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ARTYKUŁ ORYGINALNY / ORIGINAL ARTICLE

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The Integral Nature of the Scientific Enterprise

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Abstract: Science seeks to explain truths about reality. But what is truth? How do we know anything? Given human ignorance and fallibility, why trust scientists?

A view of knowledge is outlined in the light of recent advances in thermodynamics that highlight the importance of unity by showing (i) a clear physical sense for the idea of a "unitary entity" (that is holistic rather than reductionist), (ii) commensurability between the local and nonlocal (resolving the Loschmidt Paradox), and (iii) the relevance of entropic physics to all scales, from the "quantum mechanical" to the realm of "general relativity".

Integrity is likewise essential to science — whether in theory, individual practice, community standards, or obtaining the public's trust. As a human endeavour aimed at encountering reality, science also has an irreducibly poetic dimension. Though it cannot be fully defined, it consists of practices aimed at deepening our grasp of the natural world. Knowledge remains personal, shaped by individual and communal integrity.

Scientists, believing that "reality" exists and is (partially) knowable, seek coherence and favour unified theories. While reality may be truly known (if only in part), the notion of "objective" (impersonal) knowledge is, strictly speaking, an oxymoron (however useful).

Knowledge is necessarily personal.

Keywords:

Anaximander;
atom;
entanglement;
mereology;
prescientific thought;
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1. Introduction

Today there is a crisis of faith: experts are mistrusted, climate change is denied, and conspiracy theories proliferate. How should science respond? What makes the scientific enterprise trustworthy — and how can this trust be cultivated? For while its success in shaping the modern world may seem self-evident, the question remains pressing. We regard it as a truism to say that the scientific enterprise is a communal pursuit aimed at acquiring reliable *knowledge* of nature. It rests on mutual reliance: we depend on others' expertise and on the general good faith of the community, since fraud — though rare — is hard to detect. Thus, science depends deeply on the personal integrity of scientists, and public trust requires belief in the integrity of the whole community. But what *is* knowledge? How do we know?

The *epistemic challenge* has long engaged philosophers [1], and many now accept it has no definitive solution — we limp from error to error. Yet scientific knowledge has proven reliable, as shown by the technologies we use daily. This reliability

[1] Carlo Rovelli has summarised the epistemic problem very acutely: "we do not know how or why we think what we think [...] When we seek a sure foundation on which to base decisions about our actions and thoughts we find that a sure foundation does not exist [...] But this does not imply that we cannot or must not trust our own thinking. Recognising its limitations does not imply that it is not something to rely upon" (Carlo Rovelli, **Anaximander and the Nature of Science**, Penguin Random House, London 2023, p.171f (originally published as **Anaximandre de Milet, ou la naissance de la pensée scientifique**, Éditions Dunod, Paris 2009; English translation: **The First Scientist: Anaximander and his Legacy**, trans. Marion Lignana Rosenberg, Westholme Publishing, Yardley 2011)).

Rovelli's thesis is that "We must choose between hiding away in empty truths or accepting the radical uncertainty of our knowledge – remaining, like the Earth, suspended in a void [...] This is the main characteristic of scientific thinking: what seems most obvious to us about the world can be false" (Rovelli, **Anaximander and the Nature of Science...**, pp. 177 and 180). In the face of our own uncertainties and our knowledge of our previous errors, how do we respond to crazy people spouting nonsense?

Robert Crease has written a book "about how to get angry about science denial in the right way" (Robert Crease, **The Workshop and the World: What Ten Thinkers Can Teach Us About Science and Authority**, Norton, New York 2019, p. 19) quoting the famous saying of Aristotle: "Those who are not angry at the things they should be angry at are thought to be fools, and so are those who are not angry in the right way at the right time, or with the right persons" (**Nicomachean Ethics**, Bk.4 Ch.5). It is necessary to get angry, and indeed we are angry; but as Crease points out in his discussion of Hannah Arendt's contribution, "There is no quick fix" (Crease, **The Workshop and the World...**, p. 262). The issues are not simple — reality is elusive! Here we try to lay out these issues in an even-handed way.

stems from two foundations: communal integrity and, at the personal level, a desire for coherence.

Truth is *one* — for without unity, knowledge collapses [2] (presupposing the vernacular meaning of truth commonly used by scientists and leaving until later a deeper discussion). Hence, we assert the integral nature of the scientific enterprise [3]: *knowledge* depends on *unity*. For we may know truly [4] even in the face of our limitations, since the truth the poets discern is the *same sort of thing* [5] that the

[2] To forestall premature criticism of this paragraph, we note that it is legitimate for an "Introduction" to lay out the claims of the work, with the fuller justification of those claims postponed to later in the work. *Truth* is discussed in more detail below at §5 and *Knowledge* at §4: and of course these issues pervade the whole work.

Peter Epstein has supported our philosophical view of things when he shows that "our *grasp* [of scientific concepts] is *a priori*". See Peter Epstein, "A Priori Concepts in Euclidean Proof", *Proceedings of the Aristotelian Society* 2018, Vol. 118, No. 3, pp. 407–417, https://doi.org/10.1093/arisoc/aoy011 [emphases added]. Epstein and Sethi have underlined this by insisting on an *a priori* acceptance of "a unified account" (see Peter Fisher Epstein and Umrao Sethi, "An Empirical Stalemate: Why Science Fails to Settle a Central Philosophical Debate About Perception", *Philosophy and Phenomenological Research* 2026, Vol. 112, No. 1, pp. 276–289, https://doi.org/10.1111/phpr.70078). Nicholas Maxwell insists on such a unified account (the "metaphysical priority of unified theories", see Nicholas Maxwell, "Aim Oriented Empiricism and the Metaphysics of Science", *Philosophia* 2020, Vol. 48, pp. 347–364, https://doi.org/10.1007/s11406-019-00064-w).

[3] Clearly, the scientific enterprise involves *knowing stuff*; and consequently also knowing *how* we know it; and moreover *how we go about* getting to know things. That is, we shall consider *knowledge* itself, together with its *epistemology*, in the context of its *methodology*. These are massive issues on which the literature is truly enormous: we will of course be very selective in our conversation partners.

[4] The vernacular meaning of the term "truth" is, precisely, a value judgment. For our mothers teach us, "tell the truth!" and being a liar is BAD! Philosophy must not (and in fact cannot) eschew value judgments, although analytic philosophy is more concerned with the rigour of arguments than the truth of their conclusions. But scientists must make judgments regarding whether or not the model under consideration is satisfactory, given the measurements available, and indeed those measurements themselves are much more value-laden than is usually realised (this observation itself is philosophically non-trivial: see e.g. Luca Mari, Mark Wilson, and Andrew Maul, **Measurement Across the Sciences: Developing a Shared Concept System for Measurement**, Springer, Cham 2021, pp. 71–110 (chapter: "Philosophical Perspectives on Measurement"), https://doi.org/10.1007/978-3-030-65558-7_4).

[5] Arthur Koestler has corroborated this: "the artist's inspiration and the scientist's intuition are still fed by that same unitary source [...]" (Arthur Koestler, **The Ghost in the Machine**, Hutchinson, London 1967, p. 192). This is in a chapter titled "The Glory of Man". Koestler proposes the reality of "holons" (which seem pretty much identical to what we call "unitary entities").

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scientists discover — *truth is one*. Knowledge is personal [6] such that any philosophy of science must also be *metaphysical* (meaning "*the metanarrative of physics*" [7]).

Saying "Knowledge is Personal" [8] does not imply it is merely individual; rather, we know together or not at all: "No man is an island" [9]. Since individuals know little alone, knowledge belongs to the community; and scientific knowledge to the scientific community.

[6] Michael Polanyi has insisted that *knowledge is personal* (see Michael Polanyi, **Personal Knowledge: Towards a Post-Critical Philosophy**, University of Chicago Press, Chicago 1958) and Jerry Ravetz has developed Polanyi's case, calling for "a new philosophy of science which, instead of asking »what sort of truth is embodied in perfected scientific knowledge« proceeds by asking »by what activities and judgements, individual and social, can genuine scientific knowledge come to be?«" (Jerome R. Ravetz, **Scientific Knowledge and its Social Problems**, Oxford University Press, Oxford 1971, p. 10 (in the 1973 Penguin edition)). Note that social "activities and judgments" are as important as individual ones.

[7] With the wider Aristotelian meaning for "physics" ("Φυσικὴ ἀκρόασις" [*physikē akroasis*] is literally "listening to nature", probably meaning "lectures on nature"). "Metaphysics" traditionally is used to refer to the "ontology", but because the true beings of things is normally obscure to us we use it more simply to mean "the metanarrative of physics" (see Chris Jeynes, Michael C. Parker, and Margaret Barker, "The Poetics of Physics", *Philosophies* 2023, Vol. 8, No. 1, article number: 3, n. 17 passim, http://dx.doi.org/10.3390/philosophies8010003) just as Kurt Gödel (Kurt Gödel, "Über formal unentscheidbare Sätze der ***Principia Mathematica*** und verwandter Systeme I (On Formally Undecidable Propositions of ***Principia Mathematica*** and Related Systems I)", *Monatshefte für Mathematik und Physik* 1931, Vol. 38, pp. 173–198, https://doi.org/10.1007/BF01700692; reprinted in English in Stephen Hawking, **God Created the Integers**, Running Press, Philadelphia 2005) and others subsequently used "metamathematics" to refer, quite precisely, to "the metanarrative of mathematics". Gödel had studied Immanuel Kant's **The Metaphysical Foundations of Natural Science** (Immanuel Kant, **Metaphysische Anfangsgründe der Naturwissenschaft**, J.F.Hartknoch, Riga 1786; Immanuel Kant, **The Metaphysical Foundations of Natural Science**, trans. Ernest Balfour Bax, George Bell & Sons, London 1883), in which Kant clearly has the same idea that David Hilbert also had: that a "complete" metaphysical grounding was available. Gödel showed this to be untenable.

So, Kant says (for example): "[...] eine vollständige Zergliederung des Begriffs von einer Materie überhaupt zum Grunde gelegt werden müssen [...]"; "[...] a complete analysis of the conception of a matter in general must be laid at its foundation [...]". But Jeynes, Parker, and Barker, supported by Gödel's seminal result, show that this search for "completeness" cannot be successful (see Jeynes, Parker, and Barker, "The Poetics of Physics..."); since at the foundation of any knowledge is an ambiguous *poetic appreciation* rather than an (unambiguous) *analytical understanding*, such understanding itself being only a formal representation of the (prior) poetic appreciation (see Ossa-Richardson's masterful monograph on ambiguity: Anthony Ossa-Richardson, **A History of Ambiguity**, Princeton University Press, Princeton 2019).

Though scientists widely acknowledge that *intuition* is essential [10]— for both imagining and then attaining results — formal discourse avoids mentioning it [11]. Our new account of science, rooted in the refined idea of "unitary entities", which itself requires a new concept of *unity*, has only recently become possible. [12] "Unity" is a metaphysical idea largely absent from physics since the scientific revolution, yet no account of science can be adequate without addressing how physics is known.

Surprisingly, "unity" has a physical embodiment, just as "atoms" do. While atoms were only universally accepted about a century ago, real "unitary entities"

Jeynes, Parker, and Barker have shown that any physical discussion must necessarily have a metaphysical context: since every narrative only makes any sense in some suitable metanarrative (and narratives in a natural language work as their own metanarratives) (see Jeynes, Parker, and Barker, "The Poetics of Physics…"). This metaphysical context is normally tacit: indeed, so much so that it is usual for the physicists to be entirely unaware of it. The crux of the argument of Jeynes, Parker, and Barker is that poetic speech is invariably *prior* to prose speech, both logically and temporally (see Jeynes, Parker, and Barker, "The Poetics of Physics…"). Actually, Carlo Rovelli acknowledges this, "seeing [in ritual] the grounding […] of the system of legitimacy at the basis of social life, and even for the reliability of human language itself" (Rovelli, **Anaximander and the Nature of Science…**, p. 167, citing Roy Rappaport's classic 1999 work: Roy A. Rappaport, **Ritual and Religion in the Making of Humanity**, Cambridge University Press, Cambridge 1999).

It is the question of, and the justification for, the "legitimacy of science" that is our subject here. Why trust scientists? What is it about the scientific enterprise that makes it trustworthy?

"Metaphysical" is commonly used today pejoratively (both Collins and Chambers dictionary entries list "fanciful" as a synonym): philosophically it usually refers to "ontology, or the science of being". This is, for example, (approximately) how Bas van Fraassen uses it: "the [empiricist] step that leaves the entire game of metaphysics behind, and frees us forever from its illusionary charm and glamour'' (Bas C. van Fraassen, **Scientific Representation: Paradoxes of Perspective**, Oxford University Press, Oxford 2008, https://doi.org/10.1093/acprof:oso/9780199278220.001.0001; quoted in Flavia Padovani's useful 2012 review: Flavia Padovani, "Book Review: Bas C. Van Fraassen, **Scientific Representation: Paradoxes of Perspective**, *Science & Education* 2012, Vol. 21, pp. 1199–1204, http://dx.doi.org/10.1007/s11191-011-9423-7).

[8] See Polanyi, **Personal Knowledge…**

[9] See John Donne, **Devotions upon Emergent Occasions**, Meditation XVII, 1624.

[10] Classical works include Arthur Koestler (see Arthur Koestler, **The Act of Creation**, Hutchinson, London 1967) and Tom McLeish (see Tom McLeish, **The Poetry and Music of Science**, Oxford University Press, Oxford 2019). I can't resist quoting Owen Barfield: "Really, there is no distinction between Poetry and Science, as kinds of knowing, at all"! (Owen Barfield, **Poetic Diction**, Faber & Gwyer, London 1928, ch. VIII, §6). Barfield has a whole chapter (III on "Metaphor") which he insists (with Iris Murdoch, see Iris Murdoch, **The Sovereignty of Good over Other Concepts**, *The Leslie Stephen Lecture*, Cambridge University Press, Cambridge 1967; reprinted in Iris Murdoch, **The Sovereignty of Good**, Routledge & Kegan Paul, Abingdon 1970) is fundamental to our ability to express meaning. Everything cannot be defined as the analytic philosophers would like.

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were first recognized as such in 2022. [13] We explain how this and related physical advances support a holistic, rather than a reductionist, view of science — and moreover one that addresses both technical *unity* (directly) and moral *integrity* (obliquely). This new holistic explanation aims to unify physics with metaphysics, analytics with poetics — both aspects essential to a full appreciation of science.

[11] An interesting recent exception (that goes to prove the rule) is explicit: "Quantifying Intuition" (see Lucy Haddad, Diego Gianolio, David J. Dunstan, Ying Liu, Conor Rankine, and Andrei Sapelkin, "Quantifying Intuition: Bayesian Approach to Figures of Merit in EXAFS Analysis of Magic Size Clusters", *Nanoscale* 2024, Vol. 16, pp. 5768–5775, http://dx.doi.org/10.1039/D3NR05110B). The authors acknowledge that *intuition* as such is formally unmentionable ("While recognised as an important guide during data analysis, being a heuristic parameter, it [the »happiness parameter«] has no firm basis in statistics and therefore cannot be quoted in publications") but go on to cast it in a formal Bayesian framework, which of course *is* publishable (see D.J. Dunstan, J. Crowne, and A.J. Drew, "Easy Computation of the Bayes Factor to Fully Quantify Occam's Razor in Least Squares Fting and to Guide Actions", *Scientific Reports* 2022, Vol 12, article number: 993, https://doi.org/10.1038/s41598-021-04694-7).

Many authors, not only McLeish, have noted that scientists (and mathematicians) often *know* what the result is before (sometimes long before) they can *prove* it. Arthur Koestler has shown (see Arthur Koestler, **The Sleepwalkers: A History of Man's Changing Vision of the Universe**, Hutchinson, London 1959) that this was also true of Kepler's demonstration that the orbit of Mars was elliptical (published 1609): Koestler reworks Kepler's arithmetic, finding that he (Kepler) made *at least* two mistakes. Koestler is sure that Kepler got the right answer not by accident (fortuitously) but because he already knew what the answer was (serendipitously).

Another famous example is the heroic measurement of stellar parallax (of 61 Cygni: 0.314 arcseconds, or 314 milliarcseconds, a tiny quantity) by Friedrich Bessel in 1838. This was actually the first formal *proof* of the heliocentric hypothesis of Galileo, but in 1838 everyone *already* believed that the earth orbits the sun: Bessel's measurement was celebrated because of its extraordinary difficulty, not because it showed that Galileo was right all along! Indeed, Bessel only went to the trouble of making the measurements because he was already convinced of the heliocentric model. His empirical method was then of great interest since it was the observational evidence for the gigantic size of the Universe that had been thought unobtainable.

[12] See Chris Jeynes and Michael C. Parker, "Unitary Entities Are the True »Atoms«", *Entropy* 2025, Vol. 27, No. 11, article number: 1119, https://doi.org/10.3390/e27111119.

[13] The $^{4}He^{++}$ nucleus (in its ground state) was demonstrated a "unitary entity" by Parker, Jeynes, and Catford, who correctly derived its consequent matter radius (see Michael C. Parker, Chris Jeynes, and Wilton N. Catford, "Halo Properties in Helium Nuclei from the Perspective of Geometrical Thermodynamics", *Annalen der Physik* 2022, Vol. 534, No. 2, article number: 2100278, §8, http://dx.doi.org/10.1002/andp.202100278). The existence of "atoms" was long *assumed*, notably by Ludwig Boltzmann for his

2. Synopsis

Here we explore the nature of the scientific enterprise, specifically emphasizing the philosophical implications of recent developments in thermodynamic theory. We begin (§3: "*Historical Perspective*…") with Carlo Rovelli's "Third Way": a supposed path between dogmatic deference to authority and the opinionated certainty that "*My* view must be correct." We argue that Rovelli's resolution is insufficient, and that a more valid path exists — one that affirms the unity (internal integrity) of philosophical inquiry, whether poetic or scientific.

A central question (§4: "*Trusting Scientists …*") is "*Where does knowledge come from?*" — followed by "*Who decides?*" While we (necessarily) rely on experts, they can be very wrong. Still: we must act, however poor our knowledge. Scientists engaging with the public must use rhetoric because science, being human, cannot avoid human concerns; but they must use it honestly, transparently and accountably. It's no coincidence that professorships in public science communication are now common, held by experts skilled in rhetoric — today's "poets of science".

The *legitimacy* of the scientific enterprise's standing (§4) must be earned through *persuasion* since "mere facts" *prove* little (and may sometimes themselves be wrong). The scientists facing the public must make an honest use of rhetorical methods, not only to counter the falsehoods of the demagogues but also because science is a human activity in which issues of *value* are unavoidable. Science touches reality, and the truths it uncovers (however partial or fallible) remain real. After all, the widgets still work!

"statistical mechanics". But it was not *proved* until in 1908 Jean Baptiste Perrin verified Albert Einstein's 1905 treatment of the "Brownian motion" named for the 1827 observations of Robert Brown. And in 1913 Neils Bohr famously explained the structure of the hydrogen atom, relying on Ernest Rutherford's 1911 analysis of Geiger and Marsden's 1908 alpha scattering experiments.

It is interesting that in physics "unitary" is taken to refer to "unitary operators", which are of central importance in quantum mechanics. A "unitary operator" is such that the product of the operator and its adjoint is the identity operator. But here, by "unitary entity" we mean "that than which exists nothing simpler" (see Jeynes and Parker, "Unitary Entities…").

A unitary entity can be understood as being like Leibniz' monads, which are "without parts" (see Gottfried Wilhelm Leibniz, **Leibniz: Philosophical Writings** (**La Monadologie**, 1714), transl. Mary Morris, Everyman's Library, Dent, London 1934, §1.) Or like Henry More's "atoms" which may be (using More's neologisms) strictly "indivisible" or practically "indiscerpible" (see Henry More, **Philosophicall Poems**, Roger Daniel, Cambridge 1647, https://tiny.pl/8xjk4bdf8 [06.03.2024]).

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Ultimately, *truth* is what matters (§5: "*Realism* ..."), and if science is not the honest pursuit of truth, then it doesn't matter what else it is. Though science is often depicted as a set of "objective" facts (§6: "*The Illusion of Objectivity*"), this is not only false — it is illusory. Science is better understood as a search for a "unified" (coherent) worldview (§7: "*On Unity*").

So, what is truly *fundamental* in science (§8)? A strong case now exists for "unitary entities" being *more* fundamental than "fundamental particles." The *reductionist* programme that began with 17th-century atomic theory has reached its limits; we discuss a new physics involving *wholeness* and *integrity*.

As an aside, the stance affirming both the reality of the world and that "*knowledge is personal*" closely mirrors the position taken by quantum physicists confronting their discipline's paradoxes (§9: "*QBism*"). Quantum Bayesianism refocuses our understanding of *probability*, revealing that the Bayesian view applies not only to the small (needing quantum mechanics) but also to the large (cosmic scales require general relativity).

To wind up our argument we draw attention to the poetics of physics (§10: "*Poetry* ..."). Scientific reasoning can never be entirely self-contained; it always unfolds within broader social or philosophical contexts, which may prove dominant. We reflect on Artificial Intelligence and its influence on scientific practice (§11), briefly discuss some other issues (§12), summarise (§13) and conclude (§14).

3. A Historical Perspective on Scientific Enquiry: Rovelli's "third way"

Carlo Rovelli writes, "Halfway between the absolute reverence of [the student for the master] and the rejection of those who hold different views, Anaximander [6th century BCE] discovered a third way [...] he does not hesitate to say that Thales [of Miletus] is mistaken about this or that matter, or that it is possible to do better [...] this narrow third way is the most extraordinary key for the development of knowledge". [14] Rovelli characterises the "religious" approach to knowledge by its "absolute reverence", which does not allow any modification of the

[14] Rovelli, **Anaximander and the Nature of Science...**, p. 78.

master's view, contrasting it with the "scientific" approach in which the follower is (sometimes) willing to say that the master was mistaken in this or that respect. Clearly, Rovelli's representation of science is well-founded. [15]

However, his representation of Christian attitudes is less so, even if he is correct to point to "*a classic thesis*" [16] according to which "a scientific revolution comparable to the one in the West did not take place in Chinese civilization — despite the fact that for centuries Chinese civilization was in many ways broadly superior to the West — precisely because the master in Chinese culture was never criticised or questioned". [17] Rovelli contrasts the Pope's stance on infallibility [18] with a scientific view which requires "faith in human beings, their being reasonable, and their honesty in searching for the truth. This kind of faith in human beings is that of the luminous humanism of the Greek cities in the 6th century BCE at the root of the extraordinary intellectual and cultural flowering of the following centuries, which continues to bear fruit in the contemporary world. But this faith in humanity is not unchallenged. Many voices rise against it: »Cursed be the man that trusteth in man …« (Jeremiah 17:5). The conflict between these two worldviews is ancient". [19]

It seems clear to us that Rovelli does not grasp Jeremiah's point (see below), and we should also note that Nicholas Spencer [20] has carefully exploded the myth that the

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[15] Thanks to an anonymous Reviewer who points out that Rovelli relies quite heavily on Karl Popper's assessment of Anaximander's contribution. But our view of Anaximander's thought may be quite strongly coloured by our own concerns: G.S.Kirk heavily criticised Popper from a detailed knowledge of PreSocratic science (see G.S. Kirk, "Popper on Science and the Presocratics", *Mind* 1960, Vol. LXIX, No. 275, pp. 318–339, https://doi.org/10.1093/mind/LXIX.275.318).

