# The Integral Nature of the Scientific Enterprise

Chris Jeynes and Michael C. Parker *

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*Article*

# The Integral Nature of the Scientific Enterprise

**Chris Jeynes [1] and Michael C. Parker [2,*]**

[1] Independent Scholar, Tredegar NP22 4LP, Wales

[2] School of Computer Science and Electrical Engineering, University of Essex, Colchester, CO4 3SQ, England

* Correspondence: mcpark@essex.ac.uk

**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) compatibility 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 public 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; quantum gravity; prescientific thought; mereology; entanglement; atom

## 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. 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

[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*" (Rovelli 2009, p.171f).

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*" (*ibid.*, pp.177,180). 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 (2019, p.19) has written a book "*about how to get angry about science denial in the right way*" 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

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technologies we use daily. This reliability stems from science's foundation: communal *integrity*; and personally, a desire for coherence.

Truth is *one*—for without unity, knowledge collapses. Hence, we assert the integral nature of the scientific enterprise[2]: *knowledge* depends on *unity*. For we may know truly even in the face of our limitations, since the truth the poets discern is the *same sort of thing* that the scientists discover – *truth is one*. Knowledge is personal[3] such that any philosophy of science must also be *metaphysical* (meaning "*the metanarrative of physics*"[4]).

Saying "*Knowledge is Personal*" (Michael Polanyi, 1958) does not imply it is merely individual; rather, we know together or not at all: "*No man is an island*" (John Donne, 1624). Since individuals know little alone, knowledge belongs to the community; and scientific knowledge to the scientific community.

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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*" (*ibid*., p.262). The issues are not simple – reality is elusive! Here we try to lay out these issues in an even-handed way.

[2] 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.

[3] Michael Polanyi (1958) has insisted that ***knowledge is personal*** and Jerry Ravetz (1971, Introduction) 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?'*". Note that social "activities and judgments" are as important as individual ones.

[4] … with an Aristotelian meaning for "physics" ("nature"!). Jeynes *et al*. (2023) 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).

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 *et al*. (*ibid*.) is that poetic speech is invariably *prior* to prose speech, both logically and temporally: 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 2009, p.167 citing Roy Rappaport's classic 1999 work). 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 (2008) uses it: "*the [empiricist] step that leaves the entire game of metaphysics behind, and frees us forever from its illusionary charm and glamour*'' (quoted in Flavia Padovani's useful 2011 review).

Here we use it in a way cognate to "metamathematics" or "metadata" etc: that is, we use "*metaphysics*" as simply the "*metanarrative of physics*" (see n.17 *passim* in Jeynes *et al*. 2023), insisting that "physics" is used here in the wider sense Aristotle had in mind when he titled his *Physics*: "Φυσικὴ ἀκρόασις" [*physikē akroasis*] (literally "*listening to nature*", meaning perhaps "*lectures on nature*").

Note that Gödel (1931) explicitly uses "*metamathematics*" in his Incompleteness Theorem. Gödel had studied Immanuel Kant's *The Metaphysical Foundations of Natural Science* (Kant 1786), 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, supported by Gödel's seminal result, Jeynes *et al*. (2023) show that this search for "completeness" cannot be successful; 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 (and see Ossa-Richardson's masterful monograph on ambiguity, 2019).

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Though scientists widely acknowledge that *intuition* is essential—for both imagining and then attaining results—formal discourse avoids mentioning it[5]. 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 (see Jeynes & Parker, 2025). "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" were first recognized as such in 2022[6]. 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.

## 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".

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[5] An interesting recent exception (that goes to prove the rule) is explicit: "*Quantifying Intuition*" (Haddad *et al*., 2024). 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 (Dunstan *et al*., 2022).

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 (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: 286 micro-arc-seconds, 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.

[6] The $^{4}He^{++}$ nucleus (in its ground state) was demonstrated a "*unitary entity*" by Parker *et al*. (2022), who correctly derived its consequent matter radius (see §8). The existence of "atoms" was long *assumed*, notably by Ludwig Boltzmann for his "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 & 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 & Parker, 2025).

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The *legitimacy* of the scientific enterprise's standing (§4) must be earned through *persuasion* since "mere facts" *prove* little (and may sometimes 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!

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 (2009, p.78) 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*." Rovelli characterises the "religious" approach to knowledge by its "absolute reverence" which does not allow any modification of the 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.

However, his representation of Christian attitudes is less so, even if he is correct to point to "*a classic thesis*" (Geoffrey Lloyd, 2002) 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*" (Rovelli, *op. cit*., p.81). Rovelli contrasts the Pope's stance on infallibility[7] 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*" (*ibid*. p.141f).

It seems clear to us that Rovelli does not grasp Jeremiah's point (see below), and we should also note that Nicholas Spencer (2023)[8] has carefully exploded the myth that the "scientific" and the "religious" worldviews are in "conflict". The real position is much more nuanced than Rovelli says.

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[7] Rovelli says (*ibid*. p.140): "*Pope Benedict XVI ... often says that to save ourselves from the relativistic drift, we have to defend the infallible Truth*".

[8] Thanks to Sir Michael Berry for drawing our attention to Spencer's book in March 2023

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The very idea of "infallibility" is heavily contested in Christianity.[9] Infallible propositions are unavailable—to theologians and scientists alike. Catherine Elgin (2017, p.33) has made a careful epistemological case that "*scientific understanding is nonfactive*" (i.e., "*true enough*"). She compellingly argues that "*the capacity to make mistakes is an epistemic achievement … far from being a concession to frailty, [fallibility] is a source of strength*" (p.291).

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 (2021) notes that the 17th-century English "metaphysical poets" were fascinated by the revelations of the new microscopes[10], 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*" (*ibid*. p.22). 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, 1986):

Cursed is the man who trusts in men
  Who leans for support on material power
  Whose mind is alienated from Yahweh[11]
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

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9 The (Roman Catholic) theologian Hans Küng (1970) explained that the formal Roman doctrine of "Infallibility" dates only from the 1st Vatican Council (1869-1870): this Council was abandoned as a consequence of the Franco-Prussian War, which Eric Hobsbawm (1975, ch.4 §1) insists was a cynical ploy by Bismarck to promote German reunification. We should always remember that our interdisciplinary boundaries are only there for our convenience: in reality everything is interconnected. Frank Hertog (2023, p.203) claims that the utility of Stephen Hawking's new theory published posthumously (Hawking & Hertog 2018) "*lies in its capacity to unlock the interconnectedness of the universe.*" The theologians should listen to the historians, the historians to the physicists, and all of them to the philosophers. Basarab Nicolescu (2010) underlines the importance of "transdisciplinarity".

Jeynes (2014) 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 …*". 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 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 1970 Ch.4 §10). Note that "*The just shall live by faith*" ("ὁ δίκαιος ἐκ πίστεως ζήσεται", Apostolikes 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.

10 Thanks to Kevin Killeen for alerting us to Cassandra Gorman's important monograph in 2022. As Jeynes *et al*. 2023 say (in their note #80): '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 (2017), 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*".'

11 "Yahweh" [יְהוָֹה] is God's personal name, usually rendered "LORD"; see the elliptical "explanation" at Exodus 3:14: "*I am that I am*" [אֶהְיֶה אֲשֶׁר אֶהְיֶה] ("*ehyeh asher ehyeh*", JPS 2000), or "ἐγώ εἰμι ὁ ὤν" in the LXX (Apostolikes 2012).

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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*[12]. Whether or 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[13]. Theology must change just as science must, and for the same reasons – both must be open to new understandings. But both are also subject to the same unwelcome rigidities of thought[14], 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*"[15] 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.

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

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12 "*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 (2007) comments, "The Masoretic text has *kevodi*, 'my glory', but some manuscripts show *keveidi*, 'my liver'". 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 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 *et al*. 2023 for a discussion of paleoHebrew.

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

14 Max Planck's famous comment is often represented as "*Science advances one funeral at a time*" (see Planck 1950, pp.33,97)

15 "*It is possible to do better*": of course Rovelli is not the first to say this sort of thing. Karl Popper (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*", 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*" (Popper 1994).

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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 (2024) 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. 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[16]. 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[17], but Trust, underpins science. John Hardwig (1991) writes, "*scientific knowledge rests on trust … in the character of scientists*."[18]

With today's expanding knowledge and frequent multi-author papers[19] collaboration is essential (although it brings an added risk of groupthink). Authors must trust one another (Hardwig, 1985, 1991) and agree on a shared narrative[20]. We must "*rethink expertise*" (Collins & Evans, 2007). And once findings reach the public, they too must be able to trust them. But how is that trust built?[21]

*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 (2009, p.171f): "*When we seek a sure*

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16 The reason for this is that our knowledge is always ultimately founded on "personal testimony", as Richard Bauckham (2006) has recently shown in an important and very far-reaching monograph. 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*"), and he cites Paul Ricoeur's (2000) "prudential rule": "*first, trust the word of others, then doubt if there are good reasons for doing so*." *ibid*. p.478f; interestingly, Rosa Bologna *et al*. (2020) have recently applied Ricoeur's "hermeneutic spiral" to "*unconscious influences on professional practices*". John Hardwig (1985) already explored the epistemic importance of *testimony*, as of course also did Michael Polanyi (1958).

Peer-review has recently been carefully and helpfully reviewed by Tennant & Ross-Hellauer (2020) who call it a "*critical part of our knowledge infrastructure*" without a proper understanding of which "*scholarly legitimacy might decline in the future*".

17 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*" (Berry & Nye 2006; see also Ziman 1978)

18 This holds even amid widespread bias, extensively documented by Jessica Nordell (2021). Edouard Machery (2025) usefully points out that "trust" here must be understood in the sense of "rely on but corroborate". We should not assume bad faith (and thanks to Monserrat Neto for alerting us to Machery's work in September 2025). Jeroen de Ridder (2022) also investigates trusting scientists at helpful depth, showing both that "*epistemic trust among scientists is inevitable*" and also in what way it is "*justified*".

19 Derek de Solla Price (1962) long ago observed the trend to multi-author papers in scientific journals, and as an example of this John Hardwig (1985, 1991) discusses a paper with 99 co-authors (Abe *et al*. 1983) that determines a photoproduction cross-section of the charm particle.

20 C.S.Peirce (1877) long ago pointed out the importance of the *community* in establishing reasonable belief. (We thank an anonymous referee for reminding us of Peirce's contribution.) John Hardwig (1985) 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).

21 Collins & 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 & 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 (2009) in some detail for the case of climate change.

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*foundation on which to base decisions about our actions and thoughts we find that a sure foundation does not exist*". 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*" (2009 p.181). 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*[22]; 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[23]. This *entanglement* is not merely metaphorical but realistic since new physics (Parker & Jeynes 2023a) shows that the local and non-local, the reversible and irreversible, and the causal and acausal are all commensurate (see below §7).

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[24]: as always, we depend on consensus. Science

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[22] see Drew 2023, who also points out Aristotle's rhetorical tropes (the "major" ones are: *metaphor*, *metonymy*, *synecdoche* and *irony*), and in particular synecdoche (on which see Drew *et al*. 2018, 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*).

