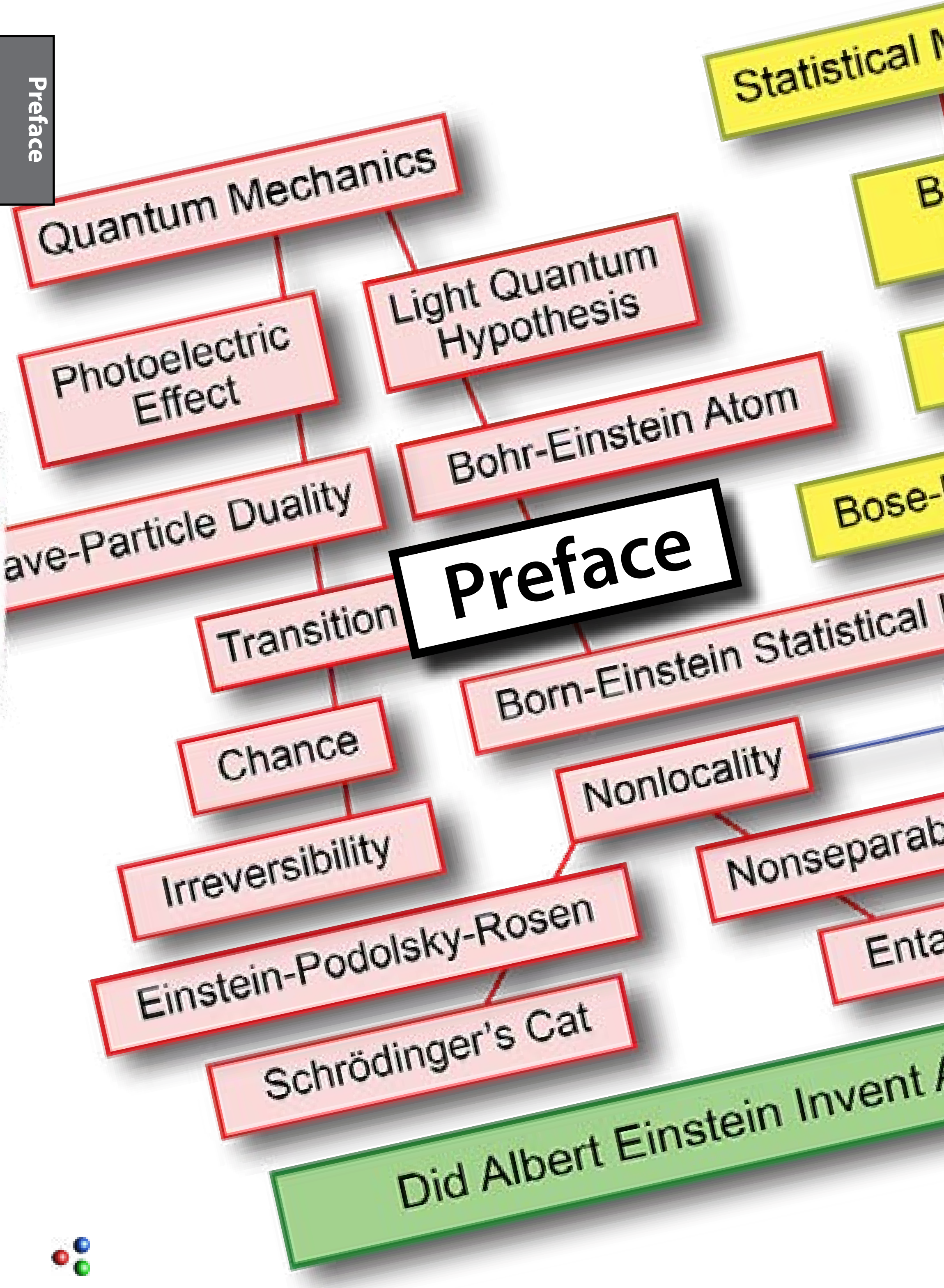
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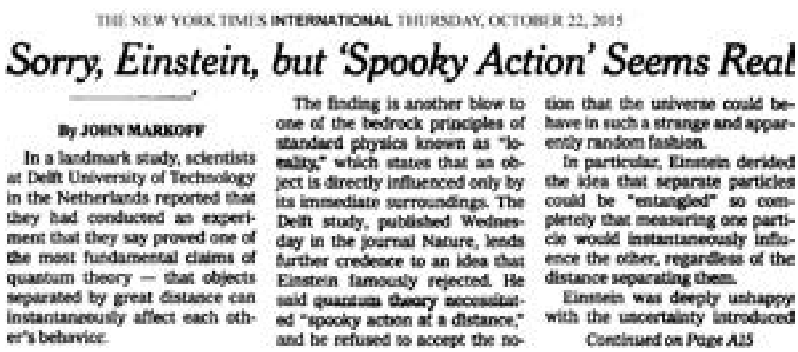
Schrödinger's Cat
Did Albert Einstein Invent