[16] See G.E.R. Lloyd, **The Ambitions of Curiosity: Understanding the World in Ancient Greece and China**, *Ideas in Context*, Series Number 64, Cambridge University Press, Cambridge 2002.

[17] Rovelli, **Anaximander and the Nature of Science…**, p. 81.

[18] Rovelli says: "Pope Benedict XVI [...] often says that to save ourselves from the relativistic drift, we have to defend the infallible Truth". Rovelli, **Anaximander and the Nature of Science…**, p. 140.

[19] Rovelli, **Anaximander and the Nature of Science…**, p. 141f.

[20] See Nicholas Spencer, **Magisteria: The Entangled Histories of Science and Religion**, One World, London 2023.

Thanks to Sir Michael Berry for drawing our attention to Spencer's book in March 2023. And thanks to an anonymous Reviewer who claims that a remaining unresolvable conflict is that "science rules out the possibility of miracles". But this is anachronistic since "miracle" is a Latin word (Englishing Jerome) where the Greek is σημεῖον (*sign*, as in Luke 23:8) or δύναμις (*wonder*, as in ποιήσει

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"scientific" and the "religious" worldviews are in "conflict". The real position is much more nuanced than Rovelli says.

The very idea of "infallibility" is heavily contested in Christianity. [21] Infallible propositions are unavailable — to theologians and scientists alike. Catherine Elgin has made a careful epistemological case that "*scientific understanding is nonfactive*" (i.e., "*true enough*") [22]. She compellingly argues that "the capacity to make

δύναμιν — "do a miracle", Mark 9:39). And in any case "science" does NOT "rule out the possibility" of signs and wonders! If we have learned anything it is how astonishing nature is. Who would have thought such things as are commonplace today were even possible? The ancients would be astonished at modern technology. But we hardly want (or need) to digress onto a Humean discussion of miracles, and the related issues of lawfulness.

[21] The (Roman Catholic) theologian Hans Küng explained that the formal Roman doctrine of "Infallibility" dates only from the 1st Vatican Council (1869-1870) (see Hans Küng, **Unfehlbar?**, Benziger, Zürich 1970; Hans Küng, **Infallible?**, trans. E. Mosbacher, Collins, London 1971): this Council was abandoned as a consequence of the Franco-Prussian War, which Eric Hobsbawm insists was a cynical ploy by Bismarck to promote German reunification (see Eric J. Hobsbawm, **The Age of Capital, 1848-1875**, Scribner, New York 1975, ch. 4, §1). We should always remember that our interdisciplinary boundaries are only there for our convenience: in reality everything is interconnected. Frank Hertog claims that the utility of Stephen Hawking's new theory published posthumously (see S.W. Hawking and Thomas Hertog, "A Smooth Exit from Eternal Inflation?", *Journal of High Energy Physics* 2018, Vol. 4, article number: 147, https://doi.org/10.1007/JHEP04(2018)147) "lies in its capacity to unlock the interconnectedness of the universe" (Thomas Hertog, **On the Origin of Time: Stephen Hawking's Final Theory**, Torva, London 2023, p. 203 [page numbers are for the Penguin 2024 edition]). The theologians should listen to the historians, the historians to the physicists, and all of them to the philosophers. Basarab Nicolescu underlines the importance of "transdisciplinarity" (see Basarab Nicolescu, "Methodology of Transdisciplinarity: Levels of Reality, Logic of the Included Middle and Complexity", *Transdisciplinary Journal of Engineering and Science* 2010, Vol. 1, pp. 19–38, https://doi.org/10.22545/2010/0009).

Jeynes has commented on Küng: "The crux of the matter is, can any infallible propositions be identified? [...] The Roman doctrine of papal infallibility [...] [is] a juridical rather than a confessional issue [...]" (Chris Jeynes, "On **Infallible?** (Hans Küng, 1970)", University of Surrey Ion Beam Centre, 2014, p. 10 [1–11], https://tiny.pl/hysn5j3k4 [04.03.2024]). The Christians will say ("confess") that God does not deceive his church, and therefore Christians are safe if they rely on the leading of God (which of course is easier said than done). But Küng takes aim at "polemical Church definitions" (treated juridically by the Roman church), denying that it is useful to say that such definitions may be regarded as "infallible": "A definition has a target; it is aimed at a specific error. But since there is no error without a kernel of truth, there is always a danger that a polemically aligned proposition will strike, not only the error, but also the truth contained in it. If a Protestant, for instance, states quite unpolemically that the just man lives by faith, the shadow of error that accompanies the proposition does not appear. But if he polemically makes the statement in reply to the error of a legalistic Catholic who exaggerates the

mistakes is an epistemic achievement [...] far from being a concession to frailty, [fallibility] is a source of strength". [23]

Jeremiah actually expresses the opposite of Rovelli's interpretation, although referencing Jeremiah (Thales' contemporary) is apt in a discussion of Anaximander (Thales' younger peer). Hebrew scholars are unusually unanimous in agreeing that Jeremiah 17:5–8 forms a poetic *unity*. Cassandra Gorman notes that the 17th-century English "metaphysical poets" were fascinated by the revelations of the new microscopes [24], which made the commonplace seem outlandishly novel. She says that they "wrote poetry that meditated on the liberating power of atoms to dissolve and recongregate into renewed and resurrected forms. This poetic history of the irreducible particle has not been written by historians of science". [25] These poets explicitly recognised poems as "atoms" (that is, indivisible: each word is indispensable). We therefore give Jeremiah's poem as an indivisible whole (following the authoritative translation of William McKane [26]):

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importance of good works, there is a danger that the shadow of error may obscure the truth of his statement by the unexpressed implication that the just man lives by faith (without doing good works)" (Küng, **Infallible...**, ch. 4, §10). Note that "The just shall live by faith" ("ὁ δίκαιος ἐκ πίστεως ζήσεται", **Η ΠΑΛΑΙΑ ΔΙΑΘΗΚΗ κατὰ τοὺς Ἑβδομήκοντα** (*H Palaia Diathēkē kata tous Hebdomēkonta*), Apostolikē Diakonia, Athens 1996) is a text of the Christian writers (Romans 1:17; Galatians 3:11; Hebrews 10:38), quoting the LXX version of Habbakuk 2:4 verbatim. This Greek translation of the Hebrew text ("Εβδομήκοντα", Latinised as the "Septuagint" or the LXX) was made in Alexandria probably in the 3rd century BCE.

[22] Catherine Z. Elgin, **True Enough**, MIT Press, Cambridge 2018, p. 33.

[23] Elgin, **True Enough...**, p. 291.

[24] See Cassandra Gorman, **The Atom in Seventeenth Century Poetry**, D.S. Brewer, Cambridge 2021.

Thanks to Kevin Killeen for alerting us to Cassandra Gorman's important monograph in 2022. As Jeynes, Parker, and Barker say: "It is hard to overestimate the importance of the advent of the microscope to natural philosophy. Suddenly things became much more complex and beautiful than anyone had imagined. This is excellently reviewed and described by Kevin Killeen (see Kevin Killeen, "Microscopy, Surfaces and the Unknowable in Seventeenth-Century Natural Philosophy (from Lucretius to Margaret Cavendish)", *Journal of the Northern Renaissance* 2017, Vol. 8, https://tiny.pl/gp9dx68sp [2.07.2026]), who thus provides a corrective to our ideas of the emergence of »scientific modernity« which (as he puts it) »*is often still viewed as a sad but necessary putting aside of the poetic*«" (Jeynes, Parker, and Barker, "The Poetics of Physics...", note 80).

[25] Gorman, **The Atom in Seventeenth Century Poetry...**, p. 22.

[26] William McKane, **A Critical and Exegetical Commentary on Jeremiah**, Bloomsbury, London 1986.

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Cursed is the man who trusts in men
Who leans for support on material power
Whose mind is alienated from Yahweh [27]

He is like one living destitute in the wilderness
He is unaware when good comes
He lives in parched places of the desert
In an uninhabited salt waste

Blessed is the man who trusts in Yahweh
Who makes Yahweh his source of safety

He is like a tree planted beside waters
Stretching out its roots along a stream
It has no fear when heat comes
Its leaves remain green
In a year of drought it has no anxiety
And does not cease to bear fruit.

Jeremiah 17:5-8.

The poem's parallelism is clear, even in translation. The Psalmist quotes it at length (Psalm 1), and Jesus alludes to it (John 4:14, explicitly referencing Jer. 2:13; 17:13). Jeremiah is deprecating reliance on external things (power in this case) and lauding internal honesty in just the way Rovelli would approve. In fact, Jeremiah goes on to be explicit (in v.10), "*I the Lord search the heart and examine the mind*," where, in Biblical terms, the *mind* is located in the *heart* [28]. Whether or

[27] "Yahweh" [יְהוָֹה] is God's personal name, usually rendered "Lord"; see the elliptical "explanation" at Exodus 3:14: "*I am that I am*" [אֶֽהְיֶ֥ה אֲשֶׁ֖ר אֶֽהְיֶ֑ה] ("*ehyeh asher ehyeh*", **Hebrew-English Tanakh**, Jewish Publication Society, Philadelphia 2000), or "ἐγώ εἰμι ὁ ὤν" in the LXX.

[28] "thoughts of the heart", Genesis 6:5, is only the first of many examples. Of course, the Biblical writers were well aware that implying that the mind is "located" in the heart was a figure of speech, just as it was obvious that God having "hands" ("*the work of his hands*" Pss.8:6; 9:16 etc) was also a figure of speech. (Similarly for God's personal pronouns "he/his/him": clearly intended to be heard as gender-neutral.) The ancient poets did not have the nonsensical literal-mindedness that seems to be common today. The substantive point is that the "heart" is at the heart of things: we tend to think of it as a (rather important) pump, but the ancient poets did not know that, they thought of it (figuratively) as central to how we make decisions, especially moral ones.

It is surely worth pointing out that any body has *only one* heart. Psalm 16 has a play on "unity" and "duality": "*my kidneys instruct me in the night seasons*" (v.7 — there are *two* kidneys); "*my heart is glad and my liver rejoices*" (v.9 — one each of heart and liver). On the liver, Robert Alter comments, "The Masoretic text has *kevodi*, »my glory«, but some manuscripts show *keveidi*, »my liver«" (Robert Alter, **The Book of Psalms**, Norton, New York 2007). The unpointed text for both words is [כבד] (*k-b-d*) with a primary implication of *weight* (the liver is a *large* organ). Similarly, Psalm 62:11 ("*One thing God has spoken, two things have*

not one believes in God, anyone of goodwill can affirm Jeremiah's point, *mutatis mutandis*.

Rovelli's depiction of religious rigidity — prioritising dogma over reason — seems insufficiently nuanced, at least regarding Christianity (accepting of course that European history is littered with shocking horrors perpetrated by the powerful, who chose to call themselves Christian). Yet Luther and Calvin opposed papal doctrine just as Copernicus opposed Ptolemy's — respectfully [29]. Theology must change just as science must, and for the same reasons – both must be open to new insights. But both are also subject to the same unwelcome rigidities of thought [30], again for the same reasons: it is difficult to get people to change the way they think, and even more difficult to get people to "*keep their oath, even when it hurts*", as the Psalmist demands (Ps. 15:4). Even though it can lead to intellectual discomfort, the pursuit of truth (with Rovelli's admonition "*it is possible to do better*" [31] in mind) has acted as the driver to the increase of knowledge.

Rovelli's position appears to be "scientistic" (having an exaggerated trust in "scientific method") which in this case means that he overlooks (or misrepresents) the metaphysical aspects we are drawing attention to.

I heard") contrasts *one* mouth and *two* ears. Ps.16 is from the first David collection and Ps.62 is from the second: they may both have been composed c.1000 BCE (see the Appendix of Jeynes, Parker, and Barker for a discussion of paleoHebrew, Jeynes, Parker, and Barker, "The Poetics of Physics…").

[29] Theologically, both Luther and Calvin were very restrained, although they were vigorous polemicists, as was customary in those days.

[30] Max Planck's famous comment is often represented as "Science advances one funeral at a time" (Max K. Planck, **Scientific Autobiography and Other Papers**, trans. Frank Gaynor, Philosophical Library, New York 1950, pp. 33 and 97).

[31] "It is possible to do better": of course Rovelli is not the first to say this sort of thing. Karl Popper (see Karl R. Popper, **The Open Society and its Enemies: Vol. II, The High Tide of Prophecy: Hegel, Marx, and the Aftermath**, Routledge, London 1945; and thanks to an anonymous referee for pointing this out) famously said, "I may be wrong and you may be right / and by an effort we may get nearer to the truth" (Popper, **The Open Society and its Enemies…**, p. 213), commenting later that the saying was "an attempt to summarise a very central part of my moral articles of faith […] [which] I called critical rationalism" (Karl R. Popper, **The Myth of the Framework: In Defence of Science and Rationality**, Routledge, London 1994, p. xii).

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4. Trusting Scientists, and the Legitimacy of the Scientific Enterprise

People (including experts!) are often wrong. Why then should the public trust scientists, and why should people regard the scientific enterprise as legitimate?

Hanna Metzen examines the concept of *trust* in science, noting that "Epistemic trust in science has become an important issue in philosophy of science," and it's equally vital in current European and American politics [32]. She does not address the internal trust within the scientific community that allows new findings to be accepted. Peer review, for instance, relies heavily on the *good faith* of all involved. [33] By publishing, authors assert that they are truthfully reporting observations, yet bad faith is notoriously hard to detect. Ultimately, *I* must trust *you* to tell the truth. Not only Truth [34],

[32] Hanna Metzen, "Objectivity, Shared Values, and Trust", *Synthese* 2024, Vol. 203, article number: 60, https://doi.org/10.1007/s11229-024-04493-3.

[33] The reason for this is that our knowledge is always ultimately founded on "personal testimony", as Richard Bauckham has recently shown in an important and very far-reaching monograph (see Richard Bauckham, **Jesus and the Eyewitnesses: The Gospels as Eyewitness Testimony**, Eerdmans, Grand Rapids 2006). Bauckham engages in an extensive critical survey of trust ("Testimony, then, of its very nature invites trust [...] A fundamental attitude of trust is not gullibility but a necessary epistemic virtue" (Bauckham, **Jesus and the Eyewitnesses...**, p. 478)), and he cites Paul Ricoeur's "prudential rule": "first, trust the word of others, then doubt if there are good reasons for doing so" (Paul Ricoeur, **La mémoire, l'histoire, l'oubli**, Seuil, Paris 2000; Paul Ricoeur, **Memory, History, Forgetting**, trans. Kathleen Blamey and David Pellauer, University of Chicago Press, Chicago 2004, p. 478f). Interestingly, Rosa Bologna, Franziska Trede, and Narelle Patton have recently applied Ricoeur's "hermeneutic spiral" to "unconscious influences on professional practices" (see Rosa Bologna, Franziska Trede, and Narelle Patton, "A Critical Imaginal Hermeneutics Approach to Explore Unconscious Influences on Professional Practices: A Ricoeur and Jung Partnership", *The Qualitative Report* 2020, Vol. 25, pp. 3486–3518, https://doi.org/10.46743/2160-3715/2020.4185). John Hardwig (see John Hardwig, "Epistemic Dependence", *The Journal of Philosophy* 1985, Vol. 82, pp. 335–349, http://dx.doi.org/10.2307/2026523) already explored the epistemic importance of *testimony*, as of course also did Michael Polanyi (see Polanyi, **Personal Knowledge...**).

Peer-review has recently been carefully and helpfully reviewed by Tennant and Ross-Hellauer who call it a "critical part of our knowledge infrastructure" without a proper understanding of which "scholarly legitimacy might decline in the future" (Jonathan P. Tennant and Tony Ross-Hellauer, "The Limitations To Our Understanding of Peer Review", *Research Integrity and Peer Review* 2020, Vol. 5, article number: 6, https://doi.org/10.1186/s41073-020-00092-1).

[34] John Ziman FRS gave a seminar in Bristol in 1973 extolling "Lord Truth". Ziman "broke fresh ground in his studies of science as a collective human enterprise" (see Michael Berry and John F. Nye, "John Michael Ziman. 16 May 1925 — 2 January 2005: Elected FRS 1967", *Biographical Memoirs of the Fellows of the Royal Society* 2006, Vol. 52, pp. 479–491, https://doi.org/10.1098/

but Trust, underpins science. John Hardwig writes, "scientific knowledge rests on trust [...] in the character of scientists". [35]

Of course, there is a distinction between *Truth* and *Truthfulness*. The *truthfulness* of actors is shown by their determination to tell the truth (as they understand it). And *truth* itself is that which is recognised as such by the truthful (deliberately using circular "definitions": truth is one of those primitive ideas impossible to define to everyone's satisfaction — as Pilate famously said to Jesus, John 18:38, Τί ἐστιν ἀλήθεια?). [36]

With today's expanding knowledge and frequent multi-author papers [37], col-

rsbm.2006.0032; see also John M. Ziman, **Reliable Knowledge: An Exploration of the Grounds for Belief in Science**, Cambridge University Press, New York 1978).

[35] John Hardwig, "The Role of Trust in Knowledge", *The Journal of Philosophy* 1991, Vol. 88, p. 706 [693–708], https://doi.org/10.2307/2027007.

This holds even amid widespread bias, extensively documented by Jessica Nordell (see Jessica Nordell, **The End of Bias: How We Change Our Minds**, Metropolitan, New York 2021; Granta, London 2021). Edouard Machery usefully points out that "trust" here must be understood in the sense of "rely on but corroborate" (Edouard Machery, "Science Without Trust?", *Philosophy of Science* 2025, Vol. 92, No. 5, pp. 1041–1049, https://doi.org/10.1017/psa.2025.10143). We should not assume bad faith (and thanks to Monserrat Neto for alerting us to Machery's work in September 2025). Jeroen de Ridder also investigates trusting scientists at helpful depth, showing both that "epistemic trust among scientists is inevitable" and also in what way it is "justified" (see Jeroen de Ridder, "How to Trust a Scientist", *Studies in History and Philosophy of Science* 2022, Vol. 93, pp. 11–20, https://doi.org/10.1016/j.shpsa.2022.02.003).

[36] We thank an anonymous reviewer for pressing us on this point. We are alethic realists (see Leon-Philip Schäfer, "How (Not) to Integrate Scientific and Moral Realism", *Synthese* 2024, Vol. 203, article number: 57, https://doi.org/10.1007/s11229-023-04467-x), but also depend on a "correspondence" theory of truth (even though such a theory does not provide an analytical criterion for recognizing truth). A true account corresponds to reality. And truthful observers will represent their observations fairly, that is, they will not lie about them. Moreover all true accounts are consistent with each other (a "coherence" theory). Of course, a *realist* will assert certain truths, whereas the *antirealist* will only assert their recognition. Unfortunately for the simple man who likes sharp definitions, reality is elusive and speaking of it coherently is hard. We take Karen Barad's line of asserting that it is an error to regard *ontology* and *epistemology* as separable: in reality one should think of *onto-epistemology* (her term) (see Karen Barad, **Meeting the Universe Halfway**, Duke University Press, Durham 2007).

[37] Derek de Solla Price long ago observed the trend to multi-author papers in scientific journals (see Derek de Solla Price, **Little Science, Big Science**, *Brookhaven National Laboratory Pegram Lectures*, Columbia University Press, New York 1963), and as an example of this John Hardwig (see Hardwig, "Epistemic Dependence...", pp. 335–349; Hardwig, "The Role of Trust..."), discusses a paper with 99 co-authors (see K. Abe, T.C. Bacon, J. Ballam, L. Berny, A.V. Bevan, H.H. Bingham, J.E. Brau, K. Braune, D. Brick, W.M. Bugg, J. Butler, W. Cameron, J.T. Carroll, C.V. Cautis, J.S. Chima, H.O. Cohn, D.C. Colley, G.T. Condo, S. Dado, R. Diamond, P.J. Dornan, R. Erickson, T. Fieguth, R.C. Field, L. Fortney, B. Franek, N. Fujiwara, R. Gearhart, T. Glanzman, J.J. Goldberg, G.P. Gopal, A.T. Goshaw, E.S. Hafen, V. Hagopian, G. Hall,

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laboration is essential (although it brings an added risk of groupthink). Authors must trust one another and agree on a shared narrative. [38] We must "*rethink expertise*". [39] And once findings reach the public, they too must be able to trust them. But how is that trust built? [40]

Good faith remains indispensable. *I* lack the expertise — and time — to verify everything *you* say. Even were it possible it would be impractical; life is too short. I can (and should) assess whether your claims are reasonable, align with your promises, meet current standards (etc), but verifying everything is unfeasible. This aligns with Carlo Rovelli's point: "When we seek a sure foundation on which to base decisions about our actions and thoughts we find that a sure foundation does not

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E.R. Hancock, T. Handler, H.J. Hargis, E.L. Hart, P. Haridas, K. Hasegawa, T. Hayashino, D.Q. Huang, R.I. Hulsizer, S. Isaacson, M. Jobes, G.E. Kalmus, D.P. Kelsey, J. Kent, T. Kitagaki, J. Lannutti, A. Levy, P.W. Lucas, M. MacDermott, W.A. Mann, T. Maruyama, R. Merenyi, R. Milburn, C. Milstene, K.C. Moffeit, J.J. Murray, A. Napier, S. Noguchi, F. Ochiai, S. O'Neale, A.P. T. Palounek, I.A. Pless, M. Rabin, P. Rankin, W.J. Robertson, A.H. Rogers, E. Ronat, H. Rudnicka, T. Sato, J. Schneps, S.J. Sewell, J. Shank, A.M. Shapiro, C.K. Sinclair, R. Sugahara, A. Suzuki, K. Takahashi, K. Tamai, S. Tanaka, S. Tether, H.B. Wald, W.D. Walker, M. Widgoff, C.G. Wilkins, S. Wolbers, C.A. Woods, Y. Wu, A. Yamaguchi, R.K. Yamamoto, S. Yamashita, G. Yekutieli, Y. Yoshimura, G.P. Yost, and H. Yuta, "Charm Photoproduction Cross-section at 20 GeV", *Physical Review Letters* 1983, Vol. 51, pp. 156–159, https://doi.org/10.1103/PhysRevLett.51.156) that determines a photoproduction cross-section of the charm particle.

[38] Charles Sanders Peirce long ago pointed out the importance of the *community* in establishing reasonable belief (see Charles Sanders Peirce, "The Fixation of Belief", *The Popular Science Monthly* 1877, November). (We thank an anonymous referee for reminding us of Peirce's contribution.) John Hardwig acknowledges this contribution in his account of *epistemic authority*: he points out that instead of saying (for some proposition *p*) that "**I** know *p*" (because some expert *A* knows *p* and I acknowledge *A*'s epistemic authority), we can say "**We** know *p*" (since it is we jointly who acknowledge *A*'s epistemic authority) (see Hardwig, "Epistemic Dependence...").

[39] See Harry Collins and Robert Evans, **Rethinking Expertise**, University of Chicago Press, Chicago 2007.

