On Connections Between the Formal Science of Cognition and Quantum Computing (QC)

Selmer Bringsjord

Rensselaer AI & Reasoning (RAIR) Lab
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Cog Sci Colloquia Series
RPI Troy NY
Oct 16 2024; Oct 17 2024 in ILBAI

Dir.

Chief Scientist

version 1017241054NY

Two Erroneous Answers to the "Why Quantum Computing (QC)" Question, & The Right Answer

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Logic-&-AI In The News :)

This AI Pioneer Thinks AI Is Dumber Than a Cat

Yann LeCun, an NYU professor and senior researcher at Meta Platforms, says warnings about the technology's existential peril are 'complete B.S.'

Yann LeCun is an AI expert who thinks AI has a long way to go.

By Christopher Mims + Follow / *Photographs by Justin J Wee for WSJ*

Updated Oct 11, 2024 10:54 p.m. ET

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Only Logic Can Save Us

From Powerful-and-Autonomous AI & Robots

Making Morally Machines

incorruptible
invulnerable
courageous
self-aware
creative
wise
courteous
heroic
⋮

DRAFT

SB[1] • NSG • JL • AB

prelim version 1015242300NY

[1]Contact Author: Selmer.Bringsjord@gmail.com.

What's going on w/ DFT+ problem??

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Let's review, carefully …

I know nothing about hardware.

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Fortunately, the first logic programmer kicked off computer science, the formal science thereof, & logic-based AI, over two millennia ago — rather long before there was any hardware.

RPI Quantum Computing

Unveiling the IBM Quantum System One

Over the course of three days in April 2024, researchers, students, and industry experts from all over the world joined the greater RPI community for workshops, technical sessions, a live podcast recording, and a keynote address, all focused on the future of computing. The event culminated on April 5 with a ribbon-cutting ceremony revealing our IBM Quantum System One, the first to be housed on a university campus.

IA Quantum Ribbon-Cutting Highlight Video

Inscrutable :).

"Universal Computational Logic"

Logic Theorist
(birth of modern logicist AI)

350 BC

Euclid

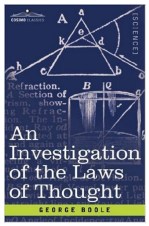
Organon

1666

Leibniz

$\int$

1854



1956

Simon

2023

2024

Quantum Computer @ RPI

The Singularity?

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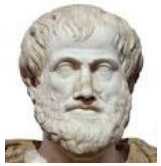

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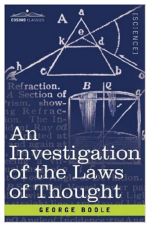

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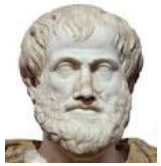

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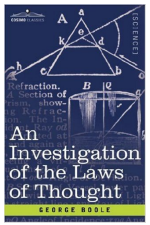

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The Singularity?

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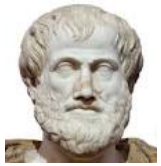

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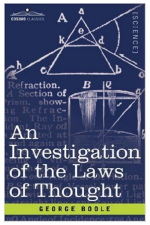

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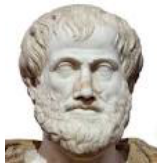

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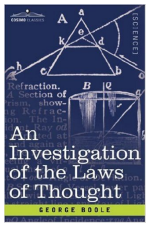

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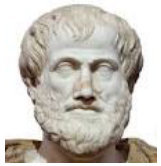

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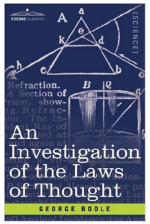

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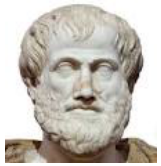

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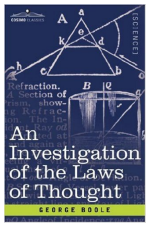

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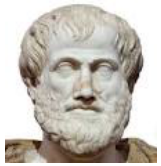

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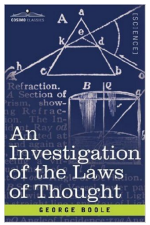

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Refines Leibniz & de-mystifies Euclid: the "compellingness" of his proofs consists in their being, at bottom, formal proofs in first-order logic (FOL).

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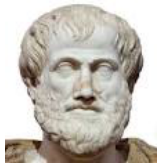

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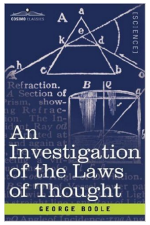

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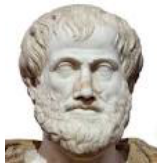

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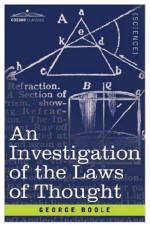

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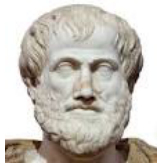

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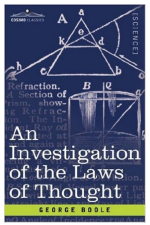

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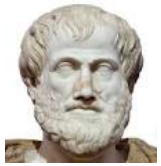

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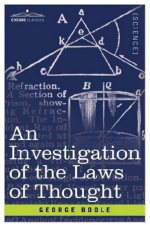

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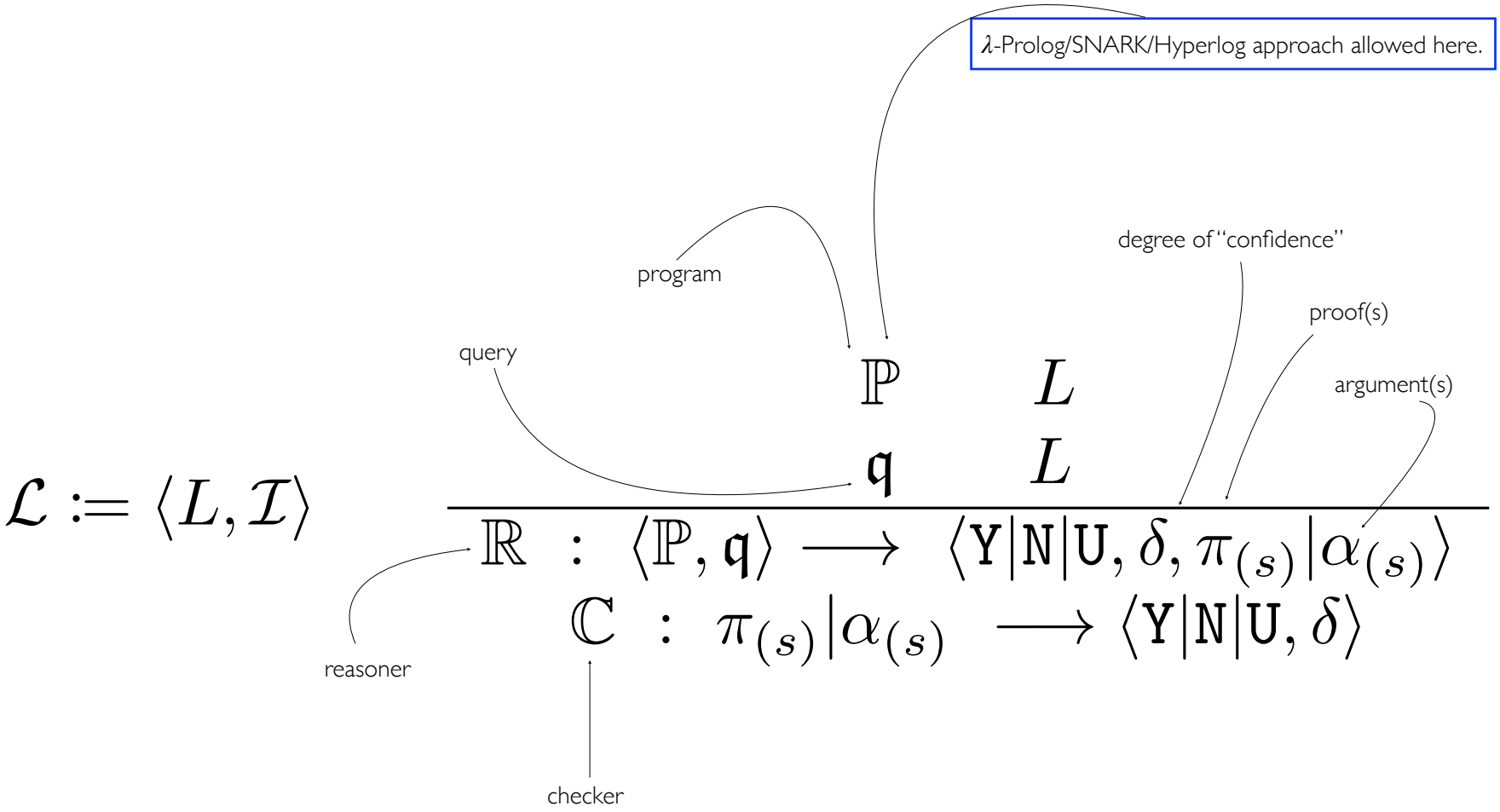
Post

Here's what a computer is, and given that, sorry, the *Entscheidungsproblem* can't be solved by such a machine!

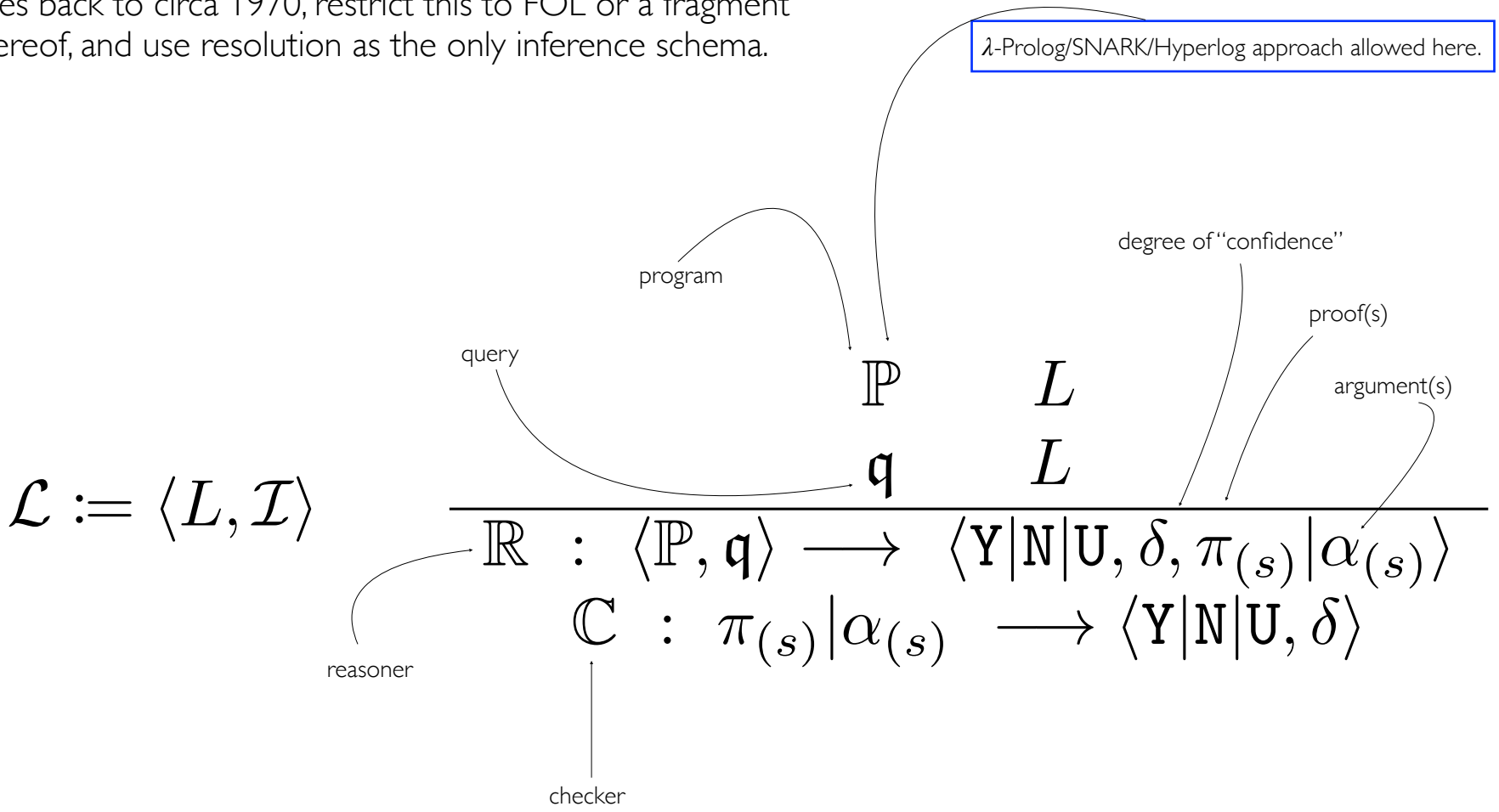
The Singularity?