[23] Brunet & Müller (2024) helpfully discuss the "feeling rules" of the peer review of major funding proposals. 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: Entradas *et al*. (2023) 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.

[24] 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 (2013, p.157f) says: "*Scientists untrained in the conjuring art of deception are the easiest people in the world to fool*." Thanks to Sir Michael Berry for drawing our attention to this book (2nd March 2023). John Hardwig (1991) quotes Arnold Relman (1983): "*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*". After all, repeating experiments is costly and usually unrewarded. See §11 for Artificial Intelligence used fraudulently.

Valentin Rodionov (2024) 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*." Jeroen de Ridder (2022) also copiously evidences both fraud and its persistence in the literature. Moreover, 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

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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 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 (1940) traced its development in Padua pre-Galileo. 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*." Seeing is not the same as understanding; in fact, we often only *see* what we *understand*![25] Certainty remains elusive.

Nevertheless, just as the scientific enterprise rests on integrity the scientific community relies on consensus authority—not unchallengeable, but foundational. Authority is unavoidable: we are social beings, nevertheless remaining free to obey and free to dissent[26].

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 (2024)[27] examines the "Value-Free Ideal" (**VFI**), which holds that science should be "value-free" or

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are often not immediately recognised. See §11 for Artificial Intelligence used to help find problematic papers (Nina Notman, 2025, points out that in 2023 Hindawi – a branch of Wiley – retracted over 8000 scientific articles).

[25] To randomly take one example of many, Jessica Nordell (2021, p.72f) comments on a 2011 class action before the US Supreme Court of sex discrimination against 1.6 million female Walmart employees. 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 (*ibid*.; *q.v.* for full references) "*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).

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).

[26] On the authority of experts, Robert Crease (2019, p.252) observes, "*Authority is a key feature of public space … The success of totalitarianism is only possible with the erosion of authority*." He cites Hannah Arendt (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; Adelphothes, 2000). John Robinson (1976) dates *Ephesians* 58 CE.

[27] Philippe Stamenkovic (2024) 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*". 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*." 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.

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"objective." Originally, VFI aimed to preserve "*public trust in science*"—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*." 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 (1962) description of Lavoisier's discovery of oxygen is an object lesson in how the very expression of "facts" is plastic and must be negotiated, and Paul Feyerabend (1975) powerfully makes comparable arguments. As Robin Ince (2021) reminds us, we only do science because we're "*interested*".

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[28]. Bauckham (2006) has shown that personal "eyewitness" testimony underpins all knowledge. Frank *et al.*'s "Blind Spot" thesis (2024) supports this from another angle, and John Hardwig long ago argued for a principle of testimony (1991) to ground "epistemic authority" (1985): "*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*." Science is human, and knowledge is personal (Polanyi 1958).

For our purposes Stamenkovic's approach appears to be insufficiently fundamental, since he appears to treat "scientific truth" as well-defined and attainable: "… *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 (2019, p.1) argues that "*felicitous falsehoods*" can be "*epistemically valuable*".

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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 expressing 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*" (JCGM 1995), 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*" (Mari *et al*. 2013, 2021). 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 may be "dispassionate", but they cannot, in principle, be "disinterested".

[28] Factual truth "*concerns events and circumstances in which many are involved; it is established by witnesses and depends upon testimony*" (Crease, 2019, p.256; quoting Arendt, 1961). It is this "*social character*" that allows science deniers to "*discount them*" (*ibid*.).

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Stamenkovic acknowledges this, calling science "*our best available, most reliable (although always revisable) knowledge*". Revisability is key. What is "fact" today may be "error" tomorrow, though the underlying phenomena (and their interpretations) remain in the record[29]. *Some* truth must have been captured, even if misarticulated.

Michael Lissack (2017) critiques the "*hidden assumptions*" (imposed as "enabling constraints" like *ceteris paribus*) that "*allow ambiguity*[30] *to be bracketed away at the expense of transparency*", acknowledging Jürgen Habermas (1996) who points out that science "*fragments into a number of competing viewpoints … shot through with values*." Examining such assumptions more transparently, as Lissack urges, 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[31], which overlooks or distorts metaphysics. Our approach is scientific, acknowledging the "metanarrative of physics"[32] —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[33] , and Plato emphasized "*the dialectical method*" as the only path to first principles. For Aristotle, science is inherently metaphysical: if first principles begin physics, then the dialectical route to them must be *metaphysical*. Jeynes *et al*. (2023) independently affirm this, noting that the meanings of the terms of a discussion cannot generally be established by the discussion itself.

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

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29 Karen Barad (2007, p.333) rightly states that the phenomenon is the "*primary ontological unit*".

30 We are grateful to Julia Jordan for alerting us in 2022 to Anthony Ossa-Richardson's important monograph on "ambiguity" (2019). Jeynes *et al*. (2023) 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.

31 Charles Lowney (2020) says, in a discussion of Polanyi's (1958) 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!

32 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 Deacon, 2011).

33 James Lennox (2015) has this account: Aristotle opens his *Physics* with a discussion of the method [meqodoς, *methodos*] proper to obtaining scientific knowledge [ἐπιστήμη, *epistēmē*] in a scientific enquiry [φύσῖν ἱστορίᾶς, *physin istorias*]. 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 διαλεκτικὴ 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.

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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[34]: indeed, two Nobel-laureates have recently published their commitments to reality (Roger Penrose 2004, and Frank Wilczek 2021). 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*" (2020) rests on the metaphysical priority of unified theories. We deeply value unity in physical theories, just as we strive for coherence in thought. We will return to *unity* (§7).

Rovelli (2007, p.177) claims we must "*choose between hiding away in empty truths or accepting the radical uncertainty of our knowledge*." But why not affirm the "truths" we hold, while also acknowledging, as Rovelli does, that we can be wrong?[35] Catherine Elgin (2017), in *True Enough*, explores *truth* epistemologically, rejecting the "veritist" view as undermined by fallibilism. She notes, "*Making mistakes is an epistemic achievement*" (p.291): 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*" (p.293). If proven wrong, we must change our minds—a process that demands honesty and courage, but is a true intellectual achievement.

Leon-Philip Schäfer (2024) 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.*"[36] Though Schäfer's claim is technical and limited, we adopt his term "alethic realism": like Rovelli, we hold that "*realism matters because it is a presupposition of fallibilism*." If truth depends on reality, then

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[34] We are "alethic realists" in Leon-Philip Schäfer's terms (2024), although Philip Pullman's (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's personal website, https://joanv.me/solipsists_plea/index.php, accessed on 8 October 2025).

[35] Kevin Scharp (2021) has attacked the very idea of "truth", claiming that "*the concept of truth is defective in the sense that its platitudes are inconsistent*" (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 (2024) has attacked this thesis on the grounds that Scharp's programme for repairing the (admittedly useful) concept is in fact empty. 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).

[36] 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.

Schäfer intends to argue against "*constructivist principles and relativist themes*" (*ibid*. n.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*" (where by "*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*".

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accessing it is difficult—and certainty impossible. We affirm both: that reality is hard to know, and that certainty is unattainable. Still, truth is out there, and we're seeking it.

## 6. The Illusion of "Objectivity"

Karen Barad[37] states, "*The primary ontological unit is the phenomenon*" (2007, p.333), 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*" (*ibid*., Ch.7, n.1).

The EPR Paradox proposed by Einstein, Podolsky & Rosen in 1935 pointed out that *entanglement* of two particles persisted over great distances, such that 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[38]. The core issue is how to interpret quantum mechanics: is quantum uncertainty[39] 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[40].

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[41], both of which

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[37] 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".

[38] See for example Tim Maudlin (2010) on the *Bell Inequality* tests confirming that Quantum Mechanics is a *non-local* theory, and Jeeva Anandan (2002) confirming the incompatibility of QM and General Relativity since GR is a *local* theory).

[39] 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 … (https://www.ams.org/publicoutreach/feature-column/fcarc-uncertainty, accessed 17th April 2024). This "Uncertainty Principle" is quite general: Parker & Jeynes (2021a; see their Eq.18a *passim*) have shown that it is a consequence of Liouville's Theorem and applies to entropic as well as energetic systems (*mutatis mutandis*).

[40] For example, Proietti *et al*. (2019) 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*" (https://www.livescience.com/objective-reality-not-exist-quantum-physicists.html, accessed 14 December 2022). 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.*"

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: *"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, "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"* (Barad 2007 p.205; quoting Petersen 1985).

[41] Thomas Hertog speaks of "*the orthodox way of reasoning in physics [which seeks] a fundamentally causal explanation for the universe's biofriendliness*" (2023, 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 and Stephen

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become seriously more complicated when time is complexified (see §7, and Parker & Jeynes 2023a). Entangled systems can be profoundly non-local—and may be more numerous and important 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)[42]. 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*" (*ibid*. p.114).

Faye & Jaksland (2021)[43] critique Barad's "***agential realism***," noting its influence in the humanities while highlighting its absence from physics or philosophy of physics discourse. They

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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*" (Bohm & Hiley, 1993. p.320).

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 *et al*. 2023). We must take Gödel's metamathematical breakthrough seriously (Gödel, 1931; see §10).

[42] The press release for the Nobel Physics Prize awarded in 2025 to Devoret, Martinis & Clarke is explicit, speaking of the superconducting system invented by the laureates in 1985 (summarised by Martinis *et al*. 2020) 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*."

[43] Karen Barad's (2007) proposal of "***agential realism***" involves "*rethinking the relationship between materiality and signification*" (*ibid*. p.132). Faye & Jaksland (2021) 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)'*" (*ibid*., quoting Barad 2007 p.36, and pointing out that Barad herself has not published on agential realism in the physics or philosophy of physics literature).

Faye & 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*" (*ibid*.). 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*" (*ibid*. p.25). (This is also closely related to Atmanspacher's (2024) idea of "psychophysical neutrality"). 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*" (Mari *et al*. 2013, 2021).

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However, we believe that Faye & Jaksland's conclusion ("*that neither Bohr nor quantum mechanics as a whole proves Barad's agential realism to be true*") 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*" (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 & 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 & 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*": 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*." This seems debatable to us (Bohr's philosophy is notoriously impenetrable) – 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 & 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*."

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*." 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 (1710) pointed out the centrality of perception to our ontological ideas (*esse est percipi*): 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 Ducheyne 2011).

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*" (2007, p.138). The practice of science is an intricately human activity. Even "doing experiments" is philosophically complicated. Barad quotes Ian Hacking (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, 2007, 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 (1975) 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*" (p.37). For Bhaskar insists (correctly) that the world is normally open, and that "*a closure is normally a human product*" (of '*experimental production*': 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* (JCGM 2008, §2.48), "*a mathematical relation among all quantities known to be involved in a measurement*". This is very demanding of the experimenters: for examples see Jeynes *et al*. 2012, and Jeynes *et al*. 2020.