[40] Collins and Evans pick over these issues in detail, explaining how (as an example they do not use) a clerk of works on a building site who has perhaps served an apprenticeship as a bricklayer is expected (and is able) to judge whether the carpenters are doing a good job. Exactly the same applies in science, *mutatis mutandis*: just as peer reviewers have to be persuaded to trust the scientific authors, so the public have to be persuaded to trust the scientific community. In particular, Collins and Evans are interested in the important question, how can the public make use of science and technology *before* there is consensus in the scientific community? Of course, the question remains: is a consensus reliable even if it exists? How (and why) we disagree even in the face of consensus has been explored by Mike Hulme in some detail for the case of climate change (see Mike Hulme, **Why We Disagree About Climate Change: Understanding Controversy, Inaction and Opportunity**, Cambridge University Press, Cambridge 2009).

exist". [41] While he was referring mainly to personal epistemics, this holds not only at individual but also at communal levels. We may find it "reasonable to believe" something, but certainty is always out of reach. Where then is *truth*?

Rovelli is right — we must live with the possibility of error. It's unsettling, yet it enables participation in the "continuous critical revision of accepted knowledge [...] [with] the ability to explore new images of the world". [42] This participation becomes possible when we draw on the community's expertise — otherwise, much would remain unknowable.

Joseph Drew and others explore how to persuade the public to support political action, highlighting Aristotle's rhetorical categories*: logos, ethos, pathos*, and *kairos* [43]; which apply equally to scientists countering antiscientism. Scientific (logical) arguments alone aren't enough! Scientists must learn to handle rhetorical methods effectively, and this is not merely a political necessity: it is also an acknowledgement of the metaphysical context of all scientific activity.

Science is pursued by individuals but also depends on the scientific community, which in turn depends on the broader public — as funders, supporters, and beneficiaries of knowledge. Without the expertise of the scientific community, individual scientists understand little. But those who "stand on the shoulders of giants" see further. The scientific community, in turn, trusts individual scientists — this is the basis of peer review.

Thus, trust is political: the individual and collective dimensions are entangled. The public must be *persuaded* to support science just as the scientific community must be *persuaded* to accept individual results. [44] This *entanglement* is not merely metaphorical but realistic since new physics shows that the local and non-local,

[41] Rovelli, **Anaximander and the Nature of Science...**, p. 171f.

[42] Rovelli, **Anaximander and the Nature of Science...**, p. 181.

[43] See Joseph Drew, who also points out Aristotle's rhetorical tropes (the "major" ones are: *metaphor*, *metonymy*, *synecdoche* and *irony*) (see Joseph Drew, **Selling Public Policy**, Springer, Singapore 2023, pp. 29–46 (Chapter 3: "Rhetoric: Not Just What Is Said, but Also Who Says It and How"), https://doi.org/10.1007/978-981-99-0381-8_3), and in particular synecdoche (on which see Drew, O'Flynn, and Grant, who point out, following the "Roman rhetor and inheritor of the Aristotelian tradition, Marcus Quintilianus", that synecdoche is just as much *totum-pro-parte* as *pars-pro-toto* (see Joseph Drew, Janine O'Flynn, and Bligh Grant, "Performing What? Exploring and Expanding the Notion of Synecdoche in Performance Management Practice", *Public Administration Quarterly* 2018, Vol. 42, No. 3, pp. 395–424, https://doi.org/10.1177/073491491804200304)).

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the reversible and irreversible, and the causal and acausal are all commensurate (see below §7). [45]

What counts as science? Typically, a researcher submits a scientific paper to a learned journal, where peer reviewers assess it. But even if published, this doesn't guarantee the work is science. Errors may be missed — even serious ones [46]: as always, we depend on consensus. Science is what the scientific community recognises as such; although ultimately it's the tangible results — the widgets — that persuade the public to continue funding science. And of course, there are

[44] Brunet and Müller helpfully discuss the "feeling rules" of the peer review of major funding proposals (see Lucas Brunet and Ruth Müller, "The Feeling Rules of Peer Review: Defining, Displaying, and Managing Emotions in Evaluation for Research Funding", *Minerva* 2024, Vol. 62, pp. 167–192, https://doi.org/10.1007/s11024-023-09518-8). These concern the various rhetorical tactics that are recognised as either legitimate or illegitimate in this context (and similar considerations will apply in other scientific contexts too). This is a welcome recognition of the human nature of science.

And *persuasion* (particularly of the wider community) is of the essence: Marta Entradas, Martin W Bauer, Frank Marcinkowski, and Giuseppe Pellegrini open by saying: "Public communication of science has become a key obligation of universities", and go on to discuss *science communication* in very useful detail (Marta Entradas, Martin W. Bauer, Frank Marcinkowski, and Giuseppe Pellegrini, "The Communication Function of Universities: Is There a Place for Science Communication?", *Minerva* 2024, Vol. 62, p. 26 [25–47], https://doi.org/10.1007/s11024-023-09499-8).

[45] See Parker and Jeynes, "Relating a System's Hamiltonian to its Entropy...".

[46] Of course, scientists are notoriously bad at detecting deliberate fraud as they generally assume that the work is done in good faith (and when Alan Sokal perpetrated his hoax in 1996 he was clearly not in good faith). For example, the Schön affair which led to a series of retractions of the work of Jan Hendrik Schön and co-authors in 2003. On fraud, Martin Gardner says: "Scientists untrained in the conjuring art of deception are the easiest people in the world to fool" (Martin Gardner, **Undiluted Hocus-Pocus**, Princeton University Press, Princeton 2013, p. 157f). Thanks to Sir Michael Berry for drawing our attention to this book (2nd March 2023). John Hardwig (Hardwig, "The Role of Trust in Knowledge...", p. 706) quotes Arnold Relman: "fraudulent data may be rapidly identified in an area of great importance where research activity is intense, but that is probably not true in most fields" (Arnold S. Relman, "Lessons from the Darsee Affair", *New England Journal of Medicine* 1983, Vol. 308, No. 23, p. 1417 [1415–1417], http://dx.doi.org/10.1056/NEJM198306093082311). After all, repeating experiments is costly and usually unrewarded. See §11 for Artificial Intelligence used fraudulently.

Valentin Rodionov speaks of "a torrent of problematic papers [...] Despite the common belief that science self-corrects, most flawed papers evade retraction [...] In fields such as chemistry and physics [...] identifying problematic papers [...] is challenging. And it is virtually impossible to get one retracted" (Valentin Rodionov, "Holes in the »Holey Graphyne« Story", *ChemistryWorld* 2024, April 11, https://tiny.pl/t7ztm599 (25.06.2026)). Jeroen de Ridder also copiously evidences both fraud and its persistence in the literature (see de Ridder, "How to Trust a Scientist..."). Moreover,

also goods other than widgets: the inspiring pictures from the Hubble Telescope and its modern successors, and the wonderful TV programmes on the natural world are some examples.

What is the "scientific method"? John Randall traced its development in Padua pre-Galileo. [47] He noted that 17th-century scientists rejected appeals to authority, relying on "natural reason", yet often misunderstood their own intellectual origins. He concluded: "the return to experience is not for the sake of certain proof [...] it is almost impossible to find any natural scientist maintaining that a mere fact can prove any certain truth". [48] Seeing is not the same as understanding; in fact, we often only *see* what we *understand*! [49] Certainty remains elusive.

Nevertheless, just as the scientific enterprise rests on integrity, the scientific community relies on consensus authority — not unchallengeable, but founda-

much work in the scientific literature is rather low quality which ends up being ignored by the community: peer review filters out some of this stuff but by no means all. And some work may look important at first but turn out to be insignificant. After all, big results are far and few between. And even when big results are published they are often not immediately recognised. See §11 for Artificial Intelligence used to help find problematic papers (Nina Notman points out that in 2023 Hindawi — a branch of Wiley — retracted over 8000 scientific articles (see Nina Notman, "AI Tools Combat Paper Mill Frauds in Publishing", *ChemistryWorld* 2025, October 20, https://tiny.pl/70955y_n7 (25.06.2026)).

[47] See John Herman Randall Jr., "The Development of Scientific Method in the School of Padua", *Journal of the History of Ideas* 1940, Vol. 1, No. 2, pp. 177–206, https://doi.org/10.2307/2707332.

[48] See Randall Jr., "The Development of Scientific Method...", pp. 177–206.

[49] To randomly take one example of many, Jessica Nordell comments on a 2011 class action before the US Supreme Court of sex discrimination against 1.6 million female Walmart employees (see Nordell, **The End of Bias...**, p. 72f). The court ultimately "disqualified the lawsuit, ruling that female employees didn't have enough in common to be a »class« for a class-action lawsuit". Judge Antonin Scalia wrote the majority opinion, maintaining "that it would be impossible for a company to reach the kind of disparities seen at Walmart without a coordinated master plan of prejudice" (of which there was no evidence, hence the judgment) (Nordell, **The End of Bias...**, p. 72f).

Goethe wrote "*Was man weiß, sieht man erst*" in an Introduction to an issue of the art magazine *Propyläen* (c.1800), and also "*Man erblickt nur, was man schon weiß und versteht*" in a letter to his friend F. von Müller (24th April 1819). And of course, Jesus famously referred to those who were supposed to understand as "*blind guides*" (ὁδηγοὶ τυφλοὶ; Matthew 23:16), and again, to those who claimed to understand, "if you were blind you would have no guilt, but now you say you see, your guilt remains" (Εἰ τυφλοὶ ἦτε, οὐκ ἂν εἴχετε ἁμαρτίαν· νῦν δὲ λέγετε ὅτι βλέπομεν· ἡ ἁμαρτία ὑμῶν μένει; John 9:41).

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tional. Authority is unavoidable: we are social beings, nevertheless remaining free to obey and free to dissent. [50]

But regarding integrity, we must ultimately trust each other to report observations honestly (however many checks we also do). More fundamentally, scientists are driven by a visceral desire to *know* how the world works. It is a passionate enterprise — we *want* to get it right! But science cannot be conveyed to the public coldly. Wholeness matters. A *valid* argument may still not be *true*. We seek truth, not mere correctness. Gaining knowledge is more than collecting data (since one can amass information yet understand nothing).

Turning to scientific practice itself — not just its reporting — Philippe Stamenkovic examines the "Value-Free Ideal" (**VFI**), which holds that science should be value-free or objective. [51] Originally, VFI aimed to preserve "*public trust in science*" —

[50] On the authority of experts, Robert Crease observes, "Authority is a key feature of public space [...] The success of totalitarianism is only possible with the erosion of authority" (Crease, **The Workshop and the World...**, p. 252). He cites Hannah Arendt (see Hannah Arendt, **Between Past and Future: Six Exercises in Political Thought**, World Publishing Company, New York 1961): "authority implies an obedience in which men retain their freedom". St. Paul enjoins us that "we henceforth be no more children, tossed to and fro, and carried about with every wind of doctrine"; ἵνα μηκέτι ὦμεν νήπιοι, κλυδωνιζόμενοι καὶ περιφερόμενοι παντὶ ἀνέμῳ τῆς διδασκαλίας (*Ephesians* 4:14; **Η ΚΑΙΝΗ ΔΙΑΘΗΚΗ μετὰ συντόμου ἑρμηνείας** (*H Kainē Diathēkē meta syntomou hermēneias*), Adelphotēs Theologōn «Ho Sōtēr», Athens 2000). John Robinson dates *Ephesians* 58 CE (see John A.T. Robinson, **Redating the New Testament**, SCM Press, London 1976).

[51] Philippe Stamenkovic argues against claims "that extra-scientific values are inevitable in scientific practice (on the descriptive level) [and] that they should influence all aspects of the scientific enterprise (on the normative level)" on the basis that such practice "does not clearly distinguish between scientifically established facts and scientifically informed claims taken as a basis for policy-making" (Philippe Stamenkovic, "Straightening the »Value-laden Turn«: Minimising the Influence of Extra-scientific Values in Science, *Synthese* 2024, Vol. 203, article number: 20, https://doi.org/10.1007/s11229-023-04446-2). Stamenkovic calls this the "Value-Laden Turn" and contrasts it with the "Value-Free Ideal" (*VFI*), specifically in the context of what he calls "*phase 2*" (the "acceptance/rejection" or A/R phase), that is, "what to conclude from the investigation". He "argues for the need to minimise as much as possible (although not exclude) the influence of values in the A/R phase where claims are accepted or rejected" (Stamenkovic, "Straightening the »Value-laden Turn..."). All these "high-level" (philosophical) discussions approximate what really goes on, of course. Scientists want results, they don't want "no result". So "rejection" is not usually in view (unless it can be glossed positively as some sort of "acceptance"). Scientists are much more interested in what results do mean (positively) than in what they don't mean (negatively). And this always colours how results are presented.

Stamenkovic acknowledges the "simplifying idealisations" he uses: because *reality is elusive* it is not always possible to be sure of the scope of, and adequately assess, such approximations. But he illustrates his argument with definite examples, which is good practice as a constructive approach to ex-

a key concern here. But as a human activity, science cannot be entirely value-free. Stamenkovic rightly distinguishes between "*scientifically informed decisions*," which are inherently value-laden, and "*scientific claims*" (ideally value-free: scientists do aim to report results dispassionately because we believe the truth we uncover should be universally recognised — also because we know our own fallibility, including the tendency to let our fixed ideas distort outcomes.)

However, Stamenkovic is too optimistic about the neutrality of scientific claims, asserting: "A science based on facts (further generalised in the form of laws and principles) represents the ideal of scientific inquiry". [52] Yet "interesting facts" rarely exist. Once a fact is accepted, it becomes uninteresting *per se* —like the Earth orbiting the Sun, which ceased to be controversial long before its formal proof by the 1838 observation of stellar parallax by Friedrich Bessel. Bessel assumed Galileo was right, which is why he went to the enormous trouble of making this very difficult measurement: important because we wanted to know how big the Universe really was. Similarly, Thomas Kuhn's description of Lavoisier's discovery of oxygen is an object lesson in how the very expression of "facts" is plastic and must be negoti-

pressing meaning adequately. He specifically argues that "science-informed claims for policy-making should naturally be influenced by extra-scientific values".

Stamenkovic has a long section on "uncertainties" which he insists (correctly) "must be stated clearly". The trouble with this is that one can conform precisely to the **Guide for the Expression of Uncertainty in Measurement** (see Joint Committee for Guides in Metrology, **Evaluation of Measurement Data – Guide to the Expression of Uncertainty in Measurement (GUM)**, JCGM 100:2008, BIPM, Paris 2008 (revised version of the first edition published in 1995), https://tiny.pl/1g4fnl1mv [10.02.2025]), but whether one's consequent statement of uncertainty is "clear" is a very strong function of its auditor. Moreover, the very idea of "measurement" is much more anthropocentric than is commonly thought, with metrologists themselves affirming that "measurement is primarily an epistemic process" (see Luca Mari, Andrew Maul, David Torres Irribarra, and Mark Wilson, "Quantification is Neither Necessary Nor Sufficient for Measurement", *Journal of Physics Conference Series* 2013, Vol. 459, article number: 012007, http://dx.doi.org/10.1088/1742-6596/459/1/012007; Mari, Wilson, and Maul, **Measurement Across the Sciences...**). In the end the scientist must act with *integrity* (as Stamenkovic acknowledges repeatedly), and integrity is primarily a human ("extra-scientific") value. This means that in principle "science" cannot be done coldly; that is, avoiding the introduction of values (which are necessarily "extra-scientific"). Scientists should be "dispassionate", but they cannot, in principle, be "disinterested".

[52] Philippe Stamenkovic, "Facts and Objectivity in Science", *Interdisciplinary Science Reviews* 2023, Vol. 48, No. 2, p. 283 [277–298], https://doi.org/10.1080/03080188.2022.2150807.

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ated [53], and Paul Feyerabend powerfully makes comparable arguments [54]. As Robin Ince reminds us, we only do science because we're "*interested*". [55]

Scientists do aim to establish facts — hence Stamenkovic's emphasis on "*ensuring the truth of scientific knowledge*" — but "facts" are only "good ideas" while they are being established. Moreover, truths (like heliocentrism) may be accepted as "fact" well before they are formally confirmed. *Truth* is always interesting; but "facts" only become interesting when questioned — at which point they cease to be "facts"! Reality is elusive.

A "fact" (as a consensus view) is inherently social. [56] Bauckham has shown that personal "eyewitness testimony" underpins all knowledge. [57] Frank *et al.*'s "Blind Spot" thesis supports this from another angle [58], and John Hardwig long ago argued for a "principle of testimony" [59] to ground "epistemic authority" [60]: "Cooperation, not intellectual self-reliance, is the key virtue in any scientific community [...] [it] is possible only on the basis of reliance on the testimony of others". [61] Science is human, and "knowledge is personal". [62]

For our purposes, Stamenkovic's approach appears to be insufficiently fundamental, since he appears to treat "scientific truth" as well-defined and attainable: "...

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[53] See Thomas S. Kuhn, **The Structure of Scientific Revolutions**, University of Chicago Press, Chicago 1962.

[54] See Paul K. Feyerabend, **Against Method: Outline of an Anarchistic Theory of Knowledge**, New Left Books, London 1975.

[55] See Robin Ince, **The Importance of Being Interested: Adventures in Scientific Curiosity**, Atlantic Books, London 2021.

[56] Factual truth "concerns events and circumstances in which many are involved; it is established by witnesses and depends upon testimony" (Crease, **The Workshop and the World...**, p. 256, quoting Arendt, **Between Past and Future...**). It is this "social character" that allows science deniers to "discount them" (Crease, **The Workshop and the World...**, p. 256).

[57] See Bauckham, **Jesus and the Eyewitnesses...**

[58] See Adam Frank, Marcelo Gleiser, and Evan Thompson, **The Blind Spot: Why Science Cannot Ignore Human Experience**, MIT Press, Cambridge 2024.

[59] See Hardwig, "The Role of Trust in Knowledge...".

[60] See Hardwig, "Epistemic Dependence...".

[61] Hardwig, "The Role of Trust in Knowledge...", p. 698.

[62] See Polanyi, **Personal Knowledge...**

without [truth] there is no science." Of course, at a practical level we can be sufficiently sure of things that we can be confident of success in proposed actions (which is his particular interest). But at a philosophical level, what sense does it make to say (for example) that Newton's physics was "true", in view of the non-Newtonian advances in physics starting with Maxwell's electrodynamics? On the other hand, it is also clearly perverse to say Newtonian physics was "false"! Catherine Elgin argues that "*felicitous falsehoods*" can be "*epistemically valuable*". [63]

Stamenkovic acknowledges this, calling science "our best available, most reliable (although always revisable) knowledge". [64] Revisability is key. What is "fact" today may be "error" tomorrow, though the underlying phenomena (and their interpretations) remain in the record. [65] *Some* truth must have been captured, even if misarticulated.

Michael Lissack critiques the "*hidden assumptions*" (imposed as "enabling constraints" like *ceteris paribus*) that "allow ambiguity [66] to be bracketed away at the expense of transparency" [67], acknowledging Jürgen Habermas who points out that science "fragments into a number of competing viewpoints [...] shot through with values". [68] Examining such assumptions more transparently, as Lissack urges,

[63] Elgin, **True Enough...**, p. 1.

[64] Stamenkovic, "Straightening the »Value-laden Turn...".

[65] Karen Barad rightly states that the phenomenon is the "primary ontological unit" (Barad, **Meeting the Universe Halfway...**, p. 333).

[66] We are grateful to Julia Jordan for alerting us in 2022 to Anthony Ossa-Richardson's important monograph on "ambiguity" (see Ossa-Richardson, **A History of Ambiguity...**). Jeynes, Parker, and Barker interpret ambiguity as the characteristic property of the *metanarrative* of science (the "poetics of physics"), saying that scientists properly strive to avoid (or at least reduce) ambiguity, where poets revel in it (see Jeynes, Parker, and Barker, "The Poetics of Physics...").

[67] See Michael Lissack, "Second Order Science: Examining Hidden Presuppositions in the Practice of Science", *Foundations of Science* 2017, Vol. 22, pp. 557–573, http://dx.doi.org/10.1007/s10699-016-9483-x.

This has been supported recently by Michael and Matthias who show that people don't like AI (artificial intelligence) allocation of resources because they have no access to the machine's "reasoning" (see Haiden Michael and Uhl Matthias, "Resource Allocation by Algorithms: People Prefer Almost Any Alternative", *AI & Soc* 2026, February 12, https://doi.org/10.1007/s00146-026-02886-1).

[68] Jürgen Habermas, **Between Facts and Norms: Contributions to a Discourse Theory of Law and Democracy**, trans. William Rehg, Polity Press/MIT Press, Cambridge 1996, p. 141 (German original: Jürgen Habermas, **Faktizität und Geltung. Beiträge zur Diskurstheorie des Rechts und des demokratischen Rechtsstaats**, Suhrkamp Verlag, Frankfurt am Main 1992).

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should promote public acceptance of science.

Stamenkovic also notes the importance of distinguishing facts from values. But since science is a human pursuit driven by our desire to understand the world, it cannot be value-free (as Habermas observed). Still, we aim for consensus — what we call "facts". This does not mean it's all "just opinion": phenomenological evidence and formal interpretations are publicly recorded. Though "facts" may evolve, the record persists.

Public trust in science depends on an open interplay between facts and values. Only by making this visible can we demonstrate the integrity of science — and persuade others that it speaks truthfully about reality.

5. Realism and the Metaphysical Existence of Truth

What is real? How do we know? The first question is ontic, the second epistemic. We offer a perspective distinct from Carlo Rovelli's scientistic view [69], which overlooks or distorts metaphysics. Our approach is scientific, acknowledging the "metanarrative of physics" [70] — where "physics" is meant in Aristotle's broader sense ("nature" or "what there is").

Aristotle (and Plato before him) clearly understood the metaphysical basis of physical knowledge. Aristotle opens **Physics** with a reflection on scientific method [71], and Plato emphasized "*the dialectical method*" as the only path to first principles. For Aristotle, science is inherently metaphysical: if first principles be-

[69] Charles Lowney says, in a discussion of Polanyi's (see Polanyi, **Personal Knowledge...**) seminal work: "the Enlightenment's [...] critical rationalism brought a »scientism« that justifies only facts based on physics and considers meaning and human values to be illusory", but we don't say that Rovelli goes that far! (Charles W. Lowney II, "Michael Polanyi: A Scientist Against Scientism", in: Gene Callahan, Kenneth B. McIntyre (eds), **Critics of Enlightenment Rationalism**, *Palgrave Studies in Classical Liberalism*, Palgrave Macmillan, Cham 2020, p. 139 [139–158], https://doi.org/10.1007/978-3-030-42599-9_10).

[70] What precisely is meant by "the metanarrative of physics" (which is what we mean by "metaphysics")? Is it an implicit philosophical framework? Or perhaps a poetic background to the logical structure of theories? Neither (or perhaps, both). We mean, the way we talk about the issue (in a natural language) so as to convey its meaning. We should try to be precise, but in the end our understandings must be incomplete and we have to live with ambiguity. Nature is what it is, but our grasp of it is necessarily limited (see also Terrence W. Deacon, **Incomplete Nature: How Mind Emerged from Matter**, W.W. Norton & Co., New York 2011).

gin physics, then the dialectical route to them must be *metaphysical*. Jeynes, Parker, and Barker independently affirm this, noting that the meanings of the terms of a discussion cannot generally be established by the discussion itself. [72]

The disconcerting fact is that physics today typically concerns a variety of phenomena that need intricate experimental apparatus to observe, and often mindbogglingly complex mathematical models to interpret. Is all this stuff even real? Physicists normally ignore philosophical questions, but they all believe that the world is really there and that (on a good day) they can touch reality [73]: indeed, two Nobel-laureates have recently published their commitments to reality. [74] We all want to know *how the world is*. Where standard empiricism glosses over the idealistic underpinnings of observation, Nicholas Maxwell's "*aim-oriented empiricism*" rests on the metaphysical priority of unified theories. [75] We deeply value unity in physical theories, just as we strive for coherence in thought. We will return to *unity* (§7).