(Pure General) Logic Programming …

$$\mathcal{L} := \langle L, \mathcal{I} \rangle \qquad \frac{\begin{array}{cc} \mathbb{P} & L \\ \mathfrak{q} & L \end{array}}{\begin{array}{c} \mathbb{R} \ : \ \langle \mathbb{P}, \mathfrak{q} \rangle \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta, \pi_{(s)} | \alpha_{(s)} \rangle \\ \mathbb{C} \ : \ \pi_{(s)} | \alpha_{(s)} \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta \rangle \end{array}}$$


λ-Prolog/SNARK/Hyperlog approach allowed here.
program
degree of "confidence"
proof(s)
query
argument(s)
reasoner
checker
$\mathcal{L} := \langle L, \mathcal{I} \rangle$
$\mathbb{P} \quad L$
$\mathfrak{q} \quad L$
$\mathbb{R} : \langle \mathbb{P}, \mathfrak{q} \rangle \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta, \pi_{(s)} | \alpha_{(s)} \rangle$
$\mathbb{C} : \pi_{(s)} | \alpha_{(s)} \longrightarrow \langle \mathtt{Y} | \mathtt{N} | \mathtt{U}, \delta \rangle$

For "logic programming" *simpliciter* and a vintage approach that goes back to circa 1970, restrict this to FOL or a fragment thereof, and use resolution as the only inference schema.



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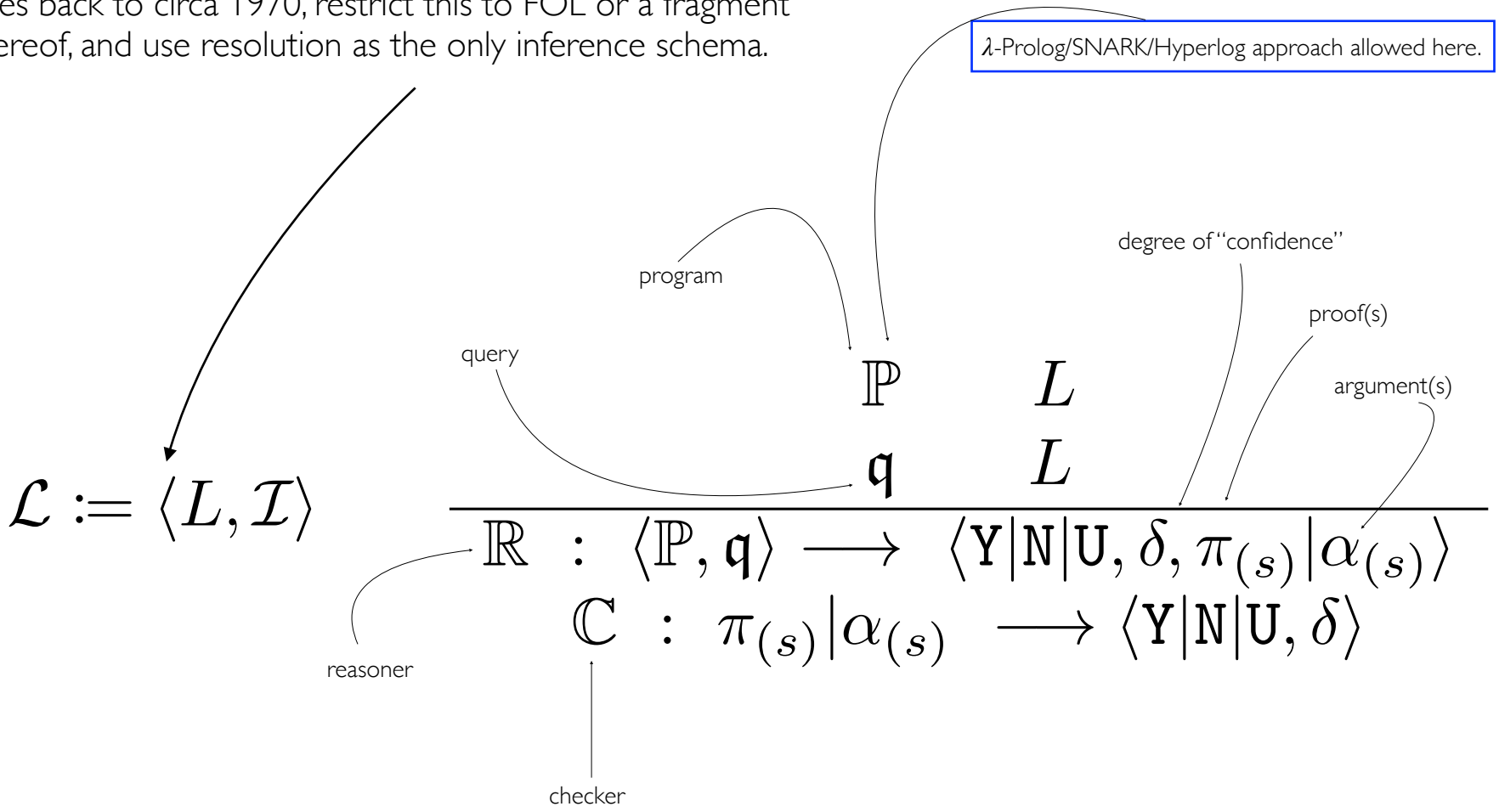

Why did we do/are we doing this? …

CogSci:AI/AGI

CogSci:AI/AGI

? ?

Google Quantum Has a Focus on CogSci:AI/AGI

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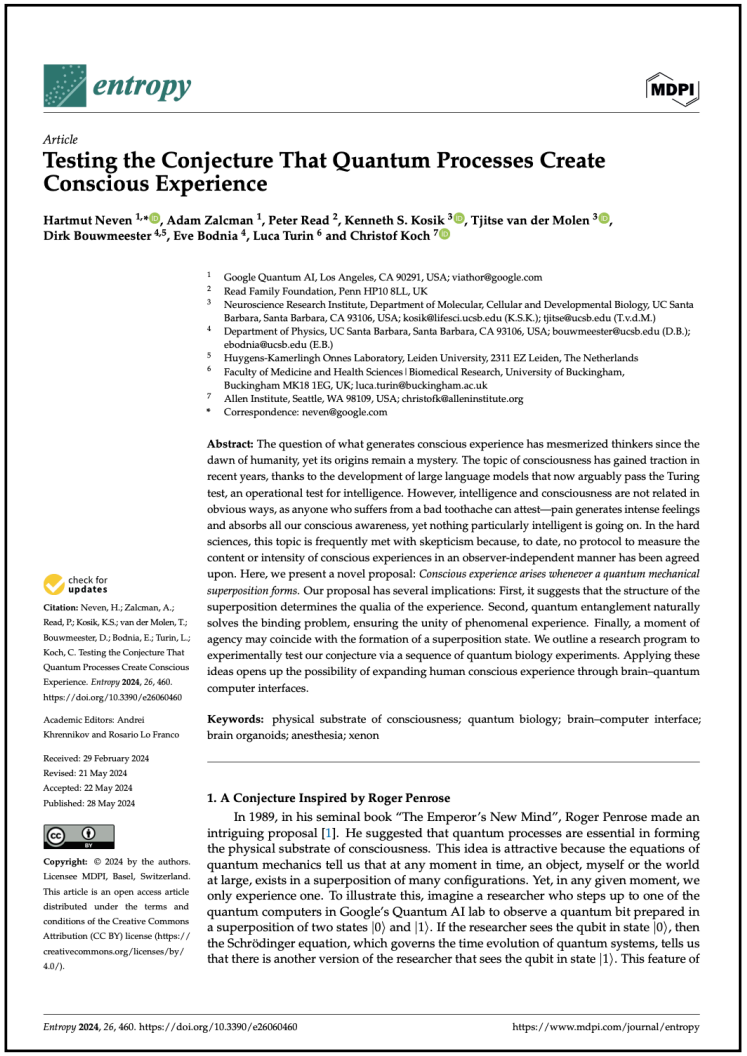

entropy

MDPI

Article

Testing the Conjecture That Quantum Processes Create Conscious Experience

Hartmut Neven [1,*], Adam Zalcman [1], Peter Read [2], Kenneth S. Kosik [3], Tjitse van der Molen [3], Dirk Bouwmeester [4,5], Eve Bodnia [4], Luca Turin [6] and Christof Koch [7]

1 Google Quantum AI, Los Angeles, CA 90291, USA; viathor@google.com
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3 Neuroscience Research Institute, Department of Molecular, Cellular and Developmental Biology, UC Santa Barbara, Santa Barbara, CA 93106, USA; kosik@lifesci.ucsb.edu (K.S.K.); tjitse@ucsb.edu (T.v.d.M.)
4 Department of Physics, UC Santa Barbara, Santa Barbara, CA 93106, USA; bouwmeester@ucsb.edu (D.B.); ebodnia@ucsb.edu (E.B.)
5 Huygens-Kamerlingh Onnes Laboratory, Leiden University, 2311 EZ Leiden, The Netherlands
6 Faculty of Medicine and Health Sciences | Biomedical Research, University of Buckingham, Buckingham MK18 1EG, UK; luca.turin@buckingham.ac.uk
7 Allen Institute, Seattle, WA 98109, USA; christofk@alleninstitute.org
* Correspondence: neven@google.com

Abstract: The question of what generates conscious experience has mesmerized thinkers since the dawn of humanity, yet its origins remain a mystery. The topic of consciousness has gained traction in recent years, thanks to the development of large language models that now arguably pass the Turing test, an operational test for intelligence. However, intelligence and consciousness are not related in obvious ways, as anyone who suffers from a bad toothache can attest—pain generates intense feelings and absorbs all our conscious awareness, yet nothing particularly intelligent is going on. In the hard sciences, this topic is frequently met with skepticism because, to date, no protocol to measure the content or intensity of conscious experiences in an observer-independent manner has been agreed upon. Here, we present a novel proposal: *Conscious experience arises whenever a quantum mechanical superposition forms.* Our proposal has several implications: First, it suggests that the structure of the superposition determines the qualia of the experience. Second, quantum entanglement naturally solves the binding problem, ensuring the unity of phenomenal experience. Finally, a moment of agency may coincide with the formation of a superposition state. We outline a research program to experimentally test our conjecture via a sequence of quantum biology experiments. Applying these ideas opens up the possibility of expanding human conscious experience through brain–quantum computer interfaces.

