Conor Cunningham[2]
https://orcid.org/0000-0002-9778-829X

UNIVERSITY OF NOTTINGHAM

Science at the critical point. What comes after naturalness?

https://doi.org/10.15633/9788383701073.11

First, let me say, this is not, despite impressions, about physics

The university was created to engage the universe, but its ability to fulfil this mission is frustrated by a Balkanisation of the sciences resulting from a pervasive commitment to the autonomy of high-energy physics as Master over the disciplines. In Plato's *Sophist*, the Stranger warns that 'if one separates each thing off from everything, that completely and utterly obliterates any discourse, since it is the interweaving of forms that gives us the possibility of talking to each other in the first place'. Our attainment of knowledge, Plato thought, was an 'art of weaving' (*huphantikē*) that precluded both Balkanisation and barren imperialism. Importantly, though, such weaving is neither unrealistic nor idealistic, for as Plato's Stranger (in the *Statesman*) points out the

2 Associate Professor in Theology and Philosophy, Faculty of Arts. Author of *Genealogy of Nihilism*, and coeditor (with Peter M. Candler Jr.) of the Interventions series. Cunningham also wrote and presented the acclaimed BBC documentary *Did Darwin Kill God?* which originally aired in March 2009.

parts of goodness (the woven hymn) are not always friends, for example, courage (*andreia)* and moderation (*sophrosyne)*. Indeed, as we shall hear towards the end, physics today is, in its mostradical moments, an act of *ressourcement*, unbeknownst to itself, no doubt, as it bumps into Plato up ahead. Indeed, and writing against Paul and Patricia Churchland, I wrote that science was but a proto-art, they having argued that the Humanities were but proto-science, full of folk psychology that required translating into proper scientific terms, but now, and in light of what follows, I would argue that science, at last, qualifies as a proper art.

The logic of Platonic weaving found an institutional home when the university was invented over a thousand years ago in Bologna gathered in the university to explore, engage, and give an account of the universe in its inexhaustible abundance of dynamic aspects – and to do so as embodied agents who were themselves parts of the universe. Such was the governing paradigm of learning and teaching, one driven by an unapologetic Eros.

Today, the *university* or *universe* relationship is languishing under the tyrannical pornography of shallow metrics of employability and corporate relevance, a symptom of which is micromanagement, imported from California, and labouring under a puerile view of 'objectivity'. All of which prepares the way for AI, because under such cultural practices humans are already self-deleting. Indeed, the academy can now be usefully characterised as an algorithmic university, to use Adam Morton's phrase. The only ivory tower (apparently) left standing is that of high-energy physics. One major reason is the widespread dream of a Master Discourse able to provide a *Theory of Everything, which would, not only be incoherent, but a miscarriage of science*, what Maurice Blondel might call superstition. This dream is undergirded by an updated version of Democritus' atomism: the belief in a foundational base of which all else is but a shadow or a merely conventional presentation and over which one science – physics, more precisely: high-energy physics – has monopoly control. Here, the disciplinary universe is a 'layer-cake', even more: it is a *pyramid* dominated by the splendidly isolated pharaoh that is (high-energy) physics. As Ernest Rutherford is supposed to have said, 'there is only physics, all else is stamp collecting.'

No matter the base (the brain, DNA, atoms, strings, and so on), however, the *politics of the campaign* is underwritten by a '*Steady State Ideology*' that approaches existence as a *once-and-for-all static given*. This remains true today. Even though Steady State Cosmology was undermined long ago, *its ideological* *world-picture has remained dominant*, despite many inconvenient facts: that there was a Big Bang, that the universe's expansion rate is accelerating and doubling in size every ten billion years or so, and that particles, whatever they are, pop in an out of existence. This persistent ideology imprisons many debates in inadequate, tired frameworks and gives rise to a plethora of *degenerative research programmes*, the monstrous progeny of which are nonsensical dualisms, such as reduction and emergence, immaterial/material, r and so on.

The layer-cake model generates the cultural neurosis called 'physics envy,' which inclines every university discipline to aspire to pharaoh-like sovereignty over its own domain. In order to recover the ordinary relation between universe and university a post-Democritean paradigm is required, one already emerging, unnoticed, at the cutting edge of science itself. A particular focus of this engagement is the crisis of so-called 'naturalness' in high-energy physics, a crisis revealing the bankruptcy of the current Democritean model. It is crucial to note that *'naturalness,' is not to be confused with naturalism*; it is a term of art in physics, and one contribution of the present project will be to make it more widely known. I would bet that very few have ever heard of it. I engage with it as a form of leverage, a thread to pull on until the attire unravels, or as an important sign of an endemic malaise, the muffled groan of a dead animal.

The key to liberation from these ideological shackles lies in recognizing that *existence is dynamic and still arriving*. There is abundant evidence for this dynamism within science itself. And as said, the crisis of so-called 'naturalness' opens the way towards a new 'un-particle physics' that deals a death-blow to the Steady State Ideology, the myth of the hegemonic base, and the physics-dominated layer-cake it props up.

What is and what's wrong with naturalness?

