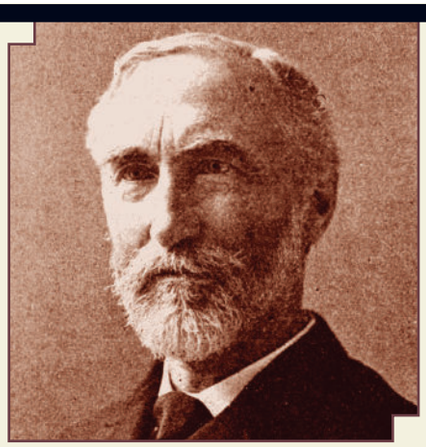
A SINGLE-MINDED PURSUIT

Josiah Willard Gibbs **rarely left New Haven**, but the impact of his work on thermodynamics **changed the world.**



Thermodynamics is the science and engineering of transformation of matter and energy. Life is matter and energy is the basis of all life, so thermodynamic principles and laws touch all of us. In the well-know text, *Thermodynamics* (1960), author Herbert B. Callen summarizes a major portion of Josiah Willard Gibbs long-life accomplishments with a positive declaration: "Gibbs not only invented modern thermodynamics but succeeded in the incredible feat of anticipating, explicitly or implicitly, almost every subsequent development."

How odd, then, that Gibbs himself was a man who saw little transformation in his life. Author Bill Bryson described Gibbs this way: "Modest to the point of near invisibility, he passed virtually the whole of his life, apart from three years spent studying in Europe, within a three-block area bounded by his house and the Yale campus in New Haven, Connecticut."

Gibbs was the son of a Yale professor and then matriculated at Yale College, first starting with an undergraduate degree awarded in 1858. Five years later, Gibbs received the first doctorate in mechanical engineering awarded in the United States for his thesis, "On the Form of the Teeth of Wheels Spur Gearing."

After he returned from France and Germany, Gibbs taught and conducted research at Yale, often with a keen eye to engineering applications. He invented and patented an improved railway car brake as well as what was soon called the Gibbs governor for steam engines. In that era, economic growth heavily depended on steam-powered railroads and marine shipping, so those inventions were critically important. But the prediction and accurate calculation of the thermodynamic properties of water (and mixtures of it) were paramount for engineering design of steam systems and engines. And that set him toward his most impactful work.

Gibbs started his invention of modern thermodynamics by publishing the results of his solitary studies in a relatively obscure journal, *Transactions of the Connecticut Academy*. Two papers published in 1873 dealt with pioneering graphic methods for dealing with the picturing of thermodynamic processes; in one of the papers, he combines the First and Second Laws of Thermodynamics to relate pure substance properties (such as entropy) with work and energy.

One of the earliest European readers of these two papers was the eminent Sottish physicist James Clerk Maxwell, who was so taken by Gibbs second graphics paper, that he constructed a three-dimensional model of Gibbs's thermodynamic surface for water. Shortly before his death, Maxwell sent a plaster cast of the model to Gibbs; that model is still on display at Yale.

In 1876 and 1878, Gibbs published his masterful two-part paper, "On the Equilibrium of Heterogeneous Substances." At more than 300 pages with 700 numbered equations, the work has been described as the "*Principia* of thermodynamics," ranking as a true masterwork for engineering, physical chemistry, and science. The physical chemist Friedrich Wilhelm Ostwald translated it into German, though he complained that the abstract style of the work demanded a higher than usual attentiveness of the reader. Gibbs strove for maximal generality and unambiguity, which can prove counterproductive to clarity of style.

After essentially inventing modern thermodynamics with those publications, Gibbs went on in the last decade of his life to establish the basic principles of statistical mechanics to look at thermodynamics on a molecular scale.

Gibbs's work is still vital, even 150 years later. The graphical representation of free energy of a body and the form of vector analysis he invented in the 1880s are still in use today.

In the opinion of Lynde Phelps Wheeler, Gibbs's former student and a fellow Yale faculty member who went on to become his biographer, "The arousing of Gibbs' interest in thermodynamics is due at least as much to an interest in engineering applications of the subject as in its theoretical foundations."

Aside from the few years in Europe, he lived his entire life in his childhood home in New Haven, along with his sister and her husband, the Yale librarian. He was known to be cordial, but elusive, and produced neither a body of correspondence or published work other than his technical papers. He also made little attempt to simplify or popularize his research.

And yet, while his own habits were unaltered throughout his life, the thermodynamics Gibbs invented transformed the engineering field and spurred countless innovations, even today. ME

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