Keywords: physical substrate of consciousness; quantum biology; brain–computer interface; brain organoids; anesthesia; xenon

Citation: Neven, H.; Zalcman, A.; Read, P.; Kosik, K.S.; van der Molen, T.; Bouwmeester, D.; Bodnia, E.; Turin, L.; Koch, C. Testing the Conjecture That Quantum Processes Create Conscious Experience. *Entropy* **2024**, *26*, 460. https://doi.org/10.3390/e26060460

Academic Editors: Andrei Khrennikov and Rosario Lo Franco

Received: 29 February 2024
Revised: 21 May 2024
Accepted: 22 May 2024
Published: 28 May 2024

1. A Conjecture Inspired by Roger Penrose

In 1989, in his seminal book "The Emperor's New Mind", Roger Penrose made an intriguing proposal [1]. He suggested that quantum processes are essential in forming the physical substrate of consciousness. This idea is attractive because the equations of quantum mechanics tell us that at any moment in time, an object, myself or the world at large, exists in a superposition of many configurations. Yet, in any given moment, we only experience one. To illustrate this, imagine a researcher who steps up to one of the quantum computers in Google's Quantum AI lab to observe a quantum bit prepared in a superposition of two states $|0\rangle$ and $|1\rangle$. If the researcher sees the qubit in state $|0\rangle$, then the Schrödinger equation, which governs the time evolution of quantum systems, tells us that there is another version of the researcher that sees the qubit in state $|1\rangle$. This feature of

Why did we do/are we doing this? …

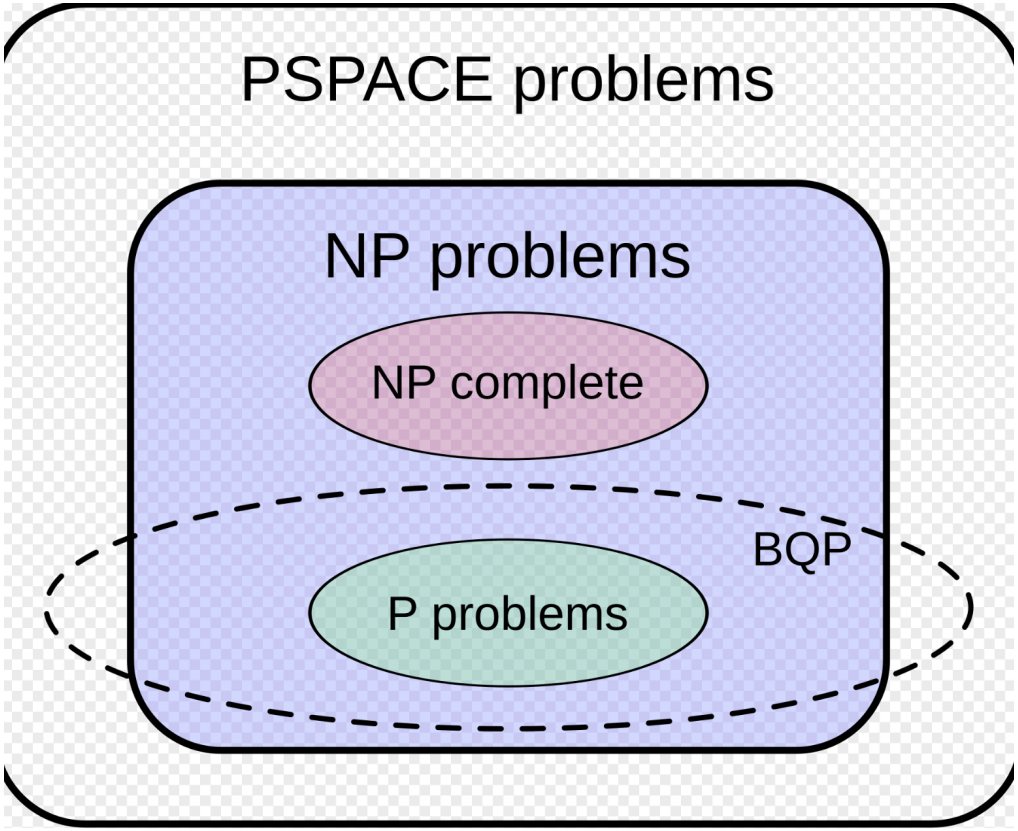
Scott Aaronson Says Complexity Theory is 'Inextricable' from Quantum Computing

Qiskit · Follow
Published in Qiskit · 9 min read · Aug 2, 2022

By Robert Davis, Technical Writer, IBM Quantum and Qiskit.

Researchers believe quantum computers will soon be able to solve certain problems more efficiently than classical computers. To measure and classify those efficiency gains, we rely on computational complexity theory, a branch of computer science that centers on measuring and comparing the computational effort that goes into solving different kinds of problems. Complexity theory gives us a useful shorthand for describing the various speedups and problem classes we encounter in computing, but it's also much more than that. In fact, at least one leading expert argues that without complexity theory, we wouldn't have quantum computing at all.

Initial Landscape for Science of Cognition/Intelligence



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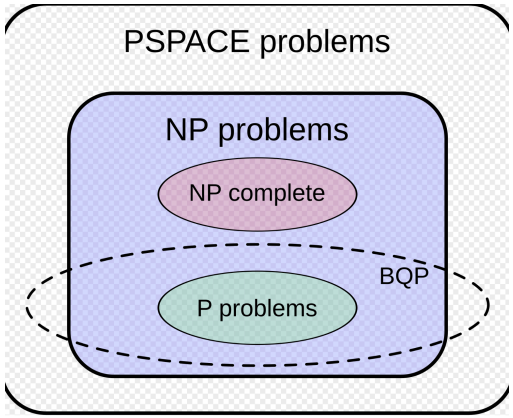

What is it ≈?

TAUT, near and dear to our HyperLogic-al hearts, is Co**NP**-complete. Hands on …

The set Σ_2^P is a nice portal to **PH**.

And a nice portal to this set of languages is MIN-EQUIV-DNF, which as a matter of fact is Σ_2^P-complete:

$\{\langle \phi, k \rangle : \exists$ DNF ψ of size $\leq k$ equivalent to DNF formaula $\phi\}$