Preface

For well over a century, Albert Einstein's many original contributions to quantum mechanics have been doubted by his colleagues. Some of those contributions have been credited to others, perhaps for the understandable reason that Einstein himself severely criticized his most revolutionary ideas.

Max Planck is often cited today as discovering the photon. Niels Bohr's discrete energy levels in atomic matter were first seen by Einstein in 1906 as explaining the anomalous specific heat of certain atoms. Max Born's 1926 statistical interpretation of the wave function was based on Einstein's 1909 insight that the light wave gives us probabilities of finding light particles. David Bohm's particle mechanics with continuous paths and properties is an attempt to achieve Einstein's "objective reality." And John Bell's claim that the "Einstein program fails" is based on a model of "hidden variables" that is physically unrealistic.


THE NEW YORK TIMES INTERNATIONAL THURSDAY, OCTOBER 22, 2015

Sorry, Einstein, but 'Spooky Action' Seems Real

By JOHN MARKOFF

In a landmark study, scientists at Delft University of Technology in the Netherlands reported that they had conducted an experiment that they say proved one of the most fundamental claims of quantum theory — that objects separated by great distance can instantaneously affect each other's behavior.

The finding is another blow to one of the bedrock principles of standard physics known as "locality," which states that an object is directly influenced only by its immediate surroundings. The Delft study, published Wednesday in the journal Nature, lends further credence to an idea that Einstein famously rejected. He said quantum theory necessitated "spooky action at a distance," and he refused to accept the notion that the universe could behave in such a strange and apparently random fashion.

In particular, Einstein derided the idea that separate particles could be "entangled" so completely that measuring one particle would instantaneously influence the other, regardless of the distance separating them.

Einstein was deeply unhappy with the uncertainty introduced

Continued on Page A15

The New York Times in 2015 loudly proclaimed on its front page Einstein's mistake in doubting that measuring one particle can instantaneously influence another at an arbitrary distance. [1]

They did not mention it was Einstein who first saw "nonlocality" in 1905, reported it in 1927, and in his EPR paper of 1935 introduced it as "nonseparability," which he attacked. But without Einstein, it is likely no one ever would have seen "entanglement."

