



SAPIENZA  
UNIVERSITÀ DI ROMA

# What is the place of *agents* in physics?

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QISS Impressionistic Café Spark

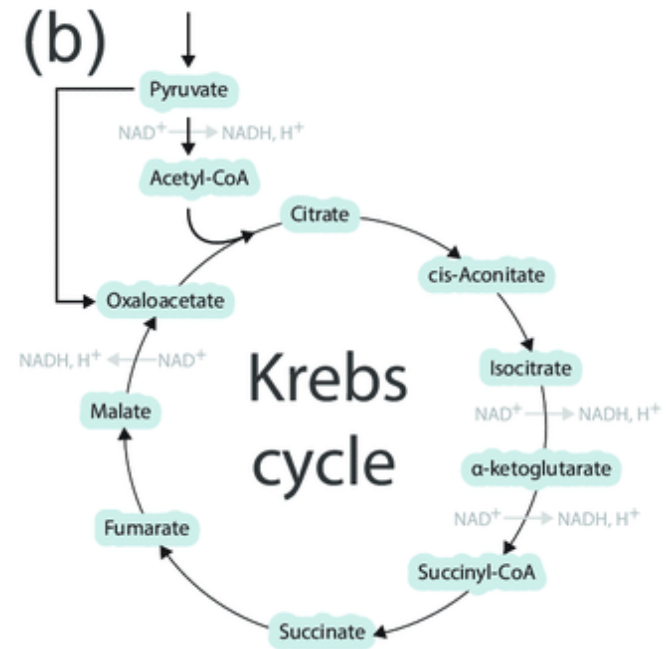
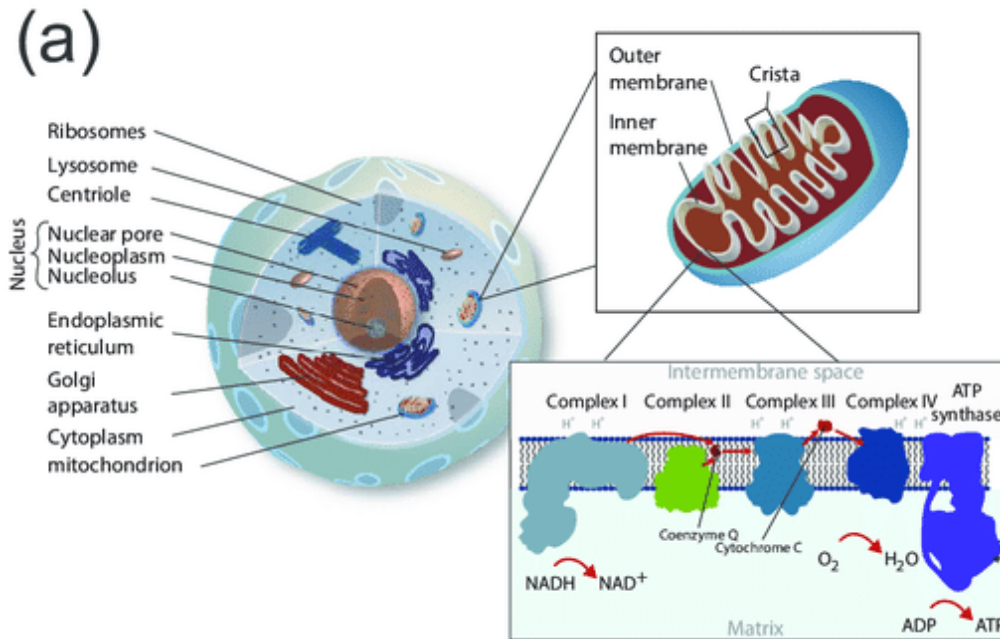
**An agent:** A person or a thing that takes an active role or produces a specified effect. (OED)

**Emergent:** Persons and things are emergent phenomena.

**Methodological:** We cannot practise science without agents.

**Fundamental:** Agents are primitive elements in the foundations of QM.

Reductionism works pretty well.