Hands on …

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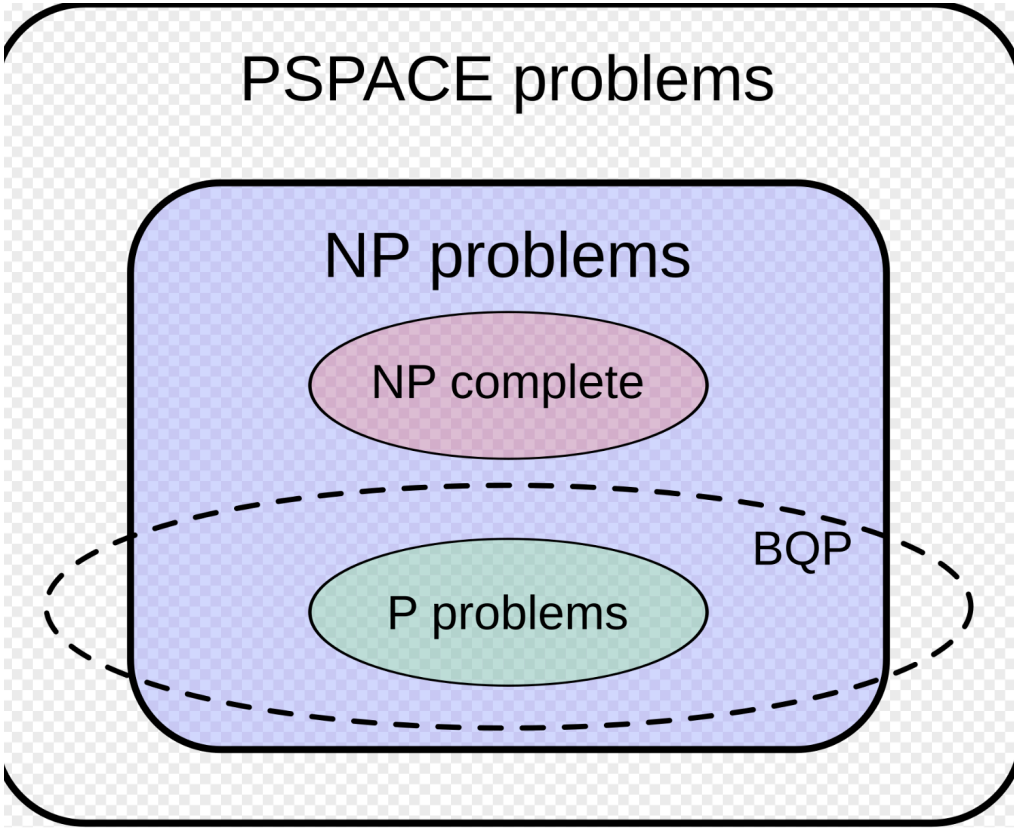
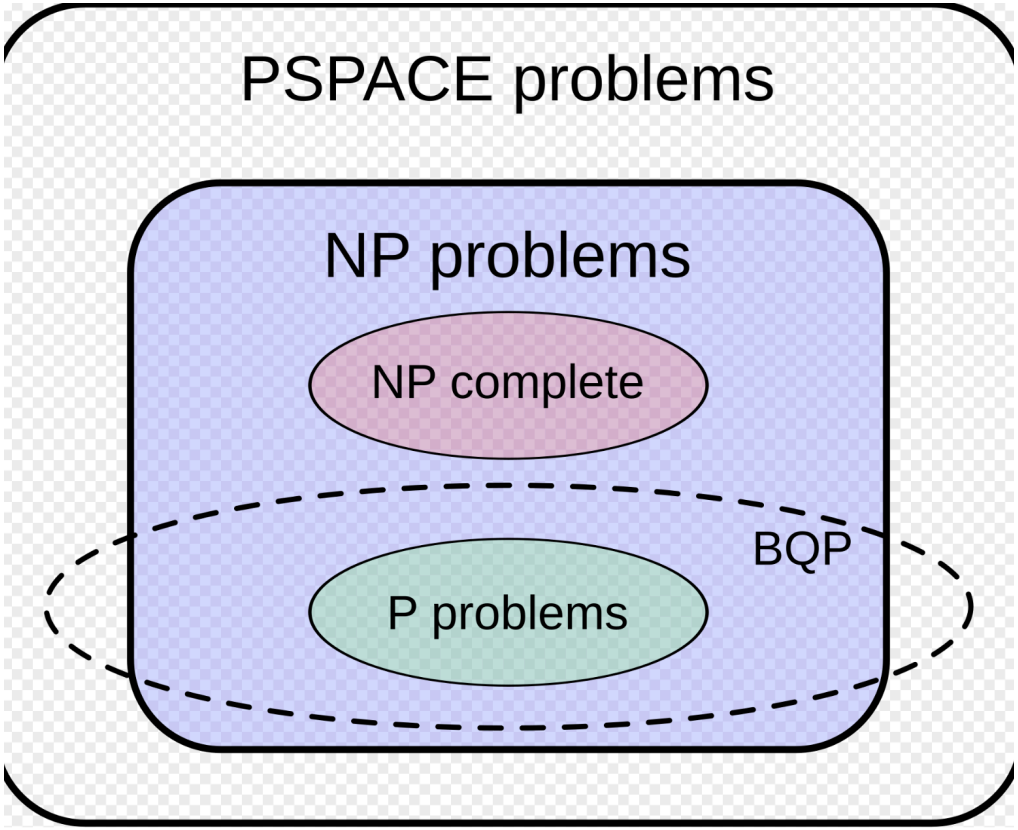
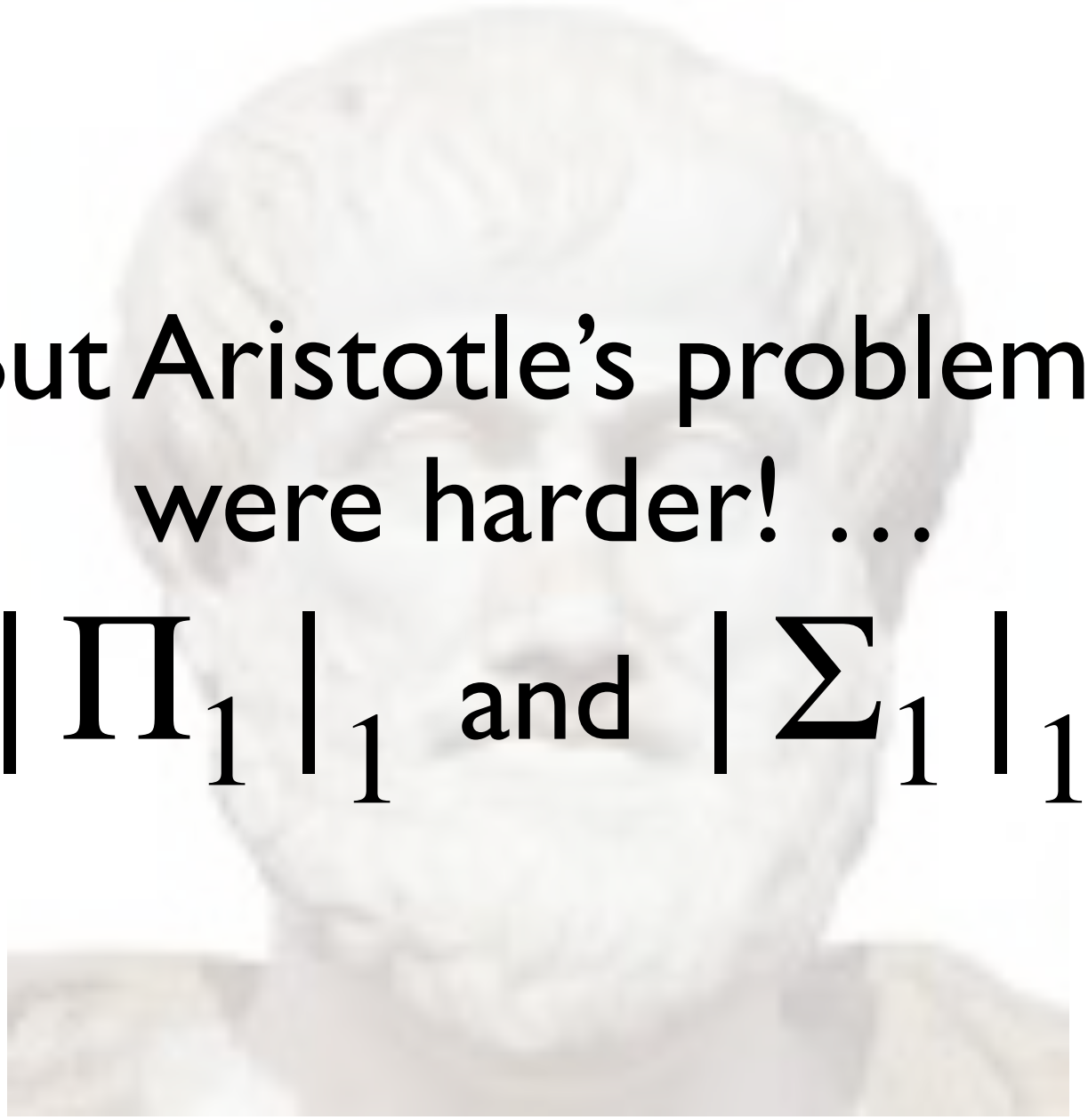


Initial Landscape for Science of Cognition/Intelligence





But Aristotle's problems were harder! …

$|\Pi_1|_1$ and $|\Sigma_1|_1$

Two Proposed Arguments; Valid?

- All mammals walk.
- Whales are mammals.
- Therefore:
- Whales walk.

- All of the Frenchmen in the room are wine-drinkers.
- Some of the wine-drinkers in the room are gourmets.
- Therefore:
- Some of the Frenchmen in the room are gourmets.

Two Proposed Arguments; Valid?

- All mammals walk. $\forall x[M(x) \rightarrow W(x)]$
- Whales are mammals. $\forall x(Wh(x) \rightarrow M(x))$
- Therefore:
- Whales walk.

  $\forall x(Wh(x) \rightarrow W(x))$

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- Therefore:
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$\forall x(Wh(x) \rightarrow W(x))$

- All of the Frenchmen in the room are wine-drinkers. $\forall x(F(x) \rightarrow W(x))$
- Some of the wine-drinkers in the room are gourmets. $\exists x(W(x) \wedge G(x))$
- Therefore:
- Some of the Frenchmen in the room are gourmets.

$\exists x(F(x) \wedge G(x))$

Two Proposed Arguments; Valid?

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- Whales are mammals. $\forall x(Wh(x) \rightarrow M(x))$
- Therefore:
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$\forall x(Wh(x) \rightarrow W(x))$

- All of the Frenchmen in the room are wine-drinkers. $\forall x(F(x) \rightarrow W(x))$

$\forall x(F(x) \rightarrow W(x))$ • `(forall (x) (if (F x) (W x)))`

- Some of the wine-drinkers in the room are gourmets.

$\exists x(W(x) \wedge G(x))$

- Therefore:
- Some of the Frenchmen in the room are gourmets.

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$\forall x(F(x) \rightarrow W(x))$ • `(forall (x) (if (F x) (W x)))`

- Some of the wine-drinkers in the room are gourmets.

$\exists x(W(x) \wedge G(x))$

$\exists x(W(x) \wedge G(x))$ • `(exists (x) (and (W x) (G x)))`

- Therefore:
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$\exists x(F(x) \wedge G(x))$

