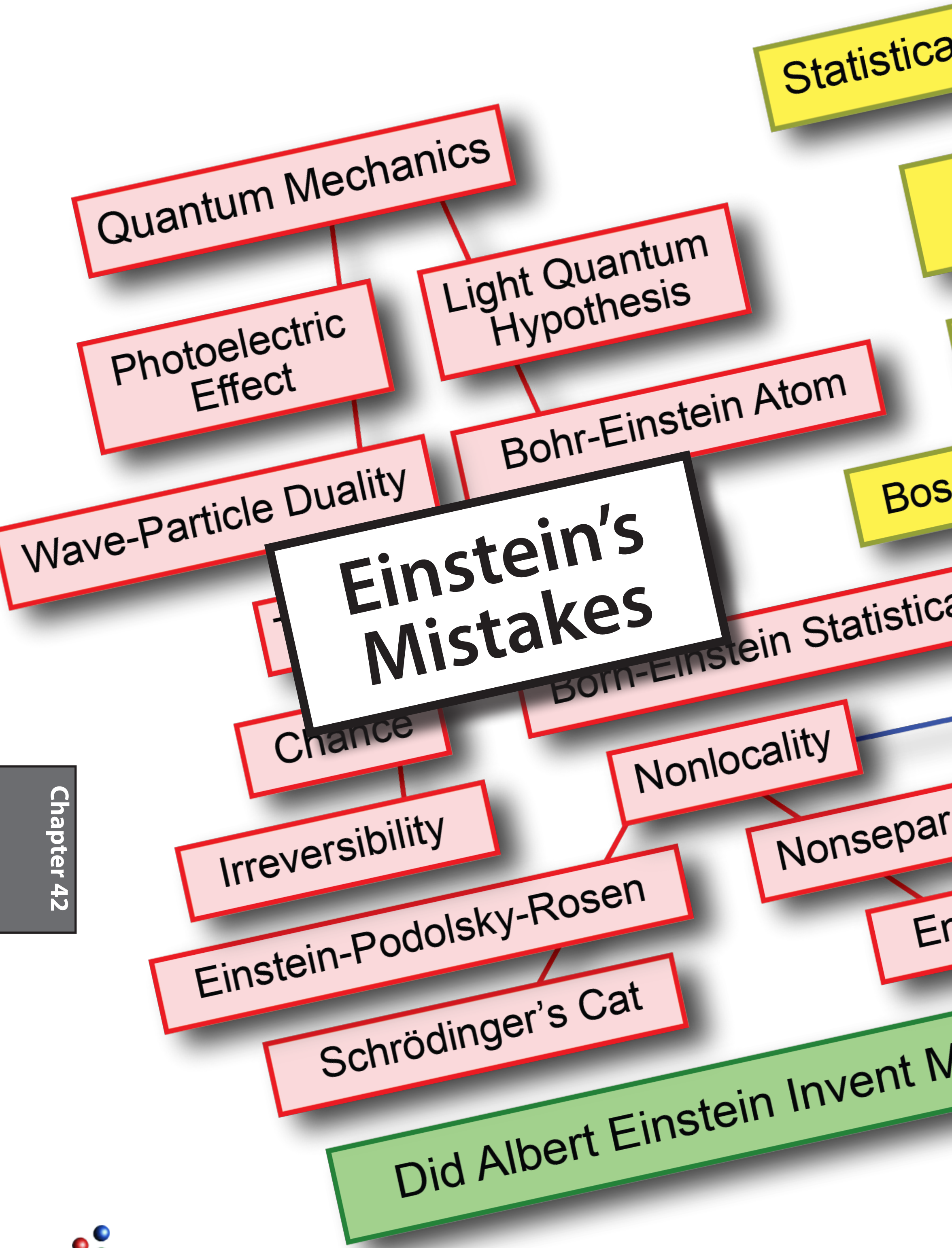
Quantum Mechanics
Light Quantum Hypothesis
Photoelectric Effect
Bohr-Einstein Atom
Wave-Particle Duality
Einstein's Mistakes
Chance
Irreversibility
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Einstein-Podolsky-Rosen
Schrödinger's Cat

Einstein's Mistakes

We must first acknowledge that Einstein's mistakes have given us in general more important theoretical insights than those of all but a handful of great physicists's successes. Einstein's mistakes lie behind the greatest puzzles and mysteries in physics today.

While Einstein did not solve these mysteries, in most of them so far neither has any other scientist provided convincing explanations. That his phenomenal mind saw them at all is his great gift to science.

When we see his mistakes for what they are, and when we add them to his extraordinary successes, Einstein emerges as the single greatest force behind both of the leading fields of physics today, relativity and quantum mechanics.

Fields and Particles

Unified Field Theory

In terms of effort spent and results achieved, surely his unified field theory was Einstein's greatest mistake, first because it was deterministic, second because there are now so many fields.

He wrote his friend Michele Besso the year before he died,

> "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." [1]

Space and Time

Einstein is said to have combined space and time into a single four-dimensional continuum. This was first done by Hermann Minkoswki, but Einstein deserves credit for developing the four-dimensional energy-momentum tensor that describes his theory of general relativity.

1 Pais, 1982, p.467

In his later years Einstein had many doubts about the reality of space and time, wondering if they may be just convenient fictions, "free creations of the human mind," which just happen to describe accurately the "real" things, the material particles.