Rovelli claims we must "choose between hiding away in empty truths or accepting the radical uncertainty of our knowledge". [76] But why not affirm the truths we

[71] James Lennox has this account: Aristotle opens his *Physics* with a discussion of the method [μέθοδος, *methodos*] proper to obtaining scientific knowledge [ἐπιστήμη, *epistēmē*] in a scientific enquiry [φύσῐν ἱστορίᾱς, *physin istorias*] (see James G. Lennox, "How to Study Natural Bodies: Aristotle's μέθοδος", in: Mariska Leunissen (ed.), **Aristotle's Physics: A Critical Guide**, *Cambridge Critical Guides*, Cambridge University Press, Cambridge 2015, pp. 10–30). The word "μέθοδος " is formed from the noun ὁδός (a *road*) and the prefix μετα- (in this context having the force of "*in quest of*"), thus meaning "a path taken in pursuit of […]" (in this case, knowledge). Plato already used μέθοδος in the **Republic** [Πολιτεία, *Politeia*] speaking of "the dialectical method" [ἡ διαλεκτική μέθοδος, *ē dialektikē methodos*] as the only way to advance to first principles. Consequently, Aristotle understood very well that the scientific method is necessarily metaphysical.

[72] See Jeynes, Parker, and Barker, "The Poetics of Physics…".

[73] We are "alethic realists" in Leon-Philip Schäfer's terms (see Schäfer, "How (Not) to Integrate Scientific…"), although Philip Pullman's (see Philip Pullman, **Northern Lights**, Scholastic, London 1995) beautiful idea of Lyra's "alethiometer" can hardly be thought to "touch reality". However, at least one eminent physicist has claimed to be a solipsist; see "The Solipsist's Plea": "*Oh Universe! / I assume that you exist. / Let me feel your far flung matter, / so that your illusion may persist*" (Joan Vaccaro, "The Solipsist's Plea", *Joan Vaccaro*, https://tiny.pl/dn1bbbsm9 [10.08.2026]).

[74] See Roger Penrose, **The Road to Reality: A Complete Guide to the Laws of the Universe**, Jonathan Cape, London 2004; Frank Wilczek, **Fundamentals: Ten Keys to Reality**, Allen Lane, London 2021.

[75] See Maxwell, "Aim Oriented Empiricism…".

[76] Rovelli, **Anaximander and the Nature of Science…**, p. 177.

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hold, while also acknowledging, as Rovelli does, that we can be wrong? [77] Catherine Elgin, in **True Enough**, explores *truth* epistemologically, rejecting the "veritist" view as undermined by fallibilism. She notes, "Making mistakes is an epistemic achievement". [78] We can know, but never infallibly! She further explains, "To accept a contention is to be willing and able to use it as a premise in cognitively serious assertoric reasoning". [79] If proven wrong, we must change our minds — a process that demands honesty and courage, but is a true intellectual achievement.

Leon-Philip Schäfer argues that "realism [...] is, in the final analysis, best characterised as an alethic view which restricts itself to an idea about the objectivity of truth, rather than an epistemic view which underwrites more extensive theses concerning the accessibility of this truth for human knowledge". [80] Though Schäfer's claim is technical and limited, we adopt his term "alethic realism": like Rovelli, we

[77] Kevin Scharp has attacked the very idea of "truth", claiming that "the concept of truth is defective in the sense that its platitudes are inconsistent" (Kevin Scharp, "Conceptual Engineering For Truth: Aletheic Properties and New Aletheic Concepts", *Synthese* 2021, Vol. 198, p. S684 [S647–S688], https://doi.org/10.1007/s11229-019-02491-4) (although he also acknowledges that "There is a meaningful English word, »true«, and there is a concept of truth expressed by that word"). But Jamin Asay has attacked this thesis on the grounds that Scharp's programme for repairing the (admittedly useful) concept is in fact empty (see Jamin Asay, "Irreplaceable Truth", *Synthese* 2024, Vol. 203, article number: 85, https://doi.org/10.1007/s11229-024-04498-y). Asay does not show that the "concept of truth" is not defective, but he does assert that (the concept) *Truth* "may well be irreplaceable". We think that to do science effectively it is necessary to believe both that the world is real and also that we can know it truly. Thus, to be a scientist we think that a commitment to truth is indispensable (and it is interesting that both Scharp and Asay use the word "commit" and its cognates repeatedly and without philosophical discussion — that is, as a philosophical primitive).

[78] Elgin, **True Enough...**, p. 291.

[79] Elgin, **True Enough...**, p. 293.

[80] Schäfer, "How (Not) to Integrate...".

Schäfer explains that the consensus philosophical view in both science and metaethics is currently that realists take the discourses of their fields at face value, and oppose approaches that do not allow clear true/false judgments (so that they do not allow truth judgments to be determined by mind states). However he argues that such a position is misleading (indeed, actively false) because scientific and moral issues are treated differently. Crudely, scientific realists holding this consensus position will *not* be (philosophically) neutral about the truth of general relativity (for example) where moral realists *will* be (philosophically) neutral about abortion rights (for example). But Schäfer points out that philosophers as such do not have the authority to make such judgments in scientific matters, just as it is widely recognised that they have no authority (as philosophers) to make such judgments in ethics.

hold that "realism matters because it is a presupposition of fallibilism". [81] If truth depends on reality, then accessing it is difficult — and certainty impossible. We affirm both: that reality is hard to know, and that certainty is unattainable.

Certainly, many different sorts of assertions may be affirmed true. But they must all be consistent with each other! In practice scientists (who are not usually professional philosophers) are driven by (or at least guided by) what could be called a "vernacular" understanding of *truth*: such a vernacular (or common) meaning of "*Truth*" lies outside the interest of *analytic philosophy*, since it represents a *choice* between the value judgments truth/lie. But even while practising science we make value judgments all the time: should philosophy not critique such activity? Marlon Bulaqueña shows that Gödel's Theorems imply that what he calls "*ontological excess*" is a structural limitation on any logical account of the scientific enterprise: this implies strong limitations on the reach of analytic philosophy. [82] In particular, Bulaqueña's "ontological gap" is precisely where our value judgments reside. Moreover, such a vernacular understanding of *truth* actually underlies the whole scientific enterprise. Science can be done only if scientists re-

Schäfer intends to argue against "constructivist principles and relativist themes" (Schäfer, "How (Not) to Integrate …", note 21). He calls "scientific realism […] much more epistemically deformed than moral realism […] because its (alethic) core idea about truth has been turned into an (epistemic) view about our cognitive access to the truth". Schäfer contrasts this with "*moral realism*" which "remains neutral regarding normative-ethical judgments [because] it does not involve any anti-sceptical commitments [identifying] metaphysical, instead of epistemic views as its primary opponents" (whereby "*metaphysical*" here he means "*ontological*"). Schäfer concludes by arguing that the approaches of the scientific realists on the one hand and the ethical realists on the other could be unified if they both embraced "a return to alethic realism", by which term he means "a realist conception of truth", that is that "the (objective) truth is deemed to be independent from (subjective) opinions". And by "objective" here he means "observer-independent". He points out that "alethic realists are not actually indifferent towards sceptical worries, but merely strive to keep their conception of realism free from such epistemic commitments".

[81] See Schäfer, "How (Not) to Integrate…".

[82] Bulaqueña asserts: "[This] structural reading […] shows that […] [taking] a single formalism […] [implies a] gap between semantic content and syntactic derivability […] [It also] highlights the need for non-syntactic justificatory practices […] these are substantive philosophical question that require argument beyond the formal theorems". It is actually irrational to think that we can prove all truths! Bulaqueña recommends "[adopting] pluralist strategies where appropriate" (Marlon Bulaqueña, "Formal Systems and What They Leave Out: Gödelian Incompleteness and Structural Limits of Representation", manuscript accepted for publication in *Synthese* (forthcoming, 2026), https://tiny.pl/28vz08vw8 [10.02.2025]).

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port their observations truthfully as they see or understand the matter (and we have discussed scientific fraud above).

The issue of *creativity* is closely related to *truth*. For example, Ursula Goodenough's account is rather explicit in how she addresses what is in effect Bulaqueña's "*ontological excess*" (which is what C.S. Peirce called "*abduction*" [83]; of course, many have commented on the centrality of creativity to the scientific enterprise, for example Tom McLeish [84], and the classical work of Owen Barfield [85]): "[the metaphoric nature of the scientific description] does not negate the truth of the description, nor the deeper truth of the insight generating the description". [86]

6. The Illusion of "Objectivity"

Karen Barad [87] states, "The primary ontological unit is the phenomenon" [88], a conclusion based on her extensive discussion of quantum mechanics and entanglement. She argues that these entanglements redefine objectivity: "Knowing is not a matter of reflecting at a distance; rather, it is an active and specific practice of engagement. To know is to become entangled: objectivity requires that one takes responsibility for one's entanglements". [89]

The EPR Paradox proposed by Einstein, Podolsky, and Rosen in 1935 pointed out that *entanglement* of two particles persists over great distances, such that

[83] See Ursula W. Goodenough, "Creativity in Science", *Zygon* 1993, Vol. 28, pp. 399–414, https://doi.org/10.1111/j.1467-9744.1993.tb01043.x.

See also Charles Sanders Peirce, "Pragmatism as the Logic of Abduction", Harvard Lecture VII (14 May 1903), in: Charles Hartshorne and Paul Weiss (eds.), **Collected Papers of Charles Sanders Peirce**, Vol. 5, Harvard University Press, Cambridge 1934, §§ 180–212.

[84] See McLeish, **The Poetry and Music of Science...**

[85] See Barfield, **Poetic Diction...**

[86] Goodenough, "Creativity in Science…", p. 400.

[87] We thank Rachel Holland for pointing us to Barad's important work. Karen Barad identifies as non-binary, so we intend the reader to treat as gender-neutral any personal pronouns we use referring to "her".

[88] Barad, **Meeting the Universe Halfway...**, p. 333.

[89] Barad, **Meeting the Universe Halfway...**, note 1.

a measurement on one affects the other — violating the prohibition on instantaneous information transfer. John Bell resolved this in 1964 with the "Bell Inequality," a test for locality. [90] The core issue is how to interpret quantum mechanics: is quantum uncertainty [91] ontic or merely epistemic? Is Schrödinger's cat truly both alive and dead (as entangled states suggest), or is this conundrum merely due to our ignorance? Is knowledge objective? Are scientific descriptions of the world real? Disconcertingly, experiments confirm that entanglement is indeed real, as shown by many tests of the Bell Inequality. [92]

[90] See for example Tim Maudlin on the *Bell Inequality* tests confirming that Quantum Mechanics is a *non-local* theory (see Tim Maudlin, "What Bell Proved: A Reply to Blaylock", *American Journal of Physics* 2010, Vol. 78, pp. 121–125, https://doi.org/10.1119/1.3243280), and Jeeva Anandan confirming the incompatibility of QM and General Relativity since GR is a *local* theory (see Jeeva Anandan, "Non-Locality of Quantum Mechanics and the Locality of General Relativity", *Modern Physics Letters A* 2002, Vol. 17, pp. 1097–1106, https://doi.org/10.1142/S0217732302007661).

[91] The Uncertainty Principle simply asserts that conjugate operators do not commute, with a definite "canonical commutation relation" which is $[\hat{x}, \hat{p}] = i\hbar$. This means (crudely), if you know exactly where you are you have no idea how fast you are going, and conversely, if you know exactly how fast you are going you have no idea where you are. Did you hear the one about Heisenberg stopped for speeding? *Policeman*: well Sir, do you know how fast you were going? *Heisenberg*: no, but I know where I am ... (see Tony Phillips, "The Mathematical Uncertainty Principle", *American Mathematical Society* 2005, November, https://tiny.pl/t_6mnpzgv [17.04.2024]). This "Uncertainty Principle" is quite general: Parker and Jeynes have shown that it is a consequence of Liouville's Theorem and applies to entropic as well as energetic systems (*mutatis mutandis*) (see Michael C. Parker and Chris Jeynes, "Entropic Uncertainty Principle, Partition Function and Holographic Principle Derived from Liouville's Theorem", *Physics Open* 2021, Vol. 7, article number: 100068, https://doi.org/10.1016/j.physo.2021.100068).

[92] For example, Proietti et al. report an elegant three-photon-pair implementation of a "Wigner's friend experiment" demonstrating a violation of the associated Bell inequality, which was glossed online as the assertion "Objective Reality Doesn't Exist, Quantum Experiment Shows" (see Massimiliano Proietti and Alessandro Fedrizzi, "Objective Reality Doesn't Exist, Quantum Experiment Shows", *Live Science* 2019, November 16, https://tiny.pl/d-4wt420v [26.06.2026]). The paper opens with the assertion, "The scientific method relies on facts, established through repeated measurements and agreed upon universally, independently of who observed them" (Massimiliano Proietti, Alexander Pickston, Francesco Graffitti, Peter Barrow, Dmytro Kundys, Cyril Branciard, Martin Ringbauer, and Alessandro Fedrizzi, "Experimental Test of Local Observer Independence", *Science Advances* 2019, Vol. 5, article number: eaaw9832, https://doi.org/10.1126/sciadv.aaw9832).

But reality is elusive. In this case the results observed are *not* objective (in the sense that they are not observer-independent). As Karen Barad explains in detail, this does not mean that reality itself is illusory, only that knowing it is not necessarily very straightforward. Quoting Niels Bohr, Aage Petersen writes: "Traditional philosophy has accustomed us to regard language as something secondary, and reality as something primary. [Niels] Bohr considered this attitude toward the relation between language and reality inappropriate. When one said to him that it cannot be language that is fundamental, but that it must be reality that, so to speak, lies beneath language, and of which language is a picture, he would reply,

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We will discuss what is "fundamental" (§8), but the EPR paradox and the consequent interest in establishing violations of the Bell Inequality are at the heart of our current understanding of the nature of reality and of our current approach to the scientific method. It turns out that for entangled systems we cannot use our standard notions of "objectivity" (observer independence), which are simply too crude: the very idea of "objectivity" is an approximation, which is sometimes just not good enough. The issue is locality vs. non-locality, and causality vs. acausality, [93] both of which become much more complicated when time is complexified. [94] Entangled systems can be profoundly non-local — and may be more numerous and important

»We are suspended in language in such a way that we cannot say what is up and what is down. The word 'reality' is also a word, a word we must learn to use correctly« (Aage Petersen, "The Philosophy of Niels Bohr", *Bulletin of the Atomic Scientists* 1963, Vol. 19, No. 7, p. 10 [8–14], https://doi.org/10.1080/00963402.1963.11454520).

[93] Thomas Hertog speaks of "the orthodox way of reasoning in physics [which seeks] a fundamentally causal explanation for the universe's biofriendliness" (Hertog, **On the Origin of Time**..., p. 198), going on to say: "The first bottom-up attempt to untangle the riddle of design was to search for a profound mathematical truth at the kernel of existence [...] But top-down cosmology turns the riddle of design upside down" (Hertog, **On the Origin of Time**..., p. 198). Hertog and Stephen Hawking had concluded (with most other commentators today, including Rovelli) that those "profound mathematical truths" just did not exist, and another way of proceeding was needed.

David Bohm also commented on these (alleged) "profound mathematical truths", also saying in effect that they did not exist, since "touching reality" is *guided* by mathematics, not *expressed* by it: "[...] until the present [20th] century, the physical concepts were, for the most part, considered as primary, while mathematical equations were regarded as providing a more precise and detailed way of talking about [them] [...] [but] during the 1920s Sir James Jeans said that God must be a mathematician, implying by this that the universe is constructed on a mathematical plan and that its essence is best grasped in terms of the mathematics itself. ... Heisenberg went much further along these lines and said very explicitly that the essential truth was in the mathematics. This view has become the common one among most of the modern theoretical physicists who now regard the equations as providing their most immediate contact with nature (the experiments only confirming or refuting the correctness of this contact). So, without an equation there is really nothing to talk about. On the other hand, in the past we began talking about our concept of physical reality and used the equations to talk about them" (David Bohm and Basil J. Hiley, **The Undivided Universe: An Ontological Interpretation of Quantum Theory**, Routledge, London–New York 2003, p. 320 (first published in 1993; paperback edition 1995)).

Bohm is right: the formulation of our ideas in mathematical terms should be regarded simply as a systematic method of ensuring the integrity of complex logical arguments, with the mathematics ensuring the *validity* of the argument but saying nothing about its *truth*. That is, mathematics provides the disambiguated analytical narrative, whereas the (poetic) metanarrative is required to discern truth (see Jeynes, Parker, and Barker, "The Poetics of Physics..."). We must take Gödel's metamathematical breakthrough seriously (see Gödel, "Über formal unentscheidbare Sätze...", §10).

[94] See §7 and Parker and Jeynes, "Relating a System's Hamiltonian to its Entropy...".

than we have thought up to now. Often, we overlook what we don't expect — or believe possible!

Barad makes the point (in the light of the quantum revolution) that our Newtonian view of the distinct knowability of *objects* as such (electrons, protons, etc.) is faulty. Strictly speaking, there is no such thing as "an electron" *per se*, since all electrons in the universe are more or less entangled together (being indistinguishable). [95] The idea of *a single electron* is a convenient (and very successful) word game that enables us to set up effective models that allow us to correctly interpret certain sufficiently simple phenomena. But Barad insists: "No inherent [...] subject/object distinction exists". [96]

Faye and Jaksland critique Barad's "*agential realism*," noting its influence in the humanities while highlighting its absence from physics or philosophy of physics discourse. [97] They assert that "*agential realism [is] a theoretical framework that [...]*

[95] The press release for the Nobel Physics Prize awarded in 2025 to Martinis, Devoret, and Clarke is explicit, speaking of the superconducting system invented by the laureates in 1985 (summarised by John M. Martinis, Michel H. Devoret, and John Clarke, "Quantum Josephson Junction Circuits and the Dawn of Artificial Atoms", *Nature Physics* 2020, Vol. 16, pp. 234–237, https://doi.org/10.1038/s41567-020-0829-5) they say: "Together, the charged particles moving through the superconductor comprised a system that behaved as if they were a single particle that filled the entire circuit" (**The Nobel Prize in Physics 2025** (Press Release), The Royal Swedish Academy of Sciences, 7 October 2025, https://www.nobelprize.org/uploads/2025/10/press-physicsprize2025.pdf [11.07.2026]).

[96] Barad, **Meeting the Universe Halfway...**, p. 114.

[97] See Jan Faye and Rasmus Jaksland, "Barad, Bohr, and Quantum Mechanics", *Synthese* 2021 Vol. 199, pp. 8231–8255, https://doi.org/10.1007/s11229-021-03160-1.

Karen Barad's proposal of "agential realism" involves "rethinking the relationship between materiality and signification" (Barad, **Meeting the Universe Halfway...**, p. 132). Faye and Jaksland comment on "the widespread reception of Barad's account of quantum mechanics [...] in the social sciences and humanities", evaluate the relation of Barad's proposal to Niels Bohr's position, and assert that they are the first to assess "Barad's claim that agential realism, apart from its importance to social theorizing, is making a »specific scientific contribution to an active scientific research field (i.e., the foundations of quantum physics)«" (Faye and Jaksland, "Barad, Bohr...", pp. 8233 and 8234, quoting Barad, **Meeting the Universe Halfway...**, p. 36, and pointing out that Barad herself has not published on agential realism in the physics or philosophy of physics literature).

Faye and Jaksland assert that they refute "Barad's claim that agential realism captures the consequences of quantum mechanics for all domains of inquiry including social theorizing" (Faye and Jaksland, "Barad, Bohr...", p. 8235). But what Barad says is not quite what they say she says: "What is needed is an analysis that enables us to theorize the social and natural together [...] To write matter and meaning into separate categories [...] is to elide certain crucial aspects by design" (Barad, **Meet-**

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aims to inform social theorizing" and are critical of her reading of Bohr.

Barad's ambition goes beyond epistemology — she aims to redefine ontology: "Existence is not an individual affair" [98]; "mattering is an integral part of the ontology of the world [...] not even a moment exists on its own" [99]. The world is really there, but only *agents* can know it. And the agents are themselves necessarily entangled in the world.

We are convinced that our best scientific insights can indeed help to expose the substance of reality. Therefore, we regard it as axiomatic that, just as truth is

ing the Universe Halfway..., p. 25). (This is also closely related to Atmanspacher's idea of "psychophysical neutrality" (see Harald Atmanspacher, "Psychophysical Neutrality and Its Descendants: A Brief Primer for Dual-aspect Monism", *Synthese* 2024, Vol. 203, article number: 25, https://doi.org/10.1007/s11229-023-04449-z)). The point of course is that one is unable to speak sensibly of "matter" without also being able to say what one *means*. We cannot say anything coherent about *matter* without also being able to say how we know such things, which involves speaking of the experiments one has to do (and interpret) and the measurements one must make. But measurement itself is much more anthropocentric than is commonly thought: metrologists themselves have drawn a careful philosophical distinction between *being a quantity* and *being measurable*. They point out that this distinction is an ontological one, and moreover, that "measurement is primarily an epistemic process" (see Mari, Maul, Irribarra, and Wilson, "Quantification is Neither Necessary Nor Sufficient..."; Mari, Wilson, and Maul, **Measurement Across the Sciences...**).

However, we believe that Faye and Jaksland's conclusion ("that neither Bohr nor quantum mechanics as a whole proves Barad's agential realism to be true" (Faye and Jaksland, "Barad, Bohr...", p. 8235)) is correct, if underwhelming. But they go on to point out, also correctly: "Barad's ideas are profound, interesting, and thought provoking, but like any other piece of social theorizing, agential realism must earn its merits, if any, by its utility and not by its quantum mechanical origin" (Faye and Jaksland, "Barad, Bohr...", p. 8235) (where "utility" in this case — counter-intuitively — must be taken as idealistic rather than utilitarian). We are of the view that one does not have to swallow all of Barad's position on "agential realism" to see the value of her position on the ontological priority of phenomena, a position that plays havoc with conventional views of "objectivity".

Together with Faye and Jaksland we also look askance at the ideas of "quantum anthropologies" or "quantum geography" (for example), but we shouldn't let the errors of youthful exuberance eclipse the deeper truth: we see as we are taught, most of the time, and it is a serious effort to see differently. And physics can help in upsetting the "common sense" views we are thoughtlessly wedded to so much of the time. We are convinced that our best scientific insights can indeed help to expose the substance of reality.