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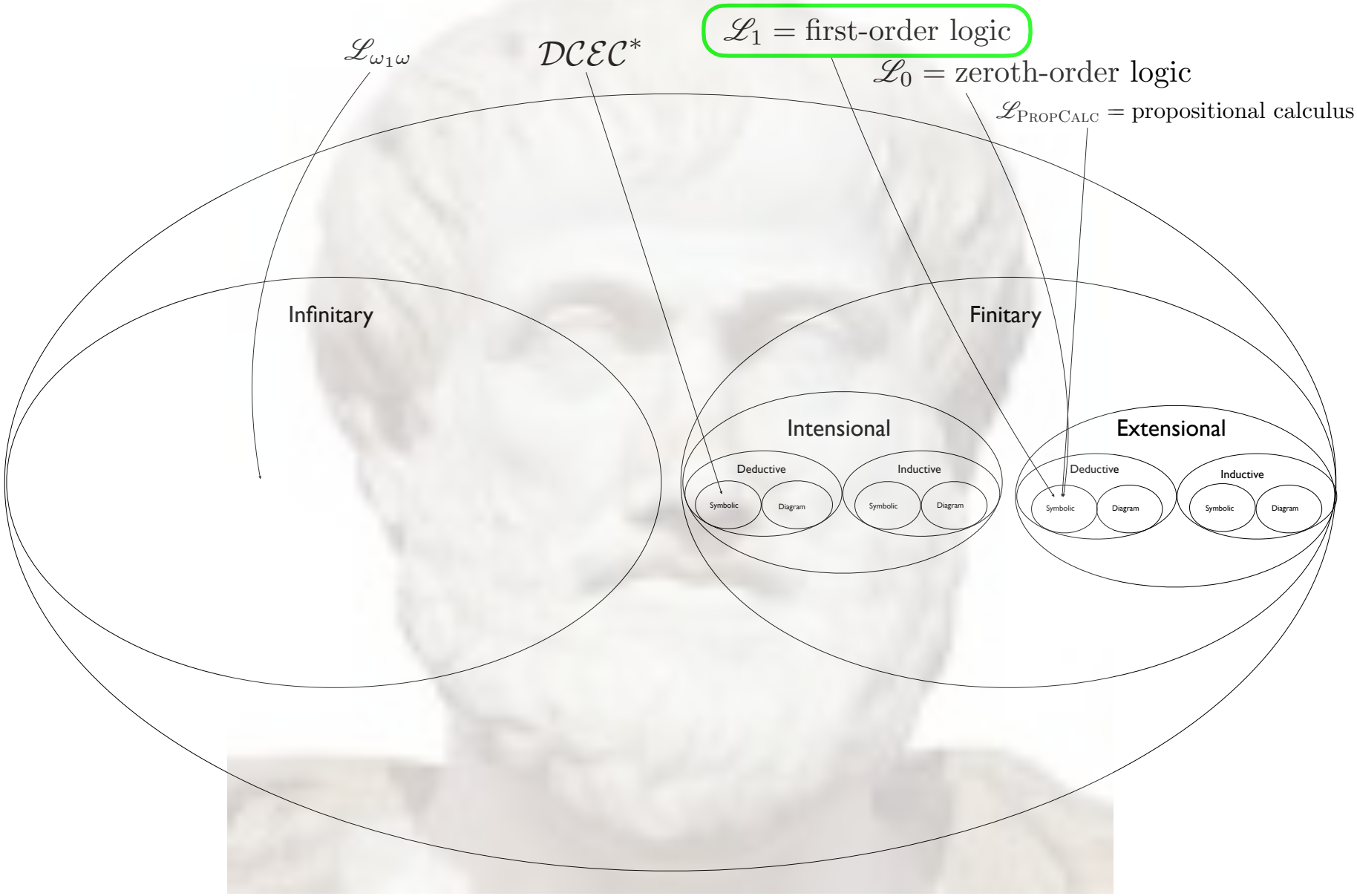
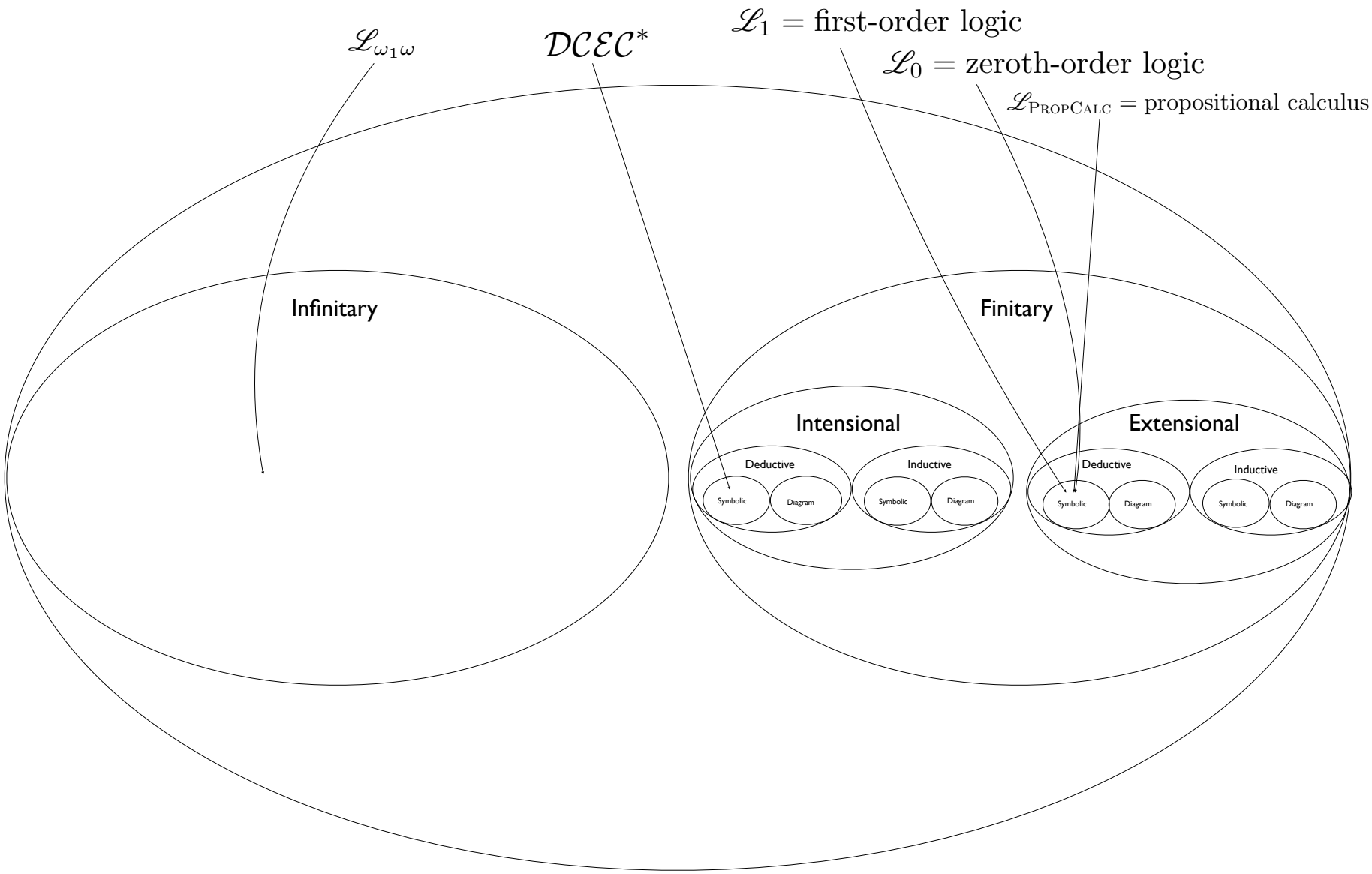
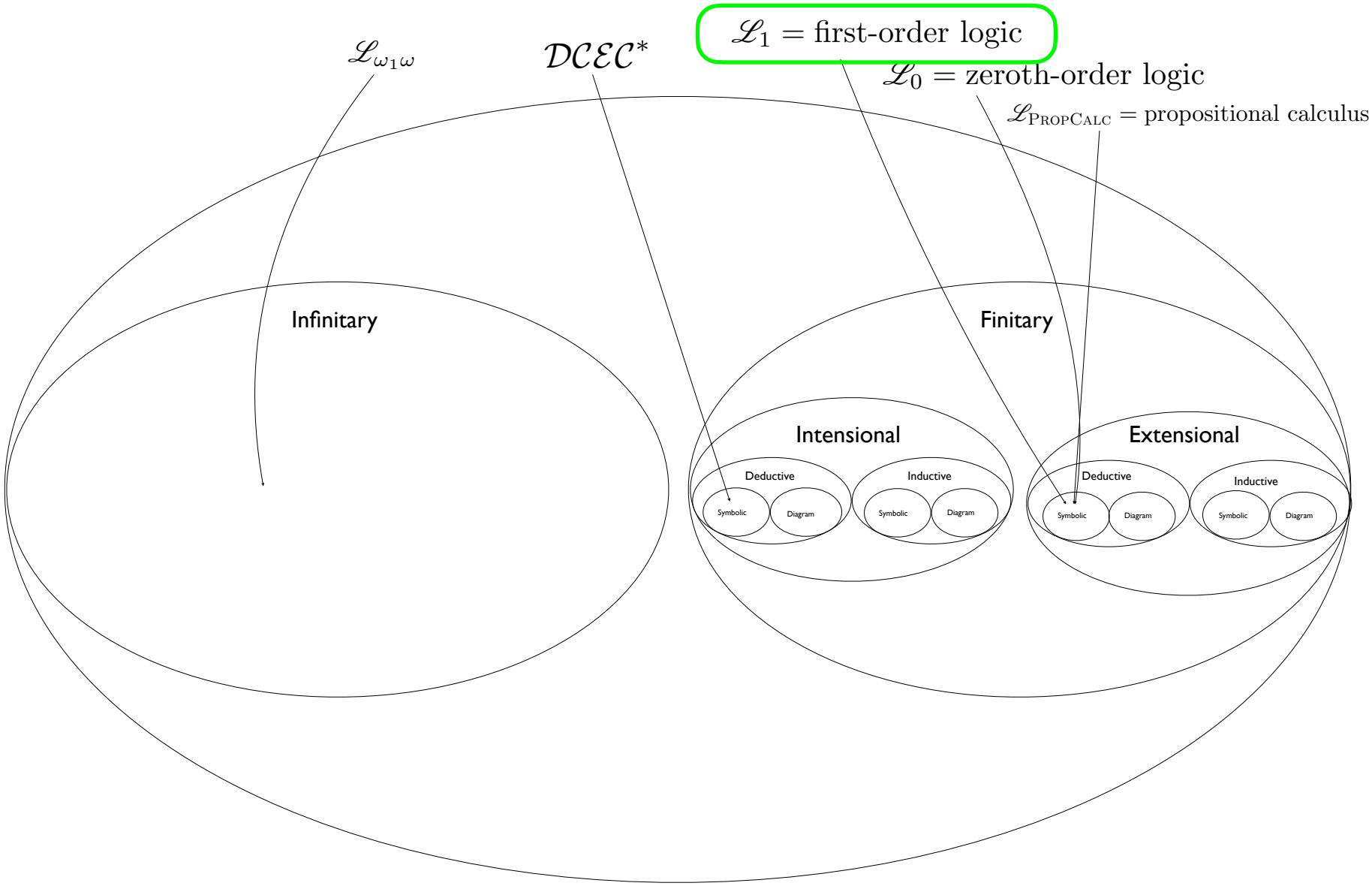
The Universe of Logics



The Universe of Logics



The Universe of Logics



REASONING RESEARCH GROUP

About News AWIL Current research People Research projects Resources RRG meetings Polish

Deductive Flexibility Test

Natalia Żyluk, Mikołaj Michta & Mariusz Urbański (2017). Yet Another Shade of Deduction. On measuring deductive flexibility and how it may relate to other cognitive abilities, *Logic and Logical Philosophy*, DOI

DFT has been developed to account empirically for different ways of understanding the concept of deduction in psychological vs logical traditions. In DFT items the task is to choose all and only these combinations of premises which justify the conclusion. Solving this kind of problem requires deductive reasoning skills as well as specific kind of "flexibility", understood as the ability to switch between different sets of premises that potentially entail a given conclusion and to think about multiple sets of premises simultaneously. In order to grasp the cognitive characteristics highlighted above, we propose the notion of deductive flexibility. We developed Deductive Flexibility Test: a reliable instrument which can be used for research purposes.

IV (1) Some psoats are sneems.
(2) Every sneem is a psoat.
(3) Some sneems are non-psoats.
(4) This is not the case that no sneem is a psoat.
(5) This is not the case that no psoat is a sneem.

Some sneems are psoats.

Answer: _____

simultaneously. In order to grasp the cognitive characteristics highlighted above, we propose the notion of deductive flexibility. We developed Deductive Flexibility Test: a reliable instrument which can be used for research purposes.

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Answer: _____

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~~All~~ ard

3 1-place/unary relations; 1 occurrence of each.
1 2-place relation; 1 occurrence thereof

All apples that like some pears are enormous..

$$\forall x((Ax \wedge \exists y(Lxy \wedge Py)) \rightarrow Ex)$$

✓ 2Q

2Q

There are

Some Yankee fans who respect all Met fans and are hyper-kind.

(-unary) (binary) (-unary) (-unary)

$$\exists x[Yx \wedge (\forall y(Rxy \quad My)) \wedge \rightarrow Hx]$$

Naveen took ∃x$ seconds

$$\exists x[Yx \wedge \forall y(My \rightarrow Rxy) \wedge HKx]$$

Karkooking Problem (J-L Variant) …

Everyone karkooks anyone who karkooks someone.

Alvin karkooks Bill.

Can you infer that everyone karkooks Bill?