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assert that "*agential realism [is] a theoretical framework that … 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*" (p.ix); "*mattering is an integral part of the ontology of the world … not even a moment exists on its own*" (p.396). 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 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 (1967[44]) 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*."

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" [45] about broader implications.

Parker & Jeynes (2023a) offer a physics that explicitly treats local/non-local, causal/acausal, and reversible/irreversible elements commensurately. Mathematically complexifying the formalism [46] makes available the power of complex analysis: the (Wick rotated) complex conjugate of the Hamiltonian (*energy*) is (in natural units) the (complex*) entropy production* [47], encoding a set of

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[44] We thank Julia Jordan for alerting us to Murdoch's significant contribution

[45] Frank *et al*. (2024, p.viii) 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 supposed to be fully describable in objective scientific terms without reference to the mind*." 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*" (*ibid*., p.xi).

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

[46] "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 (√-1) was a fiction of the mathematicians. Roger Penrose explains: "… *the seemingly mystical quantity √-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 …*" (2004, §3.5, p.67). It is telling that Penrose uses the word "magical" (figuratively, of course): his chapter 4 is even titled "Magical Complex Numbers".

[47] The (complex) Hamiltonian and the (complex) entropy production are Hilbert transforms of each other (see n.46 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 (2023, p.240) 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?*".

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, 2004, §13.8, p.281). Although recent work by Parker & Jeynes (2023a) indicates that the signature (or metric) distinguishes between dissipative and reversible processes.

But imaginary time also appears in "standard" quantum mechanics (see for example McGlynn & Simenel 2020), using the 'Wick rotation' (helpfully explained by O'Brien 1975). "Complex" time has been introduced by other contributors: most notably Ivo Dinov's "spacekime" (for example Wang *et al*. 2022); but also Carl Frederick's ideas of "granular space-time"

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(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.

## 7. On Unity

Nicholas Maxwell (2020) correctly insists that "*physics accepts only unified theories*". This aligns with Leszek Nowak's conception of the *unity of science*, explored by Mateusz Wajzer (2024): "*Nowak concluded … that scientific theories do not arise from the generalisation of empirical facts, and they are far from hypothetical-deductive systems … idealisation*[48]*, not abstraction, is at the core of the scientific method*."

Unity is a foundational metaphysical idea—without it, science (and knowledge) would collapse. Truth must be *one* to mean anything[49]. 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[50]. Reality is elusive.

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(2022), and Philip K Dick's "orthogonal time" (published posthumously, 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.)

48 This recalls Catherine Elgin's (2017) assertion that idealisations are not *true* in the way epistemologists would like (instead, they are "*true enough*"!): she urges that "*belief, assertion and knowledge should be sidelined in favor of acceptance, profession and understanding*" (p.9). We thank an anonymous referee for alerting us to Elgin's important book.

Mateusz Wajzer (2021) correctly says that "*reductionism ... can be considered as a standard cognitive procedure applied in science*". 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 (2021) that scientific models are usually "*counterfactually deformed and ontically poorer*" representations is fair: 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*" (Nowak 1990). 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*".

49 Ultimately, if truth is not one then nothing can be known. 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.

50 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* (*pace* Barad 2007), 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 (Nobel 2025) declared, in awarding the 2025 Physics Prize, that in 1984/5 Clarke, Devoret & 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 *et al*. (2020) explicitly call such "single particles" *artificial atoms*! Indeed, Jeynes & Parker (2025) have argued just that: that "unitary entities" are, properly, "atoms" ("*indiscerpible*" in Henry More's 17th century term, even if not strictly "*indivisible*"),.

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Do "unitary entities" exist? Gottfried Leibniz (1714) thought so, famously calling them "monads"; the 17th century "metaphysical poets", fascinated by "atoms", thought so too[51]. We use "unitary entity" rather than the archaic "monad" or the confusing "atom".

Using Quantitative Geometrical Thermodynamics (**QGT**: Parker & Jeynes 2019[52]), Parker *et al*. (2022) show—without quantum mechanics—that the ground-state alpha particle ($^4$He[53]) qualifies as an atom (that is, a unitary entity than which exists no simpler[54]): not strictly *indivisible*, but *indiscerpible*[55] due to its high binding energy. 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

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[51] Henry More (1642) 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: quoted in Cassandra Gorman 2021 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, 1976).

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 (2021, p.72, ch.3) cites Democritus (3rd century BCE) as author of "*the founding document of atomism*". But this is historically incorrect since the 17th century scholars put effectively no weight on Democritus (see Gorman, 2021).

We should point out that Leibniz thought that all monads were the same – a reductive idea. But we think that there are a variety of unitary entities – a holistic idea.

[52] QGT can be mathematically described using the properties of holomorphic functions (complex differentiable – a very strong condition, see Penrose 2004 §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 & Jeynes (2021b) have proved *entropy production* to be a conserved quantity.

Parker & Jeynes (2019) have used the holomorphic properties of the DLS to calculate observables of both the Milky Way (*ibid*., Figures 1 & 2 *passim*), 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 & Walker 2010, in an information-theoretic context, and later more rigorously by Parker & Jeynes 2019, Appendix A).

Parker & Jeynes (2020) also analytically proved the stability of Buckminsterfullerene, a known result previously demonstrated constructively using computational chemistry methods requiring significant super-computer time. However, such methods are much harder to understand as well as being far more expensive and not at all easy to generalise.

[53] 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, although Leibniz believed that all monads were the same, whereas there are many different unitary entities recognised by QGT. To avoid confusion we use "unitary entity".

[54] Unitary entities as revealed by QGT are reviewed by Jeynes & Parker (2025). 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.

[55] 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 *et al*. (2022) 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.

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*.

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for $^{8}$He (the "tetraneutron"). Despite its instability, the tetraneutron's lifetime can still be accurately predicted by QGT (as can also the $^{6}$He and $^{8}$He lifetimes, by treating them all as unitary: Parker & Jeynes 2023b).

Constantino Tsallis (2024) calls the Borromean rings (seen in $^{6}$He and $^{12}$C nuclei[56]) "*a beautiful metaphor for complex systems*". QGT (Parker et al. 2022) models $^{12}$C as three alpha particles, supported by experimental evidence: "[$^{12}$C] *is believed to possess a rather unusual structure, where the dominant degrees of freedom are those of α-particle clusters rather than nucleons*" (Freer & Fynbo 2014). The QGT treatment of $^{12}$C is as a union of a unitary alpha and a unitary di-alpha, where the identity of the di-alpha is indeterminate (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[57].

Raphael Bousso (2002) reviews Gerard 't Hooft's "Holographic Principle": volume information can be fully encoded on a boundary surface [58]. Parker & Jeynes (2021a) derive this principle (represented by the Bekenstein-Hawking equation[59]) from the *entropic* Liouville theorem, applying it to unitary systems (like the alpha particle) using QGT (and *no* quantum mechanics).

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*.[60]

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[56] 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: Parker & Jeynes 2023b).

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: Lakshminarayan 2007) 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 (Pictaviensis, 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, 405 CE): this image is usually referred to in English as "*Shield of the Trinity*".

[57] 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, 2009) and it seems likely that a QGT treatment of benzene like the one available for Buckminsterfullerene (Parker & Jeynes 2020) would be analytically satisfying.

[58] 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 & Walker (2014).

"Holographic" means "*writing the whole*" — encoding 3D information in 2D. Thomas Hertog waxes lyrical about "holography" (2023, p.213 *passim*): "*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 …*"

[59] Roger Penrose (2004, §27.10, p.715) 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*" (emphasis 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 (2021a, 2022, 2023a) have shown recently that it is applicable at all scales and to other unitary systems.

[60] 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.

Parker & Jeynes (2021a) derived the Liouville Equation from QGT, and Parker *et al*. (2022) derived the size of the alpha *ab initio* from QGT (using the Liouville Equation and the Holographic Principle). Parker & Jeynes (2021b) applied QGT to black holes, proving that entropy production is Noether-conserved and calculating its value explicitly for black holes, values confirmed by Parker & Jeynes (2023a).

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Berry & Dennis (2003) 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 abstractions can be grasped). Jeynes (2023) reviews these geometrical "Berry phase" methods, drawing out the relation to QGT which, as for dichroism, treats reversible and irreversible phenomena symmetrically (Parker & Jeynes 2023a). Reality is elusive: in optics as in thermodynamics.

Harald Atmanspacher's (2024) mereological review[61] of *unity* in a disunited world, focuses on distinctions between "*the mental and the physical*." He identifies a "*domain of reality*" that is neither: instead marked by "*psychophysical neutrality*". Physics examples include Roger Penrose's "mathematical Platonism" (2007) and David Bohm's "implicate order" (1980).

The ancient poet exclaimed: "*Behold, how good and joyful a thing it is: brethren, to dwell together in unity*" (Ps.133:1[62]), but the word "unity" is inferred from the original: being a relatively modern idea,

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[61] *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* (Stanford Encyclopedia of Philosophy).

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 gives wide-ranging examples of "psychophysical neutrality", including (from physics) David Bohm's idea of the "implicate order" (1980): 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*." Bohm is looking for a "qualitatively new idea" and proposes that "*What they have in common is actually a quality of* **unbroken wholeness**" (Bohm & Hiley 1993, p.351f, his emphasis). 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 algebra, 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*". Reality is elusive: it is necessary to pay close attention to at least some "subtle intricacies".

[62] 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*" (JPS 2000), or "*Look, how good and how pleasant is the dwelling of brothers together*" (Alter, 2007). 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" (Apostolikes 1996).

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in Biblical texts first explicit[63] in Ephesians 4:3 (58 CE): "*keep the unity of the Spirit in the bond of peace*")[64], 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)[65]. 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 it only in passing in a discussion of *substance* (οὐσία) widely acknowledged as esoteric[66]. 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[67]. Yet *purpose* animates all life, and scientific work increasingly supports the reality of purposes: Parker *et al*. (2025a) formally define "*entropic purpose*" as a valid physical quantity[68], and Annie Crawford (2020) has carefully explained "*that since*

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[63] "*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 (1526) who brought the word "*atonement*" (and its cognates) to a much wider public:

"*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 (1530) that interpreted [יוֹם הַכִּפֻּרִים] (*yōwm hakkippuri ̂m*), as "the Day of Atonement" (*Yom Kippur*, 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).

[64] "τηρεῖν τὴν ἑνότητα τοῦ πνεύματος ἐν τῷ συνδέσμῳ τῆς εἰρήνης" (Adelphothes 2000). 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.

[65] 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 (JPS 2000) 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" (Apostolikes 1996: 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, 2019).

[66] It is found in the *Metaphysics* (Book Delta) as "*unity of being*" (ἑνότης τίς ἐστιν): καὶ τὰ μὲν οὕτως λέγεται ταὐτά, τὰ δὲ καθ᾽ αὑτὰ 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 αὑτῷ ταὐτόν· ὡς δυσὶ γὰρ χρῆται αὐτῷ ( Τῶν Μετὰ τὰ Φυσικὰ Δ 1018a4-9; Ross 1924, p.259f; thanks to Margaret Barker for this reference).

