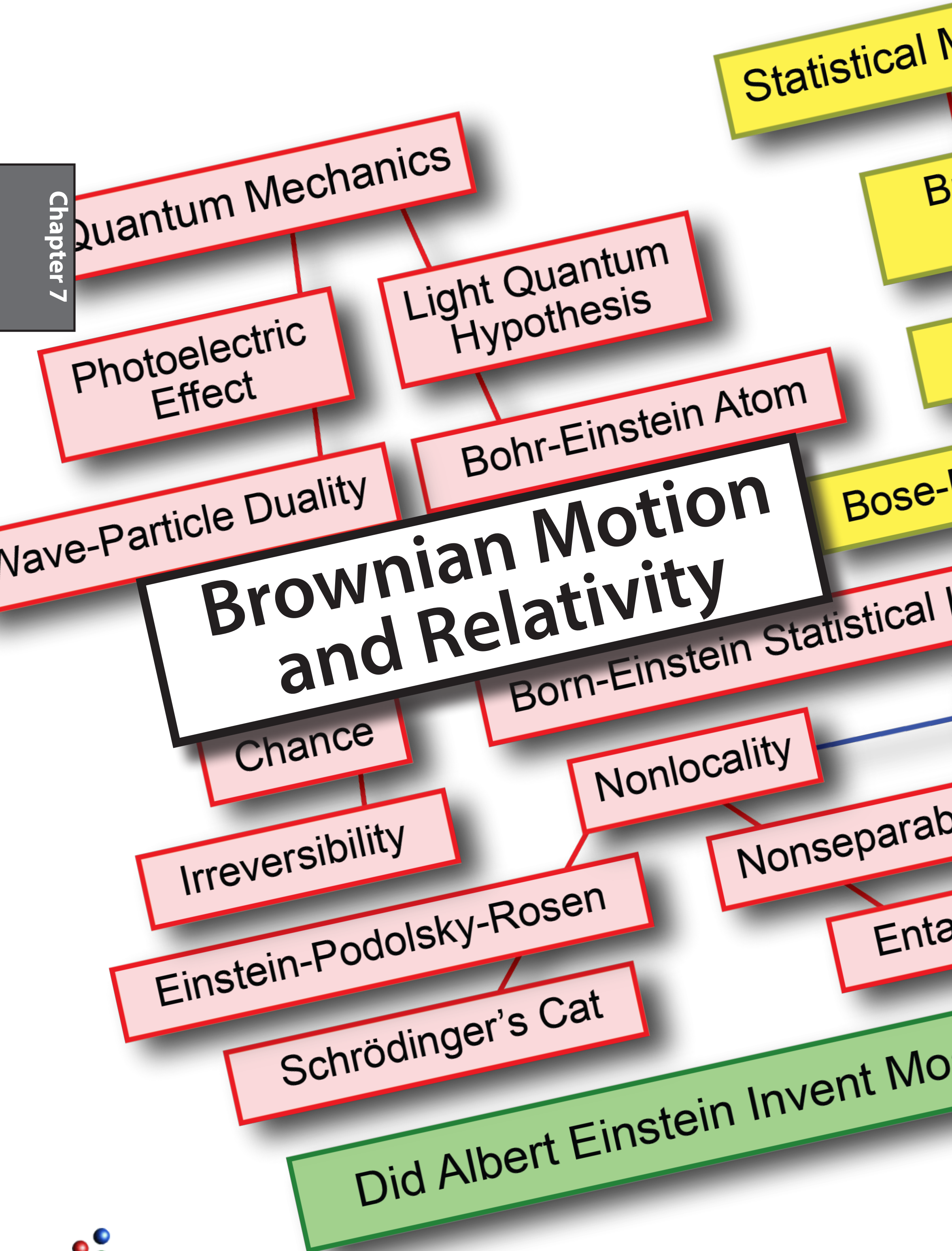
Statistical
Quantum Mechanics
Light Quantum Hypothesis
Photoelectric Effect
Bohr-Einstein Atom
Wave-Particle Duality
Bose-
Brownian Motion and Relativity
Born-Einstein Statistical
Chance
Nonlocality
Irreversibility
Einstein-Podolsky-Rosen
Schrödinger's Cat
Did Albert Einstein Invent

Brownian Motion and Relativity

In this chapter we describe two of Einstein's greatest works that have little or nothing to do with his amazing and deeply puzzling theories about quantum mechanics. The first, Brownian motion, provided the first quantitative proof of the existence of atoms and molecules. The second, special relativity in his miracle year of 1905 and general relativity eleven years later, combined the ideas of space and time into a unified space-time with a non-Euclidean curvature that goes beyond Newton's theory of gravitation.

Einstein's relativity theory explained the precession of the orbit of Mercury and predicted the bending of light as it passes the sun, confirmed by ARTHUR STANLEY EDDINGTON in 1919. He also predicted that galaxies can act as gravitational lenses, focusing light from objects far beyond, as was confirmed in 1979. He also predicted gravitational waves, only detected in 2016, one century after Einstein wrote down the equations that explain them..