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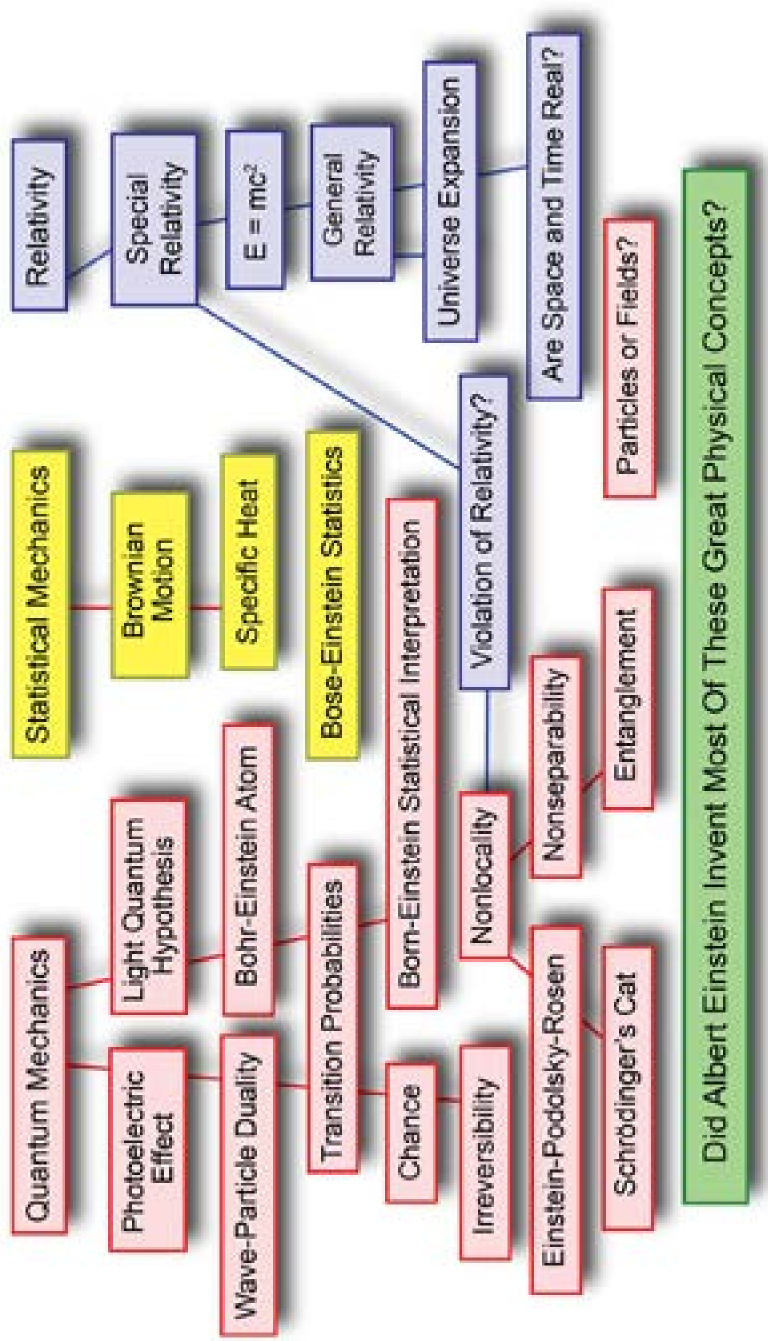
1 *The New York Times*, October 22, 2015, p.1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Special Relativity
E = mc²
General Relativity
Universe Expansion
Are Space and Time Real?
Particles or Fields?
Statistical Mechanics
Brownian Motion
Specific Heat
Bose-Einstein Statistics
Born-Einstein Statistical Interpretation
Violation of Relativity?
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Schrödinger's Cat
Did Albert Einstein Invent Most Of These Great Physical Concepts?

Thirty years ago, the *Economist* magazine described the "queerness of quanta." Quantum mechanics appears to say some rather odd things about the universe, they reported,

- There are no such things as "things". Objects are ghostly, with no definite properties (such as position or mass) until they are measured. The properties exist in a twilight state of "superposition" until then.
- All particles are waves, and waves are particles, appearing as one or the other depending on what sort of measurement is being performed.
- A particle moving between two points travels all possible paths between them simultaneously.
- Particles that are millions of miles apart can affect each other instantaneously.[2]

They also reported RICHARD FEYNMAN's critical analysis of the two-slit experiment. "The conclusion is inescapable. The photons somehow pass through both slits at once."[3]

All of these "queer" aspects of quantum mechanics were challenged by Einstein, even those that he was first to see as (perhaps unacceptable) possibilities. This led to his popular reputation as a critic of quantum mechanics. He was a critic, but he also accepted most of quantum mechanics!

> the reader should be convinced that I fully recognize the very important progress which the statistical quantum theory has brought to theoretical physics... This theory is until now the only one which unites the corpuscular and undulatory dual character of matter in a logically satisfactory fashion.. The formal relations which are given in this theory — i.e., its entire mathematical formalism — will probably have to be contained, in the form of logical inferences, in every useful future theory.
>
> What does not satisfy me in that theory, from the standpoint of principle, is its attitude towards that which appears to me to be the programmatic aim of all physics: the complete description of any (individual) real situation (as it supposedly exists irrespective of any act of observation or substantiation).[4]

2 *The Economist*, January 7, 1989, p.71
3 *ibid.*, p.72
4 "Reply to Critics," in Schilpp, 1949, p.666

This book is based on ALBERT EINSTEIN's web page on our Information Philosopher website,[5] which we started writing in 2007. We began the book in 2015 with our primary goal to review and correct the history of Einstein's contributions to quantum mechanics, which have been distorted for decades by the unfortunately biased accounts of the so-called "founders" of quantum mechanics, notably NIELS BOHR, WERNER HEISENBERG, and MAX BORN.