ANSWER:

JUSTIFICATION:

Analytical Hierarchy

Arithmetical Hierarchy

Entscheidungsproblem

Mere Calculative Cognitive Power

Exponential Hierarchy

Analytical Hierarchy

Arithmetical Hierarchy

Entscheidungsproblem

Polynomial Hierarchy

Exponential Hierarchy

Analytical Hierarchy

Arithmetical Hierarchy

Entscheidungsproblem

Polynomial Hierarchy

Exponential Hierarchy

$$\mathbf{P} \subseteq \mathbf{NP} \subseteq \mathbf{PSPACE} = \mathbf{NPSPACE} \subseteq \mathbf{EXPTIME} \subseteq \mathbf{NEXPTIME} \subseteq \mathbf{EXPSPACE}$$

Analytical Hierarchy

Arithmetical Hierarchy

$\vdots$

Π_2

Σ_2

Π_1

Σ_1

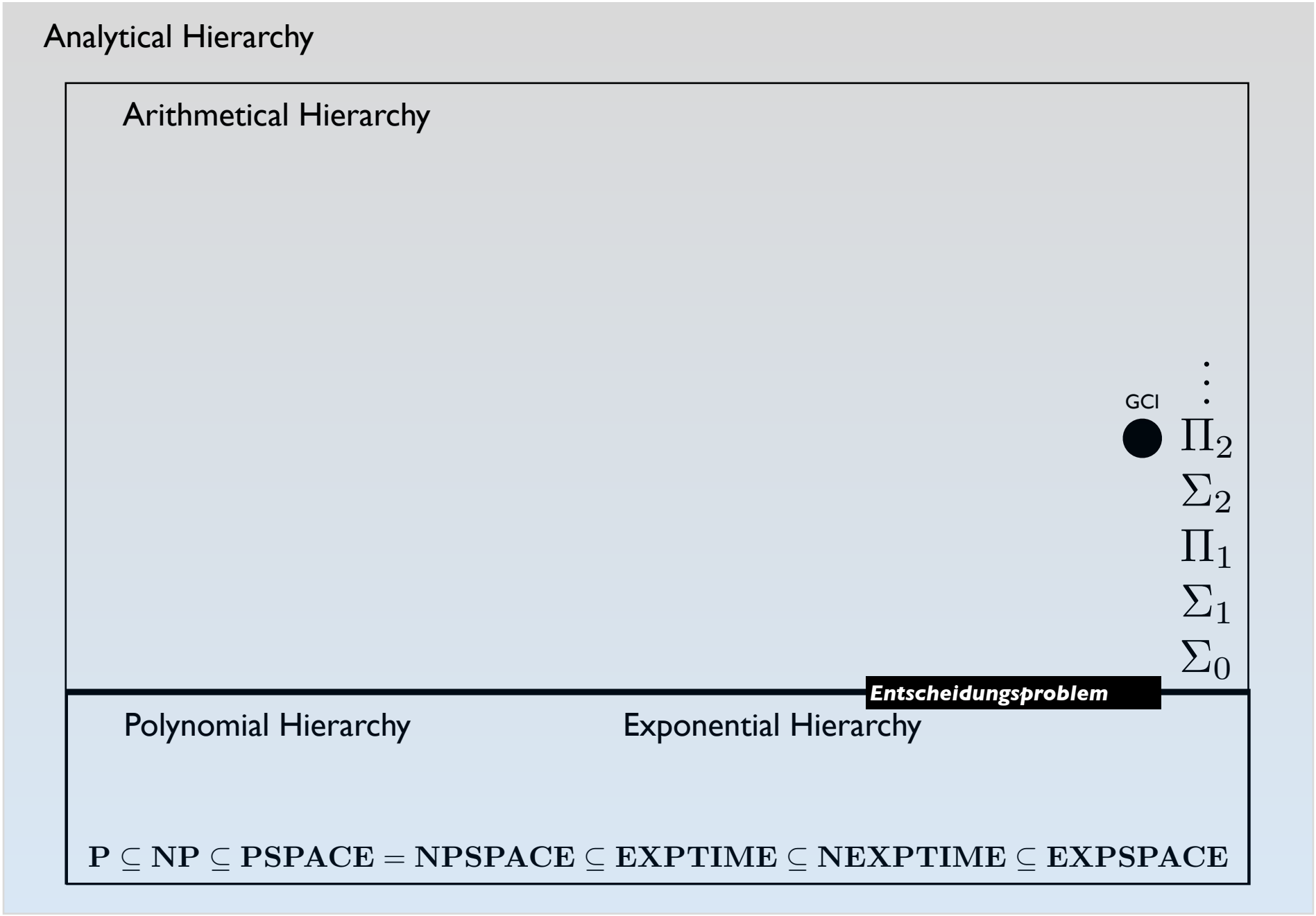
Σ_0

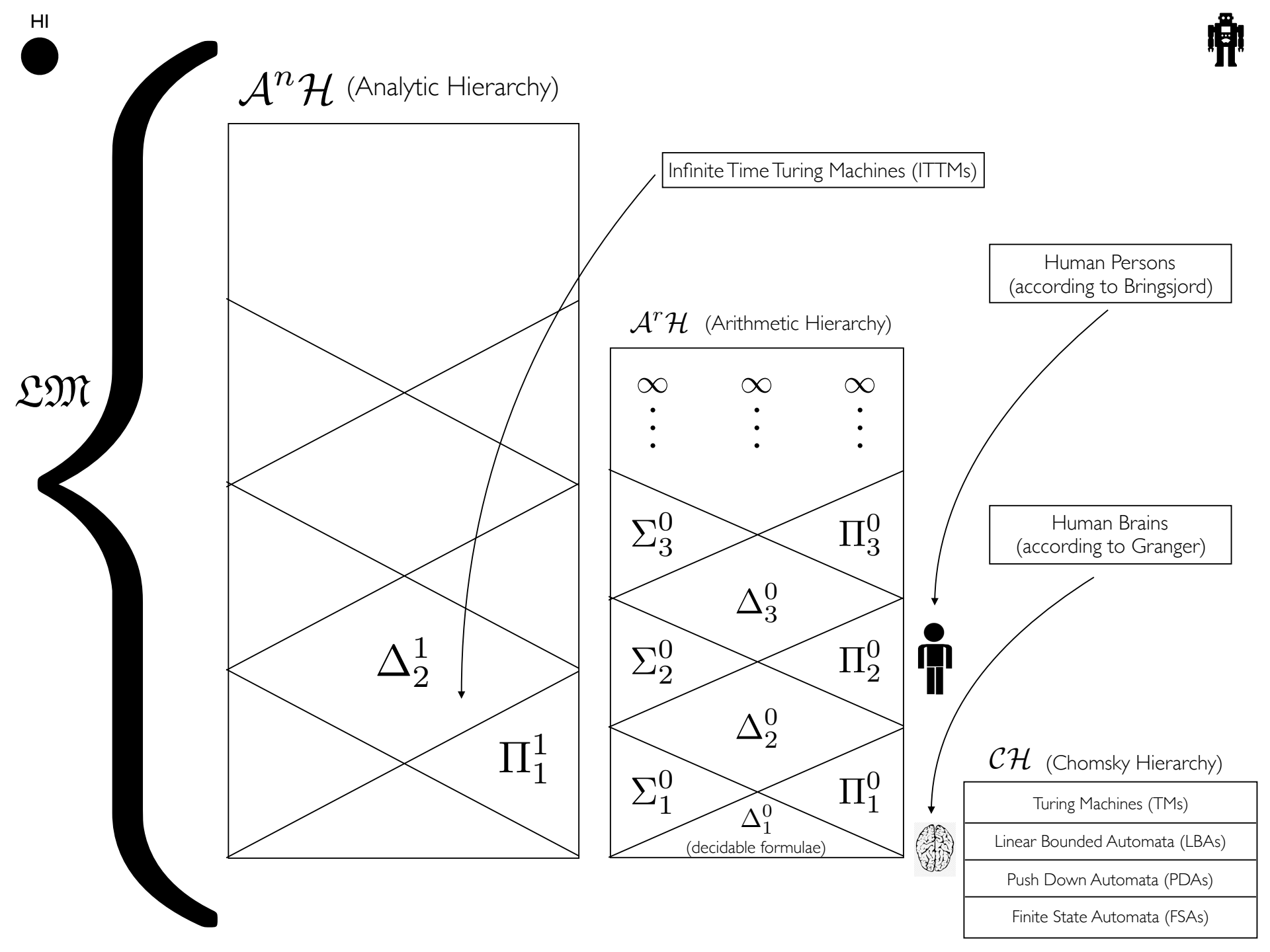
Entscheidungsproblem

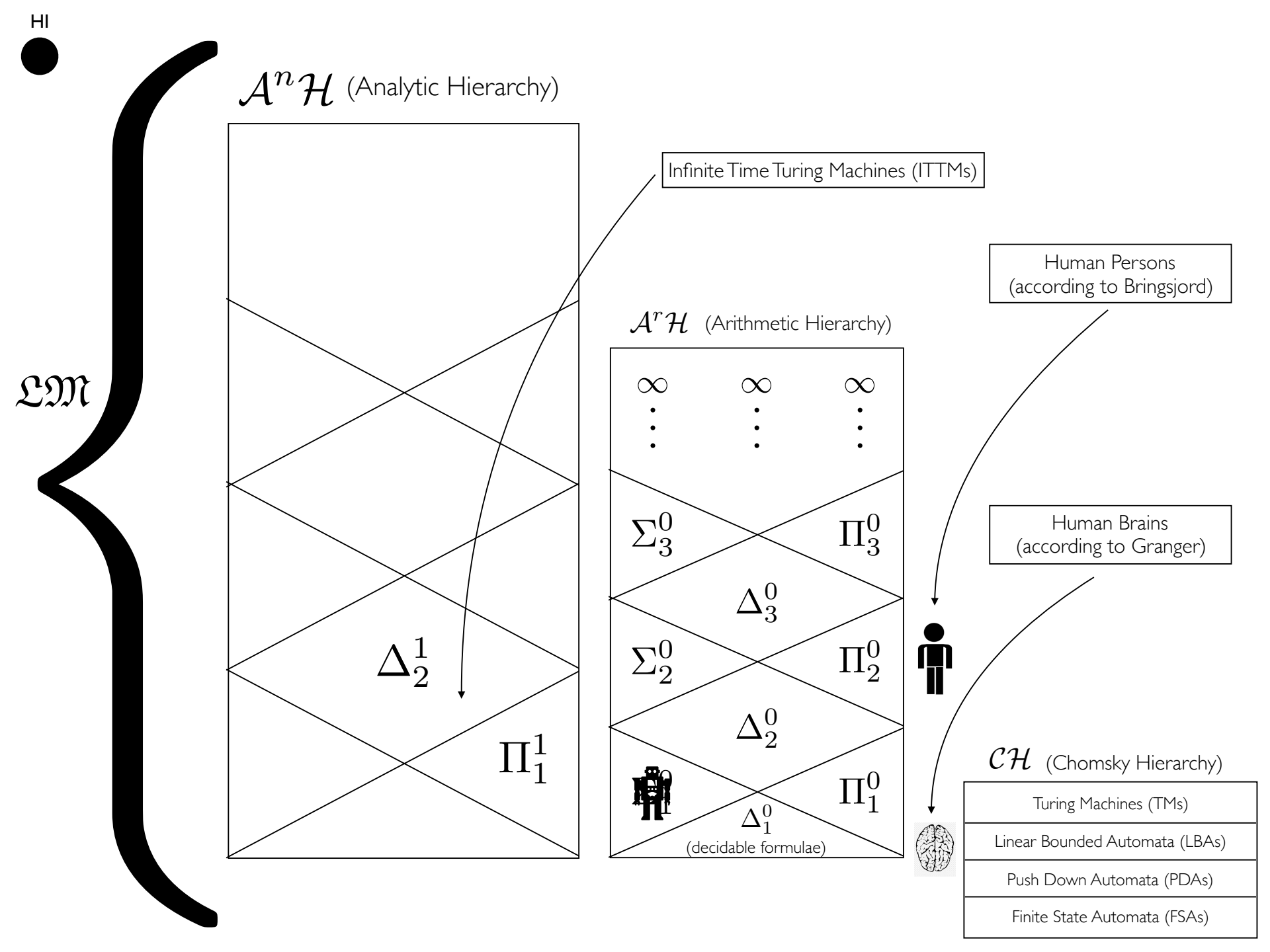
Polynomial Hierarchy

Exponential Hierarchy

$$\mathbf{P} \subseteq \mathbf{NP} \subseteq \mathbf{PSPACE} = \mathbf{NPSPACE} \subseteq \mathbf{EXPTIME} \subseteq \mathbf{NEXPTIME} \subseteq \mathbf{EXPSPACE}$$


