



Tatiana Afanassjewa & Paul Ehrenfest, Estonia, 1912

The Ehrenfest Paradox

Bear in mind that I hop around among all of you big beasts like a helpless frog who is afraid of being squashed.

Paul Ehrenfest,
Letter to Albert Einstein, 1920

THE FIRST CHAPTER OF CALTECH professor David Goodstein's graduate physics course text, *States of Matter*, opens with a curious cautionary note:

Ludwig Boltzmann, who spent much of his life studying statistical mechanics, died in 1906 by his own hand.

Paul Ehrenfest, carrying on the work, died similarly in 1933... And now it is our turn to study statistical mechanics.

The remark is a humorous, if rather unsettling observation on the difficulty of understanding the dense field of statistical mechanics, the chapter's subject.

Indeed, the complex field, jokingly called by one educator 'sadistical mechanics,' may have played a part in the untimely death of two of its most pivotal figures.

Statistical mechanics is a branch of physics that deals with large populations of particles or other objects and their statistical behavior. A pillars of modern physics, the field was pioneered by Ludwig Boltzmann, an Austrian physicist and philosopher, who developed a statistical explanation for the elusive second law of thermodynamics.

Paul Ehrenfest was born in 1880 in Vienna to Jewish parents. He graduated from the Franz Josef Gymnasium in 1899, and went on to study chemistry and physics at the Vienna Institute of Technology and the University of Vienna, where he met Boltzmann, who would have a profound effect on Ehrenfest's future career path.

In 1901, Ehrenfest transferred to the University of Göttingen, where he met his future wife, Tatyana Afanasyeva, a young Russian mathematician. Married in 1904, they had two daughters and two sons.

In 1906, Boltzmann—who suffered from bipolar disorder—hung himself while on vacation in Italy. While the death of his friend and foremost mentor was a huge emotional blow to Ehrenfest, it also opened up an unexpected opportunity for the young student's struggling academic career.

The editor of a mathematics journal had been counting on Boltzmann to author a review on statistical mechanics, and asked Ehrenfest to take over the task. (Ehrenfest and his wife worked together on the difficult paper, completing it only in 1911.)

In 1909, Ehrenfest gained a teaching post at the St. Petersburg Polytechnic Institute, but lasted only a year before—in a trait that, sadly, would repeat throughout his career—his impolitic criticism of the governing board's strict rules cost him his job. The resulting period of unemployment sent Ehrenfest spiraling into a deep depression.

In 1912, the well-received publication of his paper provided a temporary respite, encouraging Ehrenfest to embark on a tour of Europe's important universities in hopes of finding a lasting teaching position. Most memorable of the numerous cities he visited was Prague, where he met Albert Einstein, who would become a close, lifelong personal and professional friend.

Later that year, Einstein recommended Ehrenfest to succeed him in his teaching position at the German University of Prague, but once again Ehrenfest's stubborn tendency toward self-sabotage intervened, and he refused to renounce his atheism (as Einstein had) in order to secure the position.

Around the same time, however, an offer appeared at the University of Leiden, where he would remain for the rest of his career.

In Leiden, Ehrenfest's lectures and a study group he formed attracted the most eminent physicists in Europe, whose discussions left a lasting mark on the history of the field.

A skilled writer and lecturer, Ehrenfest had a genius for explaining difficult concepts with simple models and clever, often amusing analogies. (In one often-cited example, he illustrated the second law of thermodynamics using the analogy of fleas jumping between two dogs.) Einstein praised Ehrenfest as “the best teacher in our profession whom I have ever known.”

As a theorist, Ehrenfest also made lasting contributions to physics, among them the ‘Ehrenfest paradox,’ a key contribution to Einstein's theory of general relativity.

By the early 1930s, however, Ehrenfest was feeling increasingly irrelevant, unable to untangle problems in statistical mechanics that Boltzmann had also failed to resolve, and frustrated at his inability to reconcile the abstractions of quantum physics with his more concrete, visual teaching style.

In September 1933—discouraged by the increasing antisemitism accompanying Hitler's rise to power earlier that year, in despair over his presumed failing career, and perhaps still haunted by the suicide of his mentor, Boltzmann—the 53 year old Ehrenfest travelled to Amsterdam, where he fatally shot his institutionalized son, Wassik, before turning the gun on himself.

A victim of his own merciless self-criticism, unable to draw confidence from the high regard he was held in by his family, colleagues and friends, Paul Ehrenfest ultimately proved to be a tragically poor judge of the life he himself had lived. ■