This is translated (rather freely, by Hugh Lawson-Tancred, 1998) as: "*There are as many cases of this as there are of* per se ["καθ᾽ αὑτὰ"] *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*".

[67] Michael Stöltzner (2003) explains in detail the commitment of Hilbert and Max Planck to the PLA, also discussing its teleological aspects at length. Sabine Hossenfelder (2022, p.159) says of the PLA, "*It was a revelation! Why hadn't anybody told me?*", 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.

[68] Parker *et al*. (2025a) naïvely assume that the Lagrangian and Hamiltonian representations are equivalent (through the Legendre transformation, see Eq.21). This assumption is discussed at length by Clara Bradley (2025).

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*teleological concepts cannot be abstracted away from biological explanations without loss of meaning and explanatory power, life is inherently teleological*."

## 8. What is Fundamental?

Jesus famously observed that the "*wyſe man byltt his houſſe on a rocke*" (Tyndale 1526)[69]. What is the *foundation* of our knowledge? We observe the sun rising in the East and setting in 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.* 2022 think not). 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 (reviewed by Jeynes & Parker, 2025). The alpha particle's size in its ground state is correctly calculated from thermodynamics, without quantum mechanics, by treating it as *unitary* (Parker *et al*. 2022) 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[70])! Thus, a holistic view proves *more* "fundamental" than a reductionist one. QGT affirms that holistic treatments can be fundamentally valid in themselves—they don't need to "emerge" from supposedly more basic physics[71].

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![72] Yet in quantum physics, neither protons nor neutrons are "fundamental particles" since

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[69] … ἀνδρὶ φρονίμῳ, ὅστις ᾠκοδόμησε τὴν οἰκίαν αὐτοῦ ἐπὶ τὴν πέτραν: Matthew 7:24ff (Adelphothes, 2000); see parallel passage at Luke 6:48ff. The English is quoted *verbatim* with original spelling from the earliest modern English translation (Tyndale 1526): 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.

[70] contradicting Wilczek (2021), who is clear that the Second Law of Thermodynamics is ***not*** "fundamental" (see note on his p.93, ch.4), 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 construct the physical world*" (p.62, ch.3). That is: the most fundamental is the smallest. But the work of Parker and others shows this conclusion to be mistaken.

[71] See Gil Santos (2020) on "emergence". 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.

[72] Sabine Hossenfelder (2022, p.83) 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*", 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 (1961) 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*", and that this assumption is, actually, a prejudice (a mistaken one, as Parker *et al*. 2022 have shown in the case of the alpha particle). 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*" (2023, p.237f). Denis Noble (2012) is also very clear that the reductionist approach is not appropriate for biological systems, insisting instead "*that downward causation is necessary*"

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they're composed of quarks (according to the Standard Model). But what exactly are quarks? Is the Standard 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[73] supports this, showing how the reversible and irreversible (and the causal and acausal, local and non-local) are actually commensurate (Parker & Jeynes 2023a). "Local" aligns with standard cause-and-effect; "non-local" reflects system-level holistic behaviours[74]. The world will remain opaque to us unless we appropriate this new holistic physics.

It is interesting that Potter & Mitchell (2022) list 8 properties of living organisms that allow us to think of them validly as *causative agents* (without any sort of dualism): 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). This account is consistent with ours.[75]

Unity, non-locality, and irreversibility are all *fundamental* to reality—but go unrecognised by Rovelli (2009) and Wilczek (2021). Other physicists are less rigid: Penrose (2004, ch.27), for instance, devotes significant attention to the Second Law, affirming irreversibility as a fundamental reality—even if current physics treats its laws as reversible.

## 9. QBism

Since we are realists who insist that "*knowledge is personal*" (Polanyi 1958)[76], are we not also QBists ("quantum Bayesians")? QBism is widely seen as a "*philosophically rigorous approach to quantum*

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(that is, the "higher" levels determine the "lower" ones – we would put this rather differently, but the substantive point remains).

Consider Ferreira *et al*.'s (2025) proposals regarding dark matter. The search for this (reviewed by Misiaszek & Rossi, 2024) is "*an attempt to discover the microphysical model underlying the empirical regularities that suggested the existence of this type of matter*". 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 Fig.2 *passim* of Parker & Jeynes 2019): 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 2021)!

[73] 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.

[74] 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 (2023) has reviewed the use of "Berry phase analysis" as a systematic physical approach to treating irreversible systems, and says: "*[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 & Jeynes, 2023a] has shown that for a more satisfactory and unified explanation of many physical phenomena even the description of time should be complexified*". 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).

[75] Separately, Perunov *et al*. (2016) have explored the statistical physics of "*strongly driven systems that exhibit complex collective behavior … for the first time establishing general relationships between far-from-equilibrium probability distributions over states and the thermodynamic fluxes that accompany their dynamical evolution*", although they persist in imposing time-reversal symmetry. Nevertheless, these general relationships are clearly valuable for developing an appropriate "physics of living systems".

[76] 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

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*mechanics*" that "*cuts no epistemic or ontological corners*"[77]. David Mermin (2012) has summarised QBism helpfully, explaining that it elegantly disposes of the "shifty split" that John Bell deplored (the discontinuity between the microscopic and macroscopic involved in making the "observation" that "collapses the wavefunction")[78], and points out that the real issue is how we think of *probability*. The real issue is how we understand *probability*: are we "frequentist" or "Bayesian"?[79]

Michael Levine (2019) notes, "*in many problems … there is no true model*." As we've said above, "*measurement is primarily an epistemic process*" (Mari *et al*. 2013). The "*Guide to the Expression of Uncertainty in Measurement*" (JCGM 1995) 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." We seek truth, but acknowledge our epistemic and ontic limitations.

Determining probability is philosophically and technically complex. Steven Goodman (speaking to the medics, 2008) has helpfully listed various ways that people can (and do) misuse statistics to pretend to the scientific method. Howson & Urbach (1989) examine scientists' use of probability, countering claims that Bayesianism is "too subjective."

Matthew Leifer (2014) 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 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 is a bona fide field of physics*" to be resolved by "*rigorous argument and experiment*." Still, the debate remains unresolved. The Pusey–Barrett–Rudolph Theorem (Pusey 2012) shows that under certain assumptions, Ψ must be ontic—a state of reality, not merely of knowledge (with subtle implications far beyond our scope[80]). But as Karen Barad (2007) 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*" (*ibid*. p.43)[81].

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 (2005) notes a shift in Bayesian statistics toward "*objective uninformative priors*," though he adds, "*in practice, it isn't easy to specify an uninformative prior*."

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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.

77 Robert Crease, private communication 13th March 2024

78 It is this "shifty split" that Thomas Hertog (2023, p.37) 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*", 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*"

79 "*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.*" (Mermin, 2012)

80 Michael Ridley (2025) 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.

81 In her Conclusion to ch.4 ("*Agential Realism*"), 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*" (*ibid*., p.185; emphasis original).

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In the important case of a "Bertrand Paradox"[82], Parker & Jeynes (2023c) 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?). Entropy is blind to scale, and the scale-blindness of QGT (Parker & Jeynes 2019) 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: Parker *et al*. 2022) and also for entities of general relativity (like black holes: Parker & Jeynes 2023a).

David Bohm argued for an "Undivided Universe" (Bohm & Hiley 1993); QGT offers a unified treatment of QM and GR. Combined with thermodynamics' nonlocality and the holomorphic nature of actio-entropy (Parker & Jeynes 2023a[83]), QGT reflects Bohm's vision of wholeness (Bohm 1980). Addressing physicists, Mermin (2012) warns: "*you had better reexamine what you wrongly may have thought you understood perfectly well about the nature of probability*." And Parker *et al*. (2025b) show that "*probability [is] a physical quantity grounded in hyperbolic Minkowski spacetime, and [obeys] all the appropriate physical laws*". This new Bayesian understanding of the physics of probability and its scale-relativity now also offers us 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, 2019), which is always a metaphysical step (a "*leap of faith*" [84]) requiring a use of language that can only be called poetic (see Jeynes *et al*. 2023). The essential fact is

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[82] Parker & Jeynes (2023c) 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. 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 (2014) 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*."

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 (1983; he admits that "we find obscurity at the heart of the scale invariance argument", an obscurity enlightened by Parker & Jeynes' treatment, 2023c).

We thank Nicholas Shackel for alerting us to Milne's paper (private communication 13th March 2024). On the Principle of Indifference see also Shackel (2024).

[83] "actio-entropy" is an idea first introduced by Velazquez *et al*. (2022). "Action" is an important physical quantity (defined by an appropriate line integral of the Lagrangian): "entropy" is shown by Parker & Jeynes (2019) to be a quantity precisely isomorphic to the action (being defined by an appropriate line integral of the *entropic* Lagrangian).

[84] The "leap of faith" referred originally to leaping over Gotthold Lessing's "*ugly broad ditch*" (1777, "*der garstige breite Graben*"); see Yasukata (2003). 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*" (1846) and implicitly in his discussion of Abraham's faith in "*Fear and Trembling*" (1843).

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that there is no disembodied or impersonal knowing. *Knowledge is personal* (Polanyi 1958) just as much as *information is physical* (Landauer 1991, 1999)[85].

Human enterprises can't be formally *defined*—only *described* or *exemplified*. Scientists and poets all seek the same elusive reality: variously, since it's hard to grasp. "Science is what scientists do"[86] underlines the humanity of the thing. Defining "the scientific method" has failed because humans want surprising (and undefinable) things [87]. 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" [88], and the astrophysicists have delighted 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*.[89]

Positivism's effort to *define* the "scientific method" failed. Kurt Gödel's Incompleteness Theorem (1931) proved that any axiomatic system rich enough to include arithmetic is necessarily incomplete—it contains true theorems undecidable in the system[90]. Gödel was the first to make formal use of *metamathematical* methods, foreshadowed by Anselm's poetic metanarrative in the *Proslogion* (1078 CE; systematically overlooked by modern philosophers, see Jeynes *et al*. 2023).

Rather than chasing the "completeness" that Immanuel Kant popularised (1786), 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*" (Peirce 1903, emphasis original).[91]

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85 Although Landauer was speaking of "Shannon information" (which is explicitly and deliberately *impersonal*), where "knowledge" is necessarily *personal*! Similarly, Parker *et al*. (2025a) speak of "*entropic purpose*", which is explicitly *impersonal*, being measured by Shannon information.

86 Thomas Hertog (2023, p.247) also says this: "*Science is what scientists do. We advance by exchanging ideas …*". 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

87 We can avoid a discussion of "free-will" here. Sabine Hossenfelder (2022, p.128) is definite, saying (several times): "*the future is fixed, except for occasional quantum events that we cannot influence*", 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.

88 One could also point out here the assessment of Thomas Hertog (2023, p.61) that Lemaître's 1931 letter to *Nature* (Lemaître 1931) was "cosmopoetic": "*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.*"

89 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 2021 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 …*" (Gawronsky, 1949: thanks to Sir Michael Berry for drawing our attention to this story; private communication, 29th March 2024).