Faye and Jaksland claim that "Barad's summary [...] is not entirely faithful to Bohr's view [...] [going] well beyond what Bohr seems to have had in mind when [Barad] promotes the phenomenon to an ontological unit" (Faye and Jaksland, "Barad, Bohr...", p. 8240): they insist that Bohr thought that "This effect, i.e. the phenomenon, is the manifestation of a property that only exists in virtue of the interaction. It belongs neither to the object itself nor to the measuring instrument" (Faye and Jaksland, "Barad, Bohr...", p. 8240). This seems debatable to us (Bohr's philosophy is notoriously impenetrable, as is clear from Gerald Holton's extended account (see Gerald Holton, "Roots of Complementar-

one so reality must also be an integrated thing. Then our view of reality as natural scientists must be consistent with our view of it as concerned citizens (or poets). And consequently, we cannot treat insights into reality obtained from the natural sciences as "mere metaphors"; the link is stronger than that. Iris Murdoch is very definite about this: "Metaphors are not merely peripheral decoration or even useful models, they are fundamental forms of the awareness of our condition … [some] concepts are themselves deeply metaphorical and cannot be analysed into non-metaphorical components without a loss of substance". [100]

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ity", *Dædalus* 1970, Vol. 99, No. 4, pp. 1015–1055)) — in any case Barad is not compelled to follow Bohr slavishly: and even if the former master's view can be determined accurately, that does not mean that he wouldn't take a different view today in the light of the further information available. Faye and Jaksland say, "Barad misreads Bohr as if he was saying that, say, the position is a property of the phenomenon, whereas Bohr holds that the phenomenon is identical to the manifestation of a quantitative property that atomic objects can be attributed only because of its interaction with the measuring instrument. Thus, a phenomenon does not have an independent ontological status but depends on an interaction of the atomic object and the measuring instrument. Both of which, by the operational presumption of doing science, are presumed to be independently real" (Faye and Jaksland, "Barad, Bohr…", p. 8240).

Our judgment is that the last sentence is the crux: "Both [the atomic object and the measuring instrument], by the operational presumption of doing science, are presumed to be independently real" (Faye and Jaksland, "Barad, Bohr…", p. 8240). We have already quoted Bohr himself: "The word »reality« is also a word, a word we must learn to use correctly". How are we assured of the "independent reality" of the "atomic object"? We regard Barad as being correct in pointing to the systematic entanglements of (supposed) "atomic objects" in a way that plays havoc with our naïve ideas of what "objects" are. George Berkeley long ago pointed out the centrality of perception to our ontological ideas (*esse est percipi*) (see George Berkeley, **Treatise Concerning the Principles of Human Knowledge**, Jeremy Pepyat, Dublin 1710): it seems to us that Barad is only pushing this account towards a logical conclusion that appears to be consistent with the sophisticated observations of modern physics. The issue, precisely, is that our dominating intuition that integrity and unity must be of ontological significance appears to be incoherently articulated by our conventional (admittedly Newtonian) views of "objects". It seems that "cause-and-effect" is not as "simple" as we had naïvely thought, and this is underlined by the unexpected re-appearance of the idea of "non-locality" which had already disturbed Newton (he worried that gravity, "action at a distance", was not "properly" mechanistic (see Steffen Ducheyne, "Newton On Action at a Distance and the Cause of Gravity", *Studies in History and Philosophy of Science A* 2011, Vol. 42, pp. 154–159, https://doi.org/10.1016/j.shpsa.2010.11.003).

It is worth underlining this point. Barad correctly says that "for Bohr, things do not have inherently determinate boundaries or properties, and words do not have inherently determinate meanings" (Barad, **Meeting the Universe Halfway…**, p. 138). The practice of science is an intricately human activity. Apparently, "Bohr's favorite aphorism was Schiller's »Nur die Fülle führt zur Klarheit«" ("naught but fullness leads to clarity"; Holton, "Roots of Complementarity…", quoting Friedrich von Schiller, **Sprüche des Konfuzius**, Siegfried Lebrecht Crusius, Leipzig 1804 (written in 1795): the intricacy is of the essence!

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Murdoch highlights the non-analytic character of language (including *metaphor*), engaging with the *substance* of reality as both philosopher and novelist. Scientific and social realities are not separate — though scientists often have a "Blind Spot" [101] about broader implications.

Parker and Jeynes offer a physics that explicitly treats local/non-local, causal/acausal, and reversible/irreversible elements commensurately. [102] Mathematically complexifying the formalism [103] makes available the power of complex analysis: the (Wick rotated) complex conjugate of the Hamiltonian (*energy*) is (in natural units) the

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Even "doing experiments" is philosophically complicated. Barad quotes Ian Hacking (see Ian Hacking, **Representing and Intervening: Introductory Topics in the Philosophy of Natural Science**, Cambridge University Press, Cambridge 1983, p. 230): "most experiments don't work most of the time. To ignore this fact is to forget what experimentation is doing [...] only when one has got the equipment running right is one in a position to make and record observations. That is a picnic" (Barad, **Meeting the Universe Halfway...**, p.144f). How do we account, philosophically speaking, for the way the experimenter gets the experiment to work? It is important to realise that this typically takes a long time: even little experiments usually take days to set up, and big ones may take years for large teams. Roy Bhaskar emphasises this, calling it "the arduous task of science: the production of the knowledge of those enduring and continually active mechanisms of nature that produce the phenomena of our world" (Roy Bhaskar, **A Realist Theory of Science**, 2nd ed., Routledge, Abingdon 2008, p. 37 (first published by Leeds Books, Leeds 1975)). For Bhaskar insists (correctly) that the world is normally open, and that "a closure is normally a human product" (of "experimental production", Bhaskar, **A Realist Theory of Science...**, p. 43, n. 36).

Experimenters always want to *measure* something, and measurement necessarily requires a "measurement model", that is, according to the authoritative **International Vocabulary of Metrology** (see Joint Committee for Guides in Metrology, **International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM)**, 3rd ed., BIPM, Paris 2008, §2.48, https://tiny.pl/0823cswfn [17.04.2024]), "a mathematical relation among all quantities known to be involved in a measurement". This is very demanding of the experimenters: for examples see C. Jeynes, N.P. Barradas, and E. Szilágyi, "Accurate Determination of Quantity of Material in Thin Films by Rutherford Backscattering Spectrometry", *Analytical Chemistry* 2012, Vol. 84, No. 14, pp. 6061–6069, http://dx.doi.org/10.1021/ac300904c; C. Jeynes, E. Nolot, C. Costa, C. Sabbione, W. Pessoa, F. Pierre, A. Roule, G. Navarro, and M. Mantler, "Quantifying Nitrogen in GeSbTe:N Alloys", *Journal of Analytical Atomic Spectrometry* 2020, Vol. 35, No. 4, pp. 701–712, http://dx.doi.org/10.1039/C9JA00382G.

[98] Barad, **Meeting the Universe Halfway...**, p. ix.

[99] Barad, **Meeting the Universe Halfway...**, p. 396.

[100] Murdoch, **The Sovereignty of Good...**, p. 74 (2001 Routledge edition).

We thank Julia Jordan for alerting us to Murdoch's significant contribution.

[101] Frank, Gleiser, and Thompson assert that "Our scientific worldview [...] ultimately runs aground on its own paradoxes of inner versus outer, and observer versus observed, that collectively turn on the conundrum of how to understand awareness and subjectivity in a universe that was

(complex*) entropy production* [104], encoding a set of (continuum) cause-and-effect relations across the complex time plane. This result is deeply unsettling: it blurs categories we thought were distinct and challenges the notion of unique causal relationships. Though "complex time" seems strange, it is becoming more familiar.

Ultimately, using the "subjective/objective" distinction to frame discussions of reality is a category error. Grammatical terms shouldn't carry ontological weight. Rather, the truth of a statement is found through the interplay between its syntactical (narrative, analytic) and semantic (metanarrative, poetic) components.

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supposed to be fully describable in objective scientific terms without reference to the mind" (Frank, Gleiser, and Thompson, **The Blind Spot...**, p. viii). They call this conundrum the "Blind Spot" in analogy to the optical "blind spot" (where the optic nerve exits the retina): "At the heart of science lies something we do not see that makes science possible, just as the blind spot lies at the heart of our visual field and makes seeing possible" (Frank, Gleiser, and Thompson, **The Blind Spot...**, p. xi).

We are grateful to Robert Crease for introducing us to this important work.

[102] See Parker and Jeynes, "Relating a System's Hamiltonian to its Entropy…".

[103] "Complex" numbers have "real" and "imaginary" parts. But there is nothing intrinsically "imaginary" about imaginary numbers, just as "real" numbers aren't intrinsically real. We only have this terminology because Descartes thought that the square root of -1 ($\sqrt{-1}$) was a fiction of the mathematicians. Roger Penrose explains: "[...] the seemingly mystical quantity $\sqrt{-1}$ [was] first encountered in the 16th century, but treated for hundreds of years with distrust [...] until complex numbers became an indispensable, even magical, ingredient of our mathematical thinking [...] these strange numbers also play an extraordinary and very basic role in the operation of the physical universe [...]" (Penrose, **The Road to Reality...**, p. 67 (§3.5)). It is telling that Penrose uses the word "magical" (figuratively, of course): his chapter 4 is even titled "Magical Complex Numbers".

[104] The (complex) Hamiltonian and the (complex) entropy production are Hilbert transforms of each other (see note above on "complex numbers"). Apologies for the heavily technical language in the text. All these arcane terms are "standard" and "well known" to mathematical physicists: for proper explanation of them the reader is referred to the literature.

On the idea of "complex time", *time* is "imaginary" in 4D Minkowski space-time. But this is merely a convention: Thomas Hertog has mused, in the context of a deep discussion of holographic cosmology: "What if we conceive of AdS [anti-de-Sitter space] and its antipode in imaginary time?" (Hertog, **On the Origin of Time...**, p. 240).

Whether time is imaginary and space real (with the "signature" "− + + +") or time is real and space imaginary (with the "signature" "+ − − −") has generally been considered a matter of convention or even convenience (see the discussion of "signatures" in: Penrose, **The Road to Reality...**, p. 281 (§13.8)). Although recent work by Parker and Jeynes indicates that the signature (or metric) distinguishes between dissipative and reversible processes (see Michael C. Parker and Chris Jeynes, "Relating a System's Hamiltonian to its Entropy Production Using a Complex-Time Approach", *Entropy* 2023, Vol. 25, No. 4, article number: 629, http://dx.doi.org/10.3390/e25040629).

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7. On Unity

Nicholas Maxwell correctly insists that "physics accepts only unified theories". [105] This aligns with Leszek Nowak's conception of the *unity of science*, explored by Mateusz Wajzer: "Nowak concluded [...] that scientific theories do not arise from the generalisation of empirical facts, and they are far from hypothetical-deductive systems [...] idealisation [106], not abstraction, is at the core of the scientific method". [107]

But imaginary time also appears in "standard" quantum mechanics (see for example Patrick McGlynn and Cédric Simenel, "Imaginary-time Mean-field Method For Collective Tunnelling", *Physical Review C* 2020, Vol. 102, article number: 064614, https://doi.org/10.1103/PhysRevC.102.064614), using the "Wick rotation" (helpfully explained by O'Brien (see D.M. O'Brien, "The Wick Rotation", *Australian Journal of Physics* 1975, Vol. 28, No. 1, pp. 7–13, https://doi.org/10.1071/PH750007)). "Complex" time has been introduced by other contributors: most notably Ivo Dinov's "spacekime" (see for example Yuxin Wang, Yueyang Shen, Daxuan Deng, and Ivo D. Dinov, "Determinism, Well-posedness, and Applications of the Ultrahyperbolic Wave Equation in Spacekime", *Partial Differential Equations in Applied Mathematics* 2022, Vol. 5, article number: 100280, https://doi.org/10.1016/j.padiff.2022.100280); but also Carl Frederick's ideas of "granular space-time" (see Carlton Frederick, "Granular: Granular Stochastic Space-time: The Nature of Time", *arXiv* 2022, https://doi.org/10.48550/arXiv.1601.07171), and Philip K Dick's "orthogonal time" (published posthumously, Pamela Jackson and Jonathan Lithem (eds.), **The Exegesis of Philp K. Dick**, Boston: Houghton Mifflin Harcourt, Boston 2011). Exactly how these various ideas are related remains to be seen. (We are grateful to William Sarill, email 11th April 2024, for drawing our attention to these connections.)

[105] Maxwell, "Aim Oriented Empiricism...", p. 347.

[106] This recalls Catherine Elgin's assertion that idealisations are not *true* in the way epistemologists would like (instead, they are "true enough"!) (see Elgin, **True Enough...**). She urges that "belief, assertion and knowledge should be sidelined in favor of acceptance, profession and understanding" (Elgin, **True Enough...**, p. 9). We thank an anonymous referee for alerting us to Elgin's important book.

Mateusz Wajzer correctly says that "reductionism [...] can be considered as a standard cognitive procedure applied in science" (Mateusz Wajzer, "Idealisation, Genetic Explanations and Political Behaviours: Notes on the Anti-reductionist Critique of Genopolitics", *Studies in History and Philosophy of Science* 2021, Vol. 90, p. 282 [275–284], https://doi.org/10.1016/j.shpsa.2021.10.014). But, as with all procedures, there are limits! We show (§8) that it is false to regard fundamental particles as invariably the most fundamental representation: in some circumstances there demonstrably exist unitary entities at least as "fundamental" as recognised "fundamental particles". Wajzer's comment that scientific models are usually "counterfactually deformed and ontically poorer" representations is fair (Wajzer, "Idealisation...", p. 276), but scientific realists will recognise this ontic poverty and be open to richer representations.

Wajzer relies (and builds) on Leszek Nowak's distinction between idealisation and abstraction: "The fact that science applies idealizations is a commonplace. [...] The philosophical presuppositions of the idealizational method remain, however, entirely mysterious" (Leszek Nowak, "Abstracts are not

Unity is a foundational metaphysical idea — without it, science (and knowledge) would collapse. Truth must be *one* to mean anything [108]. So, this is true for everyone: the electron's rest mass is about 9.10^{-31} kg (or 511 keV). We rely on this value for scientific modelling, even if we question the ontological status of the "electron". It's telling that even a basic quantity like particle mass requires nuanced framing. [109] Reality is elusive.

Do "unitary entities" exist? Gottfried Leibniz thought so, famously calling them "monads"; the 17th century "metaphysical poets", fascinated by "atoms", thought

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our Constructs. The Mental Constructs are Abstracts", in: Jerzy Brzeziński, Francesco Coniglione, Theo A.F. Kuipers, and Leszek Nowak (eds.), **Idealization I: General Problems**, *Poznań Studies in the Philosophy of the Sciences and the Humanities*, Vol. 16, Brill, Leiden 1990, p. 193 [193–206], https://doi.org/10.1163/9789004457157_010). Nowak says that "Abstraction is generalization. Idealization is not", going on to explain that "The main difference between abstraction and idealization is that the former leads from a given level of the set-theoretical hierarchy to the next, higher, one, whereas the latter remains on one and the same level" (Nowak, "Abstracts are not our Constructs…", p. 195).

[107] Mateusz Wajzer, "On Leszek Nowak's Conception of the Unity of Science", *Foundations of Science* 2024, Vol. 29, p. 307 [307–324], https://doi.org/10.1007/s10699-022-09843-3.

[108] Ultimately, if truth is not one then nothing can be known. Unity and coherence are critical! A scientist's worst nightmare is discovering that his account is internally inconsistent. Of course, different actors have different assessments of what is true, and it may not always be possible to tell who is right. Reality is elusive. Monserrat Neto points out (email 11/4/2025) that in disciplines like sociology or psychology (for example), perceived "truth" may take more plural and context-dependent forms.

[109] We can debate the uncertainties (which are very small for this parameter), and we can debate whether an individual "electron" can be thought even to exist *per se* (see Barad, **Meeting the Universe Halfway…**), and we can debate the difference between an interpretation we put onto an observed phenomenon and the posited entity being observed, and so on; but after all, we know the value we need to use for the rest mass of the thing we model as "an electron". It is disconcerting that even for the simplest possible example (the mass of a fundamental particle) such a periphrasis is required for adequate accuracy.

On the "ontological status of the electron" (precisely what Nowak is talking about: the electron is an *idea*, not an *abstraction*) the Nobel Committee (see **Nobel Committee**, "The Nobel Prize in Physics 2025" (Press Release), Nobel Foundation, 2025, https://tiny.pl/fpv541k4d [10.10.2025]) declared, in awarding the 2025 Physics Prize, that in 1984/5 Clarke, Devoret, and Martinis showed (for a Josephson junction device) that "the [electrons] moving through the superconductor comprised a system that behaved as if they were a single particle that filled the entire circuit". In fact, Martinis, Devoret, and Clarke explicitly call such "single particles" *artificial atoms*! (see Martinis, Devoret, and Clarke, "Quantum Josephson Junction Circuits…") Indeed, Jeynes and Parker have argued just that: that "unitary entities" are, properly, "atoms" ("*indiscerpible*" in Henry More's 17th century term, even if not strictly "*indivisible*") (see Jeynes and Parker, "Unitary Entities…").

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so too. [110] We use "unitary entity" rather than the archaic "monad" or the confusing "atom".

Using Quantitative Geometrical Thermodynamics (QGT [111]), Parker, Jeynes, and Catford show — without quantum mechanics — that the ground-state alpha particle (^{4}He [112]) qualifies as an atom (that is, a unitary entity, than which exists no simpler [113]): not strictly *indivisible*, but *indiscerpible* [114] due to its high binding energy. [115] QGT also models the nuclear sizes of ^{6}He and ^{8}He which are composed of a unitary alpha plus a neutron halo — two neutrons for ^{6}He (the "dineutron"), four for ^{8}He (the "tetraneutron"). Despite its instability, the tetraneutron's lifetime can still be

[110] Henry More explained "monad" in the glossary concluding his **Philosophicall Poems**: "Monad. Μονάς, is Unitas, the principle of all numbers, an embleme of the Deity: and the Pythagoreans call it Θεός, God. It is from μένειν because it is μόνιμος, stable and unmovable, a firm Cube of itself. One time one time one still remains one" (he means, 1^3=1; More, **Philosophicall Poems...**, quoted in: Gorman, **The Atom in Seventeenth Century Poetry...**, p. 50).

More, together with all his 17th century readers, would have heard in the word "Cube" echoes not only of the Pythagorean Cube (the source of the element of earth) but also of the Biblical "Holy of Holies" (a cube of dimension "20 cubits" – that is, about 9 metres, see 1Kings 6:20, notionally a text from the 6th century BCE). See the Christian mirror of this in the "Holy City", a cube of size 12000 stadia (2200 km; see Revelation 21:16, dated 68 CE by John Robinson (see Robinson, **Redating the New Testament...**)).

On the term *monad* More explicitly cites Pythagoras, ignoring Giordano Bruno's use of the term. Gorman explains that in his earlier work More used the term "atom", only later preferring "monad" (or "physical monad"). Wilczek cites Democritus (3rd century BCE) as author of "the founding document of atomism" (Wilczek, **Fundamentals...**, p. 72). But this is historically incorrect since the 17th century scholars put effectively no weight on Democritus (see Gorman, **The Atom in Seventeenth Century Poetry...**).

We should point out that not even Leibniz thought that all monads were the same — this would be a reductive idea. But we think that there are a variety of unitary entities — a holistic idea. It is worth pointing out that Arthur Koestler noted "the scientist's unconscious dread of falling into the heresy of vitalism, of reverting to Aristotle's entelechies, Leibnitz's (sic) monads, or Bergson's *élan vital*" (Koestler, **The Ghost in the Machine...**, p. 200).

[111] See Parker and Jeynes, "Maximum Entropy…".

QGT can be mathematically described using the properties of holomorphic functions (complex differentiable — a very strong condition (see Penrose, **The Road to Reality...**, §8.2); "holomorphic" literally means "the shape of wholeness"): more than that, certain Maximum Entropy entities (the double-helix and the double logarithmic spiral, DLS) are found to be holomorphic in QGT. In fact, the double-helix is a special case of the DLS, and both are fundamental eigenvectors of the *entropic* Hamiltonian, and Parker and Jeynes (Parker and Jeynes, "A Relativistic Entropic Hamiltonian–Lagrangian Approach…") have proved *entropy production* to be a conserved quantity (see Michael C. Parker and Chris Jeynes, "A Relativistic Entropic Hamiltonian–Lagrangian Approach to the Entropy Production of Spiral Galaxies in Hyperbolic Spacetime", *Universe* 2021, Vol. 7, article number: 325, https://doi.org/10.3390/universe7090325).

accurately predicted by QGT (as can also the ^{6}He and ^{8}He lifetimes, by treating them all as unitary [116]).

Constantino Tsallis calls the Borromean rings (seen in ^{6}He and ^{12}C nuclei [117]) "a beautiful metaphor for complex systems". [118] QGT models ^{12}C as three alpha particles, supported by experimental evidence [119]: "[^{12}C] is believed to possess a rather unusual structure, where the dominant degrees of freedom are those of α-particle clusters rather than nucleons". [120] In QGT, ^{12}C is treated as a union of a unitary alpha and a unitary di-alpha, where the identity of the di-alpha is inde-

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Parker and Jeynes have used the holomorphic properties of the DLS to calculate observables of both the Milky Way (M.C. Parker and C. Jeynes, "Maximum Entropy (Most Likely) Double Helical and Double Logarithmic Spiral Trajectories in Space-Time", *Scientific Reports* 2019, Vol. 9, article number: 10779, Figures 1 & 2 *passim*, http://dx.doi.org/10.1038/s41598-019-46765), and also of DNA (including its chirality: the "right-handedness" of natural DNA was first shown to be a consequence of the Second Law of Thermodynamics by Parker and Walker (see Michael C. Parker and Stuart D. Walker, "A Dynamic Model of Information and Entropy", *Entropy* 2010, Vol. 12, No. 1, pp. 80–88, https://doi.org/10.3390/e12010080), in an information-theoretic context, and later more rigorously by Parker and Jeynes (see Parker and Jeynes, "Maximum Entropy…", Appendix A).

Parker and Jeynes also analytically proved the stability of Buckminsterfullerene, a known result previously demonstrated constructively using computational chemistry methods requiring significant super-computer time (see Michael C. Parker and Chris Jeynes, "Fullerene Stability by Geometrical Thermodynamics", *Chemistry Select* 2020, Vol. 5, pp. 5–14, http://dx.doi.org/10.1002/slct.201903633). However, such methods are much harder to understand as well as being far more expensive and not at all easy to generalise.

[112] Strictly, we should write $^{4}He^{++}$ since the helium nucleus is doubly charged (having two protons). A helium *atom* as commonly spoken of also has two bound electrons (that is, it is electrically neutral) and is enormous (radius 28 pm) compared to the $^{4}He^{++}$ nucleus (radius 1.7 fm; "pm" is picometers; "fm" is femtometers). But it is very easy to detach the electrons, so the (neutral) helium "*atom*" is misnamed (for historical reasons): that is, it is very far from being *uncuttable*! We regard $^{4}He^{++}$ as truly being an *atom* in More's sense (but indiscerpible, not indivisible); or perhaps a *monad* in Leibniz' sense, noting that there are many different unitary entities recognised by QGT. To avoid confusion, we use "unitary entity".

[113] Unitary entities as revealed by QGT are reviewed by Jeynes and Parker (see Jeynes and Parker, "Unitary Entities…"). A unitary entity is defined as that than which exists no simpler, that is, it may be considered as having no parts, or (equivalently) it has the fewest possible degrees of freedom at the relevant scale.

[114] In the 17th century they were wary of claiming strict *indivisibility* (after all, could not the omnipotent God divide it if he wished?) so they used *indiscerpible* (meaning: "resists being torn asunder"; another of Henry More's neologisms, now considered obsolete) instead. In the 21st century Parker, Jeynes, and Catford have found a real example of this indivisible/indiscerpible distinction, since treating the alpha particle as a *unitary entity* enables them to correctly calculate its size *ab initio* using QGT (see Parker, Jeynes, and Catford, "Halo Properties in Helium Nuclei…").