Quantum Physics

Ontological Chance

Without a doubt, it was Einstein's two papers in 1916 and early 1917 that established chance in the emission and absorption of his light quanta. The times and directions of light interactions with matter are completely indeterminate. Einstein gave credit to Ernest Rutherford for discovering a similar indeterminacy in radioactive decay.

Einstein said chance must be considered a "weakness in the theory."

But it was Einstein's proof that thermal equilibrium between Planck's radiation distribution and the Maxwell-Boltzmann velocities distribution of matter could not be maintained without the emission of photons going off in all directions at random.

Einstein's canonical paper on the A and B coefficients for emission and absorption is a foundational element of the statistical nature of quantum mechanics, and it predicted the stimulated emission of radiation that underlies the working of lasers.

Einstein's mistake was to not accept for many years the conclusion that natural processes involve chance. "God does not play dice."

This one "mistake" explains how the universe can create unpredictable new information structures like atoms, stars, galaxies, living things, minds, and new ideas! See chapter 43.

The Statistical Interpretation

Max Born's interpretation of the quantum mechanical wave function of a material particle as the probability (amplitude) of finding a material particle was a direct extension of Einstein's interpretation of light waves as giving probability of finding photons.

To be sure, Einstein's interpretation may be considered only qualitative, where Born's was quantitative. He made it the squared modulus of the probability amplitude $|\psi|^2$. The new quantum mechanics gives us exact calculations - of statistics!

As with his dislike of chance, Einstein was happy to give Born all the credit, including a Nobel Prize, for the statistical interpretation.

Nonlocality

When Einstein first thought about a light wave spreading out in space, only to collapse to a point when all the light was collected into a single atom in metal to eject a single electron, he briefly thought distributed energy must have moved faster than light to collect itself together.

To be sure, Einstein hypothesized that perhaps light is not continuously distributed over an increasing space but consists of a finite number of energy quanta which are localized at points in space. But this did not stop him from worrying about nonlocality.

Einstein saw spacelike separated events occurring *simultaneously*, an apparent violation of his special theory of relativity, which claims that simultaneity is impossible in an absolute sense

Symmetry and Conservation

EPR-Entanglement

Einstein's greatest biographer, Abraham Pais, concluded in 1982, that the EPR paradox "had not affected subsequent developments in physics, and it is doubtful that it ever will." [2] Einstein had drawn attention for decades to the appearance of nonlocality and in the 1935 EPR paper added his *separation principle*, but his orthodox physicist colleagues could make no sense of his paper.

Einstein's mistake was to say we should absolutely agree that the real factual situation of one system is independent of what is done with another which is spatially separated. [3] ERWIN SCHRÖDINGER immediately pointed out that the two-particle wave function would not separate without an interaction or measurement.t

2 Pais, 1982, p.456
3 Einstein, 1949a, p.85

But it was Einstein himself who first imagined two events in a spacelike separation occurring simultaneously, an impossibility according to his own special theory of relativity.

Spooky Action-at-a-Distance

Einstein described spooky action as one particle acting "telepathically" on another particle spatially separated.[4] It may be no exaggeration to say that spooky action is one of Einstein's greatest original ideas.

Adding "spooky" in 1949 to his decades of complaints about non-locality and nonseparability did catch the world's attention.

But Einstein should have seen that all these cases were not "actions" by one particle on a distant particle. Einstein added a *false asymmetry* into a symmetric situation.

Schrödinger's Cat

This famous cat began with Einstein criticizing the implication of Schrödinger's wave equation. He told Schrödinger to imagine a charge of gunpowder that can spontaneously combust, on average once a year. Then "your ψ-function describes a sort of blend of not-yet and already exploded systems." Schrödinger famously adapted Einstein's idea to his cat in a "superposition" of dead and alive.

Both Einstein and Schrödinger were making fun of superposition, but Einstein should have known it was just a mathematical tool to calculate statistical probabilities.

Schrödinger switched from joking about superposition to claiming that entanglement is the "characteristic trait" of quantum mechanics. He and Einstein parted ways.

Cosmology

The Cosmological Constant

Einstein himself described the addition of a constant to his equations of general relativity, in order to produce a static universe, his "biggest blunder," in conversation with George Gamow.[5]

4 Schilpp, 1949, p. 85
5 Gamow, 1970, p.44

The Expansion of the Universe

Had Einstein not forced his theory to match the poor observational data of his time, he might have speculated that the universe was adding space by expanding or contracting, over a decade before Edwin Hubble found the expansion of external galaxies in 1927.

The Flat Universe

As Einstein's field equations for general relativity improved in the early years, he might have noted that when the expansion rate - the motion energy gets near the gravitational binding energy, the overall curvature approaches zero and the "radius" of the observable universe approaches infinity.

As observations have improved, the universe now appears within a factor of three of having enough matter to make the universe "flat" and its geometry Euclidean.

Einstein might have appreciated this symmetry between energy and matter,

Thermodynamics and Statistical Mechanics

Gibbs-Liouville

The conservation of any particular volume of phase space (the Liouville theorem) led J. Willard Gibbs to claim that information is also conserved. Einstein claimed that he did little or nothing more than Gibbs. But this was a mistake. Gibbs' statistical mechanics is a formal theory that does not even mention material particles. Einstein's work led to the proof of the existence of atoms!