90 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.

91 Abduction has been explored by Lucia Santaella Braga (2019) and Timothy Shanahan (1986). Ernan McMullin (1992) 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*". McMullin's work is widely regarded as seminal, for example by Bas van Fraassen (2013), 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*

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## 11. Machine Intelligence

We've touched on public trust in science, but a question related to our enquiry here on "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'…*"[92] and highlights that while AI adoption demands trust, many systems remain black boxes. Efforts now 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.[93] AI can summarize conventional wisdom, but its competence boundaries remain unknown (and perhaps unknowable; usefully reviewed by Karoline Reinhardt, 2023). The "*Ethics Guidelines for Trustworthy AI*" (EU 2019) 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*. 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.

Fodor & Pylyshyn (1988) argued that artificial neural networks (ANNs) lack "*systematic compositional generalizability*." Abigail Tulenko (2024) traces this idea back to Avicenna[94], who thought that where humans can reason from universals, animals can think only about particulars. AI struggles with this, though Lake & Baroni (2023) showed that "meta-learning for compositionality" lets ANNs mimic human performance—provided the training is suitably structured. 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 (2023) 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

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*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.*"

92 "*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 *understanding* of the narrative in question). Rather, it is, again, simply a set of facts.

93 We have seen how Joseph Drew (2023) 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 (2015) has shown how explicitly Aristotle grounded his *Physics* in a prior metaphysics.

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

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b) trust is an ambivalent thing (we can after all "*trust that the world is going to end*"). 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*." The rise of AI stimulates a re-examination of what the scientific enterprise really is.

Davidiuk *et al*. (2025) have shown how generative AI can easily (and almost undetectably) fake microscopy images. However, Nina Notman (2025) also discusses the AI tools currently being used to detect fraudulent papers clogging up the peer-review process.

## 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 (Parker & Jeynes 2023a). 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 (e.g. Dinov & Velev 2022), 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 & Roberts (2024) employ complexified, 5D spacetime and a holographic approach in quantum chromodynamics to calculate the strong force over large distances (explained by Brodsky *et al*. 2024). 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!*"[95]

Treating science as *story* underlines the essential truth that *knowledge is personal*, as Michael Polanyi (1958) observed long ago. Paul Grobstein (2005) 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] what new stories develop because of it*" (emphasis original). Robert Crease has pointed out that "*Stories make things appear that you cannot see or think about otherwise*" (2019, p.263). Frank *et al*. (2024, p.ix) go further: they consider that stories "*constitute a modern form of mythos … [orienting us and structuring] our understanding of the world*".

Thomas Dillern (2019) seems to be an isolated modern proponent of Polanyi's view of *personal knowledge*, although Jerry Ravetz's (1971) school was active previously in creatively developing Polanyi's view on *craftsmanship*. 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*" and pointing 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*". We have here represented this viewpoint by insisting on the indispensable metaphysical context of our physical explanations (following Jeynes *et al*. 2023). 'Polanyi's Paradox'[96] (David Autor, 2014) is a central and necessary idea for mediating our conception of "knowledge". 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

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[95] "*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 in "*Confessions*" XI:14; c.398 CE)

[96] 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.*"

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worth pointing out explicitly that "*tacit knowledge*" (described in some detail by Polanyi, 1958) is a fine cover for unrecognised assumptions being smuggled in to 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.

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 the public for whom in the end the science is done.

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## References

K.Abe and 98 others (1983: the Stanford Linear Accelerator Centre Hybrid Facility Photon Collaboration), Charm photoproduction cross-section at 20 GeV, *Physical Review Letters* **51** (1983) 156-159; https://doi.org/10.1103/PhysRevLett.51.156

 doi:10.20944/preprints202408.1674.v3



Robert Alter (2007), *The Book of Psalms* (New York: Norton, 2007)

Jeeva Anandan (2002), Non-Locality of Quantum Mechanics and the Locality of General Relativity, *Modern Physics Letters A* **17** (2002) 1097-1106; https://doi.org/10.1142/S0217732302007661

Anselm of Bec (1078), *Proslogion*, c.1078; transl. M.J.Charlesworth, (Oxford: Clarendon Press, 1965)

Adelphothes (2000), H KAINH DIAQHKH meta suntomou ermhneiaς (Athens: Adelfoqhς Qeologwn «O Sothr» 2000)

Apostolikes (1996), H PALAIA DIAQHKH kata touς Ebdomhkonta (Athens: Apostolikhς Diakoniaς, 1996)

Hannah Arendt (1961), *Between Past and Future* (The Viking Press, 1961; revised 1968; Penguin Classics 2006)

Jamin Asay (2024), Irreplaceable truth, *Synthese* **203** (2024) 85 (20pp); https://doi.org/10.1007/s11229-024-04498-y

Harald Atmanspacher (2024), Psychophysical neutrality and its descendants: a brief primer for dual-aspect monism, *Synthese* **203** (2024) 25 (21pp); https://doi.org/10.1007/s11229-023-04449-z

Augustine of Hippo (c.398 CE), *Confessiones* (Latin Text from Pius Knöll's Editio Minor of 1898; *Confessions*, Transl.: R.S.Pine-Coffin; Penguin: London, UK, 1961; Available online: https://faculty.georgetown.edu/jod/latinconf/latinconf.html accessed 4 December 2023).

David Autor (2014), Polanyi's Paradox and the Shape of Employment Growth, (Cambridge, MA: NBER Working Paper Series) *National Bureau of Economic Research Working Paper* **20485** (2014) 1–48; http://dx.doi.org/10.3386/w20485

Karen Barad (2007), *Meeting the Universe Halfway* (Durham NC: Duke University Press, 2007)

Richard Bauckham (2006), *Jesus and the Eyewitnesses: The Gospels as Eyewitness Testimony* (Grand Rapids: Eerdmans, 2006)

George Berkeley (1710), *Treatise concerning the Principles of Human Knowledge* (Dublin: Jeremy Pepyat, 1710)

Michael Berry, John F. Nye (2006), John Michael Ziman, *Biographical Memoirs of the Fellows of the Royal Society* **52** (2006) 479-491; https://doi.org/10.1098/rsbm.2006.0032

M. V. Berry, M. R. Dennis (2003), The optical singularities of birefringent dichroic chiral crystals, *Proceedings of the Royal Society A* **459** (2003) 1261–1292; http://dx.doi.org/10.1098/rspa.2003.1155

Roy Bhaskar (1975), *A Realist Theory of Science* (Leeds: Leeds Books, 1975; 2nd ed. Abingdon: Routledge, 2008); page numbers from 2008 edition

Clara Bradley, The Relationship Between Lagrangian and Hamiltonian Mechanics: The Irregular Case, *Philosophy of Physics* **3** (2025) 9 (23pp); https://doi.org/10.31389/pop.197

David Bohm (1980), *Wholeness and the Implicate Order* (Routledge, 1980)

David Bohm, B.J.Hiley (1993), *The Undivided Universe: an ontological interpretation of quantum theory* (Abingdon: Routledge, 1993; paperback edition 1995: page numbers are from the 2003 edition)

Rosa Bologna, Franziska Trede, Narelle Patton (2020), A Critical Imaginal Hermeneutics Approach to Explore Unconscious Influences on Professional Practices: A Ricoeur and Jung Partnership, *The Qualitative Report* **25** (2020) 3486-3518. https://doi.org/10.46743/2160-3715/2020.4185

Raphael Bousso (2002), The Holographic Principle, *Reviews of Modern Physics* **74** (2002) 825–874; https://doi.org/10.1103/RevModPhys.74.825

Lucia Santaella Braga (2019), C. S. Peirce's Abduction, Induction, and Deduction (In: M.Peters (ed) *Encyclopedia of Educational Philosophy and Theory*; Springer, Singapore, 2019); https://doi.org/10.1007/978-981-287-532-7_575-1

Stanley J. Brodsky, Alexandre Deur, Craig D. Roberts (2024), The Secret to the Strongest Force in the Universe: New discoveries demystify the bizarre force that *binds* atomic nuclei together, *Scientific American Magazine* **330** (2024) 32; https://www.scientificamerican.com/article/physicists-finally-know-how-the-strong-force-gets-its-strength/ (accessed 2nd November 2024)

Lucas Brunet, Ruth Müller (2024), The Feeling Rules of Peer Review: Defining, Displaying, and Managing Emotions in Evaluation for Research Funding, *Minerva* (2023) ; https://doi.org/10.1007/s11024-023-09518-8

Annie L. Crawford (2020), Metaphor and Meaning in the Teleological Language of Biology, *Communications of the Blyth Institute* **2** (2020) 5-23; https://doi.org/10.33014/issn.2640-5652.2.2.crawford.1

Robert Crease (2019), *The Workshop and the World: what ten thinkers can teach us about science and authority* (New York: Norton, 2019)

 doi:10.20944/preprints202408.1674.v3



Harry Collins, Robert Evans (2007), *Rethinking Expertise* (University of Chicago Press, 2007)

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, Quinn A. Besford, The rising danger of AI-generated images in nanomaterials science and what we can do about it. *Nature Nanotechnology* **20** (2025) 1174–1177; https://doi.org/10.1038/s41565-025-02009-9

Jeroen de Ridder (2022), How to trust a scientist, *Studies in History and Philosophy of Science* **93** (2022) 11–20; https://doi.org/10.1016/j.shpsa.2022.02.003

Sidney Dekker (2006), *The Field Guide to Understanding Human Error* (Aldershot: Ashgate, 2006)

Alexandre Deur, Stanley J. Brodsky, Craig D. Roberts (2024), QCD running couplings and effective charges, *Progress in Particle and Nuclear Physics* **134** (2024) 104081 (143pp); https://doi.org/10.1016/j.ppnp.2023.104081

Philip K Dick (2011), *The Exegesis of Philp K Dick* (eds.Pamela Jackson, Jonathan Lithem; Boston: Houghton Mifflin Harcourt, 2011)

Thomas Dillern (2020), The Act of Knowing: Michael Polanyi Meets Contemporary Natural Science, *Foundations of Science* **25** (2020) 573–585; https://doi.org/10.1007/s10699-019-09626-3

Ivo D. Dinov, Milen V. Velev (2022), Data Science: Time Complexity, Inferential Uncertainty, and Spacekime Analytics (Berlin: Walter de Gruyter GmbH, 2022); https://doi.org/10.1515/9783110697827

J.Drew, J.O'Flynn, B.Grant (2018), Performing What? Exploring and expanding the notion of synecdoche in performance management practice. *Public Administration Quarterly* **42** (2018) 395-424; https://www.jstor.org/stable/26892945

Joseph Drew (2023), *Selling Public Policy*; Chapter 3: "*Rhetoric: Not Just What Is Said, but Also Who Says It and How*" (Singapore: Springer, 2023) pp.29-46; https://doi.org/10.1007/978-981-99-0381-8_3