Besides hypothesizing light particles (1905) and seeing their interchangeability with matter, $E = mc^2$, Einstein was first to see many of the most fundamental aspects of quantum physics - the quantal derivation of Planck's blackbody radiation law, nonlocality and instantaneous action-at-a-distance (1905), the internal structure of atoms (1906), wave-particle duality and the "collapse" of the wave aspect (1909), transition probabilities for emission and absorption processes that introduce indeterminism whenever matter and radiation interact, making quantum mechanics a statistical theory (1916-17), the indistinguishability of elementary particles with their strange quantum statistics (1925), and the nonseparability and entanglement of interacting identical particles (1935).

It took the physics community eighteen years to accept Einstein's "very revolutionary" light-quantum hypothesis. He saw wave-particle duality at least ten years before LOUIS DE BROGLIE, ERWIN SCHRÖDINGER, Heisenberg, and Bohr. He saw indeterminism a decade before the Heisenberg uncertainty principle. He saw nonlocality as early as 1905, presenting it formally in 1927, but he was misunderstood and ignored. In the 1935 Einstein-Podolsky-Rosen paper, he examined nonseparability, which was dubbed "entanglement" by Schrödinger.

Our secondary goal is to show how a revised understanding of Einstein's contributions and his deep desire to describe an "objective reality" can lead to plausible solutions for some *unsolved* problems in statistical mechanics and quantum physics.

These problems or "mysteries" include:

- The 19th-century problem of microscopic irreversibility
- Nonlocality, first seen by Einstein in 1905
- Wave and particle "duality" (1909)
- The metaphysical question of ontological chance (1916)

5 www.informationphilosopher.com/solutions/scientists/einstein/

- Nonlocality and action-at-a-distance (1927)
- The "mystery" of the two-slit experiment (1927)
- The measurement problem (1930)
- The role of a "conscious observer" (1930)
- Entanglement and "spooky" action-at-a-distance (1935)
- Schrödinger's Cat - dead and alive?
- No "hidden variables," but hidden constants
- Conflict between relativity and quantum mechanics?
- Is the universe deterministic or indeterministic?

A third ambitious goal is at once physically, metaphysically, and philosophically very deep, and yet we hope to explain it in such a simple way that it can be understood by almost everyone.

This goal is to answer a question that Einstein considered throughout his life. *Is nature continuous or discrete?*

Einstein's work on matter and light appears to show that the physical world is made up of nothing but *discrete discontinuous particles*. Continuous *fields* with well-defined values at all places and times may be simply abstract theoretical constructs, "free creations of the human mind" he called them, only "observable" as *averages* over very large numbers of discrete particles.

A year before his death, Einstein wrote to an old friend,

> "I consider it quite possible that physics cannot be based on the field concept, i.e:, on continuous structures. In that case, nothing remains of my entire castle in the air, gravitation theory included, [and of] the rest of modern physics." [6]

No one did more than Einstein to establish the *reality* of particles of matter and energy. His study of Brownian motion proved that atoms are real. His analysis of the photoelectric effect proved that localized quanta of light are real. But Einstein wrestled all his life with the apparently continuous wave aspects of light and matter.

Einstein could not accept most of his quantum discoveries because their *discreteness* conflicted with his basic idea that nature is best described by a *continuous* field theory using differential equations that are functions of "local" variables, primarily the space-time four-vector of his general relativistic theory.

6 Pais, 1982, p.467

Fields are "free creations of the human mind."

Einstein's description of wave-particle duality is as good as anything written today. He saw the relation between the wave and the particle as the relation between *probability* and the realization of one *possibility* as an *actual* event. He saw the *continuous* light wave spreading out in space as a mathematical construct giving us the probable number of *discrete* light particles in different locations.

But if light waves are carrying energy, Einstein feared their instantaneous "collapse" in the photoelectric effect might violate his special theory of relativity. He was mistaken.

Nonlocality is the idea that some interactions are transferring something, matter, energy, or minimally abstract information, faster than the speed of light. Einstein originated this idea, but this book will show that his hope for an "objective" *local* reality can be applied to deny the popular instances of nonlocal "action-at-a-distance," providing us a new insight into the mystery of "entanglement," the so-called "second revolution" in quantum mechanics.

David Bohm thought "hidden variables" might be needed to communicate information between entangled particles. We shall show that most information is transported by "hidden" constants of the motion, but at speeds equal to or below the speed of light.

