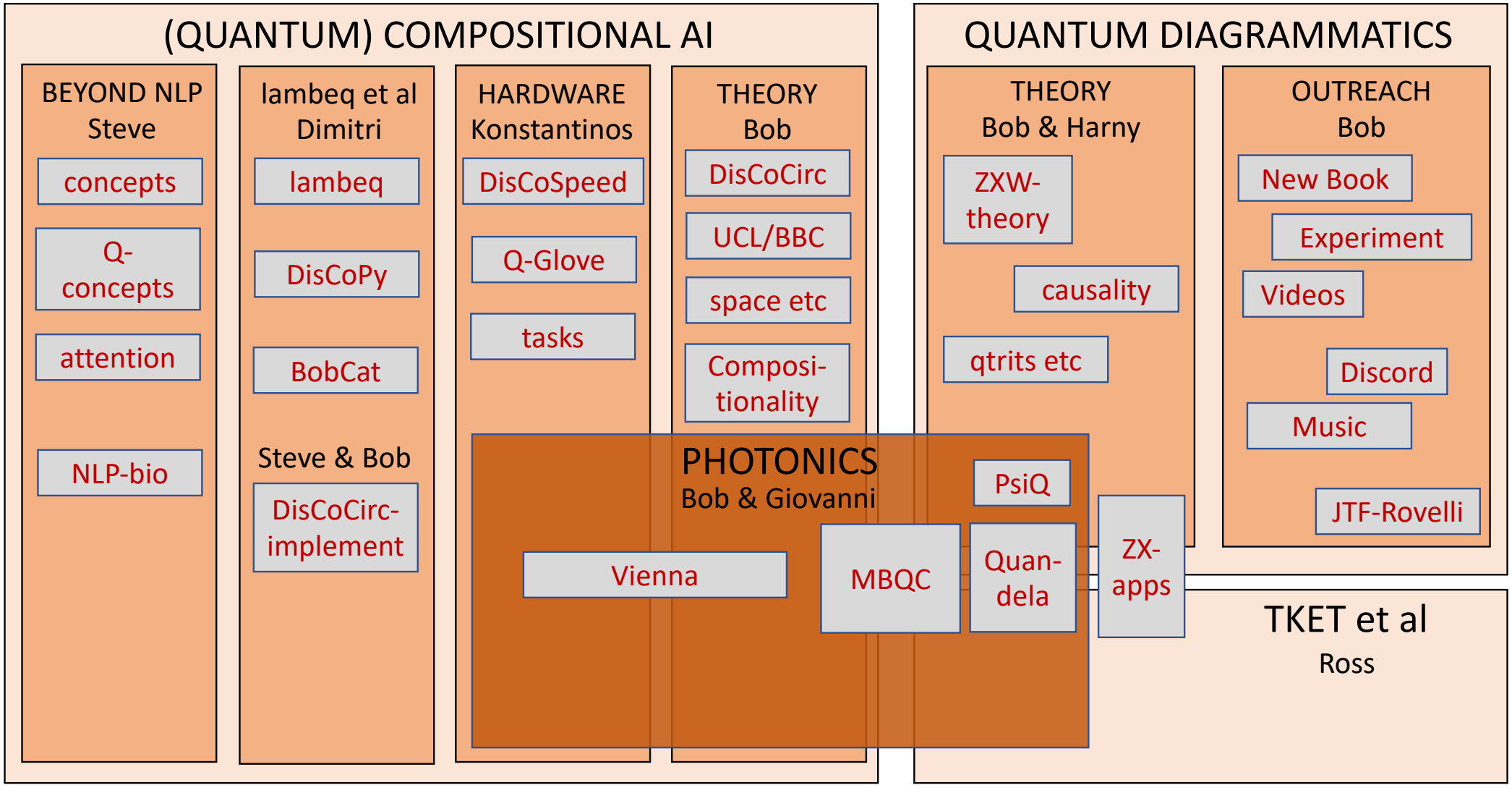
Bob Coecke

Quantinuum - Compositional intelligence

Oxford team

(QUANTUM) COMPOSITIONAL INTELLIGENCE



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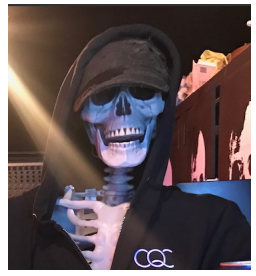
  - Practical compositional AI

what is compositionality?

there are different uses of the term!



Mathematics > Category Theory

[Submitted on 11 Oct 2021]

Compositionality as we see it, everywhere around us

Bob Coecke

There are different meanings of the term "compositionality" within science: what one researcher would call compositional, is not at all compositional for another researcher. The most established conception is usually attributed to Frege, and is characterised by a bottom-up flow of meanings: the meaning of the whole can be derived from the meanings of the parts, and how these parts are structured together.
Inspired by work on compositionality in quantum theory, and categorical quantum mechanics in particular, we propose the notions of Schrodinger, Whitehead, and complete compositionality. Accounting for recent important developments in quantum technology and artificial intelligence, these do not have the bottom-up meaning flow as part of their definitions.
Schrodinger compositionality accommodates quantum theory, and also meaning-as-context. Complete compositionality further strengthens Schrodinger compositionality in order to single out theories like ZX-calculus, that are complete with regard to the intended model. All together, our new notions aim to capture the fact that compositionality is at its best when it is `real', `non-trivial', and even more when it also is `complete'.
At this point we only put forward the intuitive and/or restricted formal definitions, and leave a fully comprehensive definition to future collaborative work.

Frege compositionality in formal linguistics:

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Meaning of a whole (cf. sentence) should only depend on meanings of its parts (cf. words) and how they are fitted together (cf. grammar).