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terminate (that is: of the three alphas in ^{12}C only two form the di-alpha, but *which* two is indeterminate). This has a molecular parallel in the benzene molecule, which has three single bonds and three double bonds in the carbon ring, but specifically which carbon atoms have which bonds is indeterminate. [121]

Raphael Bousso reviews Gerard 't Hooft's "Holographic Principle": volume information can be fully encoded on a boundary surface. [122] Parker and Jeynes (2021a) derive this principle (represented by the Bekenstein-Hawking equa-

Of course, the alpha (consisting of two protons and two neutrons) is not *indivisible*, but with an enormous binding energy of 28.3 MeV it is *indiscerpible*.

[115] See Parker, Jeynes, and Catford, "Halo Properties in Helium Nuclei...".

[116] See Michael C. Parker and Chris Jeynes, "*Ab Initio* Thermodynamics Calculation of Beta Decay Rates", *Annalen der Physik* 2023, Vol. 535, No. 10, article number: 2300259, http://dx.doi.org/10.1002/andp.202300259.

[117] For ^{6}He, if the alpha (the ^{4}He) or either of the halo neutrons is lost the resulting nucleus (the dineutron or ^{5}He) is particle-unstable and disintegrates. If any of the constituent alphas is lost to the ^{12}C nucleus, the resulting nucleus (^{8}Be, an isotope of beryllium: this element has only one stable isotope ^{9}Be) is particle-unstable and disintegrates (with a lifetime also obtainable by QGT, see Parker and Jeynes, "*Ab Initio* Thermodynamics Calculation...").

Borromean rings are an ancient and widely distributed symbol of unity: there are well known examples in 6th century India (a temple in Thiruvanmayur, South Chennai, see Arul Lakshminarayan, "Borromean Triangles and Prime Knots In an Ancient Temple, *Resonance* 2007, Vol. 12, pp. 41–47, https://doi.org/10.1007/s12045-007-0049-7) and in 7th century Norway (on the *Stora Hammars I* image stone). The Borromean rings were also well known in the Christian world as a metaphor for the unity of the Trinity: the earliest known image is in a c.1210 manuscript of Peter of Poitiers (see Petrus Pictaviensis, **Compendium Historiae in Genealogia Christi**, MS Cotton Faustina B. VII, fol. 42v, British Library, London 1210). This is the *Scutum Fidei* ("shield of faith" – see Ephesians 6:16 in the Vulgate: "*in omnibus sumentes scutum fidei, in quo possitis omnia tela nequissimi ignea extinguere*"; Jerome of Stridon, **Biblia Sacra Vulgata**, Alberto Colunga and Laurentius Turrado (eds.), La Editorial Católica, Madrid 1946, https://tiny.pl/vm17ws4hz [2.07.2026]: this image is usually referred to in English as "Shield of the Trinity").

[118] Constantino Tsallis, "Reminiscences of Half a Century of Life in the World of Theoretical Physics", *Entropy* 2024, Vol. 26, article number: 158, https://doi.org/10.3390/e26020158.

[119] See Parker, Jeynes, and Catford, "Halo Properties in Helium Nuclei...".

[120] M. Freer and H.O.U. Fynbo, "The Hoyle state in ^{12}C", *Progress in Particle and Nuclear Physics* 2014, Vol. 78, p. 1 [1–23], https://doi.org/10.1016/j.ppnp.2014.06.001.

[121] Benzene is usually spoken of in terms of "*Kekulé resonances*" and "*delocalisation of the π electrons*". The details of the benzene ring continue to stimulate research (see Yirong Mo, "The Resonance Energy of Benzene: A Revisit", *Journal of Physical Chemistry A* 2009, Vol. 113, pp. 5163–5169,

tion [123]) from the *entropic* Liouville theorem, applying it to unitary systems (like the alpha particle) using QGT (and *no* quantum mechanics). [124]

Both alpha particles and black holes may be treated as "atoms" or *unitary entities*, yielding quantitatively correct results. But where the alpha is *indiscerpible*, the black hole is *indivisible*. [125]

Berry and Dennis find an unexpected richness in classical crystal optics (chirality, dichroism, and birefringence) with "*[an entirely classical] geometrical approach*" that "*unifies and clarifies*" these phenomena (provided their abstraction of

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https://doi.org/10.1021/jp808941h) and it seems likely that a QGT treatment of benzene like the one available for Buckminsterfullerene would be analytically satisfying (see Parker and Jeynes, "Fullerene Stability…").

[122] See Raphael Bousso, "The Holographic Principle", *Reviews of Modern Physics* 2002, Vol. 74, pp. 825–874, https://doi.org/10.1103/RevModPhys.74.825.

Information and thermodynamics have a very close relation since a communications system in thermodynamic equilibrium can transmit no actual information, as was proved by Parker and Walker (see Michael C. Parker and Stuart D. Walker, "A Unified Carnot Thermodynamic and Shannon Channel Capacity Information-Theoretic Energy Efficiency Analysis", *IEEE Transactions on Communications* 2014, Vol. 62, pp. 3552–3559, http://dx.doi.org/10.1109/TCOMM.2014.2351412).

"Holographic" means "writing the whole" — encoding 3D information in 2D. Thomas Hertog waxes lyrical about "holography": "The theoretical discovery of holography ranks among the most important and far-reaching discoveries in physics of the late twentieth century […] The development of a holographic cosmology […] is a journey deep into the cutting edge of theoretical physics, interlinking far-flung fields, from quantum information to black holes and cosmology […]" (Hertog, **On the Origin of Time...**, p. 213 *passim*).

[123] Roger Penrose explains: "According to the famous Bekenstein-Hawking formula, a well-defined entropy can indeed be attributed to a black hole […] Note the appearance of Planck's constant, as well as the gravitational constant, indicating that this entropy is a "quantum-gravitational" effect. Indeed, this is the first place where we have encountered both the fundamental constant of quantum mechanics […] and that of general relativity […] (appearing together in the same formula" (Penrose, **The Road to Reality...**, p. 715 [emphasis in the original]).

The Bekenstein-Hawking equation was originally devised by Jacob Bekenstein in 1972 to express the entropy of black holes. But although the BH equation expresses "black hole thermodynamics", Parker and others have shown recently that it is applicable at all scales and to other unitary systems (see Parker and Jeynes, "Entropic Uncertainty Principle…"; Parker, Jeynes, and Catford, "Halo Properties in Helium Nuclei…"; Parker and Jeynes, "Relating a System's Hamiltonian to its Entropy…").

[124] See Parker and Jeynes, "Entropic Uncertainty Principle…".

[125] In 17th century terms, an entity being *indivisible* meant that not even God could divide it: that is, to speak of its division is to speak nonsense.

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abstractions can be grasped). [126] Jeynes reviews these geometrical "Berry phase" methods, drawing out the relation to QGT which, as for dichroism, treats reversible and irreversible phenomena symmetrically. [127] Reality is elusive: in optics as in thermodynamics.

Harald Atmanspacher's mereological review [128] of *unity* in a disunited world, focuses on distinctions between "*the mental and the physical*". [129] He identifies a "*domain of reality*" that is neither: instead marked by "*psychophysical neutrality*".

Parker and Jeynes derived the Liouville Equation from QGT (Parker and Jeynes, "Entropic Uncertainty Principle..."), and Parker, Jeynes, and Catford derived the size of the alpha *ab initio* from QGT (using the Liouville Equation and the Holographic Principle) (see Parker, Jeynes, and Catford, "Halo Properties in Helium Nuclei..."). Parker and Jeynes applied QGT to black holes, proving that entropy production is Noether-conserved and calculating its value explicitly for black holes, values confirmed by Parker and Jeynes (see Parker and Jeynes, "Relating a System's Hamiltonian to its Entropy..."; Parker and Jeynes, "A Relativistic Entropic Hamiltonian–Lagrangian Approach...").

[126] See M.V. Berry and M.R. Dennis, "The Optical Singularities of Birefringent Dichroic Chiral Crystals", *Proceedings of the Royal Society A* 2003, Vol. 459, pp. 1261–1292, http://dx.doi.org/10.1098/rspa.2003.1155.

[127] See Chris Jeynes, "How »Berry Phase« Analysis of Non-adiabatic Non-Hermitian Systems Reflects Their Geometry", *Entropy* 2023, Vol. 25, article number: 390, https://doi.org/10.3390/e25020390.

[128] Mereology (from the Greek μερος, "part") is the theory of parthood relations: of the relations of part to whole and the relations of part to part within a whole (see Achille C. Varzi, "Mereology", in: Edward N. Zalta and Uri Nodelman (eds.), *The Stanford Encyclopedia of Philosophy* 2020, Summer Edition, https://tiny.pl/dfxv5q2_3 [11.07.2026]).

Atmanspacher speaks of "mathematical Platonism" which he says is "a position in the philosophy of mathematics that has been promoted by many outstanding mathematicians from Gauss to Frege, Gödel, Penrose, Connes, and others [...] Mathematicians prove theorems with their mental capacities, but the truth of a theorem is anchored in the psychophysically neutral domain" (Atmanspacher, "Psychophysical Neutrality...").

Atmanspacher gives wide-ranging examples of "psychophysical neutrality", including (from physics) David Bohm's idea of the "implicate order": Bohm points out that "It is generally agreed that [...] relativity [has not been] united with quantum theory in a fully consistent way [...] the basic order implied in relativity theory and quantum theory are qualitatively in complete contradiction. Thus relativity requires strict continuity, strict causality and strict locality in the order of the movement of particles and fields [...] in essence quantum mechanics implies the opposite" (David Bohm, **Wholeness and the Implicate Order**, Routledge, London – New York 1980, p. 106). Bohm is looking for a "qualitatively new idea" and proposes that "What they have in common is actually a quality of *unbroken wholeness*" (Bohm and Hiley, **The Undivided Universe...**, p. 351f [emphasis in the original]). Atmanspacher says of Bohm's idea that it has "much beauty and stringency" (although Bohm's treatment is "hardly transparent" to "non-expert readers", involving detailed discussion of Clifford alge-

Physics examples include Roger Penrose's "mathematical Platonism" [130] and David Bohm's "implicate order" [131].

The ancient poet exclaimed: "Behold, how good and joyful a thing it is: brethren, to dwell together in unity" (Ps.133:1 [132]), but the word "unity" is inferred from the original: being a relatively modern idea, in Biblical texts first explicit [133] in Ephesians 4:3 (58 CE): "keep the unity of the Spirit in the bond of peace" [134], even though the idea of "one" (as a cardinal number) is very ancient ("*Hear O Israel, the Lord your God, the Lord is one*": Deuteronomy 6:4) [135]. The idea of "unity" (ἑνότητα, the quality of oneness) seems to have been current for barely two millennia. Perhaps "unity" is harder to grasp than expected? Before St.Paul's usage in *Ephesians*, it was rare: Aristotle used

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bra, Hilbert space etc. — such things are beloved of mathematicians and theoretical physicists and there is a very large and interesting literature on them, unfortunately way beyond our scope here).

Interestingly for us, Atmanspacher regards "meaning" as an important example of substantiating some *relationship* with the physical aspect of reality: "However seductive it may be to regard the concept of meaning »simply« as an element of the mental domain, the view presented here considers this as [...] the fallacy of a misplaced reification of a fundamentally relational concept — far too »simplistic« [...] to do justice to the subtle intricacies of the mind-matter problem" (Atmanspacher, "Psychophysical Neutrality..."). Reality is elusive: it is necessary to pay close attention to at least some "subtle intricacies".

[129] See Atmanspacher, "Psychophysical Neutrality...".

[130] See Penrose, **The Road to Reality...**

[131] See Bohm, **Wholeness...**

[132] Coverdale's wording, taken from the Book of Common Prayer (originally authorised in 1558 by Elizabeth I's Act of Uniformity).

Psalms are very hard to date, but Ps.133 may have been composed c.9th century BCE. The present Hebrew text (with vocalisation) is [הִנֵּה מַה־טּוֹב וּמַה־נָּעִים שֶׁבֶת אַחִים גַּם־יָחַד], translated as: "How good and how pleasant it is that brothers dwell together" (**Hebrew-English Tanakh...**), or "Look, how good and how pleasant is the dwelling of brothers together" (Alter, **The Book of Psalms...**). The unvocalised text is usually taken as c.500BCE. The idea of "unity" can be thought to be implied in the text, but it is not explicit. Nor is it explicit in the Septuagint (the 3rd century BCE translation of the Hebrew into Greek): "Ἰδοὺ δὴ τί καλὸν ἢ τί τερπνόν, ἀλλ᾽ ἢ τὸ κατοικεῖν ἀδελφοὺς ἐπὶ τὸ αὐτό" (**Η ΠΑΛΑΙΑ ΔΙΑΘΗΚΗ...**).

[133] "*Unity*" was not a neologism of Paul's (appearing as "ἑνότητα" in *Ephesians*) since Aristotle used it previously (as "ἑνότης" in the **Metaphysics** 1018a7). In just the same way, "*atonement*" ("*at-one-ment*": an Englishing of the Latinate "*reconciliation*") was not a neologism of William Tyndale, since the Oxford English Dictionary credits Thomas More with first usage a decade earlier. But just as Paul brought the idea of "*unity*" to a much wider public it was Tyndale (see Tyndale, **The New Testament...**, facsimile of the copy held by the Württembergische Landesbibliothek, British Library, London 2008) who brought the word "*atonement*" (and its cognates) to a much wider public:

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it only in passing in a discussion of *substance* (οὐσία) widely acknowledged as esoteric. [136] But Paul addresses everyone, not just philosophers.

Today's physics rejects Aristotle's teleology. But a unified account presupposes the variational Principles — David Hilbert famously regarded the *Principle of Least Action* (PLA) as fundamental, even though it has always seemed disturbingly teleological [137]. Yet *purpose* animates all life, and scientific work increasingly supports the reality of purposes: Parker, Jeynes, and Walker formally define

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"Therefore, yff eny mā be in Chriſt/he is a newe creature. [...] Nevertherleſſe all thigſ are of god / which hath reconciled us unto hym ſelfe by Jesus Chriſt/and hath geven unto us the office to preache the *atonement*. For God was ī Chriſt/ād made agreement bitwene the worlde and hym ſelfe / and imputed not their ſynnes unto them: and hath committed to us the preachynge of the *atonment*. [...] So praye we you ī Chriſtes ſtede/that ye be *atone* with God [...]" (2Corinthians 5:17ff, Tyndale 1526) using the original spelling, including the long s ("ſ") and the abbreviation for "n" (so that "ād" means "and").

It was Tyndale's influential translation of the Pentateuch (see William Tyndale, **The Pentateuch (the Five Books of Moses)**, printed by Hans Luft [Johan Hoochstraten], Antwerp 1530. Copy preserved in the Cambridge University Library, https://tiny.pl/624p5p59y [27.06.2026]) that interpreted [יוֹם הַכִּפֻּרִים] (*yōwm hakkippurîm*, now commonly known as *Yom Kippur*), as "the Day of Atonement" (Leviticus 23:27 *passim*), an interpretation that has stuck in English, even though the primary meaning of [כפר] is "cover" (see Genesis 6:14, "ἀσφαλτ" in the LXX).

[134] "τηρεῖν τὴν ἑνότητα τοῦ πνεύματος ἐν τῷ συνδέσμῳ τῆς εἰρήνης" (**Η ΚΑΙΝΗ ΔΙΑΘΗΚΗ...**). Here "unity" ἑνότητα is explicit and underlined in the next verse: "ἓν σῶμα καὶ ἓν πνεῦμα [...] εἷς κύριος, μία πίστις, ἓν βάπτισμα". Although this usage is commonplace today, the use of ἑνότητα here looks like a deliberate neologism explained in the following verse. Plainly, Paul had Ps.133 in mind: deliberately recasting the Hebrew texts to make them accessible to his pagan hearers.

[135] Deuteronomy is usually dated c.8th century BCE, although it is traditionally claimed that an original version was composed by Moses, perhaps 17th century BCE. The (unvocalised) text we have is usually credited to Ezra the Scribe, c.500 BCE.

The Hebrew text (with vocalisation) is: [שְׁמַע יִשְׂרָאֵל יְהוָה אֱלֹהֵינוּ יְהוָה אֶחָד] which is translated (**Hebrew-English Tanakh...**) as: "Hear, O Israel, the Lord is our God, the Lord alone". Note that JPS interprets [אֶחָד] as "alone" rather than the cardinal number "one" (as in other places). The Septuagint Greek (3rd century BCE) is: "Ἄκουε, Ἰσραήλ· Κύριος ὁ Θεὸς ἡμῶν Κύριος εἷς ἐστι" (**Η ΠΑΛΑΙΑ ΔΙΑΘΗΚΗ...**; using εἷς puts a slightly different gloss on the Hebrew). The ancient poets always want us to hear multiple meanings: they intend (and relish) ambiguity (see Ossa-Richardson, **A History of Ambiguity...**).

[136] It is found in the **Metaphysics** (Book Delta) as "unity of being" (ἑνότης τίς ἐστιν): καὶ τὰ μὲν οὕτως λέγεται ταὐτά, τὰ δὲ καθ᾽ αὐτὰ ὁσαχῶσπερ καὶ τὸ ἕν· καὶ γὰρ ὧν ἡ ὕλη μία ἢ εἴδει ἢ ἀριθμῷ ταὐτὰ λέγεται καὶ ὧν ἡ οὐσία μία, ὥστε φανερὸν ὅτι ἡ ταυτότης **ἑνότης τίς ἐστιν** ἢ πλειόνων τοῦ εἶναι ἢ ὅταν χρῆται ὡς πλείοσιν, οἷον ὅταν λέγῃ αὐτὸ αὐτῷ ταὐτόν· ὡς δυσὶ γὰρ χρῆται αὐτῷ (Τῶν Μετὰ τὰ Φυσικὰ Δ 1018a4-9; W.D. Ross, **Aristotle's Metaphysics**, Oxford University Press, Oxford 1924, copy in Trent University Library digitised 2019 by Internet Archive, p. 259f, https://tiny.pl/

"*entropic purpose*" as a valid physical quantity [138], and Annie Crawford has carefully explained "that since teleological concepts cannot be abstracted away from biological explanations without loss of meaning and explanatory power, life is inherently teleological". [139]

In one sense this is obvious: it is ubiquitously observed that people (and all living things) are purposeful: indeed, it is an insult to call someone "aimless". But physics is widely thought to be "purposeless" (George Ellis is explicit about

b_kb82hb9 [27.06.2026]; thanks to Margaret Barker for this reference). This is translated (rather freely, by Hugh Lawson-Tancred as: "There are as many cases of this as there are of per se ["καθ' αὐτὰ"] unity. Those things are said to be the same whose matter is either formally or numerically one and also those things whose substance is one so that it is clear that identity is a kind of *unity of being* either for a plurality or for a single thing treated as a plurality, as is the case when we say that something is the same as itself and thereby treat it as two" (Hugh Lawson-Tancred, **Aristotle, the Metaphysics**, *Penguin Classics*, Penguin, London 1998, p. 127f).

[137] Michael Stöltzner explains in detail the commitment of Hilbert and Max Planck to the PLA, also discussing its teleological aspects at length (see Michael Stöltzner, "The Principle of Least Action as the Logical Empiricist's Shibboleth", *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 2003, Vol. 34, No. 2, pp. 285–318, https://doi.org/10.1016/S1355-2198(03)00002-9). Sabine Hossenfelder says of the PLA, "It was a revelation! Why hadn't anybody told me?" (Sabine Hossenfelder, **Existential Physics: A Scientist's Guide to Life's Biggest Questions**, Atlantic Books, London 2022, p. 159; page numbers refer to the paperback edition 2023), saying that they don't teach the PLA in schools because then everyone would get hooked on physics. She exaggerates of course, but she confirms our emphasis here on the importance of the PLA.

[138] Parker, Jeynes, and Walker naïvely assume that the Lagrangian and Hamiltonian representations are equivalent (through the Legendre transformation, see Eq.21) (see Michael C. Parker, Chris Jeynes, and Stuart D. Walker, "A Metric for the Entropic Purpose of a System", *Entropy* 2025, Vol. 27, article number: 131, https://doi.org/10.3390/e27020131). This assumption is discussed at length by Clara Bradley (see Clara Bradley, "The Relationship Between Lagrangian and Hamiltonian Mechanics: The Irregular Case", *Philosophy of Physics* 2025, Vol. 3, article number: 9, https://doi.org/10.31389/pop.197).

[139] Annie L. Crawford, "Metaphor and Meaning in the Teleological Language of Biology", *Communications of the Blyth Institute* 2020, Vol. 2, p. 5 [5–23], https://doi.org/10.33014/issn.2640-5652.2.2.crawford.1.

Philip Ball cites Crawford's paper in his book saying, "Pretending agency doesn't exist is asking for trouble [...] agency is a real property [...] because we do not understand agency, we do not know where to locate it [...]" (Philip Ball, **How Life Works: A User's Guide to the New Biology**, University of Chicago Press, Chicago 2023, p. 363). Ball's book is usefully reviewed by Felipe Aizpún (see Felipe Aizpún, "A Paradigm Shift in Biology?", *Filozoficzne Aspekty Genezy* 2026, Vol. 23, No. 1, pp. 6, https://doi.org/10.53763/fag.2026.23.1.257). We remind readers that Karen Barad's book

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this [140]) and therefore purpose must "emerge" somehow. [141] But Parker, Jeynes, and Walker have shown that "*entropic purpose*" (a cut-down form of *purpose*) may be defined validly in a (complexified) canonical physics formalism (although Kyriaki Aslani has shown that such complexification is not a general approach [142]). [143]

The point is that living things necessarily have a *unity*, with a boundary that separates the thing from its environment, enabling it to maintain a low-entropy state (by excreting entropy across the boundary). Moreover, Arthur Koestler pointed out long ago that such unitary entities are *holons*, which, like alpha particles, are *indiscerpible*: although they have parts and may be divided, such division would destroy them. [144] Koestler drew particular attention to the necessarily *hierarchical* nature of holons, an aspect that Terrence Deacon has also emphasised in work which aims to give a physical basis for "teleodynamics". [145] But currently a canonical analytical physics treatment is not available even for such simple self-organising systems as the Bénard convection cell (Cerisier et al. provide a recent numerical treatment [146]).

8. What is Fundamental?

Jesus famously observed that the "*wyſe man byltt his houſſe on a rocke*" [147]. What is the *foundation* of our knowledge? We observe the sun rising in the East and setting in

(**Meeting the Universe Halfway**) is all about "agential realism".

[140] See George F.R. Ellis, "How Purposeless Physics Underlies Purposeful Life", *Nature* 2023, Vol. 622, pp. 247–249, https://doi.org/10.1038/d41586-023-03061-y.

[141] See George F.R. Ellis, "Emergence in Solid State Physics and Biology", *Foundations of Physics* 2020, Vol. 50, pp. 1098–1139, https://doi.org/10.1007/s10701-020-00367-z.

[142] See Kyriaki-Evangelia Aslani, "Multivector Time Generator of Evolution in Phase Plane", *Pre-Prints* 2026, February 4, https://doi.org/10.20944/preprints202602.0263.v1.

[143] See Parker, Jeynes, and Walker, "A Metric for the Entropic Purpose...".