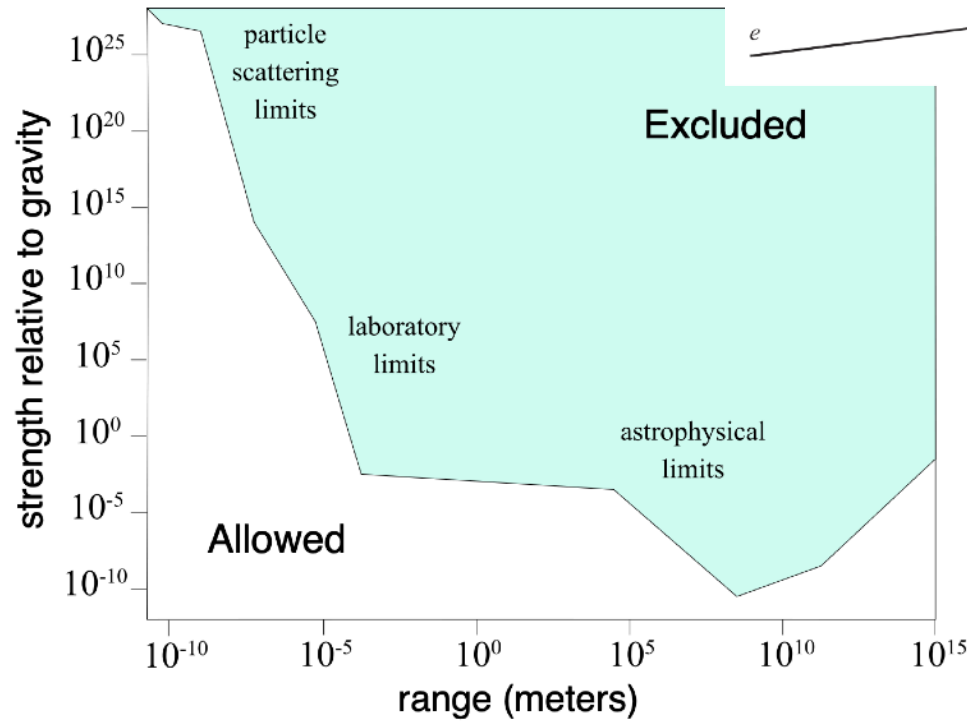
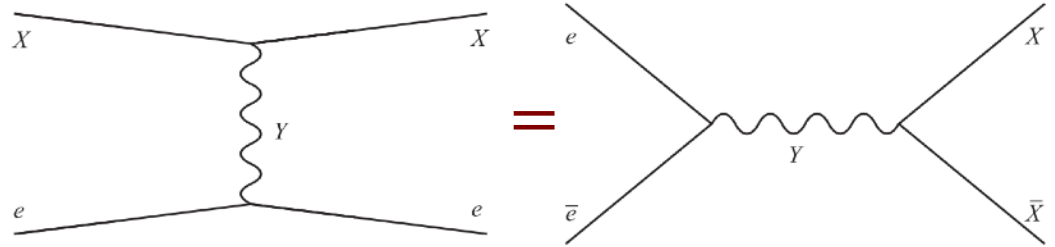


## Core Theory

F. Wilczek

S.M. Carroll, [arxiv.org/abs/2101.07884](https://arxiv.org/abs/2101.07884)

$$A = \int_{k < \Lambda} [Dg][DA][D\psi][D\Phi] \exp \left\{ i \int d^4x \sqrt{-g} \left[ \frac{1}{16\pi G} R - \frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\psi} \gamma^\mu D_\mu \psi + |D_\mu \Phi|^2 - V(\Phi) + (\bar{\psi}_L^i Y_{ij} \Phi \psi_R^j + \text{h.c.}) + \sum_a \mathcal{O}^{(a)}(\Lambda) \right] \right\}.$$



Adelberger et al, *Progress in Particle and Nuclear Physics* 62, 1, 102-134, 2009