Nonlocality is only the *appearance* of faster-than-light action

Two particles travel away from the center in what quantum mechanics describes as a *superposition* of two possible states. Either particle has either spin down or spin up. The two-particle wave function is

$$\psi = (1/\sqrt{2}) (| + - > - | - + >).$$

In "objective reality," a specific pair starts off in just one of these states, say | + - >, as explained by Paul Dirac. See chapter 19.

A few moments later they are traveling apart in a |+ - > state, with the left electron having spin +1/2 and the right -1/2. But neither has a definite spatial spin component in a given direction such as z+.

A *directionless* spin state is symmetric and isotropic, the same in all directions. It is rotationally invariant. Spin values of + and - are traveling with the particles from their entanglement in the center.

Because they are entangled, the + spin in the left-moving electron is always perfectly opposite that of the - spin electron moving right..

While there might not be Bohmian "hidden variables," the conserved spin quantities might be called "hidden constants" ("hidden in plain sight) that explain the *appearance* of nonlocal, nonseparable behavior.

But when the two particles are measured, they project spatial components of the two directionless spins, the two projections are occurring simultaneously in a spacelike separation. Einstein's special theory of relativity maintains such simultaneity is impossible.

Although nonlocality and nonseparability are only appearances, "objectively real" entanglement is all that is needed for quantum information, computing, encryption, teleportation, etc.

Information about probabilities and possibilities in the wave function is *immaterial*, not material. But this abstract information has real causal powers. The wave's *interference* with itself predicts *null points* where no particles will be found. And experiments confirm that no particles are found at those locations.

But how can mere probability influence the particle paths?

This is the one deep mystery in quantum mechanics.

Information philosophy sees this *immaterial* information as a kind of modern "spirit." Einstein himself described a wave as a "ghostly field" (*Gespensterfeld*) and as a "guiding field" (*Führungsfeld*). This idea was taken up later by Louis de Broglie as "pilot waves," by Erwin Schrödinger, who developed the famous equation that describes how his wave function moves through space *continuously* and *deterministically, and* by Max Born in his "statistical interpretation" (actually based on a suggestion by Einstein!).

Schrödinger objected his whole life to Born's idea that his *deterministic* wave function was describing the *indeterministic* behavior of particles. That quantum mechanics is statistical was of course the original idea of Einstein. But Born put it succinctly,

> The motion of the particle follows the laws of probability, but the probability itself propagates in accord with causal laws. [7]

---

7 Born. 1926, p. 803.

Einstein believed that quantum mechanics, as good as it is, is "incomplete." Although the "founders" denied it, quantum theory is in fact incomplete. Its *statistical* predictions (phenomenally accurate in the limit of large numbers of identical experiments), tell us nothing but "probabilities" for *individual* systems.

Einstein's idea of an "objective reality" is that particles have paths and other properties independent of our measurements. He asked whether a particle has a position before we measure it and whether the moon only exists when we are looking at it? The fact that it is impossible *to know* the path or properties of a particle without measuring them does not mean that they do not exist.

Einstein's idea of a "local" reality is one where "action-at-a-distance" is limited to causal effects that propagate at or below the speed of light, according to his theory of relativity. This *apparent* conflict between quantum theory and relativity can be resolved using an explanation of nonlocality and nonseparability as merely "knowledge-at-a-distance," or "information-at-a-distance."

Einstein felt that his ideas of a local and objective reality were challenged by an *entangled* two-particle system which *appears* to produce instantaneous correlations between events in a space-like separation. He mistakenly thought this violated his theory of special relativity. This was the heart of his famous Einstein-Podolsky-Rosen paradox paper in 1935. But we shall show that Einstein had been concerned about faster-than-light transfer of energy or information from his very first paper on quantum theory in 1905.

In most general histories, and in the brief histories included in modern quantum mechanics textbooks, the problems raised by Einstein are usually presented as arising *after* the "founders" of quantum mechanics and their "Copenhagen Interpretation" in the late 1920's. Modern attention to Einstein's work on quantum physics often starts with the EPR paper of 1935, when his mysteries about nonlocality, nonseparability, and entanglement were not yet even vaguely understood as a problem by his colleagues.

Even today, when entanglement is advertised as the "second revolution" in quantum mechanics," few physicists understand it.

We will see that entanglement challenged Einstein's idea that his special theory of relativity shows the "impossibility of simultaneity."

