

By: ~~Oct 17, 2006~~ Senior Editor, Sci-Tech News

[Random Walks of Ellipsoids](#)

Experiments finally test the theory put forward by Francis Perrin in the 1930s

More than 100 years ago, Einstein described mathematically the random motion experienced by a small spherical particle suspended in a liquid. The particle moves because it is pushed around by the molecules in the liquid. When Jean Perrin later observed this motion experimentally, it became clear that [Boltzmann's theory](#) about the foundations of thermodynamics must be correct. Perrin received a Nobel Prize in 1926. The son of Jean Perrin, Francis, had then computed in the 1930s how a small ellipsoid should behave when suspended in a liquid. While in case of spherical particles their rotation is irrelevant to the overall motion, it becomes an important factor in the case of ellipsoid particles. However, until recently, Francis Perrin's paper has been virtually forgotten. The reason was that experimentalists couldn't make sufficiently precise observations to test Perrin's predictions. But that has now changed. "Brownian motion arises from the aggregate effect of the random collisions of many molecules with suspended objects. It is such a profound and fundamental phenomena that, as a physicist, I want to learn everything about it," said Arjun Yodh, professor in the Department of Physics and Astronomy in the School of Arts and Sciences at the University of Pennsylvania. "Our work explored the movement of rod-like particles in order to understand how their spinning motion affects the displacement or translation of their centers." The image shows twenty seconds of a measured random walk trajectory for a micrometer-sized ellipsoid undergoing Brownian motion in water. The ellipsoid orientation, labeled with rainbow colors, illustrates the coupling of orientation and displacement and shows clearly that the ellipsoid diffuses faster along its long axis compared to its short axis. Scientists have obtained this image using digital video microscopy. This way, they managed to observe directly the twisty random walks arising from the combined effects of random rotations and displacements of ellipsoids in water. "One of the exciting aspects of this work is the precise agreement between a relatively simple theory and experiments. We developed the theory at Penn but later found many of our results in the forgotten French papers by Perrin," said Tom Lubensky, professor and chair of Penn's Department of Physics and Astronomy and co-author of the Science paper. On average, particles undergoing [Brownian motion](#) do not move very far. For example, in one second, the largest number of particles will stay very close, say within one micron, of their starting point; a smaller number will move between one micron and two microns; a still smaller number will move between two microns and three microns, and so on. A plot of the number of particles traveling specific distances yields the famous bell-shaped or Gaussian curve from statistics. The Penn researchers found that the same experiment, carried out on ellipsoidal particles, produces a curve that is not Gaussian. "Since ellipsoids are longer than they are wide, they experience more water resistance going in one direction than the other," said Yilong Han, a post-doc in Yodh's research group. "These effects are larger in two-dimensions than in three, and the coupling of the rotational movement -- spinning -- with the translational movement -- the distance traveled -- give rise to the weirdly non-Gaussian behavior we observed." Image credit: University of Pennsylvania