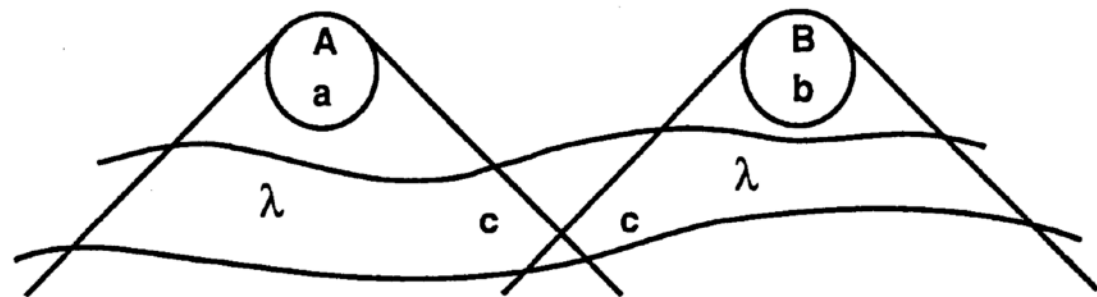
Testing theories requires setting up experiments.

Concept of *intervention* is central in hypothesis testing.

Need concept of free choice for causal discovery.



C. Nolan, *Tenet*, Warner Bros 2020



J.S. Bell, *Found. QM*, 216-234,2001

## Operationalism...

- Lucien Hardy, “Quantum Theory From Five Reasonable Axioms,” (2001), [arXiv:quant-ph/0101012](#).
- Borivoje Dakic and Časlav Brukner, “Quantum theory and beyond: Is entanglement special?” (2009), [arXiv:0911.0695 \[quant-ph\]](#).
- Lluís Masanes and Markus P. Müller, “A derivation of quantum theory from physical requirements,” *New Journal of Physics* **13**, 063001 (2011).
- G. Chiribella, G. M. D’Ariano, and P. Perinotti, “Informational derivation of Quantum Theory,” *Physical Review A* **84**, 012311 (2011), [arXiv:1011.6451](#).
- Lucien Hardy, “Reconstructing quantum theory,” (2013), [arXiv:1303.1538 \[gr-qc, physics:hep-th, physics:quant-ph\]](#).
- Philipp A. Höhn, “Toolbox for reconstructing quantum theory from rules on information acquisition,” *Quantum* **1**, 38 (2017), [arXiv:1412.8323](#).
- Philipp A. Höhn and Christopher Wever, “Quantum theory from questions,” *Physical Review A* **95**, 012102 (2017), [arXiv:1511.01130](#).
- John H. Selby, Carlo Maria Scandolo, and Bob Coecke, “Reconstructing quantum theory from diagrammatic postulates,” [arXiv:1802.00367 \[quant-ph\]](#) (2018), [arXiv:1802.00367 \[quant-ph\]](#).
- Ding Jia, “Quantum from principles without assuming definite causal structure,” *Physical Review A* **98**, 032112 (2018), [arXiv:1808.00898](#).
- Robert Oeckl, “A local and operational framework for the foundations of physics,” *Advances in Theoretical and Mathematical Physics* **23**, 437–592 (2019), [arXiv:1610.09052](#).

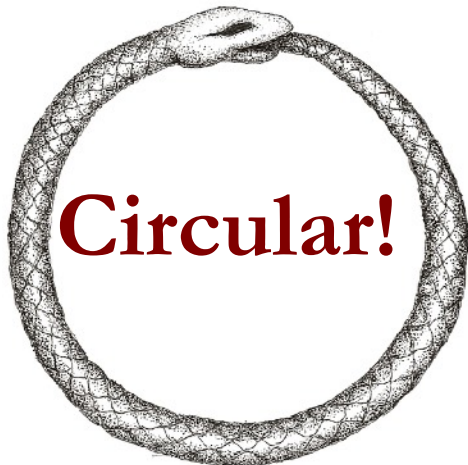
# Fundamental?

QM allows to calculate probabilities of outcomes of experiments.

**Probability** is a primitive concept of QM.

Foundation of QM, requires **foundation of probability theory**.