Most physics students are taught that quantum mechanics *begins* with the 1925 Heisenberg (matrix/particle) formulation, the 1926 Schrödinger (wave) formulation, Born's statistical interpretation of the wave function in 1926, Heisenberg's uncertainty (indeterminacy) principle in 1927, then Dirac's transformation theory and von Neumann's measurement problem in 1930.

The popular image of Einstein post-EPR is either in the role of critic trying to expose fundamental flaws in the "new" quantum mechanics or as an old man who simply didn't understand the new quantum theory.

Both these images of Einstein are seriously flawed, as we shall see. It was actually the "founders" who did not understand Einstein's concerns, especially nonlocality. When physicists began to appreciate them between the 1960's and 1980's, they labeled them "quantum mysteries" that dominate popular discussions today.

Einstein and Schrödinger wanted to *visualize* quantum reality. Bohr and Heisenberg's Copenhagen Interpretation says don't even try to look for an underlying "quantum reality." But Einstein's ability to visualize quantum reality was unparalleled, despite errors that continue to mislead quantum physicists today.

While almost none of Einstein's contemporaries knew what his "spooky action-at-a-distance" was talking about, today "entanglement" is at the height of popularity and at the heart of quantum computing and encryption.

Einstein's best known biographer, Abraham Pais, said of the EPR paper, "It simply concludes that objective reality is incompatible with the assumption that quantum mechanics is complete. This conclusion has not affected subsequent developments in physics, and it is doubtful that it ever will."[8] Today, the EPR paper is the most cited of all Einstein's work, and perhaps of all physics!

We will focus on restoring Einstein's reputation as a *creator*, rather than a destructive critic of quantum mechanics. It is astonishing how many things that he was first to see have become central to quantum theory today. A close reading of Einstein recognizes him as the *originator* of both great theories of 20th-century physics, both relativity and quantum mechanics.

8 Pais, 1982, p. 456

Questions to Consider

As you read through this book, please keep in mind the following questions that we will explore throughout. Some of these issues Einstein was best known for denying, but he was first to see them and he considered them as very serious possibilities.

1) Are the fundamental constituents of the universe discrete discontinuous localized particles, and not continuous fields?

Nuclear, electromagnetic, and gravitational fields are theoretical constructs predicting the *forces* that would be felt by a test particle located at a given position in space.

Quantum mechanical fields, squares of the probability amplitudes $|\psi^2|$, predict the *probabilities* of finding particles at that position.

Probability amplitudes are calculated by solving the Schrödinger equation for eigenvalues consistent with the distribution of matter, the local "boundary conditions." Thus, probability amplitudes are different when one or two slits are open, independent of the presence of any test particle.

Can particles be successfully represented as singularities in continuous fields that carry substance? Can they be described as localized "wave packets," made from superimposed waves of different frequencies? Probably not.

2) Does ontological chance exist, or as Einstein might have put it, "Does God play dice"?

Einstein was the discoverer of ontological chance in his 1916 derivation of the Planck radiation law and the transition probabilities for emission and absorption needed to maintain thermal equilibrium. This led to his seeing the statistical nature of quantum mechanics.

Chance underlies indeterminacy and irreversibility. Without it there are no alternative possible futures and no free will.

3) Was Einstein right about an "objective reality"?

Can particles have continuous paths even though individual paths cannot be observed without disturbing them?

Just because we cannot continuously observe particles does not mean they are free to change their properties in ways that violate conservation principles.

Just because paths are not "observables" and we don't know them does not mean that those paths do not exist, as mistakenly insisted by the Copenhagen Interpretation, which claims that particle positions only come into existence when a measurement is made.

Regarding such extreme anthropomorphism, John Bell quipped, does the experimenter need a Ph.D.?

Can "objective reality" give us a picture of particles moving along unobservable paths that conserve all the particle properties, so that when they are observed, properties like electron and photon spins are perfectly correlated with the values they were created with.

These "constants of the motion" would appear to be *communicating*, when they are actually just *carrying* information along their paths. We call them "hidden constants."

Measurements of electron spin spatial components by Alice and Bob are an exception, since they create the values.

6) Did Einstein see space and time as mathematical constructs?

We project continuous coordinates onto space to describe the changing relations between discrete discontinuous particles.

