

# Quantum entanglement experiments Nobel awarded: philosophical consequences

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# Realism, locality or free choice?

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## Violations of locality and free choice are equivalent resources in Bell experiments

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Bell inequalities rest on three fundamental assumptions: **realism**, **locality**, and **free choice**, which lead to nontrivial constraints on correlations in very simple experiments. **If we retain realism**, then violation of the inequalities implies that **at least one of the remaining two assumptions must fail**, which can have profound consequences for the causal explanation of the experiment.

We investigate the extent to which a given assumption needs to be relaxed for the other to hold at all costs, based on the observation that a violation need not occur on every experimental trial, even when describing correlations violating Bell inequalities. How often this needs to be the case determines the degree of, respectively, locality or free choice in the observed experimental behavior. Despite their disparate character, we show that **both assumptions are equally costly**.

# Causality, locality, free choice

- "Realism is a physical concept in which we describe the world in terms of **cause-and-effect relationships**. Locality means that **actions cannot disseminate instantaneously**. So if physical reality is to meet the requirements of local realism, the result of the experiment will be influenced only by what is in its immediate vicinity, and not by what is happening right now in a distant galaxy," explains Dr. Pawel Blasiak, the first author of the article.
- „Spooke action at distance” (A. Einstein)
- Free choice, an apparently typically philosophical concept, can also be treated as a physical or even mathematical problem. In this approach, free choice refers to the variables that describe the parameters of an experiment, i.e. what we measure in the laboratory. We assume that we can choose these variables freely, **regardless of what has happened in the past**.
- <https://www.eurekalert.org/news-releases/671079>

# Locality < Determinism < Causality

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ON DETERMINISM, CAUSALITY, AND FREE WILL:  
CONTRIBUTION FROM PHYSICS

## 1. INTRODUCTION

Determinism, causality, chance, free will and divine providence form a class of interlaced problems lying in three domains: philosophy, theology, and physics.<sup>1</sup> Dariusz Łukasiewicz in recent issue of *Roczniki Filozoficzne* opened a discussion on chance in nature and compatibility of such chance with divine providence. He writes in the introduction: “Contemporary science is the best source of knowledge available to us about the world we live in” (ŁUKASIEWICZ 2020, 5). Physics — that starting from Copernicus, Kepler, Galileo and Newton, with its deductive theories and the paradigm of repeatable experiments is a prototype *par excellence* of natural sciences. Nature became mathematical and predictable with Newtonian physics. Robert Crease, physicist and

# Bi-directional time arrow < Determinism < Causality

## Between Physics and Metaphysics — on Determinism, Arrow of Time and Causality

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*Contemporary physics, with two Einstein's theories (called "relativity" what can be interpreted erroneously) and with Heisenberg's principle of indeterminacy (better: "lack of epistemic determinism") are frequently interpreted as a removal of the causality from physics. We argue that this is wrong. There are no indications in physics, either classical or quantum, that physical laws are indeterministic, on the ontological level. On the other hand, both classical and quantum physics are, practically, indeterministic on the epistemic level: there are no means for us to predict the detailed future of the world. Additionally, essentially all physical principles, including the arrow of time and the*

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# The goat to be sacrificed?

- Locality
- Determinism
- Causality

Please, vote!