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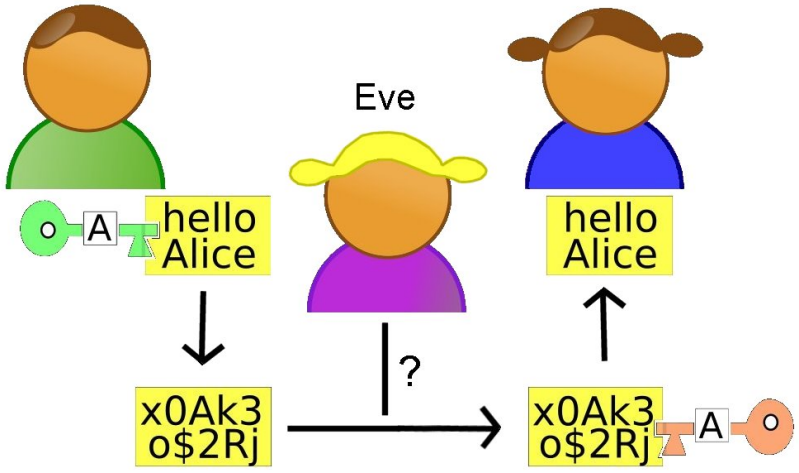
$\Longrightarrow$ top-down meaning flow

These Alice’s get easily disambiguated by context:



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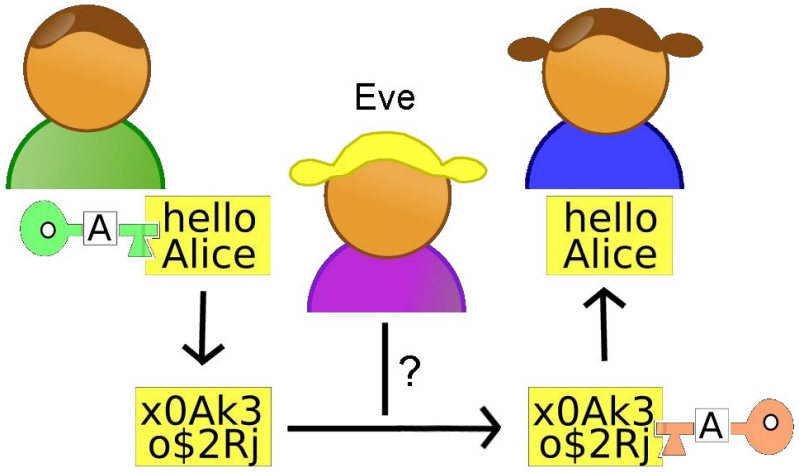

These Alice’s get less easy disambiguated by context:

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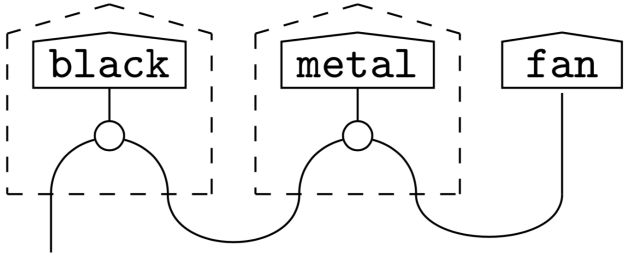
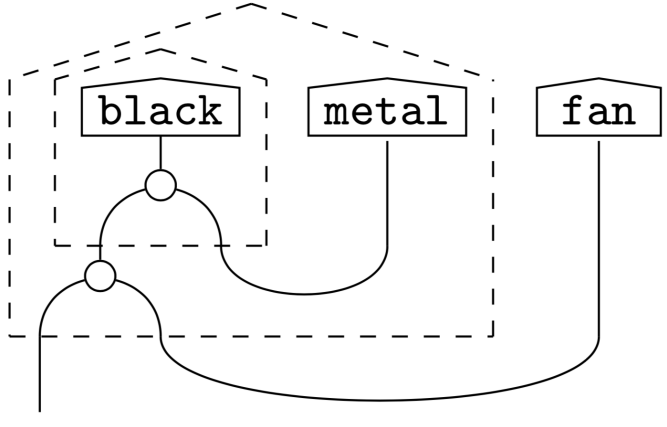
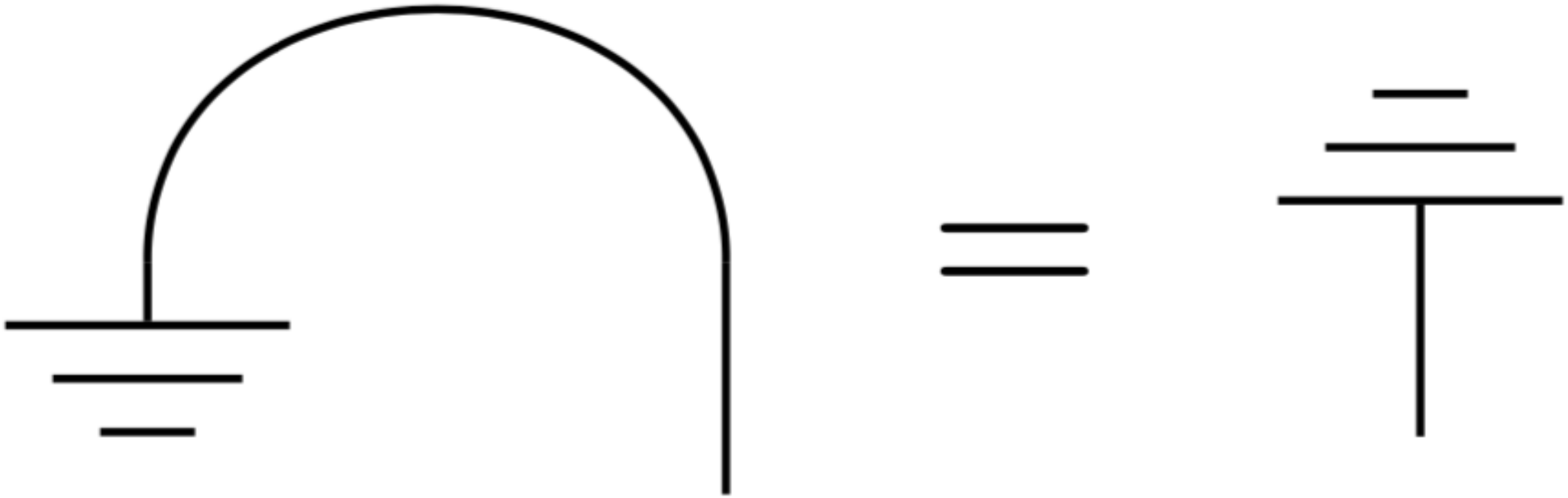
Respectively:





In quantum the situation is even worse e.g. Bell-state:



quantum industry use of quantum picturalism

circuit optim

optical MBQC

error-corr/surg

q-crypto

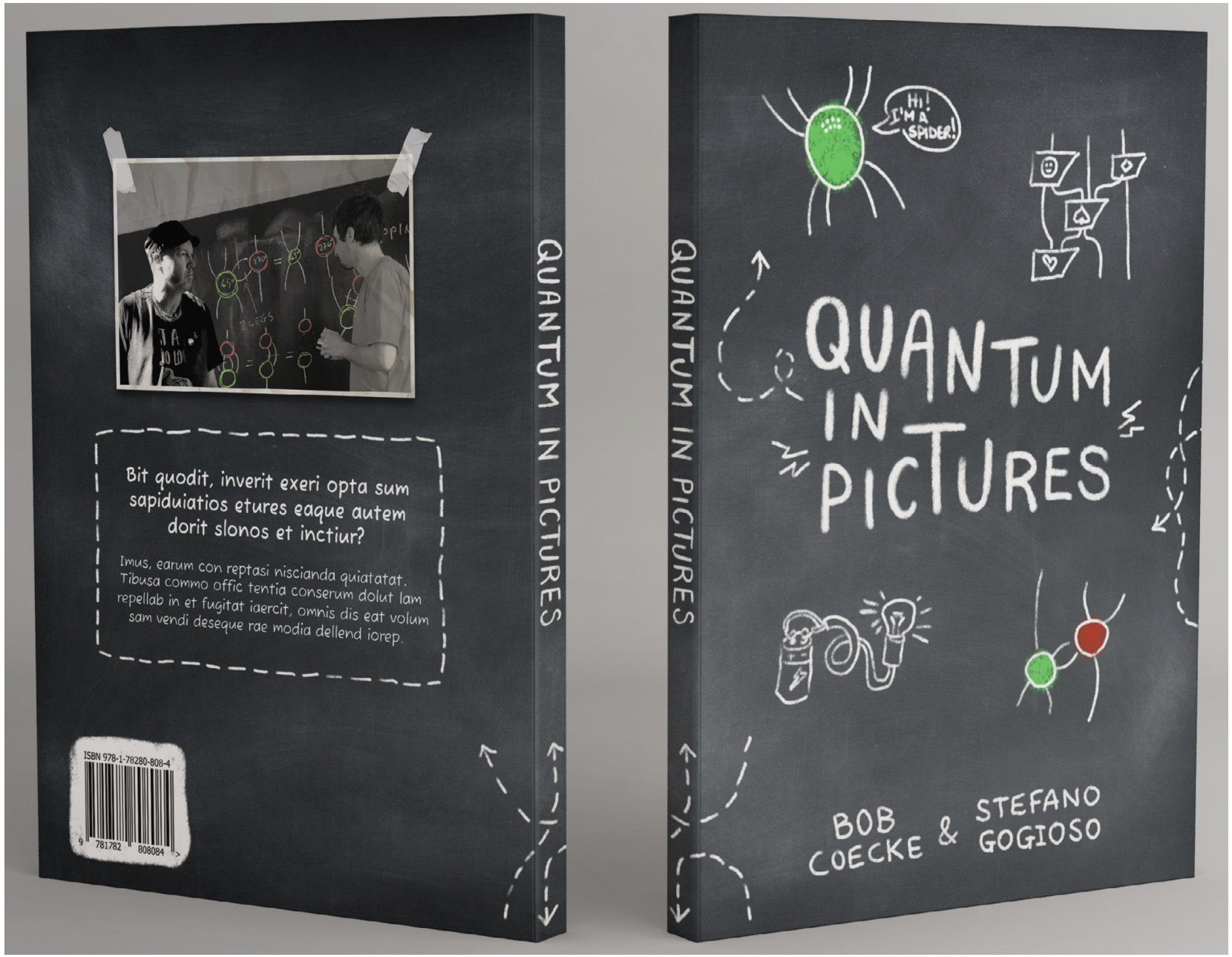
other

pro education

mass education

quantum AI

chem/bio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ISBN 978-1-78280-808-4
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QUANTUM IN PICTURES
HI! I'M A SPIDER!
QUANTUM IN PICTURES
BOB COECKE & STEFANO GOGIOSO


45°
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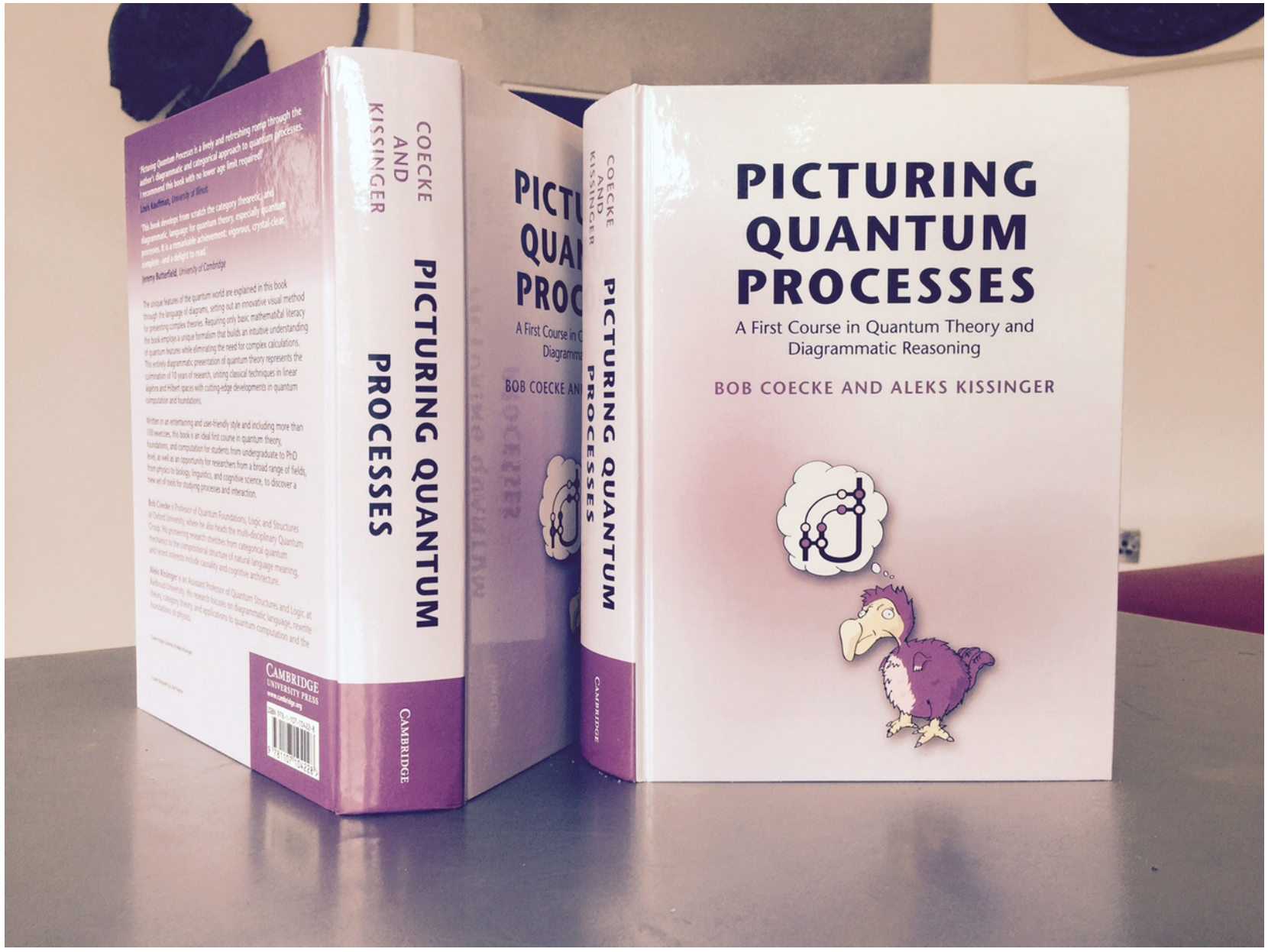
COECKE AND KISSINGER
PICTURING QUANTUM PROCESSES
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CAMBRIDGE UNIVERSITY PRESS
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PICTURING QUANTUM PROCESSES
A First Course in Quantum Theory and Diagrammatic Reasoning
BOB COECKE AND ALEKS KISSINGER