[144] See Koestler, **The Ghost in the Machine...**

[145] Terrence W. Deacon, "Teleodynamics: Specifying the Dynamical Principles of Intrinsically End-Directed Processes", Preprint, Superior, CO: International Association for the Integration of Science and Engineering 2020 (IAISAE), IAISAE/CP-T2020- W117, https://tiny.pl/97dn9r_x2 [28.06.2026]. See also: Terrence W. Deacon and Miguel García-Valdecasas, "A Thermodynamic Basis for Teleological Causality", *Philosophical Transactions of the Royal Society A* 2023, Vol. 381, article number: 20220282, https://doi.org/10.1098/rsta.2022.0282.

the West, but understand that this is an effect of the rotation of the Earth, not simply the sun riding his chariot across the sky (the obvious interpretation of the phenomenon). We observe the green leaf and understand that the *greenness* comes from the wonderful process of photosynthesis, whose details are still being elucidated and which may rely on quantum mechanics (although Runeson et al. think not [148]). What is *fundamental* (Frank Wilczek's 2021 book is actually called **Fundamentals**!)? Is it quantum mechanics or gravity? Or perhaps integrity (which we might call "*the wisdom of wholeness*")? Or?

Michael Parker and others have shown constructively that *unitary entities* (than which exist no simpler) can coherently be thought to exist. [149] The alpha particle's size in its ground state is correctly calculated from thermodynamics, without quantum mechanics, by treating it as *unitary* [150] (even though we know that ^{4}He is made of two protons and two neutrons (2+2=4)). Which is more "fundamental" — the alpha's *unitary* nature or its parts? The reductionist insists that the protons and neutrons are basic, but Parker shows that the explanation of the alpha's size depends on its unitary nature and, surprisingly, disassembling it does *not* yield something "simpler" (challenging reductionism [151])! Thus, a holistic view proves *more* "fundamental" than a re-

[146] See P. Cerisier, B. Porteriea, A. Kaiss, and J. Cordonnier, "Transport and Sedimentation of Solid Particles in Bénard Hexagonal Cells, *European Physical Journal E* 2005, Vol. 18, pp. 85–93, https://doi.org/10.1140/epje/i2005-10033-7.

[147] See Tyndale, **The New Testament**, (1526), Matt. 7:24.

[...] ἀνδρὶ φρονίμῳ, ὅστις ᾠκοδόμησε τὴν οἰκίαν αὐτοῦ ἐπὶ τὴν πέτραν: Matthew 7:24ff (**Η ΚΑΙΝΗ ΔΙΑΘΗΚΗ...**); see parallel passage at Luke 6:48ff. The English is quoted *verbatim* with original spelling from the earliest modern English translation: the "ſ" is the long "s" (which can still be seen in modern German orthography as a component of "ß", the "*Eszett*" or "*scharfes S*"). Tyndale used Erasmus' critical edition of the original Greek (first published 1516 based on Greek MSS no earlier than 10th century), and his Bible was printed (secretly) in Germany in a blackletter font. At that time Tyndale's New Testament was *samizdat* literature regarded by the English political establishment as deeply subversive.

[148] See Johan E. Runeson, Joseph E. Lawrence, Jonathan R. Mannouch, and Jeremy O. Richardson, "Explaining the Efficiency of Photosynthesis: Quantum Uncertainty or Classical Vibrations?", *The Journal of Physical Chemistry Letters* 2022, Vol. 13, No. 15, pp. 3392–3399, https://doi.org/10.1021/acs.jpclett.2c00538.

[149] See Jeynes and Parker, "Unitary Entities...".

[150] See Parker, Jeynes, and Catford, "Halo Properties in Helium Nuclei...".

[151] Contradicting Wilczek, who is clear that the Second Law of Thermodynamics is *not* "fundamental" (see note on Wilczek, **Fundamentals...**, p. 93), and who is also clear that "It pays to analyse matter into the smallest units you can. After doing that correctly you can build back up, conceptually, and con-

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ductionist one. QGT affirms that holistic treatments can be fundamentally valid in themselves — they don't need to "emerge" from supposedly more basic physics. [152]

These new results in physics prompt a *gestalt* shift in what we consider "fundamental." We once very plausibly equated "smaller" with "more fundamental" — as bricks are to a house. Reductionism ruled ok! [153] Yet in quantum physics, neither protons nor neutrons are "fundamental particles" since they're composed of quarks (according to the Standard Model). But what exactly are quarks? Is the Standard

struct the physical world" (Wilczek, **Fundamentals...**, p. 62). That is: the most fundamental is the smallest. But the work of Parker and others shows this conclusion to be mistaken.

[152] See Gil Santos on "emergence" (Gil Santos, "Integrated-structure Emergence and Its Mechanistic Explanation, *Synthese* 2021, Vol. 198, pp. 8687–8711, https://doi.org/10.1007/s11229-020-02594-3). It is curious that the reductionist demands higher energies to probe smaller scales (the resolution of a microscope depends on the wavelength of the probing radiation). For example, the binding energy of the alpha is >28 MeV, so that the 2 MV terminal voltage of the accelerator at the UK National Ion Beam Facility (uknibc.co.uk) is not sufficient to access the interior of the alpha.

[153] Sabine Hossenfelder says, "Fact is, we have never observed an object made of many particles whose behaviour falsified reductionism [...] If you say »holism«, I hear »bullshit«"; although she claims she is "not a reductionist hardliner" (Hossenfelder, **Existential Physics** 2022, p.83), so that she acknowledges that all possible experiments have not been done so that facts may eventually contradict her. We think they have already (since the alpha particle is "made of" four nucleons but in its ground state behaves as a unitary entity). We also draw attention to G. Schlesinger who points out that "It is usually assumed for instance that propositions describing the properties of a physically »complex« whole are logically more »complex« than those referring to the properties of its constituent parts" (G. Schlesinger, "The Prejudice of Micro-Reduction", *British Journal for the Philosophy of Science* 1961, Vol. 12, No. 47, p. 215 [215–224], https://doi.org/10.1093/bjps/XII.47.215), and that this assumption is, actually, a prejudice (a mistaken one, as Parker, Jeynes, and Catford have shown in the case of the alpha particle (see Parker, Jeynes, and Catford, "Halo Properties in Helium Nuclei...")).

As further examples, Thomas Hertog speaks of "the end of the old reductionist dream [...] even the most elementary law-like regularities are ultimately grounded in the complexity of the universe around us" (Hertog, **On the Origin of Time...**, p. 237f). Denis Noble is also very clear that the reductionist approach is not appropriate for biological systems, insisting instead "that downward causation is necessary" (that is, the "higher" levels determine the "lower" ones – we would put this rather differently, but the substantive point remains) (see Denis Noble, "A Theory of Biological Relativity: No Privileged Level of Causation", *Interface Focus* 2012, Vol. 2, No. 1, pp. 55–64, https://doi.org/10.1098/rsfs.2011.0067).

Consider Ferreira, Wolf, and Read's proposals regarding dark matter (see Pedro G. Ferreira, William J Wolf, and James Read, "The Spectre of Underdetermination in Modern Cosmology", *Philosophy of Physics* 2025, Vol. 3, article number: 11, https://doi.org/10.31389/pop.218). The search for this dark matter (reviewed by Misiaszek and Rossi (see Marcin Misiaszek and Nicola Rossi, "Direct Detection of Dark Matter: A Critical Review", *Symmetry* 2024, Vol. 16, article number: 201, https://

Model even correct? Quantum gravity remains elusive, and there are far more questions than are comfortable, even for physicists.

If "fundamental" includes holistic concepts like "unitary entities," then perhaps our whole approach to the scientific enterprise needs revision? Parker's resolution of the Loschmidt Paradox [154] supports this, showing how the reversible and irreversible (and the causal and acausal, local and non-local) are actually commensurate. [155] "Local" aligns with standard cause-and-effect; "non-local" reflects system-level holistic behaviours. [156] The world will remain opaque to us unless we appropriate this new holistic physics.

It is interesting that Potter and Mitchell list 8 properties of living organisms that allow us to think of them validly as *causative agents* (without any sort of dualism):

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doi.org/10.3390/sym16020201)) is "an attempt to discover the microphysical model underlying the empirical regularities that suggested the existence of this type of matter" (Ferreira, Wolf, and Read, "The Spectre of Underdetermination…"). But strong evidence has been shown for the proposal that an important "empirical regularity" (the existence of spiral galaxies) has an entirely different (entropic) explanation (see Parker and Jeynes, "Maximum Entropy…", Fig. 2 *passim*). Moreover, this is an explanation that generalises the non-local effects of the variational principles (such as the Principle of Least Action) in such a way as to allow the close physical description of "unitary entities" — the indivisible things that used to be called "atoms"; an example of which is the alpha particle (which is, in Henry More's 17th century terminology, not strictly *indivisible* but "*indiscerpible*": see Gorman, **The Atom in Seventeenth Century…**)!

[154] In 1876 and in response to Boltzmann's "H Theorem", Josef Loschmidt pointed out to Boltzmann that one shouldn't be able to derive an irreversible process (the Second Law of Thermodynamics) from fundamentally reversible equations.

[155] See Parker and Jeynes, "Relating a System's Hamiltonian to its Entropy…".

[156] Note that when we speak of a *system*, we always mean a composite comprised of a set of components; in which case a "system" can *never* be a "unitary entity", which has no parts at the relevant scale.

Jeynes, Parker, and Barker have reviewed the use of "Berry phase analysis" as a systematic physical approach to treating irreversible systems, and say: "[This] approach (which is deeply geometrical) is connected to other more explicitly thermodynamic approaches (also deeply geometrical) [and] is of great importance as the geometry of a system embodies its nonlocal properties, which are usually expressed in terms of the variational principles (least action, maximum entropy, etc.). Reality is elusive precisely because it can be handled correctly only in a fully complexified theoretical framework in which eigenvalues are not real in the general case. Recent work (Parker and Jeynes, "Relating a System's Hamiltonian to its Entropy…") has shown that for a more satisfactory and unified explanation of many physical phenomena even the description of time should be complexified" (Jeynes, Parker, and Barker, "The Poetics of Physics…"). Real systems are invariably irreversible — this is an essential consequence of the Second Law of Thermodynamics. Geometrical thermodynamics emphasises the fundamentally *non-local* nature of physical systems (expressing their *holistic* character).

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the first is "*thermodynamic autonomy*" (that is, the entity is in a stable low-entropy state), and the fourth is "*holistic integration*" (that is, pointing to the necessity of non-local effects). [157] This account is consistent with ours. [158]

Unity, non-locality, and irreversibility are all *fundamental* to reality — but go unrecognised by Rovelli [159] and Wilczek [160]. Other physicists are less rigid: Penrose, for instance, devotes significant attention to the Second Law, affirming irreversibility as a fundamental reality — even if current physics treats its laws as reversible. [161]

9. QBism

Since we are realists who insist that "knowledge is personal" [162], are we not also QBists ("quantum Bayesians")? QBism is widely seen as a "philosophically rigorous approach to quantum mechanics" that "cuts no epistemic or ontological corners". [163] David Mermin has summarised QBism helpfully, explaining that it elegantly disposes of the "shifty split" that John Bell deplored (the discontinuity between the microscopic

[157] See Henry D. Potter and Kevin J. Mitchell, "Naturalising Agent Causation", *Entropy* 2022, Vol. 24, article number: 472, https://doi.org/10.3390/e24040472.

[158] Separately, Perunov, Marsland, and England have explored the statistical physics of "strongly driven systems that exhibit complex collective behaviour [...] for the first time establishing general relationships between far-from-equilibrium probability distributions over states and the thermodynamic fluxes that accompany their dynamical evolution" (Nikolay Perunov, Robert A. Marsland, and Jeremy L. England, "Statistical Physics of Adaptation", *Physical Review X* 2016, Vol. 6, article number: 021036, http://dx.doi.org/10.1103/PhysRevX.6.021036), although they persist in imposing time-reversal symmetry. Nevertheless, these general relationships are clearly valuable for developing an appropriate "physics of living systems".

[159] See Rovelli, **Anaximandre de Milet...**

[160] See Wilczek, **Fundamentals...**

[161] See Penrose, **The Road to Reality...**, ch. 27.

[162] We use Polanyi's formula: "personal knowledge". But both Polanyi and we are acutely aware of the social context of knowledge. We know rather little individually! Monserrat Neto (email 11/4/2025) points out that it might be better to speak of "*interpersonal knowledge*". Of course, this is correct, but although knowledge is necessarily interpersonal it must also be grounded in the personal integrity of the individual. After due consideration it is *I myself* that must (or must not) approve what *you* say. Therefore, it is also correct to speak of *personal* knowledge.

[163] Robert Crease, private communication 13th March 2024.

and macroscopic involved in making the "observation" that "collapses the wavefunction") [164], and points out that the real issue is how we think of *probability*. [165] Are we "frequentist" or "Bayesian"? [166]

Michael Lavine notes, "in many problems [...] there is no true model". [167] As we've said above, "measurement is primarily an epistemic process". [168] The "Guide to the Expression of Uncertainty in Measurement" explicitly avoids referring to a "true value" of a measurand, since such a value is unknowable in principle: any estimate of it must include its "measurement uncertainty". [169] We seek truth, but acknowledge our epistemic and ontic limitations.

Determining probability is philosophically and technically complex. Steven Goodman (speaking to the medics) has helpfully listed various ways that people can (and do) misuse statistics to pretend to the scientific method. [170] Howson and Urbach examine scientists' use of probability, countering claims that Bayesianism is too subjective. [171]

Matthew Leifer offers a valuable review of QBism, seeking to expose the implications of choosing an ontic rather than an epistemic interpretation of the wavefunction ψ (the basic entity in quantum mechanics), insisting that it is strictly

[164] It is this "shifty split" that Thomas Hertog also has in mind, that casts "a cloud that still hovers over the frontier of physics today: the problem of how the macro and the micro worlds fit together" (Hertog, **On the Origin of Time...**, p. 37), although the context is the "radically different directions" taken by the "two full-scale revolutions" at the beginning of the 20th centuries: "relativity and quantum mechanics".

[165] See Mermin, "Commentary: Quantum Mechanics...".

[166] "Most physicists have a frequentist view of probability: Probabilities describe objective properties of ensembles of »identically prepared« systems. [Contrast the] Bayesian view: An agent assigns a probability p to a single event as a measure of her belief that the event will take place" (N. David Mermin, "Commentary. Quantum Mechanics: Fixing the Shifty Split", *Physics Today* 2012, Vol. 65, p. 8 [8–10], https://doi.org/10.1063/PT.3.1618).

[167] See Michael Lavine, "Frequentist, Bayes, or Other?", *The American Statistician* 2019, Vol. 73, No. 1, p. 312 [312–318], https://doi.org/10.1080/00031305.2018.1459317.

[168] Mari, Maul, Irribarra, and Wilson, "Quantification is Neither Necessary Nor Sufficient...".

[169] Joint Committee for Guides in Metrology, **Evaluation of Measurement Data...**

[170] See Steven Goodman, "A Dirty Dozen: Twelve P-Value Misconceptions", *Seminars in Hematology* 2008, Vol. 45, No. 3, pp. 135–140, https://doi.org/10.1053/j.seminhematol.2008.04.003.

[171] See Colin Howson and Peter Urbach, **Scientific Reasoning: The Bayesian Approach**, Open Court, La Salle 1989 (added to Internet Archive 2021).

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a technical ("scientific") issue of physics, backing up this assertion with a careful mathematical exposition: "what Bell's Theorem really shows us is that the foundations of quantum theory [are] a bona fide field of physics" to be resolved by "rigorous argument and experiment". [172] Still, the debate remains unresolved. The Pusey–Barrett–Rudolph Theorem[173] shows that under certain assumptions ψ must be ontic — a state of reality, not merely of knowledge (with subtle implications far beyond our scope [174]). But as Karen Barad persuasively argues, the categories "ontic" and "epistemic" are entangled, and we should instead speak of the "onto-epistemic": "there is good reason to question the traditional Western philosophical belief that ontology and epistemology are distinct concerns". [175]

Bayesian methods incorporate prior beliefs, while "frequentist" approaches aim for strict "objectivity." Frequentists pretend to "objectivity" where the Bayesians admit to their beliefs on the grounds that no-one decides anything without believing something. Bradley Efron notes a shift in Bayesian statistics toward "objective uninformative priors," though he adds, "in practice, it isn't easy to specify an uninformative prior". [176]

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[172] Matthew Saul Leifer, "Is the Quantum State Real? An Extended Review of ψ-ontology Theorems", *Quanta* 2014, Vol. 3, No. 1, p. 67 [67–155], http://dx.doi.org/10.12743/quanta.v3i1.22.

[173] See Matthew F. Pusey, Jonathan Barrett, and Terry Rudolph, "On the Reality of the Quantum State", *Nature Physics* 2012, Vol. 8, pp. 475–478, https://doi.org/10.1038/nphys2309.

[174] Michael Ridley has discussed these issues at depth, as related to quantum probabilities as required in the many-worlds interpretation of quantum mechanics, asserting a link to the frequentist/Bayesian distinction (see Michael Ridley, "Many Retrocausal Worlds: A Foundation For Quantum Probability", *European Journal for Philosophy of Science* 2025, Vol. 15, article number: 70, https://doi.org/10.1007/s13194-025-00696-8).

[175] Barad, **Meeting the Universe Halfway...**, p. 43.

In her Conclusion to chapter 4, Barad goes further, saying: "The separation of epistemology from ontology is a reverberation of a metaphysics that assumes an inherent difference between the human and non-human, subject and object, mind and body, matter and discourse. *Onto-epistem-ology* — the study of practices of knowing in being – is probably a better way to think about the kind of understandings that we need to come to terms with how specific interactions matter. Or, for that matter, what we need is something like an *ethico-onto-epistem-ology* [...] because the becoming of the world is a deeply ethical matter" (Barad, **Meeting the Universe Halfway...**, p. 185 [emphasis in the original]).

[176] Bradley Efron, "Bayesians, Frequentists, and Scientists", *Journal of the American Statistical Association* 2005, Vol. 100, No. 469, p. 5 [1–5], https://doi.org/10.1198/016214505000000033.

In the important case of a "Bertrand Paradox" [177], Parker and Jeynes have shown how to introduce the required uninformative prior in the form of an additional natural constraint: *scale invariance*, also eliminating the quantum "shifty split" (where exactly is the boundary between the micro and macro worlds?). [178] Entropy is blind to scale, and the scale-blindness of QGT is explicitly a feature of its hyperbolic spacetime. Therefore, QGT is demonstrably valid (over a length range of at least 35 orders of magnitude) both for quantum mechanical entities (like alpha particles [179]) and also for entities of general relativity (like black holes [180]).

David Bohm argued for an "Undivided Universe" [181]; QGT offers a unified treatment of QM and GR. Combined with thermodynamics' nonlocality and the holo-

[177] Parker and Jeynes have given an example of exactly this difficulty of specifying the uninformative prior in their resolution of a longstanding "Bertrand Paradox" that appears to undermine a cornerstone of logical inference (see Parker and Jeynes, "A Maximum Entropy…"). The Principle of Indifference (the simplest non-informative prior in Bayesian probability) has been shown to lead to paradox for non-discrete problems. But if the Principle of Indifference is faulty then our ability to think straight is also called into question! This Paradox is therefore important since if unresolved it would undermine the whole legitimacy of our standard methods of logic (including Bayesian ones): if they don't work properly in the continuous case then they are hardly to be relied upon ontically! Indeed, Leifer's review of issues associated with QBism is undertaken using a formalism (a "rigorous measure theoretic probability theory") explicitly designed to work for "continuous spaces", since, as he says, "the wavefunction involves continuous parameters […] It would be odd to attempt to prove the reality of the wavefunction within a framework that does not admit a model in which the wavefunction is real in the first place" (Leifer, "Is the Quantum State Real…", p. 68).

But it turns out that the Bertrand Paradoxes can be resolved provided that the correct uninformative prior is used, and to properly express the Principle of Indifference requires one to introduce a scale invariance prior (that is, a relativity of scale) which results in a non-uniform (but still Maximum Entropy) probability distribution (contrary to expectation). The "scale invariance" requirement has been described in some detail, if rather inconclusively, by Peter Milne. He admits that "we find obscurity at the heart of the scale invariance argument" (Peter Milne, "A Note on Scale Invariance", *The British Journal for the Philosophy of Science* 1983, Vol. 34, No. 1, p. 55 [49–55], https://doi.org/10.1093/bjps/34.1.49), an obscurity enlightened by Parker and Jeynes' treatment (see Parker and Jeynes, "A Maximum Entropy…").

We thank Nicholas Shackel for alerting us to Milne's paper (private communication 13th March 2024). On the Principle of Indifference see also: Nicholas Shackel, **Bertrand's Paradox and the Principle of Indifference**, Routledge, New York 2024, https://doi.org/10.4324/9781003456308.

[178] See Parker and Jeynes, "A Maximum Entropy…".

[179] See Parker, Jeynes, and Catford, "Halo Properties in Helium Nuclei…".

[180] See Parker and Jeynes, "Relating a System's Hamiltonian to its Entropy…".

[181] See Bohm and Hiley, **The Undivided Universe…**

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morphic nature of actio-entropy [182], QGT reflects Bohm's vision of wholeness. [183] Addressing physicists, Mermin warns: "you had better reexamine what you wrongly may have thought you understood perfectly well about the nature of probability". [184] And Parker, Jeynes, and Walker show that "probability [is] a physical quantity grounded in hyperbolic Minkowski spacetime, and [obeys] all the appropriate physical laws". [185] This new Bayesian understanding of the physics of probability and its scale-relativity also offers new insights into reality itself.

10. The Poetry of Physics

It is now widely accepted that understanding requires a leap of the imagination. *Knowing* is imaginative. To establish the terms they use for new concepts, scientists must "*negotiate their meaning*" (using Martin Edwardes' phrase [186]), which is always a metaphysical step (a "*leap of faith*" [187]) requiring a use of lan-

[182] "actio-entropy" is an idea first introduced by Velazquez, Parker, and Jeynes (see Luisberis Velazquez, Michael C. Parker, and Chris Jeynes, "The Geometry of Thermodynamics III", preprint, July 2022, http://dx.doi.org/10.13140/RG.2.2.17505.99686). "Action" is an important physical quantity (defined by an appropriate line integral of the Lagrangian): "entropy" is shown by Parker and Jeynes (see Parker and Jeynes, "Maximum Entropy…") to be a quantity precisely isomorphic to the action (being defined by an appropriate line integral of the *entropic* Lagrangian).

[183] See Bohm, **Wholeness...**

[184] Mermin, "Commentary: Quantum Mechanics…", p. 10.

[185] Michael C. Parker, Chris Jeynes, and Stuart D. Walker, "A Hyperbolic Sum Rule for Probability: Solving Recursive 'Chicken & Egg' Problems", *Entropy* 2025, Vol. 27, No. 4, article number: 352, https://doi.org/10.3390/e27040352.

[186] See M.P.J. Edwardes, **The Origins of Self**, UCL Press, London 2019, https://doi.org/10.14324/111.9781787356306.