Analytical Hierarchy
Arithmetical Hierarchy
GCI
Π_2
Σ_2
Π_1
Σ_1
Σ_0
Entscheidungsproblem
Polynomial Hierarchy
Exponential Hierarchy
$\mathbf{P} \subseteq \mathbf{NP} \subseteq \mathbf{PSPACE} = \mathbf{NPSPACE} \subseteq \mathbf{EXPTIME} \subseteq \mathbf{NEXPTIME} \subseteq \mathbf{EXPSPACE}$


HI
$\mathfrak{LM}$
$\mathcal{A}^n\mathcal{H}$ (Analytic Hierarchy)
Δ_2^1
Π_1^1
Infinite Time Turing Machines (ITTMs)
$\mathcal{A}^r\mathcal{H}$ (Arithmetic Hierarchy)
∞ ∞ ∞
Σ_3^0 Π_3^0
Δ_3^0
Σ_2^0 Π_2^0
Δ_2^0
Σ_1^0 Π_1^0
Δ_1^0
(decidable formulae)
Human Persons
(according to Bringsjord)
Human Brains
(according to Granger)
$\mathcal{CH}$ (Chomsky Hierarchy)
Turing Machines (TMs)
Linear Bounded Automata (LBAs)
Push Down Automata (PDAs)
Finite State Automata (FSAs)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∞ ∞ ∞
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Π_3^0
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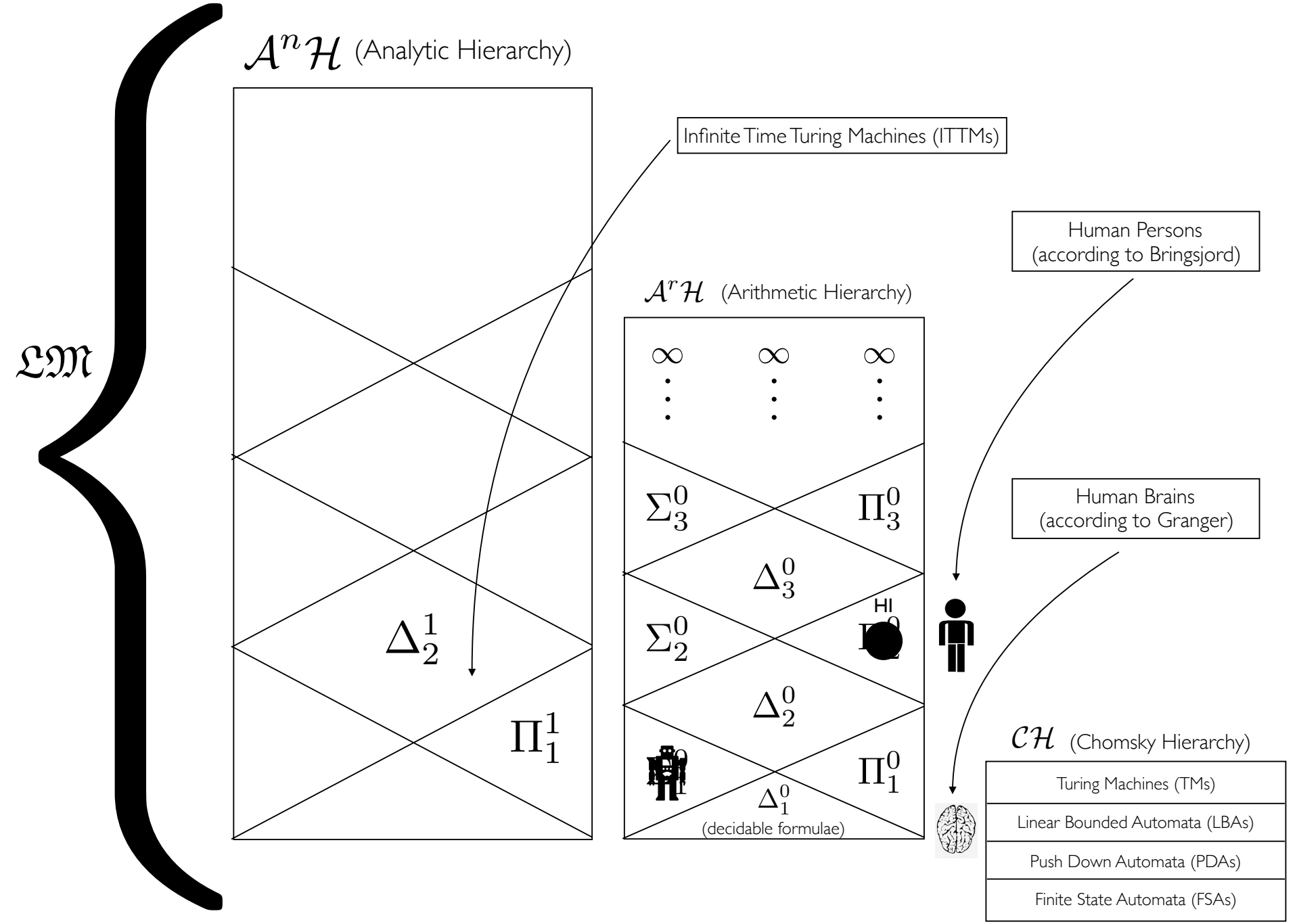
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Π^1_1
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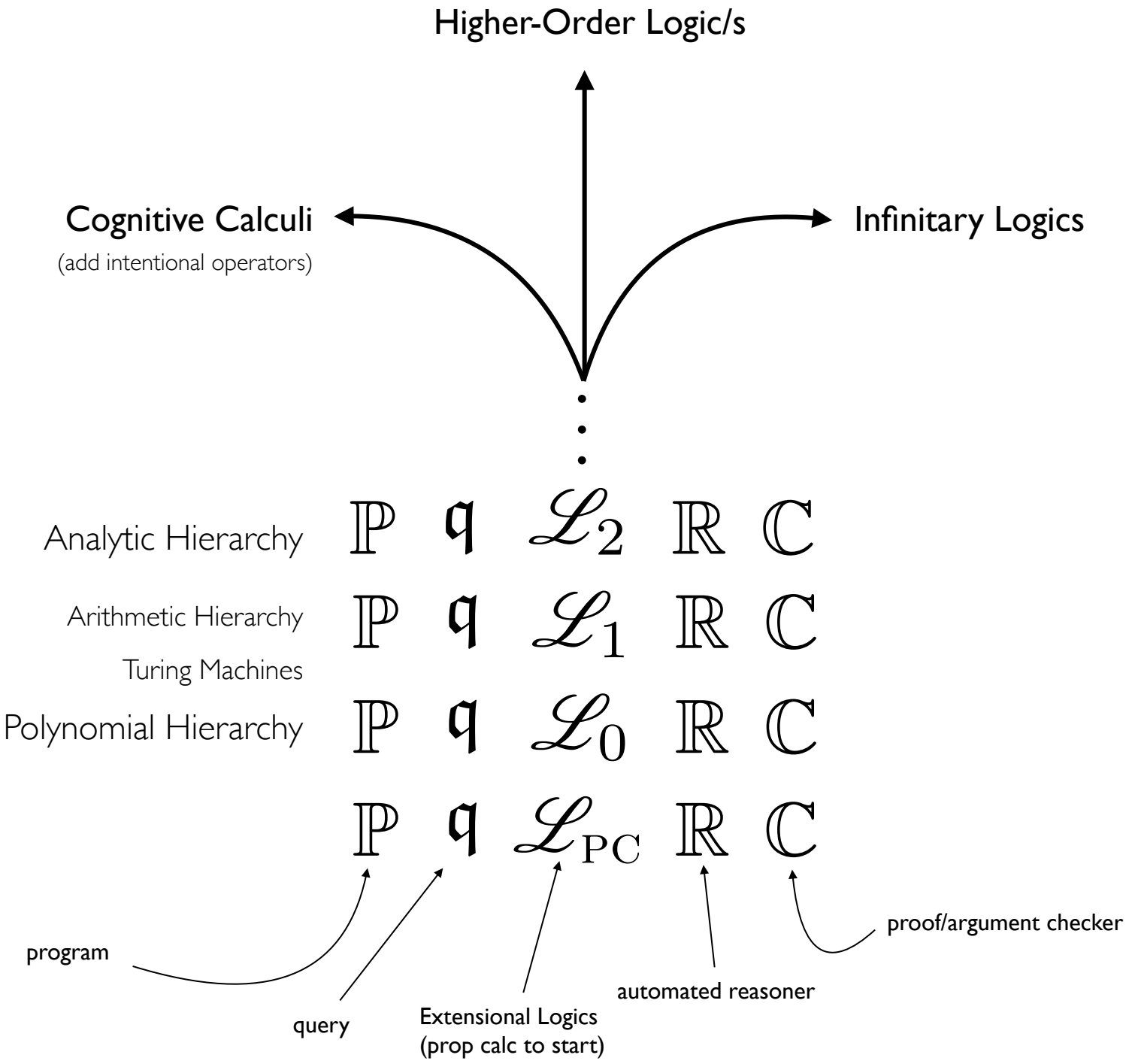
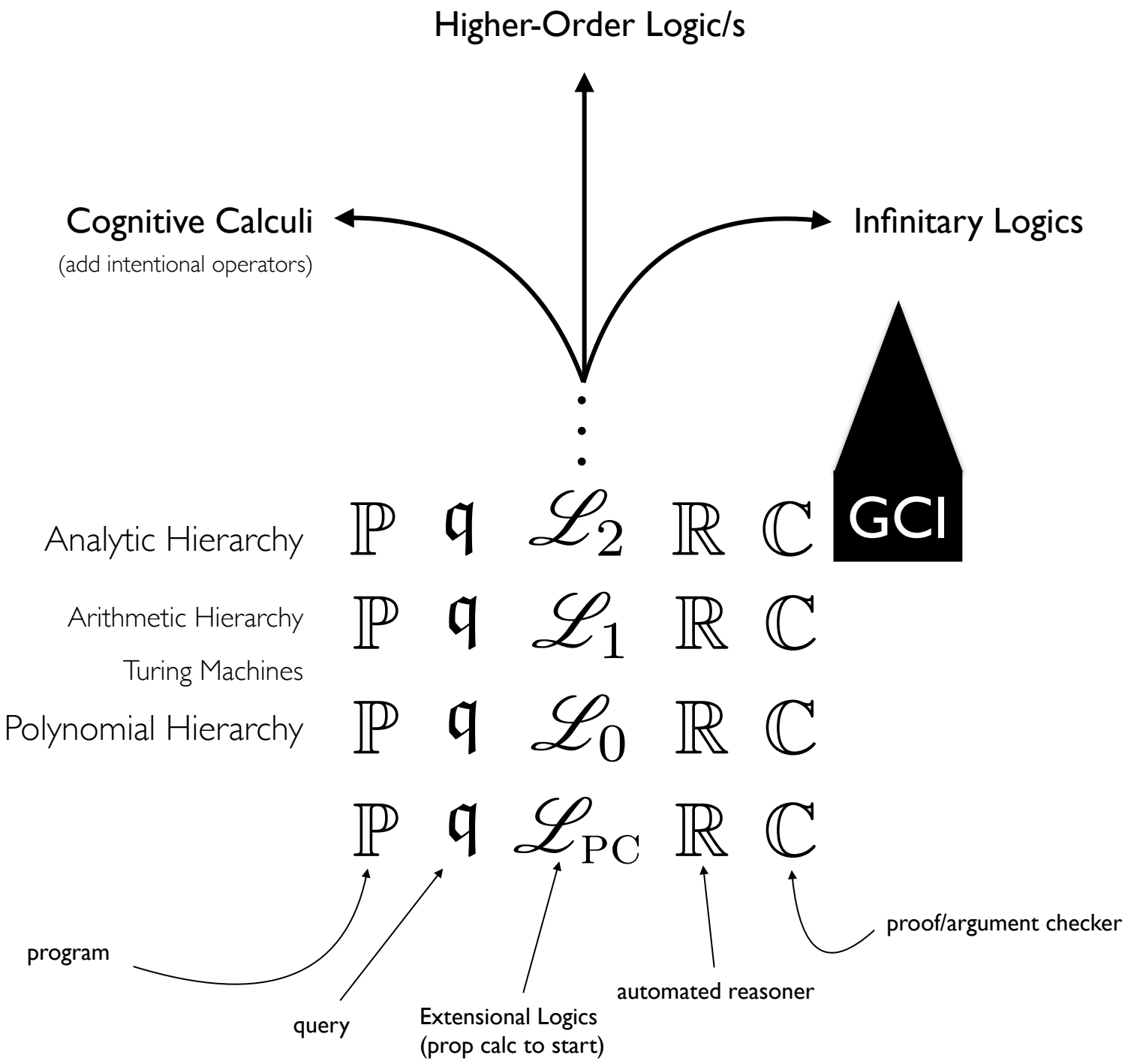