Are space and time just mathematical fictions, mere ideas invented by scientists? Two great nineteenth-century mathematicians were a great inspiration for Einstein.

One, Leopold Kronecker, said "God created the integers. All else is the work of man." The other, Richard Dedekind, said mathematical theories are "free creations of the human mind," a favorite phrase of Einstein, who called theories "fictions," however amazing they are in predicting phenomena.

7) Does the "expansion of space," which Einstein saw first, just mean that some particles are separating from one another?

Many visible objects, galaxies, stars, planets are not participating in the expansion. Their gravitational binding energy exceeds their kinetic energy, partly thanks to invisible dark matter.

Between large clusters of galaxies, the creation of more phase-space cells allows for new arrangements of particles into low-entropy information structures. New information created since the origin of the universe led first to the creation of elementary particles and atoms, then the galaxies, stars, and planets. The "negative entropy" radiating from the Sun supported the evolution of life.

Plausible, If Radical, Answers to Quantum Questions

- *On "spooky" action-at-a-distance.* Two entangled particles yield perfectly correlated properties at enormous distances, as long as they have not interacted with their environment. Have they somehow communicated with one another faster than light? Or do they simply conserve the same properties they had when first created, as the conservation laws suggest? Einstein showed that particles fired off in opposite directions, with equal and opposite momenta, can tell us the position of the second by measuring the first. Einstein used the conservation of momentum to reach this conclusion, which is still valid. But when David Bohm in 1952 changed the EPR experiment to include electron spins, the measurements by Alice and Bob of spin or polarization in spatial coordinates introduced a different kind of nonlocality. Alice's and Bob's values of spin components z+ and z- are *created* by her measurement. They are *nonlocal,* appearing simultaneously at a spacelike separation. But there is no action by one particle on the other! This nonlocality is only "knowledge-at-a-distance." See chapters 29 and 34.
- *On "hidden variables" and entanglement.* There are no hidden variables, local or nonlocal. But there are "hidden *constants*." Hidden in plain sight, they are the "constants of the motion," conserved quantities like energy, momentum, angular momentum, and spin, both electron and photon. These hidden constants explain why entangled particles retain their perfect correlation as they travel apart to arbitrary distances. The Copenhagen Interpretation says there are no properties until Alice's measurement, but this is wrong. The particles' objectively real properties are local and constant from their moment of entanglement, as long as they are not decohered by interactions with the environment. These + and - spins are *directionless*. Alice's measurement creates the *nonlocal* directional spin components z+ and z-. See chapters 30 to 32.

- *On the "one mystery" in the two-slit experiment.* Richard Feynman made the two-slit experiment the defining mystery of quantum mechanics. How can a particle interfere with itself if it does not go through both slits? Einstein's "objective reality" imagines a continuous particle path, so it goes through one slit. But the wave function, determined by the solution of the Schrödinger equation given the surrounding boundary conditions, is different when two slits are open. Incoming particles show the two-slit interference pattern whichever slit they come through. See chapter 33.
- *On microscopic irreversibility*. Collisions between atoms and molecules are irreversible whenever radiation is emitted or absorbed. Einstein showed that an emitted photon goes off in a random direction, introducing the "molecular disorder" Ludwig Boltzmann wanted. See chapter 12.
- *On nonlocality.* In his photoelectric effect explanation, Einstein wondered how the light wave going off in all directions could suddenly gather together and deposit all its energy at one location. No matter, energy, or information moves at greater than light speed when correlated information appears after a two-particle wave function collapse. See chapter 23.
- *On the conflict between relativity and quantum mechanics.* Einstein thought nonlocality - simultaneous events at space-like separations - cause a conflict between special relativity and quantum mechanics. He was wrong. We think there is a conflict between general relativity and quantum mechanics. The conflict disappears if gravity consists of discrete particles, whose separations are limited by inter-particle forces. Einstein suggested quantum mechanics and gravitation should be treated by discrete algebraic equations, not continuous differential equations with their unrealistic singularities.