[187] The "leap of faith" referred originally to leaping over Gotthold Lessing's "ugly broad ditch" (see Gotthold Ephraim Lessing, "On the Proof of the Spirit and of Power" (1777), in: Hugh Barr Nisbet (ed.), **Lessing: Philosophical and Theological Writings**, trans. Hugh Barr Nisbet, Cambridge University Press, Cambridge 2005, pp. 83–88, https://doi.org/10.1017/CBO9780511810138.012, "*der garstige breite Graben*"); see: Toshimasa Yasukata, **Lessing's Philosophy of Religion and the German Enlightenment**, *Reflection and Theory in the Study of Religion*, Oxford University Press, New York 2003, pp. 56–71, chapter 4 "Lessing's »Ugly Broad Ditch«", https://doi.org/10.1093/0195144945.003.0005. An imaginative leap (or an "intuitive leap") is just the same thing as the leap of faith (properly the "leap *by* faith") proposed by Søren Kierkegaard explicitly in his **Unscientific Postscript** (see Søren Kierkegaard, **Afsluttende uvidenskabelig Efterskrift til de philosophiske Smuler**, Reitzel, Copenhagen 1846; Søren Kierkegaard, **Concluding Unscientific**

guage that can only be called poetic. The essential fact is that there is no disembodied or impersonal knowing. *Knowledge is personal* [188] just as much as *information is physical*. [189]

Human enterprises can't be formally *defined* — only *described* or *exemplified*. Scientists and poets all seek the same elusive reality, albeit in different ways, since it is hard to grasp. "Science is what scientists do" [190] underlines the humanity of the thing. Defining "the scientific method" has failed because humans want surprising (and undefinable) things. [191] Terms like "aspiration" or "wonder" resist definition but are ever-present among scientists, who are drawn not by the utility of science but by the poetry of the thing.

It is becoming fashionable to bracket science together with poetry. Carlo Rovelli is regularly called "the poet of science" [192], and the astrophysicists have delighted

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Postscript to the Philosophical Fragments, trans. David F. Swenson and Walter Lowrie, Princeton University Press, Princeton 1974) and implicitly in his discussion of Abraham's faith in **Fear and Trembling** (Søren Kierkegaard, **Frygt og Bæven**, Lynge & Son, Copenhagen 1843; Søren Kierkegaard, **Fear and Trembling**, trans. Alastair Hannay, Penguin, London 1985).

[188] See Polanyi, **Personal Knowledge...**

[189] See Rolf Landauer, "Information is Physical", *Physics Today* 1991, Vol. 44, pp. 23–29, http://dx.doi.org/10.1063/1.881299; Rolf Landauer, "Information is a Physical Entity", *Physica A: Statistical Mechanics and its Applications* 1999, Vol. 263, pp. 63–67, https://doi.org/10.1016/S0378-4371(98)00513-5.

Although Landauer was speaking of "Shannon information" (which is explicitly and deliberately *impersonal*), "knowledge" is necessarily *personal*! Similarly, Parker, Jeynes, and Walker speak of "*entropic purpose*", which is explicitly *impersonal*, being measured by Shannon information (see Parker, Jeynes, and Walker, "A Metric for the Entropic Purpose...").

[190] Thomas Hertog also says this: "Science is what scientists do. We advance by exchanging ideas [...]" (Hertog, **On the Origin of Time...**, p. 247). Knowing true things about reality indeed has many material benefits, but scientists typically do not labour diligently for this knowledge because of its "usefulness" (or to get rich) but because they are moved by the poetry of the thing.

[191] We can avoid a discussion of "free-will" here. Sabine Hossenfelder is definite, saying (several times): "the future is fixed, except for occasional quantum events that we cannot influence" (Hossenfelder, **Existential Physics...**, p. 128), which seems to rule out free-will. But her discussion of this is quite long and complex, with the conclusion that she doesn't deny the reality of imagination. The future (in her view) is fixed, but it is still unpredictable. What could be meant by "free-will" turns out to be hard (and contentious) to define.

[192] One could also point out here the assessment of Thomas Hertog that Lemaître's 1931 letter to "Nature" (see Georges Lemaître, "The Beginning of the World from the Point of View of Quantum Theory", *Nature* 1931, Vol. 127, p. 706, https://doi.org/10.1038/127706b0) was "cosmopoetic":

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the world with their wonderful pictures of the cosmos. There are many examples. These things should be taken seriously also by philosophers: they are not merely media froth. Reality is slippery and very hard to grasp: our methods for learning about it depend essentially on inspiration — a poetic quality *par excellence*. [193]

Positivism's effort to *define* the scientific method failed. Kurt Gödel's Incompleteness Theorem [194] proved that any axiomatic system rich enough to include arithmetic is necessarily incomplete — it contains true theorems undecidable in the system. [195] Gödel was the first to make formal use of *metamathematical* methods, foreshadowed by Anselm's poetic metanarrative in the *Proslogion* (1078 CE [196]; systematically overlooked by modern philosophers [197]).

Rather than chasing the "completeness" that Immanuel Kant popularised, Charles Peirce proposed that science begins with "*abduction*": the creative act that precedes the well-known processes of induction from data and deduction of consequences. "The abductive suggestion comes to us like a flash. It is an act of *insight*, although of extremely fallible insight". [198]

"Lemaître's cosmopoetic letter is one of the most audacious scientific texts of the twentieth century. It counts no more than 457 words but can be regarded as the charter of big bang cosmology" (Hertog, **On the Origin of Time...**, p. 61).

[193] Robin Ince also points out: "even the most solid and sure things you can set your watch by become malleable and slippery. This includes time itself" (Ince, **The Importance of Being Interested...**, p. 89).

The renowned philosopher Ernst Cassirer "[...] liked to tell the following story: once he met the great mathematician [David] Hilbert, the »Euclid of our time«, and asked him about one of the latter's disciples. Hilbert answered: »He is all right. You know, for a mathematician he did not have enough imagination. But he has become a poet and now he is doing fine.« Cassirer always heartily laughed, when he told this story [...]" (Dimitry Gawronsky, "Ernst Cassirer: His Life and His Work", in: Paul Arthur Schilpp (ed.), **The Philosophy of Ernst Cassirer**, *The Library of Living Philosophers*, Vol. 6, The Library of Living Philosophers Inc., Evanston 1949, p. 28 [1–38]). Thanks to Sir Michael Berry for drawing our attention to this story; private communication, 29th March 2024).

[194] See Gödel, "Über formal unentscheidbare Sätze…".

[195] Strictly these are only "well-formed formulae" (not "theorems" which must have proofs): they are formally proved "not meaningless", but they also demonstrably have no proof in the system.

[196] Anselm of Bec, **Proslogion** (c. 1078), trans. M.J. Charlesworth, Clarendon Press, Oxford 1965.

[197] See Jeynes, Parker, and Barker, "The Poetics of Physics...".

[198] Charles Sanders Peirce, **Pragmatism as the Logic of Abduction**, in: C. Hartshorne and P. Weiss (eds.), **C.S. Peirce, Collected Papers 1931–1958**, *Harvard Lecture* Vol. 5, Harvard University Press,

11. Machine Intelligence

We've touched on public trust in science, but another question central to our enquiry into "the integral nature of the scientific enterprise" is: Can Artificial Intelligence (AI) be trustworthy? After all, AI is a scientific enterprise, isn't it? Microsoft's AI ("Bing") answers this question quite well: "Artificial intelligence is not human, so we should avoid terms like »trustworthy AI«" [199] and highlights that while AI adoption demands trust, many systems remain black boxes. Efforts now

Harvard 1903, § 181 [180–212] (emphasis in the original).

Abduction has been explored by Lucia Santaella Braga (see Lucia Santaella Braga, "C. S. Peirce's Abduction, Induction, and Deduction", in: Michael A. Peters, **Encyclopedia of Educational Philosophy and Theory**, Springer, Singapore 2019, pp. 1–6, https://doi.org/10.1007/978-981-287-532-7_575-1) and Timothy Shanahan (see Timothy Shanahan, "The First Moment of Scientific Inquiry: C.S. Peirce on the Logic of Abduction", *Transactions of the Charles S. Peirce Society* 1986, Vol. 22, pp. 449–466). Ernan McMullin discusses abduction, but prefers "retroduction" (also used by Peirce): "central to retroduction [...] is the imaginative modification of existing concepts, or the creation of new ones quite remote from the universals or forms that might be abstracted from perceptual experience" (Ernan McMullin, "The Inference that Makes Science", given as the 1992 "Aquinas Lecture" at Marquette University, republished in: *Zygon: Journal of Religion and Science* 2013, Vol. 48, No. 1, p. 185 [143–191], https://doi.org/10.1111/j.1467-9744.2012.01319.x). McMullin's work is widely regarded as seminal, for example by Bas van Fraassen, who says that he "takes us on a fabulous journey through the history of philosophy of science", concluding "When McMullin states [...] that the success of retroductive inference is a contingent matter, he [...] does not go far enough. That the contingent conditions for the success of retroduction actually obtain could only be inferred by retroductive inference: an insight that sweeps the rug from under any assurance of epistemic safety to be found there" (Bastiaan C. van Fraassen, "Scientific Realism and the Empiricist Challenge: An Introduction to Ernan McMullin's Aquinas Lecture", *Zygon: Journal of Religion and Science* 2013, Vol. 48, No. 1, p. 141 [131–142], https://doi.org/10.1111/j.1467-9744.2012.01322.x).

[199] "Artificial intelligence is not human, so we should avoid terms like »trustworthy AI« that not only humanize AI but also imply a level of dependability that simply does not exist. However, broad adoption of AI systems will require humans to trust their output. Many AI systems to date have been black boxes, where data is fed in and results come out. Trust is a priority, but many organizations haven't taken enough steps to ensure AI is trustworthy. Many current efforts are aimed to measure system trustworthiness, through measurements of Accuracy, Reliability, and Explainability, among other system characteristics".

A supplementary question to Bing about the "metanarrative" of its answer also elicited a sensible response under six headings: (i) *Context & Background*; (ii) *The Nature of AI* (not human, therefore lacking human characteristics); (iii) *The Dual Nature of AI* (good and bad aspects); (iv) *Trust and Trustworthiness*; (v) *Challenges and Responsibilities*; (vi) *Operationalizing Trustworthiness* (mentioning that "practical philosophy" can "guide the development of AI"). This response is revealing from our point of view here: it appears sensible and competent (and useful), but really it hasn't grasped what we have tried to explain here as "metanarrative" (that is, the context that enables our *under-*

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aim to measure trustworthiness through metrics like Accuracy, Reliability, and Explainability. A follow-up query about the "metanarrative" yielded a coherent six-part summary, covering AI's nature, dual aspects, trust issues, and ethical development. Yet despite its apparent competence, the response failed to grasp what we meant by "metanarrative": not merely factual points, but some substantial *understanding*. Could poetry be written as bullet points?

Scientific narratives aim to clarify ambiguity but don't, by themselves, engender *understanding*. To grasp the meaning, we look to the (metaphysical) metanarrative. [200] AI can summarize conventional wisdom, but its competence boundaries remain unknown (and perhaps unknowable; usefully reviewed by Karoline Reinhardt [201]). The "Ethics Guidelines for Trustworthy AI" proposed a seven-point "Trustworthy AI Assessment List," emphasizing: (i) *Human Oversight*, (ii) *Technical Robustness*, (iii) *Privacy*, (iv) *Transparency*, (v) *Fairness*, (vi) *Societal Well-being*, and (vii) *Accountability*. [202] The guidance urges adapting the list contextually, deliberately using value-laden terms ("identifying", "evaluating", "ensuring") which implicitly acknowledge the *metanarrative* that this present work is explicitly articulating. Large language models output a useful narrative but fail to infer the deeper metanarrative. Michael and Matthias have shown that people distrust AI allocation of resources specifically because the machines' "reasoning" is not transparent. [203]

Fodor and Pylyshyn argued that artificial neural networks (ANNs) lack "systematic compositional generalizability". [204] Abigail Tulenko traces this idea back to

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standing of the narrative in question). Rather, it is, again, simply a set of facts.

[200] We have seen how Joseph Drew (see Drew, **Selling Public Policy...**) has drawn attention to the real benefit available from a proper attention to Aristotle's methods of rhetoric to persuade people to trust scientists, and James Lennox (see Lennox, "How to Study Natural Bodies...") has shown how explicitly Aristotle grounded his **Physics** in a prior metaphysics.

[201] See Karoline Reinhardt, "Trust and Trustworthiness in AI Ethics", *AI and Ethics* 2023, Vol. 3, pp. 735–744, https://doi.org/10.1007/s43681-022-00200-5.

[202] See European Commission, **Ethics Guidelines for Trustworthy AI**, prepared by the High-Level Expert Group on Artificial Intelligence, European Commission, Brussels 2019, https://tiny.pl/8tn2n_4qp [2.07.2026].

[203] See Michael and Matthias, "Resource Allocation by Algorithms...".

[204] Jerry A. Fodor and Zenon W. Pylyshyn, "Connectionism and Cognitive Architecture: A Critical Analysis", *Cognition* 1988, Vol. 28, p. 38 [3–71], https://doi.org/10.1016/0010-0277(88)90031-5.

Avicenna [205], who thought that where humans can reason from universals, animals can think only about particulars. [206] AI struggles with this, though Lake and Baroni showed that "meta-learning for compositionality" lets ANNs mimic human performance — provided the training is suitably structured. [207] Yet philosophically, that success is grounded on our intelligence, our training, and our continual intervention. AI systems may apparently behave intelligently, but they are amoral: they lack both *judgment* and the *understanding* of the metanarrative.

More generally, Reinhardt makes the points well that a) *trust* and *trustworthiness* are two different things (people can trust the untrustworthy and distrust the trustworthy), and also that b) trust is an ambivalent thing (we can after all "trust that the world is going to end"). [208] She emphasizes the need for a *normative foundation*, aligning with our *metanarrative*. Trust must be freely given, and *persuasion* remains necessary even for what *is* trustworthy — malign actors will also seek to persuade. She provocatively concludes: "it might turn out that in the end what we need is not more trust in AI but rather institutionalized forms of distrust". [209] The rise of AI stimulates a re-examination of what the scientific enterprise really is.

Davidiuk and others have shown how generative AI can easily (and almost undetectably) fake microscopy images. [210] However, Nina Notman also discusses the

[205] Ibn Sina was an 11th century Persian philosopher who was very influential in Europe (where he was known as "Avicenna").

[206] See Abigail Tulenko, "What Philosopher Ibn Sina Can Teach Us about AI", *Scientific American* 2024, April 18, Opinion, https://tiny.pl/sb4j2d119 [2.07.2026].

[207] See Brenden M. Lake and Marco Baroni, "Human-like Systematic Generalization Through a Meta-learning Neural Network", *Nature* 2023, Vol. 623, pp. 115–121, https://doi.org/10.1038/s41586-023-06668-3.

[208] See Reinhardt, "Trust and Trustworthiness…", pp. 735–744.

[209] Reinhardt, "Trust and Trustworthiness…", p. 741.

[210] See Nadiia Davydiuk, Elisha Krieg, Jens Gaitzsch, Patrick M. McCall, Günter K. Auernhammer, Mu Yang, Joseph B. Tracy, Sara Bals, Wolfgang J. Parak, Nicholas A. Kotov, Luis M. Liz-Marzán, Andreas Fery, Matthew Faria, and Quinn A. Besford, "The Rising Danger of AI-generated Images in Nanomaterials Science and What We Can Do About It", *Nature Nanotechnology* 2025, Vol. 20, pp. 1174–1177, https://doi.org/10.1038/s41565-025-02009-9.

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AI tools currently being used to detect fraudulent papers clogging up the peer-review process. [211]

12. Discussion

We have illustrated how the scientific enterprise depends on the idea of unity, emphasizing the contribution of the new physics of Parker and others, especially the resolution of the Loschmidt Paradox via complexified time. [212] We now briefly consider further aspects of complex time, and also the *personal* nature of knowledge, particularly through *storytelling*.

Complex time is emerging as a powerful paradigm applied systematically by Ivo Dinov's group to "Big Data" analytics [213], transforming 4D spacetime into 5D "*spacekime*" to reveal solution paths obscured in lower dimensions. It's interesting that two completely independent groups have used complexified time for quite different applications, but for the same underlying mathematical reason: namely that complex analysis has extraordinary mathematical power.

Similarly, Deur, Brodsky, and Roberts employ complexified, 5D spacetime and a holographic approach in quantum chromodynamics to calculate the strong force over large distances (explained by Brodsky and others [214]). [215] These parallel developments suggest that complex time may underpin a new interpretation of reality — an exciting prospect still unfolding. Time has long puzzled philosophers — Augustine famously remarked, "I know very well what time is, until someone asks me!" [216]

Treating science as *story* underlines the essential truth that *knowledge is personal*, as Michael Polanyi observed long ago. Paul Grobstein has urged us to develop a "story of science as story telling and story revising" which "may provide a foundation for a less wrong view of science [...] the ultimate test of [which is]

[211] See Notman, "AI Tools Combat Paper...".

[212] See Parker and Jeynes, "Relating a System's Hamiltonian to its Entropy...".

[213] See Ivo D. Dinov and Milen V. Velev, **Data Science: Time Complexity, Inferential Uncertainty, and Spacekime Analytics**, Walter de Gruyter GmbH, Berlin 2022, https://doi.org/10.1515/9783110697827.

[214] See Alexandre Deur, Stanley J. Brodsky, and Craig D. Roberts, "QCD Running Couplings and Effective Charges", *Progress in Particle and Nuclear Physics* 2024, Vol. 134, article number: 104081, https://doi.org/10.1016/j.ppnp.2023.104081.

what new stories develop because of it". [217] Robert Crease has pointed out that "Stories make things appear that you cannot see or think about otherwise". [218] Frank and others go further: they consider that stories "constitute a modern form of mythos [...] [orienting us and structuring] our understanding of the world". [219]

Thomas Dillern seems to be an isolated modern proponent of Polanyi's view of *personal knowledge* [220], although Jerry Ravetz's school was active previously in creatively developing Polanyi's view on *craftsmanship* [221]. Dillern says that "the things that are most interesting to gain knowledge about are things that [...] provide something meaningful to humanity, which is something the modern mechanical science view fails to accomplish on its own" [222] and points out Polanyi's insight that "tacit knowledge is the basis of all explicit knowledge [...] tacit powers are the ultimate faculty through which humans acquire and hold all knowledge" [223]. We

[215] See Stanley J. Brodsky, Alexandre Deur, and Craig D. Roberts, "The Secret to the Strongest Force in the Universe: New Discoveries Demystify the Bizarre Force that Binds Atomic Nuclei Together", *Scientific American Magazine* 2024, Vol. 330, No. 5, p. 32, https://doi.org/10.1038/scientificamerican0524-32.

[216] "*quid est ergo tempus? si nemo ex me quaerat, scio*" ["*What is time? I know well enough what it is, provided nobody asks me*"] (Augustine of Hippo, **Confessions**, trans. R.S. Pine-Coffin, Penguin, London 1961. Latin text based on Pius Knöll's **Editio Minor** (1898), XI:14; c. 398 CE, https://tiny.pl/w3gzv5sdt [27.06.2026]). It seems obvious that Newton's bold representation of time simply as a scalar must have been only a (brilliant) approximation. It seems likely that the complexification of time used by all the authors cited (together with Aslani (see Kyriaki-Evangelia Aslani, "Complex Time Approach to the Hamiltonian and the Entropy Production of the Damped Harmonic Oscillator", *Entropy* 2025, Vol. 27, article number: 883, https://doi.org/10.3390/e27080883)) is also only an approximation, with a more complete account being given by Kyriaki Aslani (see Aslani, "Multivector Time Generator...").

[217] Paul Grobstein, "Revisiting Science in Culture: Science as Story Telling and Story Revising", *Journal of Research Practice* 2005, Vol. 1, No. 1, article number: M1m, https://tiny.pl/88s8ftgbm [18.03.2024] [emphasis in the original].

[218] Crease, **The Workshop and the World...**, p. 263.

[219] Frank, Gleiser, and Thompson, **The Blind Spot...**, p. ix.

[220] See Thomas Dillern, "The Act of Knowing: Michael Polanyi Meets Contemporary Natural Science", *Foundations of Science* 2020, Vol. 25, pp. 573–585, https://doi.org/10.1007/s10699-019-09626-3.

[221] See Ravetz, **Scientific Knowledge...**

[222] Dillern, "The Act of Knowing...", p. 580.

[223] Dillern, "The Act of Knowing...", p. 581.

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have here represented this viewpoint by insisting on the indispensable metaphysical context of our physical explanations (following Jeynes, Parker, and Barker). [224] "Polanyi's Paradox" [225] is a central and necessary idea for mediating our conception of "knowledge". [226] All knowledge is formally incomplete, and the idea that "scientific knowledge" is somehow different is simply mistaken. But all human knowledge (and we know no other) is metaphysical: the metanarrative is invariably indispensable (even when it is tacit), and even physical knowledge cannot be *understood* without its metaphysical contexts. "Grasping truth" is essentially metaphysical. It's worth pointing out explicitly that "*tacit knowledge*" (described in some detail by Polanyi) is a fine cover for unrecognised assumptions being smuggled into the interpretations of the data, so that understanding how the metanarratives work has become essential.

13. Summary

Over the past four centuries, the scientific enterprise has evolved from marvelling at microscopic wonders and celebrating celestial simplicity to wielding the power to destroy the world; from the clockwork universe to quantum uncertainty; from rational triumph to ontological puzzles. Yet reality has proven far more baffling than expected. Newton thought he could specify the scientific method, but with every advance in knowledge it seems that our account becomes less complete.

We emphasize the central idea of unity: to understand the world, seek a *coherent* account — with utmost diligence and honesty. Reality is elusive; casual efforts yield only dead ends. Only a focused, good-faith pursuit can yield genuine discovery.

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[224] See Jeynes, Parker, and Barker, "The Poetics of Physics…".

[225] Summarised as "we can know more than we can tell". This is related to the classical "Meno Paradox", referring to Plato's Socratic dialogue: "a man cannot enquire either about that which he knows, or about that which he does not know; for if he knows, he has no need to enquire; and if not, he cannot; for he does not know the very subject about which he is to enquire".

[226] See David Autor, **Polanyi's Paradox and the Shape of Employment Growth**, *National Bureau of Economic Research Working Paper* No. 20485, National Bureau of Economic Research, Cambridge 2014, pp. 1–48, https://doi.org/10.3386/w20485.

For it turns out that unity remains a powerful idea: even in physics "*unitary entities*" have been shown to successfully model things that — looked at another way — are clearly composites of other "fundamental" particles.

14. Conclusions

The scientific enterprise seeks to gain knowledge of the natural world, where the very *possibility* of knowledge is premissed on an appreciation of *unity*. Unity is a metaphysical concept, but it is physically embodied in the alpha particle and the black hole, both of which are *unitary entities* ("than which exist nothing simpler"). Radically new physics now articulates these ideas.

New physics enables and informs new philosophy. The recognition that there are real examples of unitary entities which we can specify and discuss, has allowed a much more definite idea of what is *fundamental* (also fatally undermining a reductionist view). Unity always was a powerful idea. Now that it is underpinned by physical reality it is more powerful still.

The idea of *unity* is fundamental to our idea of reality itself, essential not only to the basic physics but also to the *integrity* with which we (both personally and socially) engage in, report, and receive the scientific enterprise. That is, it is essential at all levels: the mathematico-physical, the experimental, the scientific community; and also the public, for whom after all the science is ultimately done.

Chris Jeynes, Michael C. Parker

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