Does Randomness Fundamentally Exist?

Sonny A. Fullerton

University of Pennsylvania

PHIL 1000

Final Paper

Table of Contents

Does Randomness Fundamentally Exist?

Whether or not randomness exists may appear to be a trivial question on initial inspection. When we flip a coin, we do not know whether it lands heads or tails; this everyday randomness is usually epistemic – arising from our ignorance of subtle physical details. Could we not predict the outcome of the flip if we knew everything about its initial state, its motion through the air, etc.? Thus, this is not intrinsic uncertainty.

The question becomes more pressing when we examine quantum phenomena. At this scale, outcomes such as spin measurements and radioactive decay appear to lack determinate values prior to observation. Consequently, many have taken quantum mechanics to show that there does exist *irreducible* randomness, which is not determined by some deeper law.

In what follows, I will assert whether this proposition is warranted. Ultimately, I shall argue that genuine randomness does appear in observable events, yet it does not depict a fundamental feature of reality. Instead, it emerges from complex dynamic interactions between a system’s laws. My aim is to demonstrate that spontaneity at the macroscopic and quantum levels does not necessarily demand that nature itself is metaphysically random.

Establishing Definitions

To effectively explore randomness, it is vital to ensure the accurate use of relevant language. In what follows, I distinguish between ontic randomness (randomness in events’ outcomes) and fundamental randomness (which is built into the basic structure of reality). My claim will be that the former does whereas the latter does not.

Determinism

In a metaphysical sense, this is the idea that the specific initial conditions will invariably result in the same outcomes. It is not predictability – determinism concerns what is necessitated in reality, whereas predictability refers to what agents can know.

Epistemic and ontic randomness

These are the two main schools of thought regarding randomness. The epistemic view is that randomness is simply ignorance of causes; randomness is an apparent feature of our knowledge rather than of nature. The ontic perspective opposes this by asserting randomness to be a true, existent attribute of reality.

Fundamental

If a quality is fundamental, it is completely primitive – built in – to reality. It does not depend on anything to be as it is and cannot be reduced to more basic phenomena. The converse is true: something is non-fundamental if it depends on something else. Many argue that elementary particles, like electrons, are fundamental to reality. Heat, for example, is certainly real (ontic) but not fundamental: it can be reduced to measurements of kinetic energy (although not necessarily implying that kinetic energy is fundamental).

Epistemic Randomness

Epistemic randomness alludes to our use of “randomness” to substitute for our ignorance of why something occurs. It describes unpredictability evolving due to incomplete knowledge of the world.

In *An Essay on Probabilities,* Laplace introduces his “demon”[1]: an intellect knowing of all conditions of a system. Armed with this and sufficient knowledge of the laws of physics, it could surely predict the outcome of any scenario. If a deck of cards is shuffled, and one knows the initial ordering and the transformation each shuffle applies to the deck, predicting the final position of every card becomes trivial, portraying the classical metaphysical idea that randomness is a simple mark of ignorance.

[1] Pierre Simon Laplace, *A Philosophical Essay on Probabilities*, trans. Frederick Wilson Truscutt and Frederick Lincoln Emory (New York: Dover Publications, 1951), 4-5.

Leibniz's *Principle of Sufficient Reason*[2] dictates that everything has a well-defined justification for why it is the way it is (and why it is not the way it is not), therefore there is always a cause for any given event. In accordance with this, randomness is a blanket term used to describe a scenario where we have not sufficiently identified these reasons for something occurring. The demon knows all said reasons and thus can predict all deterministic outcomes.

Issues – The Uncertainty Principle

The issue with the demon and overall epistemic view is that it breaks down at the quantum level owing to Heisenberg's *Uncertainty Principle*[3]. This states that the precise position and velocity of a quantum particle at any given time cannot be simultaneously known; there is an inherent uncertainty in the measurement which means it cannot be well represented. Thus, the demon fails owing to this concrete limit on the structure of the world, meaning the outcomes of some events are unpredictable.

Even if epistemic randomness accounts for classical uncertainty, it does fail to explain quantum results, where we observe truly random outcomes upon measurement[4] of an outcome. These situations where an outcome is truly unpredictable lead pleasantly onto the ontic approach to randomness.

Why Epistemic Randomness Is Insufficient: The Ontic Argument

This brings us to the competing view - that randomness is the perspective that randomness is a real, existent feature of objects and events. Its foundations lay in Aristotle's proposition of tychē[5]; this describes "chance" arising from interaction between causal chains

---

[2] G.W. Leibniz, *The Monadology and Other Philosophical Writings*, trans. Robert Latta (Oxford: Oxford University Press, 1898), 13-16.

[3] Wener Heisenberg, *The Physical Principles of the Quantum Theory* (Chicago: University of Chicago Press, 1930), 13-16.