– process theory (from dodo-book) –

A *process theory* consists of:

- systems S represented by wires,
- processes P represented by boxes, with systems in S as inputs/outputs,
- composition of processes, represented by wirings, resulting in a process D.

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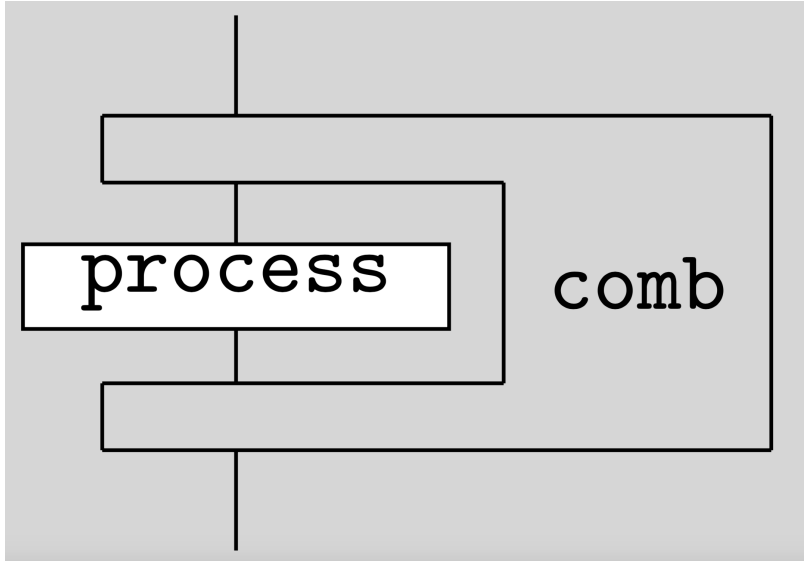
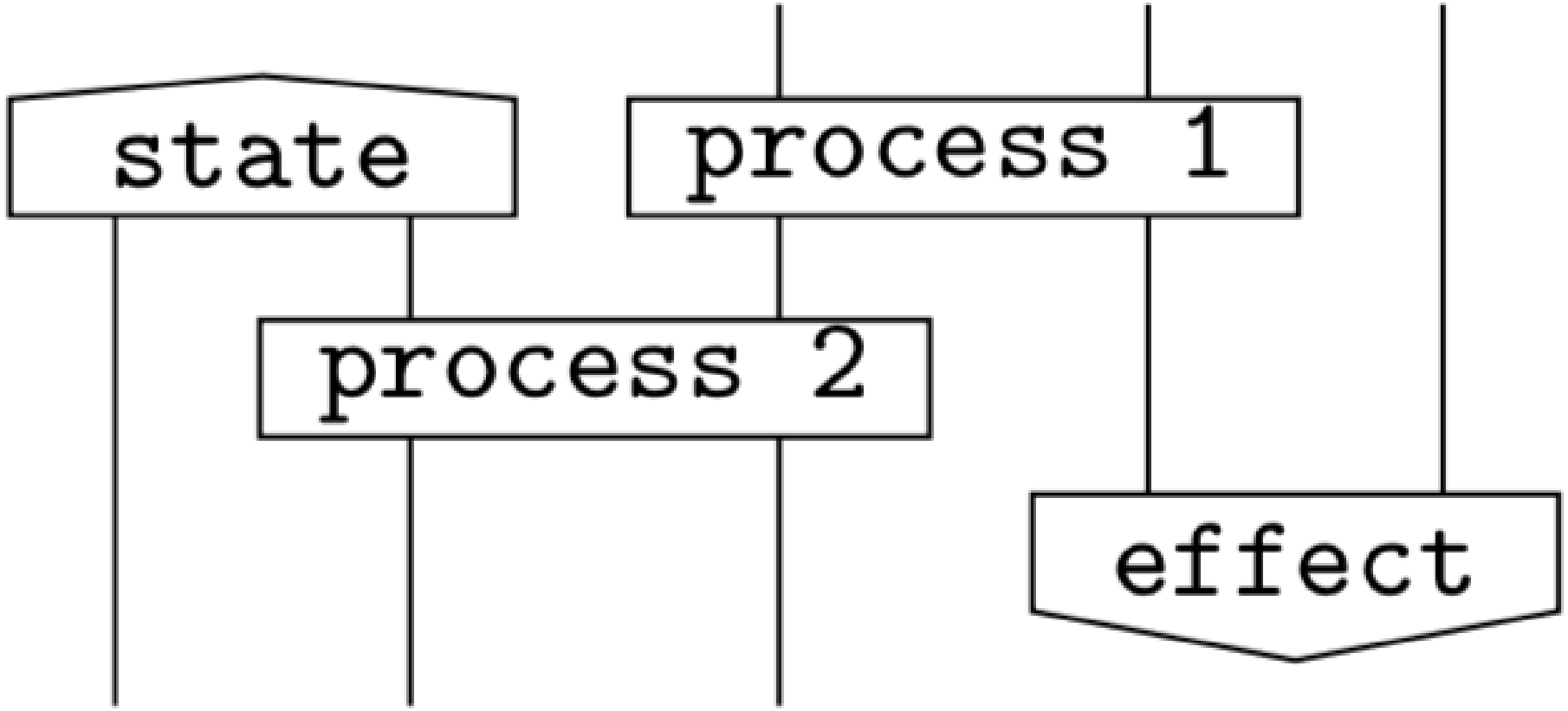
Could be generalised further e.g.:



A **Schrödinger compositional theory** is a process theory with diagrams:



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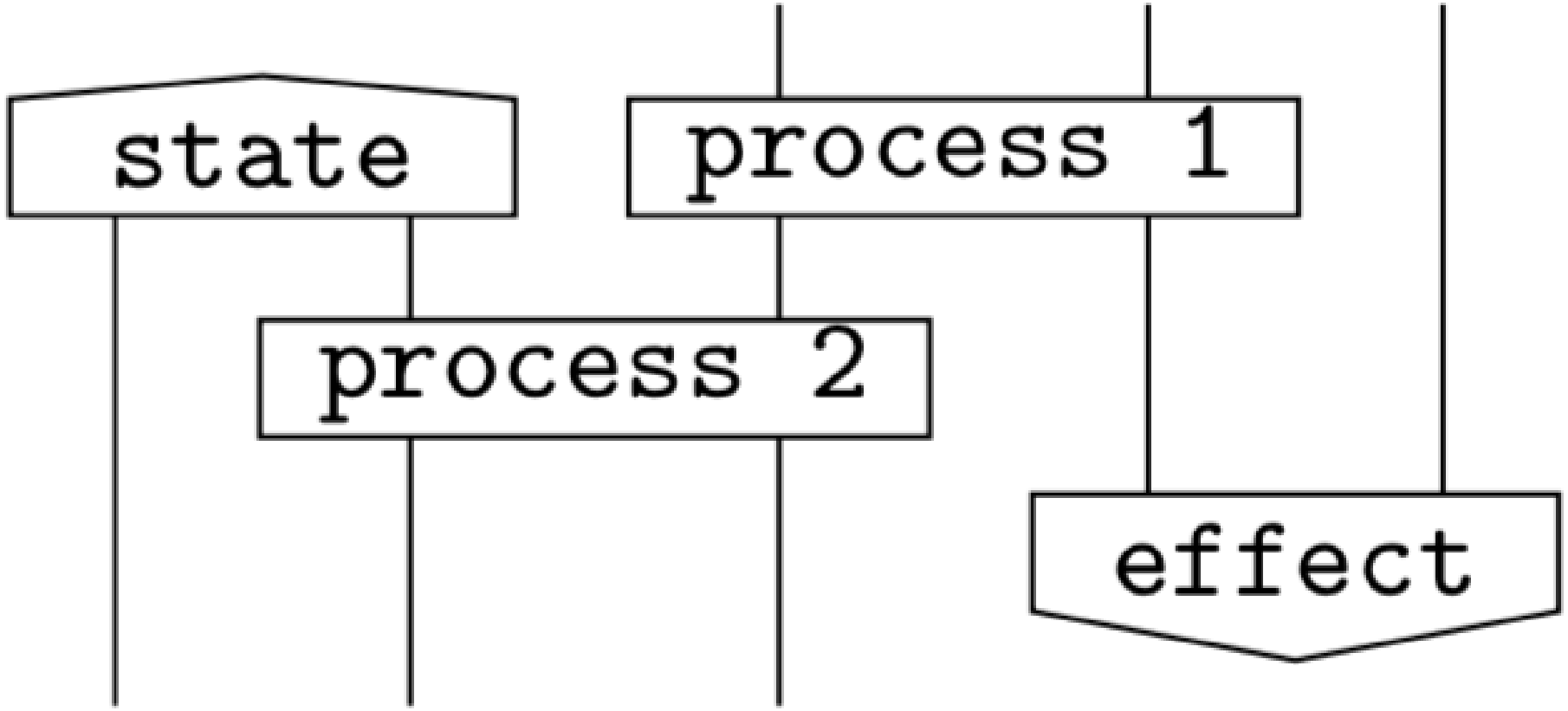

such that:

- Composition is non-trivial, i.e. a whole cannot be decomposed meaningfully.