Steffen Ducheyne (2011), Newton on action at a distance and the cause of gravity, *Studies in History and Philosophy of Science A* **42** (2011) 154-159; https://doi.org/10.1016/j.shpsa.2010.11.003

D. J. Dunstan, J. Crowne, A. J. Drew (2022), Easy computation of the Bayes factor to fully quantify Occam's razor in least-squares ftting and to guide actions, *Scientific Reports* **12** (2022) 993 (10pp); https://doi.org/10.1038/s41598-021-04694-7

M.P.J.Edwardes (2019), *The Origins of Self* (London: UCL Press, 2019); https://doi.org/10.14324/111.9781787356306

Bradley Efron (2005), Bayesians, Frequentists, and Scientists, *Journal of the American Statistical Association* **100** (2005) 1-5; https://doi.org/10.1198/016214505000000033

Catherine Z. Elgin (2017), *True Enough* (MIT Press, 2017)

Marta Entradas, Martin W. Bauer, Frank Marcinkowski & Giuseppe Pellegrini (2023), The Communication Function of Universities: Is There a Place for Science Communication? *Minerva* **62** (2024) 25–47; https://doi.org/10.1007/s11024-023-09499-8

EU (2019), *Ethics Guidelines for Trustworthy AI: High-Level Expert Group on Artificial Intelligence*, Pekka Ala-Pietilä (Chair), Barry O'Sullivan (Vice-Chair), Nathalie Smuha (Coordinator), and 49 others; https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai

Jan Faye, Rasmus Jaksland (2021), Barad, Bohr, and quantum mechanics, *Synthese* **199** (2021) 8231–8255; https://doi.org/10.1007/s11229-021-03160-1

Pedro G. Ferreira, William J. Wolf, and James Read, The Spectre of Underdetermination in Modern Cosmology, *Philosophy of Physics* **3** (2025) 11 (28pp); https://doi.org/10.31389/pop.218

Paul Feyerabend (1975), *Against Method: Outline of an Anarchistic Theory of Knowledge* (London: New Left Books; 1975)

Jerry A. Fodor, Zenon W. Pylyshyn (1988), Connectionism and cognitive architecture: A critical analysis, *Cognition* **28** (1988) 3-71; https://doi.org/10.1016/0010-0277(88)90031-5

Adam Frank, Marcelo Gleiser, Evan Thompson (2024), *The Blind Spot: Why Science cannot ignore Human Experience* (MIT Press, 2024)

Carlton Frederick (2022), Granular Space–time: The Nature of Time; https://doi.org/10.48550/arXiv.1601.07171

M. Freer, H.O.U. Fynbo (2014), The Hoyle state in $^{12}$C, *Progress in Particle and Nuclear Physics* **78** (2014) 1-23; https://doi.org/10.1016/j.ppnp.2014.06.001

Martin Gardner (2013), *Undiluted Hocus-Pocus* (Princeton University Press, 2013)

 doi:10.20944/preprints202408.1674.v3



Dimitry Gawronsky (1949), "Ernst Cassirer: his life and his work", in *The Philosophy of Ernst Cassirer*, ed. Paul Arthur Schilpp (Evanston, Ill.: The Library of Living Philosophers Inc., 1949)

Kurt Gödel (1931), 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* **38** (1931) 173–198; https://doi.org/10.1007/BF01700692; reprinted in English in Stephen Hawking, *God Created the Integers* (Philadelphia: Running Press, 2005).

Steven Goodman (2008), A Dirty Dozen: Twelve P-Value Misconceptions, *Seminars in Hematology* **45** (2008) 135-140; https://doi.org/10.1053/j.seminhematol.2008.04.003

Cassandra Gorman (2021), *The Atom in Seventeenth Century Poetry* (Cambridge: D.S.Brewer, 2021)

Paul Grobstein (2005), Revisiting Science in Culture: Science as Story Telling and Story Revising, *Journal of Research Practice* **1** (2005) M1 (18pp); http://jrp.icaap.org/index.php/jrp/article/view/9/17 [accessed Mar 18 2024].

Jürgen Habermas (1996), *Faktizität und Geltung. Beiträge zur Diskurstheorie des Rechts und des demokratischen Rechtsstaats* (Frankfurt am Main: Suhrkamp Verlag, 1992; transl. William Rehg, *Between Facts and Norms: Contributions to a Discourse Theory of Law and Democracy*; Cambridge: Polity, MIT Press, 1996)

Ian Hacking (1983), *Representing and Intervening: Introductory topics in the philosophy of natural science* (Cambridge University Press, 1983)

Lucy Haddad, Diego Gianolio, David J. Dunstan, Ying Liu, Conor Rankine, Andrei Sapelkin (2024), Quantifying Intuition: Bayesian Approach to Figures of Merit in EXAFS Analysis of Magic Size Clusters, *Nanoscale* **16** (2024) 5768-5775; http://dx.doi.org/10.1039/D3NR05110B

John Hardwig (1985), Epistemic Dependence, *The Journal of Philosophy* **82** (1985) 335-349; http://dx.doi.org/10.2307/2026523

John Hardwig (1991), The role of trust in knowledge, *The Journal of Philosophy* **88** (1991) 693-708; https://doi.org/10.2307/2027007

S.W. Hawking, Thomas Hertog (2018), A Smooth Exit from Eternal Inflation? *Journal of High Energy Physics* **4** (2018) 147 (13pp); https://doi.org/10.1007/JHEP04(2018)147

Thomas Hertog (2023), *On the Origin of Time: Stephen Hawking's final theory* (London: Torva, 2023) page numbers are for the Penguin 2024 edition

E.J. Hobsbawm (1975), *The Age of Capital, 1848-1875* (New York: Scribner, 1975)

Sabine Hossenfelder (2022), *Existential Physics: A Scientist's Guide to Life's Biggest Questions* (London: Atlantic Books, 2022; page numbers refer to the paperback edition 2023)

Colin Howson, Peter Urbach (1989), *Scientific Reasoning: The Bayesian Approach* (La Salle: Open Court, 1989); added to Internet Archive 2021

Mike Hulme (2009), *Why we disagree about climate change: understanding controversy, inaction and opportunity* (Cambridge University Press, 2009)

Robin Ince (2021), *The Importance of Being Interested: adventures in scientific curiosity* (London: Atlantic Books, 2021)

JCGM (1995), *Guide to the Expression of Uncertainty in Measurement*, 1st ed.; JCGM (Joint Committee for Guides in Metrology): Paris, France, (2010: 2008 version with minor corrections); 2008 is 1995 version with minor corrections; JCGM 100:2008 (BIPM: Paris); https://www.bipm.org/documents/20126/2071204/JCGM_100_2008_E.pdf (accessed 10 March 2024)

JCGM (2008), *Vocabulaire international de métrologie* (Joint Committee for Guides in Metrology) *International Vocabulary of Metrology—Basic and General Concepts and Associated Terms* (VIM), 3rd ed.; BIPM: Paris, 2008 (with minor corrections – JCGM 200:2012); https://www.oiml.org/en/files/pdf_v/v002-200-e07.pdf (accessed 17 April 2024).

Jerome of Stridon (405 CE), *Biblia Sacra Vulgata* ("the sacred book in the common tongue"), "Clementine" text edited by A. Colunga and L. Turrado (La Editorial Católica, Madrid, 1946; see "The Clementine Text Project": www.biblegateway.com and https://vulsearch.sourceforge.net/gettext.html). Jerome translated the original Hebrew and Greek texts into Latin. His "Vulgate" text was used by all European Christians for the next millennium and remains influential today.

C. Jeynes, N.P.Barradas, E. Szilágyi (2014), Accurate determination of Quantity of Material in thin films by Rutherford backscattering spectrometry, *Analytical Chemistry* 84 (2012) 6061-6069; http://dx.doi.org/10.1021/ac300904c

 doi:10.20944/preprints202408.1674.v3



C.Jeynes (2014), *On "Infallible?" (Hans Küng, 1970)*; (University of Surrey Ion Beam Centre, 2014, 11pp); https://www.surrey.ac.uk/sites/default/files/2021-03/Infallibility.pdf (accessed 4th March 2024)

C.Jeynes, E.Nolot, C.Costa, C. Sabbione, W. Pessoa, F. Pierre, A. Roule, G.Navarro, M.Mantler (2020), Quantifying nitrogen in GeSbTe:N alloys, *Journal of Analytical Atomic Spectrometry* **35** 701-712; http://dx.doi.org/10.1039/C9JA00382G

Chris Jeynes, Michael C.Parker, Margaret Barker (2023), The Poetics of Physics, *Philosophies* **8** (2023) 3 (54pp); http://dx.doi.org/10.3390/philosophies8010003

C.Jeynes (2023), How "Berry Phase" analysis of non-adiabatic non-Hermitian systems reflects their geometry, *Entropy* **25** (2023) 390 (10pp); https://doi.org/10.3390/e25020390

C.Jeynes, M.C.Parker (2025), Unitary Entities are the true "atoms", *Entropy* **27** (2025) 1119 (22pp); https://doi.org/10.3390/e27111119

JPS (2000), *Hebrew-English Tanakh* (Philadelphia, Jewish Publication Society, 2000)

Immanuel Kant (1786), *Metaphysische Anfangsgründe der Naturwissenschaft* (Riga: J.F.Hartknoch, 1786; "*The Metaphysical Foundations of Natural Science*" *transl*. Ernest Balfour Bax, London:George Bell & Sons, 1883)

Søren Kierkegaard (1843), *Frygt og Bæven* (Copenhagen: Lynge & Son, 1843; *Fear and Trembling*, transl; Alastair Hannay London: Penguin, 1985).

Søren Kierkegaard (1846), *Afsluttende uvidenskabelig Efterskrift til de philosophiske Smuler* (Copenhagen: Reitzel, 1846; *Concluding Unscientific Postscript*, trans. David F. Swenson and Walter Lowrie; Princeton University Press, 1974)

Kevin Killeen (2017). Microscopy, Surfaces and the Unknowable in Seventeenth-Century Natural Philosophy (from Lucretius to Margaret Cavendish), *Journal of the Northern Renaissance* (Issue 8, Spring 2017 - *Scrutinizing Surfaces*); https://core.ac.uk/download/pdf/96767929.pdf (accessed 26/4/2024)

Arthur Koestler (1959), *The Sleepwalkers: A History of Man's Changing Vision of the Universe* (London: Hutchinson, 1959)

Thomas Kuhn (1962), *The Structure of Scientific Revolutions* (University of Chicago Press, 1962)

Hans Küng (1970), *Unfehlbar?* (Zürich: Benziger, 1970; *Infallible?* transl. E.Mosbacher, Collins, 1971)

Brenden M. Lake & Marco Baroni (2023), Human-like systematic generalization through a meta-learning neural network, *Nature* **623** (2023) 115–121; https://doi.org/10.1038/s41586-023-06668-3

Arul Lakshminarayan (2007), Borromean triangles and prime knots in an ancient temple, *Resonance* **12** (2007) 41–47; https://doi.org/10.1007/s12045-007-0049-7

Rolf Landauer (1991), Information is Physical, *Physics Today* **44** (1991) 23-29; http://dx.doi.org/10.1063/1.881299

Rolf Landauer (1999), Information is a physical entity, *Physica A: Statistical Mechanics and its Applications* **263** (1999) 63-67; https://doi.org/10.1016/S0378-4371(98)00513-5

Michael Lavine (2019), Frequentist, Bayes, or Other? *The American Statistician* **73** (2019) 312-318; https://doi.org/10.1080/00031305.2018.1459317

Hugh Lawson-Tancred (1998), *Aristotle, the Metaphysics* (Penguin, 1998)

G.W.Leibniz (1714), *La Monadologie* (MS, 1714; *Lehrsätze über die Monadologie*, 1720; "Principia philosophiae", *Acta Eruditorum* 1721; *Leibniz: Philosophical Writings*, transl. Mary Morris, Everyman's Library, Dent, London 1934). Available online: https://plato-philosophy.org/wp-content/uploads/2016/07/The-Monadology-1714-by-Gottfried-Wilhelm-LEIBNIZ-1646-1716.pdf (transl. Robert Latta, 1898; accessed on 6 March 2024).