[4] Niels Bohr, "Discussion with Einstein on Epistemological Problems in Atomic Physics," in *Albert Einstein: Philosopher-Scientist,* ed. Paul Arthur Scilpp (la Salle, IL: Open Court, 1949), 200-241

[5] Aristotle, *Physics,* trans. Robin Waterfield (Oxford: Oxford University Press, 1996), Book II, Part 5, pp.180-182

which results in genuine openness. One man goes to the market to see a show, and another goes to purchase food. They happen to bump into one another, allowing one to collect the debt he is owed from the other. Here, a random event has arisen from intertwining causal chains: the man would not have collected his debt had the interaction not happened – this demonstrates event level randomness as a real feature, not simply a placeholder for ignorance.

Quantum Particles

Again, quantum behavior sufficiently implies randomness is genuine. Quantum particles obey a wavefunction before being observed. Their physical state is encoded in a deterministic wavefunction describing probability amplitudes, not definite values. Then, upon measurement, the wavefunction "collapses" and a truly random outcome becomes actualized. *Bell's theorem* indicates there is no local deterministic theory that can reproduce data collected by quantum behavior[6], forming a profound argument for real randomness.

Radioactive decay is another invaluable reference. When particles are decaying from the nucleus of an unstable atom, quantum theory asserts that it is impossible to predict when these particles will leave the nucleus. For a single atom, the decay event is unpredictable, but the decay law arises from the same deterministic wavefunction evolution, as above. This unpredictability cannot be attributed to any hidden conditions but reflects genuine indeterminacy of the event.

Thus, the ontic view makes room for authentic openness in reality; outcomes which are not at all governed by any deterministic laws do indeed exist. This then raises the metaphysical question: does this indeterminacy belong to reality itself or to the relational structure through which phenomena emerge.

[6] John S. Bell, "On the Einstein Podolsky Rosen Paradox," *Physics Physique* 1, no. 3 (1964), 195-200.

Ontic Randomness Does Not Imply Fundamentality

Thus far, we have established that randomness does exist as a feature of reality. We then question if this is fundamental, which is dependent on which part of quantum theory we treat as metaphysically basic. I propose that if the continuous evolution of the wavefunction is taken as fundamental, as is common to many interpretations, then randomness arises only at the measurement level, as opposed to within the underlying laws.

Let us return to one of the main indicators of randomness being real – the quantum argument. Randomness arises in the outcome when an observation is made and the wavefunction collapses. The probabilities themselves are governed by structured, repeatable laws. The indeterminacy appears only upon interaction, when discrete values are observed from the continuous wave evolution. Before said interaction, the system evolves deterministically according to the wavefunction and the Schrödinger Equation[7], which encodes probability amplitudes as opposed to definite values.

This also deals with the ontic randomness of atomic decay. It is indeed random at the level of events i.e. the atom decays at this time, but the randomness does not belong to the base level of reality. It is again emerging from the same deeper, structured notion (the waveform). The randomness is present at the level of actualization as opposed to the basic metaphysics of the world.

Thus, quantum randomness is metaphysically real at the event level, but arises from more profound, law-abiding dynamics that need not necessarily be random. To rationalize randomness' existence without fundamentality, we can analyze this notion of emergence.

Emergent Randomness

We are now tasked with finding a sound justification for how randomness can exist yet not be inherent to the deepest level of reality. By the *observer effect*, quantum randomness

---

[7] Schrödinger, Erwin. "Quantisierung als Eigernwertproblem (I)." *Annalen der Physik* 79 (1926): 361-376.

appears to arise from the relationship between the observer and the particle – it is relationally random. Unpredictability arising from interactions between agents is the structure I propose randomness follows.

Chaos Theory as an Analogy

Chaos theory is a vital parallel (note *parallel*, not exact model) to explore[8]. In essence, it details the irregularity that ensues in a system with interacting deterministic laws. Due to the convoluted interactions between these laws, the system's outcomes become *effectively* random due to extreme sensitivity in initial conditions. *The Butterfly Effect* is often cited to demonstrate this; a butterfly flapping its wings in Mexico may set off a hurricane in New Orleans, illustrating how minuscule initial differences can escalate into disproportionate outcomes. Were the butterfly to have not flapped its wings at this exact time, said hurricane would have never occurred. The laws triggered by the wings – the flap moving one air particle etc. – are all fully deterministic; the contact between the particles will consistently result in the same outcome. It is when the different elements of the system interact in an orderly fashion on the micro-level that macro-level chaos can ensue.

Critically, however, the form of randomness which stems from laws in chaos theory is epistemic. The outcomes are *essentially* unpredictable as initial conditions vary, owing to a great sensitivity, but they are not ontically random. The outcomes, in theory, can be predicted if we had the means to do so. Where chaos theory exhibits value is in its structural analogy for how higher-level behavior can be unpredictable, even when the governing laws are deterministic. Chaos theory does not itself show ontic randomness, but it provides a model of how structured laws can yield unpredictability. Quantum systems show that this unpredictability can become ontic – not because chaos is ontic, but because the underlying laws differ.

---

[8] Ilya Prigogine, *From Being to Becoming: Time and Complexity in the Physical Sciences* (San Francisco: W. H. Freeman, 1980), 36-41.

Thus, emergence provides a middle ground; even if the fundamental layer contains no stochastic element, it can still arise at the level where different systems interact.