Higher-Order Logic/s
Cognitive Calculi
(add intentional operators)
Infinitary Logics
Analytic Hierarchy
Arithmetic Hierarchy
Turing Machines
Polynomial Hierarchy
$\mathbb{P}$ $\mathfrak{q}$ $\mathscr{L}_2$ $\mathbb{R}$ $\mathbb{C}$
$\mathbb{P}$ $\mathfrak{q}$ $\mathscr{L}_1$ $\mathbb{R}$ $\mathbb{C}$
$\mathbb{P}$ $\mathfrak{q}$ $\mathscr{L}_0$ $\mathbb{R}$ $\mathbb{C}$
$\mathbb{P}$ $\mathfrak{q}$ $\mathscr{L}_{\mathrm{PC}}$ $\mathbb{R}$ $\mathbb{C}$
program
query
Extensional Logics
(prop calc to start)
automated reasoner
proof/argument checker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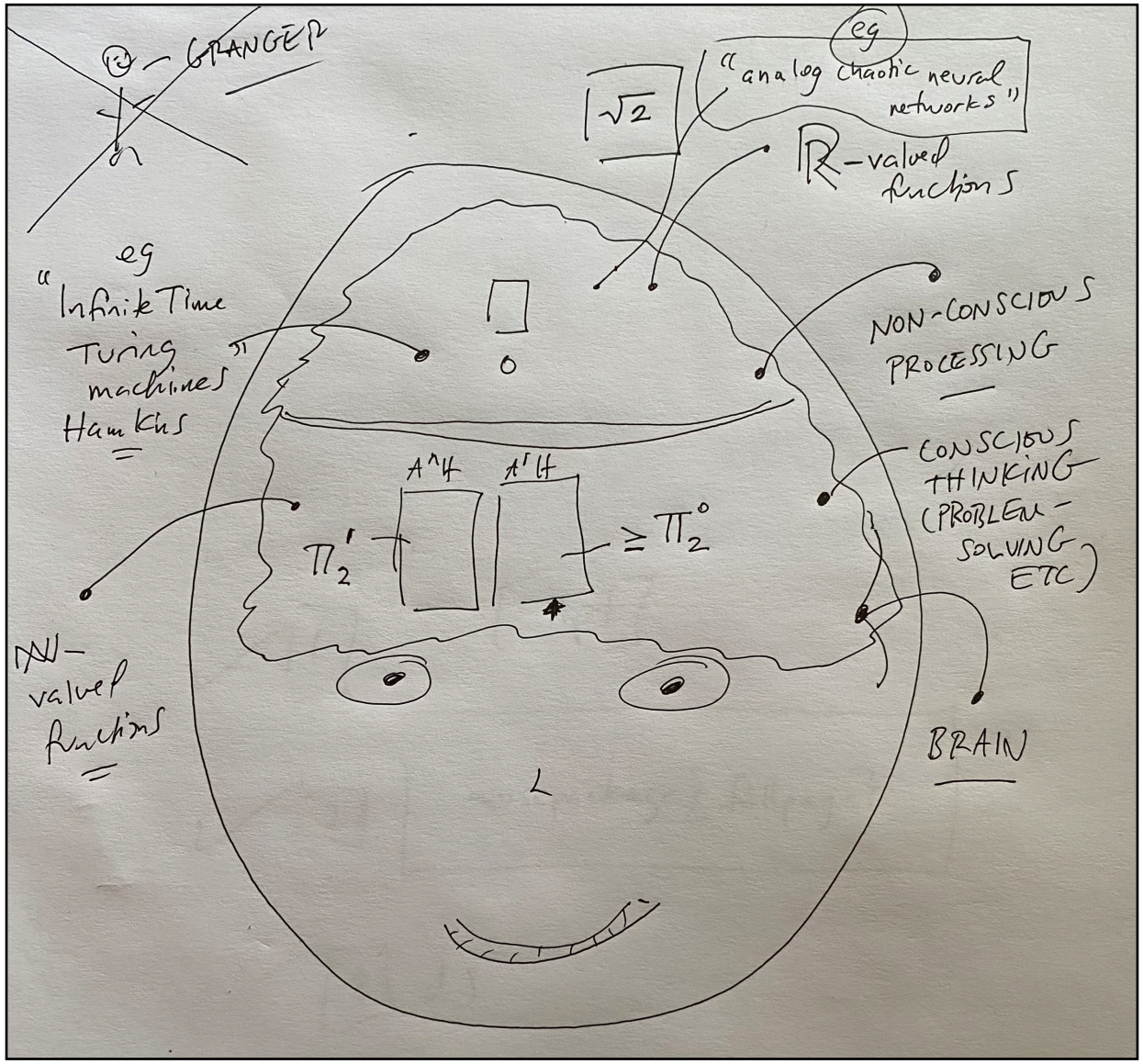
$\mathbb{P}$ $\mathfrak{q}$ $\mathscr{L}_{\mathrm{PC}}$ $\mathbb{R}$ $\mathbb{C}$
program
query
Extensional Logics
(prop calc to start)
automated reasoner
proof/argument checker

Picture of HI, *Contra* Granger



ANNUAL REVIEWS

Annual Review of Psychology

Quantum Cognition

Emmanuel M. Pothos[1] and Jerome R. Busemeyer[2]

[1]Department of Psychology, City University of London, London EC1V 0HB, United Kingdom; email: Emmanuel.Pothos.1@city.ac.uk

[2]Department of Psychological and Brain Sciences, Indiana University, Bloomington, Indiana 47405, USA; email: jbusemey@indiana.edu

Probabilities are used to quantify uncertainty and make inferences from uncertain premises. A probability theory is a set of mathematical axioms for how to combine and update probabilities. This review concerns three overarching traditions regarding the relevance of probability theory to cognition. The first is Bayesian/classical probability theory (CPT). CPT axioms embody some of our basic intuitions regarding how to deal with probabilities. In a famous quote by Laplace (cited in Perfors et al. 2011, p. 313), CPT is described as "nothing but common sense reduced to calculation." The axioms of CPT number only four, yet they are the foundation of a mathematical edifice which encompasses any kind of probabilistic reasoning. CPT cognitive models have clearly attracted great interest in the last few decades (Griffiths et al. 2010, Oaksford & Chater 1994, Tenenbaum et al. 2011). Second, there are heuristics and biases, a toolbox of rules which offer fast and frugal accounts that describe numerous behavioral findings. Heuristics and biases have also attracted significant interest (Gigerenzer & Todd 1999, Kahneman et al. 1982). Third, there

ingdom;

is quantum probability theory (QPT), which is a newer direction and is the focus of the present review. Like CPT, QPT is a general probability theory, that is, a set of rules for how to combine and update probabilities. QPT and CPT axioms are different, so we often reach different conclusions when we employ QPT versus CPT. We can consider any of the questions above (e.g., "Will it rain tonight?") and compute the corresponding probabilities with either CPT or QPT.

Some readers may have come across quantum mechanics, which is a theory of physics. The pioneering physicists who developed quantum mechanics soon realized that CPT was not suitable for this new physical theory—it seemed that uncertain information for microscopic particles obeyed probability rules different from the familiar ones from CPT. So, together with a new physics theory, they developed a new theory of probability as well—what we call QPT. QPT is the theory of probability from quantum mechanics, without any of the physics. In fact, Bohr (1958), one of the founding fathers of quantum theory, was one of the earliest to propose that principles of quantum physics, such as complementarity, could be applied outside of physics to human knowledge (for a recent example, see Lu & Busemeyer 2014). An important qualification is that the use of QPT in cognitive science makes no assumptions regarding the nature of brain neurophysiology; all current quantum cognitive models do not rely on a quantum brain hypothesis, which has been heatedly contested (Hameroff 2007, Litt et al. 2006).

Jerry Forgot the Fourth Option; and Aaronson is Wrong.

Jerry Forgot the Fourth Option; and Aaronson is Wrong.

The Commonsense Theory (CT):

Humans generally avoid being logical, unless intrinsically motivated, or paid not to avoid.

The main point of QC should be to see if gains on Turing-unsolvable problems can be made with it.

Med nok penger, kan logikk løse alle våre problemer.