Matthew Saul Leifer (2014), Is the Quantum State Real? An Extended Review of ψ-ontology Theorems, *Quanta* **3** (2014) 67-155; http://dx.doi.org/10.12743/quanta.v3i1.22

G. Lemaître (1931), The Beginning of the World from the Point of View of Quantum Theory, *Nature* (9 May 1931) 706; https://www.nature.com/articles/127706b0.pdf (accessed 26/4/2024)

James G. Lennox (2015), ch.1 in Mariska Leunissen (ed.), *Aristotle's Physics: A Critical Guide* (Cambridge University Press, 2015)

Gotthold Ephraim Lessing (1777), On the proof of the spirit and of power (1777); Ch.7 in *Lessing: philosophical and theological writings* (Hugh Barr Nisbet (ed and trans); Cambridge: Cambridge University Press, 2005) pp 83–88; https://doi.org/10.1017/CBO9780511810138.012

Michael Lissack (2017), Second Order Science: Examining Hidden Presuppositions in the Practice of Science, *Foundations of Science* **22** (2017) 557–573; http://dx.doi.org/10.1007/s10699-016-9483-x

 doi:10.20944/preprints202408.1674.v3



G.E.R.Lloyd (2002), *The Ambitions of Curiosity* (Cambridge University Press, 2002)

Charles W. Lowney II (2020), Michael Polanyi: A Scientist Against Scientism (in: Callahan, G., McIntyre, K.B. (eds) *Critics of Enlightenment Rationalism*; Palgrave Studies in Classical Liberalism. Palgrave Macmillan, 2020) pp.139-158 https://doi.org/10.1007/978-3-030-42599-9_10

LXX ("Septuagint", c.250BCE): see Apostolikes 1996. This is the translation into Greek made in Alexandria (at the request of Ptolemy II, d.246 BCE) by the Jewish scholars of the Hebrew Scriptures. It was probably complete by the 2nd century BCE.

Edouard Machery (2025), Science Without Trust? *Philosophy of Science*, (accepted paper) https://doi.org/10.1017/psa.2025.10143

L.Mari, A.Maul, D.T.Irribarra, M.Wilson (2013), Quantification is Neither Necessary Nor Sufficient for Measurement, *Journal of Physics Conference Series* **459** (2013) 012007 (6pp); http://dx.doi.org/10.1088/1742-6596/459/1/012007

Luca Mari, Mark Wilson, Andrew Maul (2021), Philosophical perspectives on measurement; ch.4 in: *Measurement across the Sciences - Developing a shared concept system for measurement* (Springer, 2021); https://link.springer.com/chapter/10.1007/978-3-030-65558-7_4 (accessed 10th March 2024)

John M. Martinis, Michel H. Devoret, John Clarke (2020), Quantum Josephson junction circuits and the dawn of artificial atoms, *Nature Physics* **16** (2020) 234–237; https://doi.org/10.1038/s41567-020-0829-5

Tim Maudlin (2010), What Bell proved: A reply to Blaylock, *American Journal of Physics* **78** (2010) 121–125; https://doi.org/10.1119/1.3243280

Nicholas Maxwell (2020), Aim Oriented Empiricism and the Metaphysics of Science, *Philosophia* **48** (2020) 347–364; https://doi.org/10.1007/s11406-019-00064-w

Patrick McGlynn, Cédric Simenel (2020), Imaginary-time mean-field method for collective tunnelling, *Physical Review C* **102** (2020) 064614; https://doi.org/10.1103/PhysRevC.102.064614

William McKane (1986), *A Critical and Exegetical Commentary on Jeremiah* (Bloomsbury, 1986)

Tom McLeish (2019), *The Poetry and Music of Science* (Oxford University Press, Oxford, 2019)

Ernan McMullin (1992), *The Inference that Makes Science* (given as the 1992 "*Aquinas Lecture*" at Marquette University, republished in: *Zygon: Journal of Religion and Science* **48** (2013) 131-142; https://doi.org/10.1111/j.1467-9744.2012.01319.x

N. David Mermin (2012), Commentary: Quantum mechanics: Fixing the shifty split, *Physics Today* **65** (2012) 8–10; https://doi.org/10.1063/PT.3.1618

Hanna Metzen (2024), Objectivity, shared values, and trust, *Synthese* **203** (2024) 60 (19pp); https://doi.org/10.1007/s11229-024-04493-3

Peter Milne (1983), A Note on Scale Invariance, *The British Journal for the Philosophy of Science* **34** (1983) 49-55; https://www.journals.uchicago.edu/doi/abs/10.1093/bjps/34.1.49 (accessed 15th March 2024)

Marcin Misiaszek, Nicola Rossi (2024), Direct Detection of Dark Matter: A Critical Review, *Symmetry* **16** (2024) 201 (33pp); https://doi.org/10.3390/sym16020201

Yirong Mo (2009), The Resonance Energy of Benzene: A Revisit, *Journal of Physical Chemistry A* **113** (2009) 5163–5169; https://doi.org/10.1021/jp808941h

Henry More (1647), *Philosophicall Poems* (Cambridge University, 1647; printed by Roger Daniel); full text at: https://quod.lib.umich.edu/e/eebo2/A51310.0001.001/1:33.11?rgn=div2;view=fulltext (accessed 6 March 2024)

Iris Murdoch (1967), *The Sovereignty of Good over Other Concepts* (The Leslie Stephen Lecture; Cambridge University Press: Cambridge, UK, 1967; reprinted in *The Sovereignty of Good*, Routledge & Kegan Paul: Abingdon, Oxon, 1970)

Basarab Nicolescu (2010), Methodology of Transdisciplinarity—Levels of reality, logic of the included middle and complexity, *Transdisciplinary Journal of Engineering and Science* **1** (2010) 19–38; https://doi.org/10.22545/2010/0009

Nobel Committee (2025), *The Nobel Prize in Physics 2025 (Press Release)*; https://www.nobelprize.org/uploads/2025/10/press-physicsprize2025.pdf (accessed 10/10/2025)

Denis Noble (2012), REVIEW A theory of biological relativity: no privileged level of causation, *Interface Focus* **2** (2012) 55–64 http://dx.doi.org/10.1098/rsfs.2011.006

 doi:10.20944/preprints202408.1674.v3



Jessica Nordell (2021), *The End of Bias: How we change our Minds* (New York: Metropolitan, 2021; London: Granta, 2021)

Nina Notman, AI tools combat paper mill frauds in publishing, *Chemistry World* **22**(11) (November 2025) 44-47; https://www.chemistryworld.com/features/ai-tools-tackle-paper-mill-fraud-overwhelming-peer-review/4022253.article?%24web_only=true (accessed 10 Nov. 2025)

Leszek Nowak (1990), Abstracts are not our Constructs. The Mental Constructs are Abstracts (ch.9, pp.193–206 in: *Idealization I: General Problems*, eds. Jerzy Brzeziński, Francesco Coniglione, Theo A.F. Kuipers, Leszek Nowak. vol.16 of Series: *Poznań Studies in the Philosophy of the Sciences and the Humanities*, ed. Katarzyna Paprzycka-Hausman; Leiden: Brill); https://doi.org/10.1163/9789004457157_010

D.M.O'Brien (1975), The Wick Rotation, *Australian Journal of Physics* **28** (1975) 7–13; https://doi.org/10.1071/PH750007

Anthony Ossa-Richardson (2019), *A History of Ambiguity* (Princeton University Press, 2019)

Flavia Padovani (2012), BOOK REVIEW: Bas C. Van Fraassen: Scientific Representation: Paradoxes of Perspective, *Science & Education* **21** (2012) 1199–1204; http://dx.doi.org/10.1007/s11191-011-9423-7

M.C.Parker, S.D. Walker (2010), A Dynamic Model of Information and Entropy**,** *Entropy* **12** (2010) 80-88; https://doi.org/10.3390/e12010080

Michael C. Parker, Stuart D. Walker (2014), A Unified Carnot Thermodynamic and Shannon Channel Capacity Information-Theoretic Energy Efficiency Analysis, *IEEE Transactions on Communications* **62** (2014) 3552-3559; http://dx.doi.org/10.1109/TCOMM.2014.2351412

M.C.Parker, C.Jeynes (2019), Maximum Entropy (Most Likely) Double Helical and Double Logarithmic Spiral Trajectories in Space-Time, *Scientific Reports* **9** (2019) 10779 (10 pp, 44 pp Appendices); http://dx.doi.org/10.1038/s41598-019-46765-w

M.C.Parker, C.Jeynes (2020), Fullerene Stability by Geometrical Thermodynamics, *ChemistrySelect* **5** (2020) 5-14; http://dx.doi.org/10.1002/slct.201903633

M.C.Parker, C.Jeynes (2021a), Entropic Uncertainty Principle, Partition Function and Holographic Principle derived from Liouville's Theorem, *Physics Open* **7** (2021) 100068 (11pp); https://doi.org/10.1016/j.physo.2021.100068

Michael C. Parker, Chris Jeynes (2021b), A Relativistic Entropic Hamiltonian–Lagrangian Approach to the Entropy Production of Spiral Galaxies in Hyperbolic Spacetime, *Universe* **7** (2021) 325 (15pp); https://doi.org/10.3390/universe7090325

M.C.Parker, C.Jeynes, W.N.Catford (2022), Halo Properties in Helium Nuclei from the Perspective of Geometrical Thermodynamics, *Annalen der Physik* **534** (2022) 2100278 (11pp); http://dx.doi.org/10.1002/andp.202100278

M.C.Parker, C.Jeynes (2023a), Relating a system's Hamiltonian to its Entropy Production using a Complex-Time approach, *Entropy* **25** (2023) 629 (19pp); http://dx.doi.org/10.3390/e25040629

M.C.Parker, C.Jeynes (2023b), *ab initio* thermodynamics calculation of beta decay rates, *Annalen der Physik* **535** (2023) 2300259 (11pp); http://dx.doi.org/10.1002/andp.202300259

M.C.Parker, C.Jeynes (2023c), A Maximum Entropy Resolution to the Wine/Water Paradox, *Entropy* **25** (2023) 1242 (10pp); https://doi.org/10.3390/e25081242

Michael C. Parker, Chris Jeynes, Stuart D. Walker (2025a), A Metric for the Entropic Purpose of a System, *Entropy* **27** (2025) 131 (40pp); https://doi.org/10.3390/e27020131

M.C.Parker, C.Jeynes (2025b), A hyperbolic sum rule for probability: solving recursive "Chicken & Egg" problems, *Entropy* **27** (2025) 352 (40pp); https://doi.org/10.3390/e27040352

Charles Sanders Peirce (1877), The Fixation of Belief, *The Popular Science Monthly*, November 1877.