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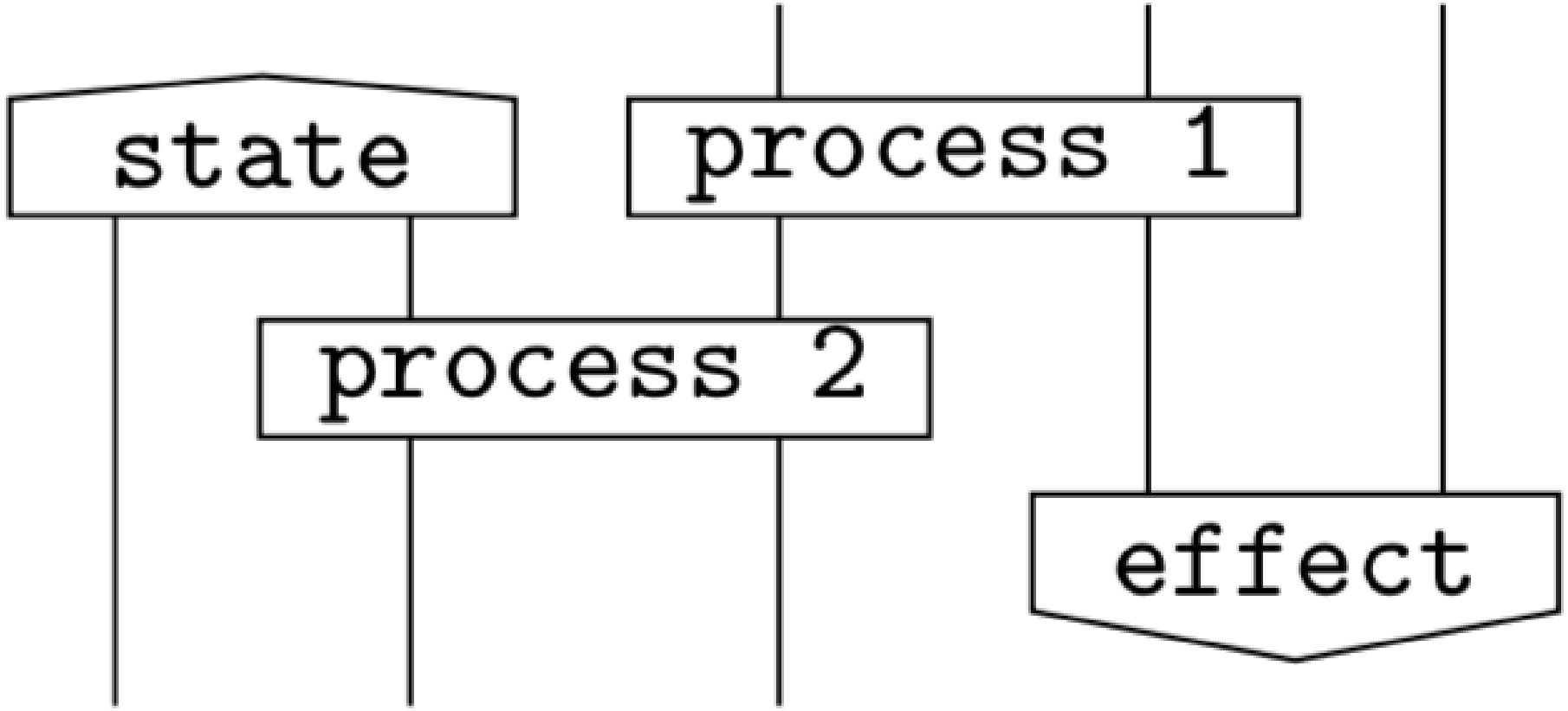
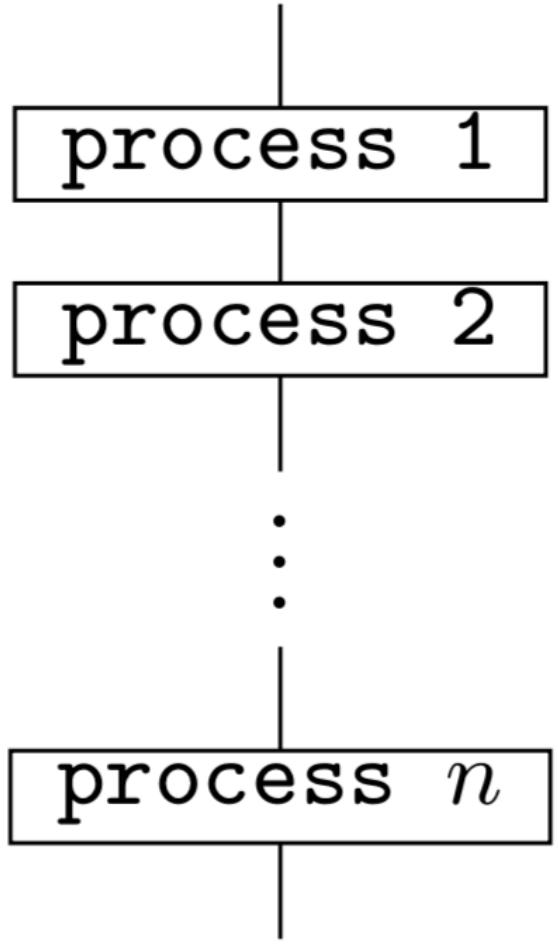


such that:

- Composition is non-trivial, i.e. a whole cannot be decomposed meaningfully.
- All ingredients have clear meaningful ontological counterparts in reality.

Whitehead-compositional theory is a process theory with diagrams:



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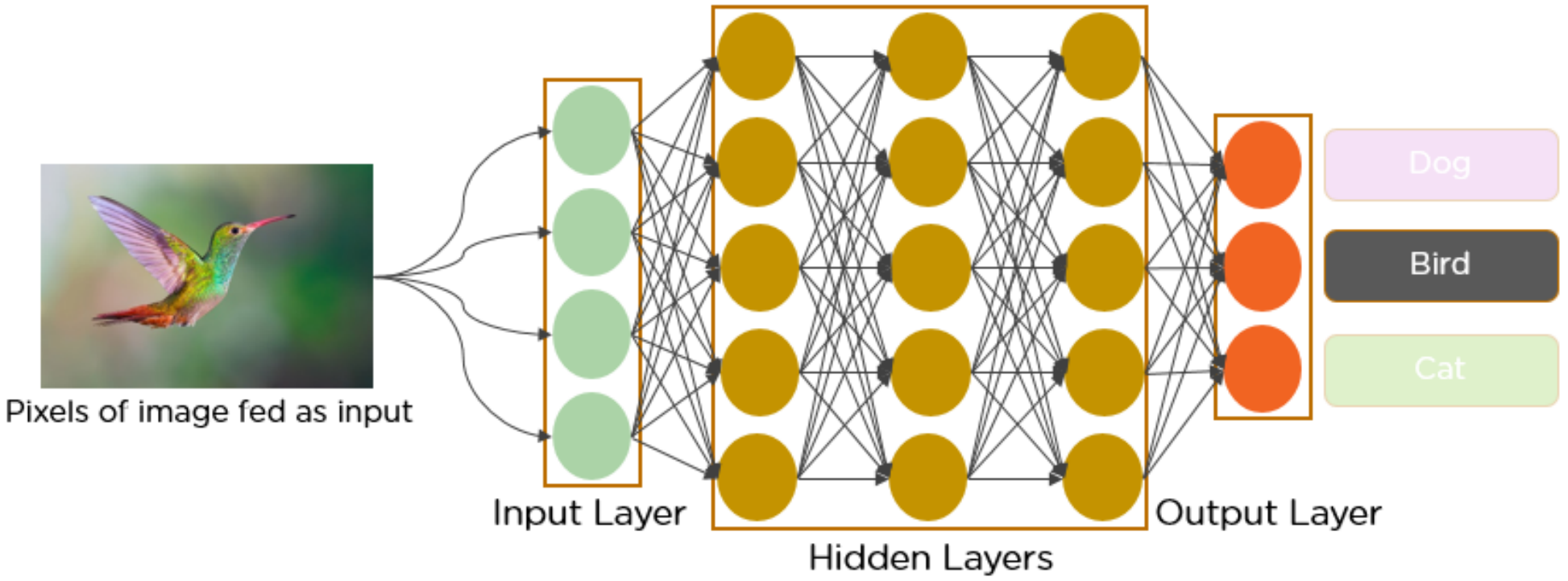
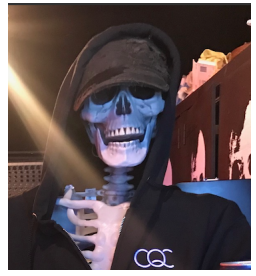
non-example:


Pixels of image fed as input
Input Layer
Hidden Layers
Output Layer
Dog
Bird
Cat

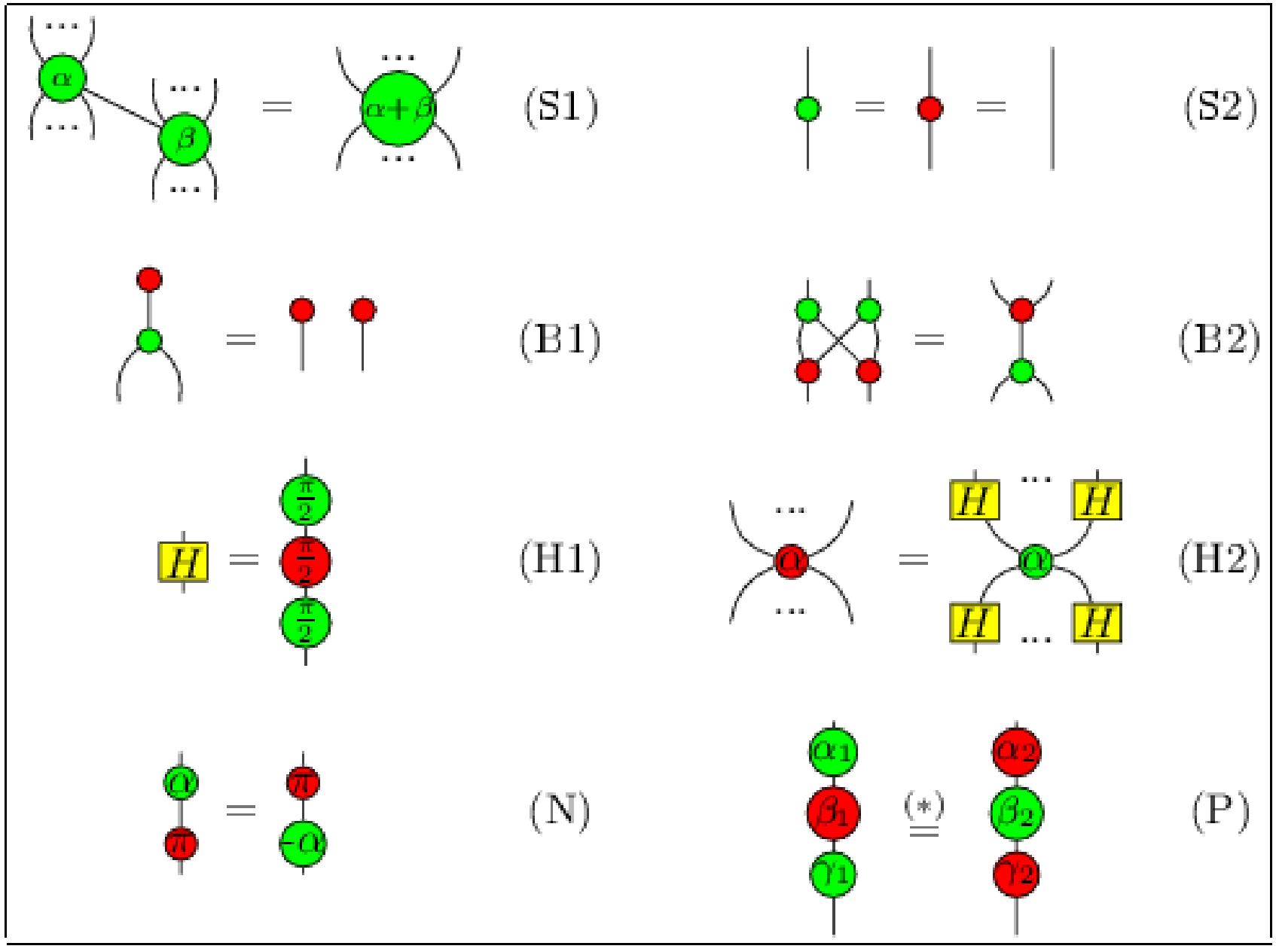
ZX-calculus, 2007

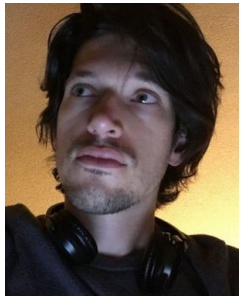
A graphical calculus for quantum observables

Bob Coecke and Ross Duncan
Oxford University Computing Laboratory

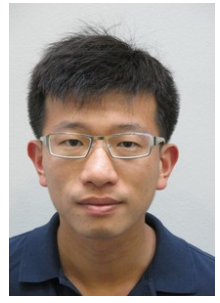
We present novel laws describing the interaction of a pair of mutually unbiased observables. These laws yield a diagrammatic calculus which enables matrix-free reasoning about quantum systems. To illustrate the elegance of this approach we establish some properties of standard quantum logic gates, compute the quantum Fourier transform and demonstrate equivalence between certain cluster state and quantum circuit computations.


α
β
α+β
(S1)
(S2)
(B1)
(B2)
H
π/2
π/2
π/2
(H1)
α
H
H
H
H
(H2)
α
π
π
-α
(N)
α1
β1
γ1
(*)
α2
β2
γ2
(P)

Everything!






Two complete axiomatisations of pure-state qubit quantum computing

Authors: Amar Hadzihasanovic, Kang Feng Ng, Quanlong Wang Authors Info & Claims

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Online: 09 July 2018 Publication History