Layered Ontology

To sharpen the notion of emergence, I draw from Nancy Cartwright's *Layered Ontology,* which depicts reality as consisting of overlapping layers which are all governed by different laws and can possess different properties, rejecting objective universal laws[9]. Consequently, different metaphysical structures can reside at different levels. This layered picture reframes randomness as a property of the level where events occur, rather than a component of the universe's basic ontology.

On this view, the properties that appear at higher levels need not belong to the metaphysics of the base layer. Hence, randomness can belong to the layer of phenomena – where interactions produce discrete events – rather than the fundamental layer, which is governed by smooth deterministic evolution[10]. This allows a more nuanced metaphysical perspective on the matter.

Objections

It may be argued that the unpredictability exhibited by quantum events is primitive and underivable from any deeper law, but it is vital to recognize that ontic randomness can plausibly emerge from deterministic structures. The alternate *Many-World Interpretation* of quantum experimentation illustrates how deterministic structures can give rise to genuine relational indeterminacy[11]. It depicts that the wavefunction never collapses; instead, all possible outcomes occur in a different branch of the universe. Each observer occupies one branch; hence outcomes are experienced as unpredictable from the perspective of an observer

[9] Nancy Cartwright, *How the Laws of Physics Lie* (Oxford: Clarendon Press, 1983), 19-22.
[10] Alfred North Whitehead, *Process and Reality* (New York: Free Press, 1978), 21-25.
[11] Hugh Everett III, "Relative State Formulation of Quantum Mechanics," *Reviews of Modern Physics* 29, no. 3 (1957), 454-462

embedded within a single branch, despite the global process being deterministic. This explicitly supports the claim that observed randomness is not necessitated to be fundamental.

Some may respond that while Many-Worlds is deterministic, there are other interpretations that attempt to build in fundamental randomness. A prominent example is the GRW collapse theory[12], which dictates that a wavefunction's collapse occurs spontaneously and randomly, without an observer necessary. Upon first inspection, this may appear to support the fundamentality of randomness. Yet, the randomness in GRW is inserted as a postulate into the equation; this addition is not mandated by the structure of quantum theory. There are alternative interpretations which reproduce same predictions without implementing these fundamental stochastic events. Thus, GRW demonstrates that fundamental randomness is plausible, but not necessary or built into reality. The burden of proof resides in showing that randomness must be fundamental, not just that it is possible.

Final Argument

My case suggests that randomness does indeed exist. It is more than mere ignorance, as is demonstrated through quantum outcomes which we are unable to explain through any hidden variables, laws, or other means. It manifests as unpredictability in chaotic systems and as ontic indeterminacy in quantum measurement events. Yet, it is not necessarily primitive to reality; it does not appear in every layer on ontology, instead emerging relationally. Metaphysical indeterminacy need not reside at the fundamental level – it instead occurs where interactions give rise to definite outcomes.

---

[12] Gian Carlo Ghirardi, Alberto Rimini, and Tullio Weber, "Unified Dynamics for Microscopic and Macroscopic Systems," *Physical Review D* 34, no. 2 (1986): 470-91

References

Aristotle. *Physics*. Translated by Robin Waterfield. Oxford: Oxford University Press, 1996.

Bell, John S. “On the Einstein Podolsky Rosen Paradox.” *Physics Physique Физика* 1, no. 3 (1964)

Bohr, Niels. “Discussion with Einstein on Epistemological Problems in Atomic Physics.” In *Albert Einstein: Philosopher-Scientist*, edited by Paul Arthur Schilpp, 200–241. La Salle, IL: Open Court, 1949.

Cartwright, Nancy. *How the Laws of Physics Lie*. Oxford: Clarendon Press, 1983.

Everett, Hugh III. “‘Relative State’ Formulation of Quantum Mechanics.” *Reviews of Modern Physics* 29, no. 3 (1957)

Ghirardi, Gian Carlo, Alberto Rimini, and Tullio Weber. “Unified Dynamics for Microscopic and Macroscopic Systems.” *Physical Review D* 34, no. 2 (1986): 470–91.

Heisenberg, Werner. *The Physical Principles of the Quantum Theory*. Chicago: University of Chicago Press, 1930.

Laplace, Pierre-Simon. *A Philosophical Essay on Probabilities*. Translated by Frederick Wilson Truscott and Frederick Lincoln Emory. New York: Dover Publications, 1951.

Leibniz, G. W. *The Monadology and Other Philosophical Writings*. Translated by Robert Latta. Oxford: Oxford University Press, 1898.

Prigogine, Ilya. *From Being to Becoming: Time and Complexity in the Physical Sciences*. San Francisco: W. H. Freeman, 1980.

Schrödinger, Erwin. “Quantisierung als Eigenwertproblem (I).” *Annalen der Physik* 79 (1926)

Whitehead, Alfred North. *Process and Reality*. New York: Free Press, 1978.

ChatGPT was used to aid in brainstorming, researching, and curating sources to support my thesis. All information ultimately used was verified beforehand.