What are we to make of this man who could see things that others could not? Our thesis is that if we look very closely at the things he said, especially his doubts expressed privately to friends, today's mysteries of quantum mechanics may be lessened.

As great as Einstein's theories of Brownian motion and relativity are, they were accepted quickly because measurements were soon made that confirmed their predictions. Moreover, contemporaries of Einstein were working on these problems. Marion Smoluchowski worked out the equation for the rate of diffusion of large particles in a liquid the year before Einstein. He did not publish, hoping to do the experimental measurements himself.

In the development of special relativity, Hendrik Lorentz had assumed the constancy of the velocity of light and developed the transformation theory that predicted the apparent contraction of space and/or time when measured by moving clocks. Henri Poincaré used the Lorentz transformation and had described a "principle of relativity" in which the laws of physics should be the same in all frames unaccelerated relative to the ether (which Poincaré continued to believe in for years). Hermann Minkowski combined space and time into a four-dimensional "space-time."

With regard to general relativity, the mathematician David Hilbert took a great interest in Einstein's ideas about a general relativity. He invited Einstein to give six lectures in Göttingen several months before Einstein completed his work. Einstein stayed at Hilbert's home and they began an extensive exchange of ideas which led Hilbert close to a theory unifying gravitation and electromagnetism.

Einstein was very concerned that Hilbert might beat him to the correct equations, which Hilbert knew Einstein had been working on since 1913. In the end, Hilbert stated clearly that Einstein had been the original author of general relativity.

A excellent survey of these priority debates is on Wikipedia. [1]

Einstein's 1905 explanation for the motions of tiny visible particles in a gas or liquid, that they are caused by the motions of *invisible* particles - atoms or molecules - was hardly new, having been suggested exactly as such by Lucretius in his *De Rerum Natura* at the dawn of the theory of atoms.

> It clearly follows that no rest is given to the atoms in their course through the depths of space... This process, as I might point out, is illustrated by an image of it that is continually taking place before our very eyes. Observe what happens when sunbeams are admitted into a building and shed light on its shadowy places. You will see a multitude of tiny particles mingling in a multitude of ways in the empty space within the light of the beam...From this you may picture what it is for the atoms to be perpetually tossed about in the illimitable void...their dancing is an actual indication of underlying movements of matter that are hidden from our sight. [2]

The importance of Einstein's work is that he *calculated* and *published* the motions of molecules in ordinary gases, predictions confirmed by experiment just a few years later by Jean Perrin.

Now chemists and many physicists had *believed* in atoms for over a century in 1905 and they had excellent reasons. But we must understand Einstein's work as leading to experimental evidence for the existence of atoms, that is to say material particles. But it was the first of Einstein's insights into the *discrete* nature of reality that conflicted with his deeply held *beliefs* about reality as *continuous*.

1 en.wikipedia.org/wiki/Relativity_priority_dispute

2 *On the Nature of Things*, Book II, lines 115-141

The goal of this book is to show that many things Einstein clearly saw provide a better picture of reality than those of most of today's physicists and philosophers of science, many of whom pursue physical theories that Einstein *believed*, not what he *saw*.

We will study what Einstein thought went on in "objective reality."

For Einstein, the model of a physical theory was a "field theory." A field is a *continuous* function of four-dimensional space-time variables such as Newton's gravitational field and Maxwell's electrodynamics. Einstein said "The most difficult point for such a field-theory at present is how to include the atomic structure of matter and energy." [3] It is the question of the nature of reality we raised in the introduction - is the nature of reality *continuous* or *discrete*. Does nature consist primarily of *particles* or *fields*?

Einstein could never see how to integrate the discrete particles of matter and of light into his ideas for a "unified field theory." He hoped all his life to show that the light particles he discovered and all material particles are singularities in his unified field.

Einstein said many time that the theories of physics are *fictions* and "free creations of the human mind." Although theories must be tested by experiment, one cannot *derive* or *construct* the basic laws from experience. They must depend on *principles.*

In his 1905 article "On the Movement of Small Particles Suspended in a Stationary Liquid Demanded by the Molecular Kinetic Theory of Heat," Einstein wrote

> In this paper it will be shown that according to the molecular-kinetic theory of heat, bodies of microscopically-visible size suspended in a liquid will perform movements of such magnitude that they can be easily observed in a microscope, on account of the molecular motions of heat. It is possible that the movements to be discussed here are identical with the so-called "Brownian molecular motion"; however, the information available to me regarding the latter is so lacking in precision, that I can form no judgment in the matter.[4]

Because Einstein published, leaving experiments to others, the credit is his rather than Smoluchowski's. But more important than credit, Einstein saw these particles, and the light quanta of the last chapter, though he could never integrate them into his field theory.

3 "On the Method of Theoretical Physics," p.168
4 CPAE, vol. 2, p.123