Interacting Bialgebras Are Frobenius

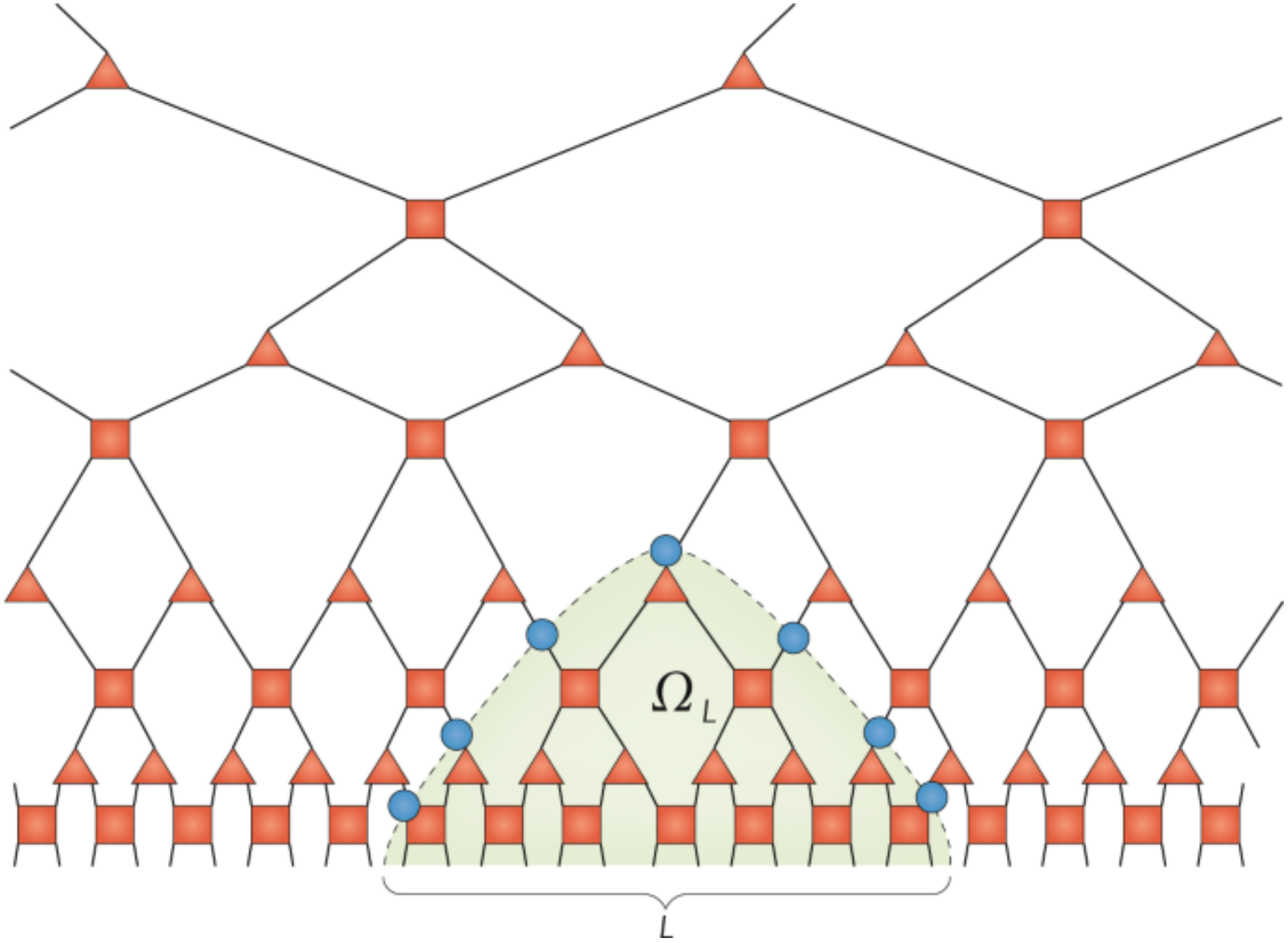
Filippo Bonchi[1], Paweł Sobociński[2], and Fabio Zanasi[1]

[1] ENS de Lyon, Université de Lyon, CNRS, INRIA, France
[2] University of Southampton, UK

Abstract. Bialgebras and Frobenius algebras are different ways in which monoids and comonoids interact as part of the same theory. Such theories feature in many fields: e.g. quantum computing, compositional semantics of concurrency, network algebra and component-based programming.

In this paper we study an important sub-theory of Coecke and Duncan's ZX-calculus, related to strongly-complementary observables, where two Frobenius algebras interact. We characterize its free model as a category of $\mathbb{Z}_2$-vector subspaces. Moreover, we use the framework of PROPs to exhibit the modular structure of its algebra via a universal construction involving span and cospan categories of $\mathbb{Z}_2$-matrices and distributive laws between PROPs. Our approach demonstrates that the Frobenius structures result from the interaction of bialgebras.

non-example:



summary:

- Whitehead compositionality
- Schrödinger compositionality
- Complete compositionality

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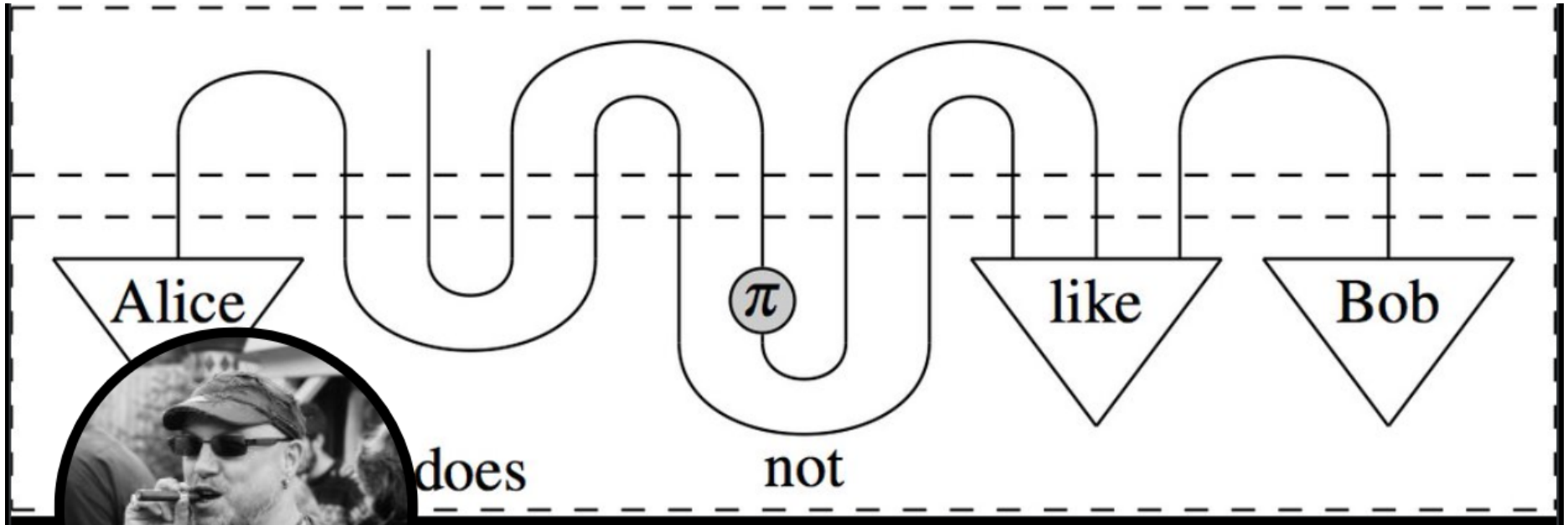
- LEGO compositionality



Edit profile

bOb cOeCke

@coecke

Chief Scientist @ CQ/Quantinuum
Ex Professor @ Oxford University (CS)
Emeritus Professor @ Wolfson College (Ox)