltzmann is best known for pioneering the field of statistical mechanics. This work was done independently of J. Willard Gibbs (who never moved from his home in Connecticut). Together their theories connected the seemingly wide gap between the macroscopic properties and behavior of substances with the microscopic properties and behavior of atoms and molecules. Interestingly, the history of statistical mechanics begins with a mathematical prize at Cambridge in 1855 on the subject of evaluating the motions of Saturn's rings. (Laplace had developed a mechanical theory of the rings concluding that their stability was due to irregularities in mass distribution.) The prize was won by James Clerk Maxwell who then went on to develop the theory that, without knowing the individual motions of particles (or molecules), it was possible to use their statistical behavior to calculate properties of a gas such as viscosity, collision rate, diffusion rate and the ability to conduct heat.

In the late 1860s Boltzmann expanded on Maxwell's work by establishing that the factor for determining the probability that a system has a certain total energy $E$ is proportional to $e^{-hE}$, where $h$ (the "Boltzmann factor") depends only on temperature. The result was that if any physical quantity, say the entropy ($S$), could be expressed as a function of molecular coordinates, the average entropy could be calculated statistically simply by multiplying each possible entropy value by its corresponding probability and then adding by integration. While this method was only applicable to reversible processes, he went even further by introducing a molecular velocity distribution function very similar to Maxwell's except that Boltzmann's function could evolve with time. His "$H$-theorem" provided a molecular analog of the second law of thermodynamics: an isolated gaseous system will evolve in time in a particular direction (the one that maximizes entropy) until it reaches equilibrium. A crucial ingredient in his theory was its reliance on the laws of probability, not just mechanics. He proposed that the probability for a certain physical state of a system is proportional to "the number of ways ($W$) the inside [of the system] can be arranged so that from the outside it looks the same" (quoting Feynman). Thus, gas molecules will distribute themselves evenly in a room rather than collect at one corner. The connection Boltzmann made between entropy and disorder is summarized by the relation $S \quad ln\ W$. (The equation $S = k\ ln\ W$ is carved on Boltzmann's grave in Vienna's Central Cemetery. The proportionality constant $k$ ("Boltzmann's constant") is now ubiquitous in statistical mechanics.)

Boltzmann was constantly being attacked by his critics, most prominently the antiatomist Ernst Mach and Wilhelm Ostwald. His depression grew worse and at a summer holiday in 1906 he commited suicide at the resort town of Duino, near Trieste in Italy. He was unaware of Einstein's theoretical 1905 paper and Jean Perrin's subsequent meticulous experiments that would vindicate him in the war against molecules waged by his critics.


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