Charles Sanders Peirce (1903), *Pragmatism as the logic of abduction*, Harvard Lecture VII (14th May 1903); In *C.S.Peirce, Collected Papers 1931–1958* (Vol. 5, eds. C.Hartshorne & P.Weiss, Harvard University Press) §§ 180–212

Roger Penrose (2004), *The Road to Reality: a complete guide to the Laws of the Universe* (Jonathan Cape, 2004)

Nikolay Perunov, Robert A. Marsland, Jeremy L. England (2016), Statistical Physics of Adaptation, *Physical Review X* **6** (2016) 021036 (12pp); http://dx.doi.org/10.1103/PhysRevX.6.021036

A.Petersen (1985), *The Philosophy of Niels Bohr*, in "Niels Bohr: A Centenary Volume" (Eds. A.P.Kennedy, C.J.French; Harvard University Press: Cambridge MA, 1985).

 doi:10.20944/preprints202408.1674.v3



Petrus Pictaviensis (1210), *Compendium Historiae in Genealogia Christi*, c.1210 ("Peter of Poitiers"; Cotton Faustina manuscript B. VII, folio 42v; London: British Library)

Michael Polanyi (1958), *Personal Knowledge: Towards a Post-Critical Philosophy* (University of Chicago Press, 1958).

Karl R. Popper (1945), *The Open Society and its Enemies: Vol.II, The High Tide of Prophecy: Hegel, Marx, and the Aftermath* (London: Routledge, 1945)

Karl R. Popper (1994), *The Myth of the Framework: in defence of science and rationality* (London: Routledge, 1994)

Henry D. Potter, Kevin J. Mitchell (2022), Naturalising Agent Causation, *Entropy* **24** (2022) 472 (18pp); https://doi.org/10.3390/e24040472

M.Proietti, A.Pickston, F.Graffitti, P.Barrow, D.Kundys, C.Branciard, M.Ringbauer, A.Fedrizzi (2019), Experimental test of local observer independence, *Science Advances* **5** (2019) eaaw9832 (6pp); https://doi.org/10.1126/sciadv.aaw9832

Max K. Planck, (1950), *Scientific Autobiography and Other Papers* (New York: Philosophical Library, 1950; transl. Frank Gaynor)

Derek de Solla Price (1962), *Little Science, Big Science* (*1962 Brookhaven National Laboratory Pegram Lectures*; Columbia University Press, 1963)

Philip Pullman (1995), *Northern Lights* (London: Scholastic, 1995)

Matthew F. Pusey, Jonathan Barrett, Terry Rudolph (2012), On the reality of the quantum state, *Nature Physics* **8** (2012) 475–478; https://doi.org/10.1038/nphys2309

John Herman Randall Jr. (1940), The Development of Scientific Method in the School of Padua, *Journal of the History of Ideas*, **1** (1940) 177-206; https://doi.org/10.2307/2707332

Roy A. Rappaport (1999), *Ritual and Religion in the Making of Humanity* (Cambridge University Press, 1999)

J.R.Ravetz (1971), *Scientific Knowledge and its Social Problems* (Oxford University Press, 1971)

James Reason (1990), *Human Error* (Cambridge University Press, 1990)

Karoline Reinhardt (2023), Trust and trustworthiness in AI ethics, *AI and Ethics* **3** (2023) 735–744; https://doi.org/10.1007/s43681-022-00200-5

Arnold S. Relman (1983), Lessons from the Darsee Affair, *New England Journal of Medicine* **308** (1983) 1415-1417; http://dx.doi.org/10.1056/NEJM198306093082311

Paul Ricoeur (2000), *La mémoire, l'histoire, l'oubli*" (Paris: Seuil, 2000; "*Memory, History, Forgetting*", transl. Kathleen Blamey, David Pellauer, University of Chicago Press, 2004)

Michael Ridley (2025), Many retrocausal worlds: A foundation for quantum probability. *European Journal for Philosophy of Science* **15** (2025) 70 (48pp). https://doi.org/10.1007/s13194-025-00696-8

J.A.T.Robinson (1976), *Redating the New Testament* (London: SCM Press, 1976)

Valentin Rodionov (2024), Holes in the 'holey graphyne' story, *ChemistryWorld*, **21(5)** (May 2024) 5; https://www.chemistryworld.com/opinion/holes-in-the-holey-graphyne-story/4019235.article

W.D.Ross (1924), *Aristotle's Metaphysics* (Oxford University Press, 1924; the copy in Trent University Library digitised 2019 by Internet Archive)

Carlo Rovelli (2009), *Anaximander and the Nature of Science* (Penguin, Random House 2023; *Anaximandre de Milet, ou la naissance de la pensée scientifique*, Éditions Dunod, 2009; *The First Scientist: Anaximander and his Legacy*, Westholme Publishing, 2011, transl. Marion Lignana Rosenberg) page numbers given refer to the 2023 English edition.

Johan E. Runeson, Joseph E. Lawrence, Jonathan R. Mannouch, Jeremy O. Richardson (2022), Explaining the Efficiency of Photosynthesis: Quantum Uncertainty or Classical Vibrations? *The Journal of Physical Chemistry Letters* **13** (2022) 3392-3399; https://doi.org/10.1021/acs.jpclett.2c00538

Gil Santos (2020), Integrated-structure emergence and its mechanistic explanation, *Synthese* **198** (2021) 8687–8711; https://doi.org/10.1007/s11229-020-02594-3

Leon-Philip Schäfer (2024), How (not) to integrate scientific and moral realism, *Synthese* **203** (2024) 57 (24pp); https://doi.org/10.1007/s11229-023-04467-x

Kevin Scharp (2021), Conceptual engineering for truth: aletheic properties and new aletheic concepts, *Synthese* **198** (2021) S647–S688; https://doi.org/10.1007/s11229-019-02491-4

G.Schlesinger (1961), The Prejudice of Micro-Reduction, *British Journal for the Philosophy of Science* **12** (1961) 215-224; https://www.jstor.org/stable/685208 (accessed 29th September 2025).

 doi:10.20944/preprints202408.1674.v3



Nicholas Shackel (2024), *Bertrand's Paradox and the Principle of Indifference* (New York: Routledge, 2024); https://doi.org/10.4324/9781003456308

Timothy Shanahan (1986), The First Moment of Scientific Inquiry: C. S. Peirce on the Logic of Abduction, *Transactions of the Charles S. Peirce Society* **22** (Fall, 1986) 449-466 (Indiana University Press); http://www.jstor.com/stable/40320156

Nicholas Spencer (2023), *Magisteria: The Entangled Histories of Science and Religion* (London: One World, 2023)

Philippe Stamenkovic (2024), Straightening the 'value-laden turn': minimising the influence of extra-scientific values in science, *Synthese* **203** (2024) 20 (38pp); https://doi.org/10.1007/s11229-023-04446-2

Michael Stöltzner (2003), 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* **34** (2003) 285-318; https://doi.org/10.1016/S1355-2198(03)00002-9

Jonathan P. Tennant, Tony Ross-Hellauer (2020), The limitations to our understanding of peer review, *Research Integrity and Peer Review* **5** (2020) 6 (14pp); https://doi.org/10.1186/s41073-020-00092-1

Constantino Tsallis (2024), Reminiscences of Half a Century of Life in the World of Theoretical Physics, *Entropy* **26** (2024) 158 (22pp); https://doi.org/10.3390/e26020158

Abigail Tulenko (2024), What Philosopher Ibn Sina Can Teach Us about AI, *Scientific American* (Opinion) 18th April 2024

William Tyndale (1526), *The New Testament* (Worms: Peter Schoeffer, 1526; Facsimile of copy found in the Landesbibliothek, Stuttgart: The British Library, 2008)

William Tyndale (1530), *The Pentateuch* (the five "books of Moses"), "*Imprented at Malborow in the lande of Hesse* [Antwerp]: *By me Hans Luft* [Johan Hoochstraten], *M.CCCCC.xxx the xvij dayes of Januarij* [27Jan.1530 in the Gregorian calendar]"; copy now in University of Cambridge library displayed on the Internet Archive, https://archive.org/details/ThePentateuch/

Bastiaan C. van Fraassen (2008), *Scientific Representation: Paradoxes of Perspective* (Oxford University Press, 2008) https://doi.org/10.1093/acprof:oso/9780199278220.001.0001

Bastiaan C. van Fraassen (2013), Scientific Realism and the Empiricist Challenge: An Introduction to Ernan McMullin's Aquinas Lecture, *Zygon: Journal of Religion and Science* **48** (2013) 131-142; https://doi.org/10.1111/j.1467-9744.2012.01322.x

Luisberis Velazquez, Michael C. Parker, Chris Jeynes (2022), *The Geometry of Thermodynamics III* (preprint, July 2022); http://dx.doi.org/10.13140/RG.2.2.17505.99686

Yuxin Wang, Yueyang Shen, Daxuan Deng, Ivo D. Dinov (2022), Determinism, well-posedness, and applications of the ultrahyperbolic wave equation in spacekime, *Partial Differential Equations in Applied Mathematics* **5** (2022) 100280 (13pp); https://doi.org/10.1016/j.padiff.2022.100280

Mateusz Wajzer (2021), Idealisation, genetic explanations and political behaviours: Notes on the anti-reductionist critique of genopolitics, *Studies in History and Philosophy of Science* **90** (2021) 275–284; https://doi.org/10.1016/j.shpsa.2021.10.014

Mateusz Wajzer (2024), On Leszek Nowak's Conception of the Unity of Science, *Foundations of Science* **29** (2024) 307–324; https://doi.org/10.1007/s10699-022-09843-3

Frank Wilczek (2021), *Fundamentals: Ten Keys to Reality* (Allen Lane, 2021)

Toshimasa Yasukata (2003), Lessing's "Ugly Broad Ditch" (Ch.4, pp.56-71, in *Lessing's Philosophy of Religion and the German Enlightenment*, New York: Oxford University Press, 2003); https://doi.org/10.1093/0195144945.003.0005

John M. Ziman (1978), *Reliable knowledge: an exploration of the grounds for belief in science* (New York: Cambridge University Press, 1978)