**Frequentist Probability:** The outcome of an experiment has probability  $p$  if, in the limit of many trials, the frequency of the outcome is **likely** to be **close to**  $p$ .



OK FAPP, but not for fundamental theory.

Non-circular definitions of probability are based on *agents*.

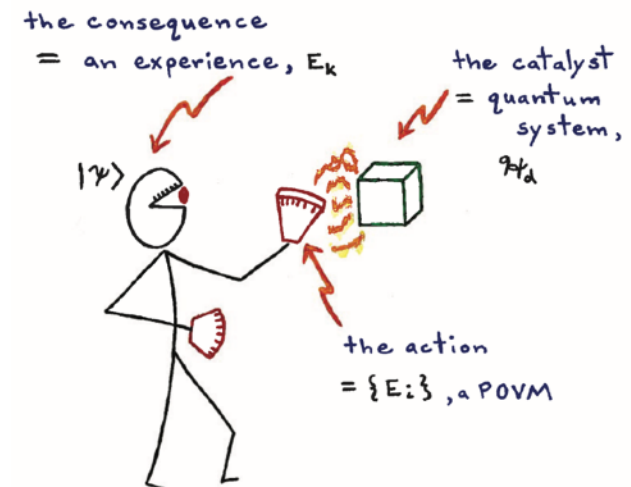
**Bettability probability** An agent assigns probability  $p$  to an outcome  $E$  if they are willing to pay  $\$p$  for a ticket that says: "worth  $\$1$  if  $E$  happens".

**Dutch-Book Argument** Consistency in betting strategy implies probability theory

QBism: Quantum Theory as a Hero's Handbook

Christopher A. Fuchs<sup>1</sup> and Blake C. Stacey<sup>1</sup>

Agents and their agency are central to the QBist view of QM.





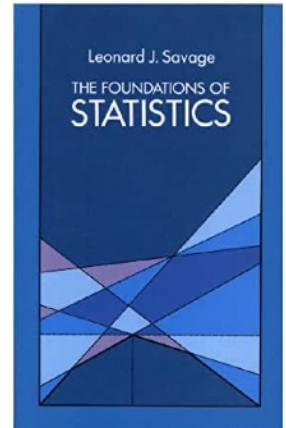
Non-circular definitions of probability are based on *agents*.

Greaves & Myrvold [philsci-archive.pitt.edu/4222/](http://philsci-archive.pitt.edu/4222/)

**Decision-theoretic:** Rational decision making agents with preferences will act *as if* maximising expected utility. (Savage)

$$U(A) = \sum_i u(a_i)p(a_i)$$

The concept of probability emerges as a way to parametrise the behaviour of agents.



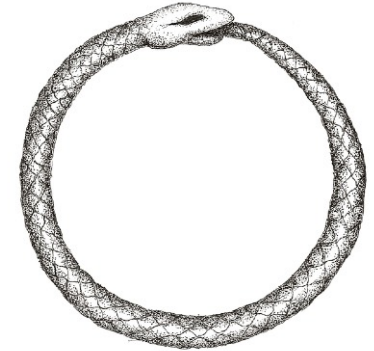
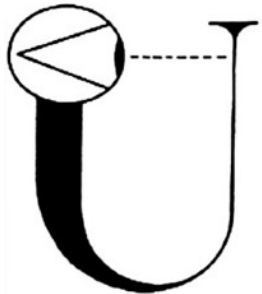
**(de' Finetti)** When repeating experiments, rational agents act *as if* there are objective (but unknown) probabilities to the outcomes.

Probability  $\neq$  Physical chance  
(agent) (physical theory)

**Confirmation-theoretic role of chances.** If theory T assigns a chance to event E higher than rival theories, and an agent observes E, then T is confirmed relative to the other theories.

**Confirmation-theoretic role of branch weight.** If theory T assigns a branch weight to event E higher than rival theories, and an agent observes E, then T is confirmed relative to the other theories.

## What is the place of *agents* in physics?



**An agent:** A person or a thing that takes an active role or produces a specified effect.

Emergent?

Methodological?

Alternate definition?

Fundamental?