- *On the "measurement problem."* Copenhageners think particles have no properties until they are measured. Indeed they say that those properties do not exist until they reach the mind of a "conscious observer." Einstein responded, "Look, I don't believe that when I am not in my bedroom my bed spreads out all over the room, and whenever I open the door and come in, it jumps into the corner." Conservation laws prevent the particles from moving erratically. See chapter 42.
- *On Schrödinger's Cat.* The cat was a challenge to the idea that a quantum system, actually the system's wave function Ψ, can be in a linear combination or *superposition* of states. It led to the absurd idea that a quantum cat can be both dead and alive, or that a particle can be in two places at the same time, or go through both slits in the two-slit experiment. Recall Einstein's view that the wave function is a "ghost field" guiding the particle, and is not "objectively real." See chapter 28.
- *On indeterminism.* Standard "orthodox" quantum mechanics accepts indeterminism and acausality. Einstein initially rejected indeterminism. "God does not play dice," he said repeatedly. But he came to accept that quantum physics is the most perfect theory we have at the moment, including its indeterminism. He thought nothing within the theory could change that fact. Only a much deeper theory might be found, he hoped, out of which the current theory might emerge, But quantum processes are statistical, introducing creative new possibilities, not pre-determined by past events. Indeterminism is the source of all creativity, physical, biological, and intellectual, "free creations of the human mind.".
- *On chance.* When Einstein explained the rates of "quantum jumps" between energy levels in the Bohr Atom, he found that a light particle had to be emitted in a random direction and at a random time, in order to maintain the equilibrium between radiation and matter, so they could both have the same temperature. This Einstein called "chance," and a "weakness in the theory." Einstein's chance is *ontological*. Heisenberg's uncertainty principle is *epistemological*. See chapter 11.

- *On the "collapse" of the wave function.* The Copenhagen Interpretation and standard quantum physics describe the "collapse" as the "reduction of the wave packet" from a linear combination or "superposition" of many quantum states into a single quantum state. Werner Heisenberg described the collapse as acausal, uncertain, indeterministic, and dependent on the "free choice" of the experimenter as to what to measure. This is correct, but he did not connect it to Einstein's *ontological* "chance." See chapter 24.
- *On waves and particles.* When Einstein showed that matter is made of *discrete* particles and hypothesized that light is also particles, he described the light waves as "ghost" fields, insubstantial but somehow governing the paths and ultimate positions of the substantial particles, so also "guiding" fields. The wave is only a mathematical device for calculating probabilities of finding photons. Only the light particles are "objectively real." Einstein pointed out that fields are convenient "fictions" that allow us to make amazingly accurate, though *statistical*, predictions. See chapter 9.
- *Why particles are more "objectively real" than fields* One of Einstein's earliest accomplishments was to reject the idea of a universal ether, a field which was the medium in which light could be the vibrations. James Clerk Maxwell's electric and magnetic fields have replaced the ether. Now quantum theory sees the electromagnetic field as only the average behavior of large numbers of Einstein's light quanta or photons. Particles are physical. Fields, especially continuous fields, are metaphysical.
- *On the incompleteness of quantum mechanics.* Einstein finally caught the attention of physicists and the general public with his claim in 1935 that quantum mechanics is "incomplete," that it is a *statistical* theory saying nothing certain about individual particles. Niels Bohr responded that the new quantum mechanics is complete, based on his philosophical idea of *complementarity*. But he offered no proof. Einstein was right. Quantum theory is incomplete. See chapters 26 to 29.

- *Is quantum mechanics epistemological or ontological?* Does quantum mechanics provide only the words and language we use to talk about the world, or does it access what philosophers call the "things in themselves.? Einstein's hopes for seeing an "objective reality" were dashed by almost all his physicist colleagues in the 1920's. We must give full credit to the "founders of quantum mechanics" who at that time gave us the extraordinary mathematical apparatus - and not just language - that allows us to predict the behavior of the physical world, albeit only statistically as Einstein was first to discover. But we hope to show that many of the concepts underlying their mathematics were discovered or invented by Einstein. Niels Bohr ignored or attacked those concepts for many years, especially light as a particle. Bohr was a positivist influenced by linguistic philosophers who think talk about an objectively real world is "metaphysics." He was unequivocal.

> "There is no quantum world. There is only an abstract quantum physical description. It is wrong to think that the task of physics is to find out how nature is. Physics concerns what we can say about nature. [9]

My goal is to change Einstein's reputation from "the best known critic of quantum mechanics" [10] to the "inventor of most of the basic concepts in quantum mechanics," including his objective reality.

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Cambridge, MA
December, 2018

9 *Bulletin of the Atomic Scientists*. Sep 1963, Vol. 19 Issue 7, p.12
10 Nielsen and Chuang, 2010, p.2