A prominent physicist calls naturalness 'the best-kept secret of physicists from the public'. Naturalness is, however, central for the ideological framework of theoretical physics; it is a founding 'myth', a 'prejudice', a 'central dogma', purely 'aesthetic', an 'unmotivated presupposition', an extra-empirical assessment, 'the opposite of what the physics community usually regards as scientific knowledge', which 'screams out for explanation', yet, for all that, it is ubiquitous. This secret is buried under a seem in glyanodyne exterior: the obvious-looking belief that a good theory will (of course) deliver the 'expected' experimental results 'naturally', without fine-tuning. Naturalness-based reasoning, therefore, entails the veneration of sensitivity prohibition, underwritten by the principle of decoupling, which at first blush seems promising. But this is misdirection, indeed it is, in truth, a *euphemism for the autonomy of high-energy physics*. Decoupling allows for HEP to remain aloof, Pharaoh-like, from the *hoi polloi*, goings on below – floating above the crudity of low energy physics, and the ever-more tabloid disciplines, such as the Humanities, which are even further away from Pharaoh's throne.

Naturalness is not just bad philosophy, however. It's also bad science (apart from its one success, the 'charm quark'). At every turn, the empirical evidence mocks attempts to prohibit fine-tuning in the name of the autonomy of energy levels. Indeed, the very Standard Model itself has proved to be 'spectacularly unnatural'. Consequently, our understanding of the SM has changed radically. It is now construed as an effective field theory (EFT): that which captures what is relevant physically in, or at, a given domain, doing so effectively – it works, and it does so by ignoring all else. In other words, it isn't the truth: there's a cut-off scale below which the theory breaks down, and is inapplicable.

Regarding naturalness, take Einstein's cosmological constant, used to help reconcile theory and experiment (crudely, a uniform repulsive force permeating space, which was believed to be zero, but is not: It entails a correction or fine tuning at a scale of 10^{100} (a number exceeding that of all the observable atoms in the universe) to render it 'natural. 'Similarly, and seemingly inspired by Alice and her wonderland, the attempt to get around this problem by removing the fine-tuning to a hypothetical multiverse requires 10^{500} universes to make the tuning appear 'natural.'. The anthropic principle is the same hubristic fantasy in different trousers, a strategy of which Baron Munchausen would be proud. Incidentally, Aquinas, in his commentary on John's Gospel, had already addressed the question of many worlds.

Here we witness the cultural pathology of '*et alibi*' – what is before us is elsewhere, which comes in four flavours, variations on *J'accuse*, though here the direction of accusation should be reversed: diachronic, you are nothing but your past (Darwinian phylogeny – the genetic fallacy); synchronic, you are nothing but your microphysical particles-the fallacy of composition; prospective, you are nothing given the coming usurpation by AI-incidentally, AI offers theology, and only theology, a unique opportunity, as it it's the only discipline immune to its impact; lastly, modal, here this universe is not, because it is one of an infinity. Despite cultural addiction to these flavors, all four strategies have but the gait of a phantom limb.

Very briefly, regarding the false contrast of reduction and emergence, insufficient attention is paid to the fact that reduction is not univocal: For example, it travels in opposite directions in physics and philosophy, a fact that is more crucial than is supposed even by those who deign to notice it. We thus have *reduction1* (*philosophy*): the older, coarser theory is reduced (deposed) by the more refined, newer theory, through connect ability and deducibility with the help of 'bridge-laws' that, acting as a Rosetta stone, provide co extensionality between theories. On the other hand, we have *reduction2* (*physics*): the newer theory reduces to the older, coarser one, like the marbling of Easter bread or the laying down of heartwood of a tree. Rather than flimsy reduction, there is recovery at a certain limit: The older theory is *recovered*. Crucially, this is precisely how theology works in terms of creedal orthodoxy, wherein a later Church Council reduces to, or *recovers*, the earlier/older one, otherwise, it would have no reason to exist, and be bereft of an ability to speak. Of singular importance is that without *reduction2*, reduction *tout court* is illegitimate, if not impossible. Why? Because *it is a fact* that the reducing theory, however successful, *is finite* or limited, thus, the reducing theory, interacting with the past, must also implicate the future, opening up to its own ineluctable surpassing (as a theory *emeritus*), which itself is not a Whiggish triumph, but a profound supplement that indicates a certain blending or weaving of frames of reference.

Returning to naturalness. We have to talk about Higgs (forget Kevin)

Closer to home, the much-trumpeted Higgs Boson, the discovery of which was a 'five-star nightmare', as one physicist at CERN put it. It would, in one sense, have been better if nothing had been discovered, for in a way it brings physics to a grinding halt, as there is no BSM physics forthcoming. The televised joy of the scientists was misdirection, put on to justify the billions spent – Smiles of the Cheshire cat, sported by many a chilly Emperor, or here Pharaoh. In shortest terms, the Higgs requires industrial fine-tuning at a scale of 10^{34} to achieve its mass. Indeed, the Higgs field itself is *ad hoc*; technically, because it is quadratic rather than logarithmic, which renders it scalar. A situation that is profoundly problematic and disturbing for the prevailing paradigm.

It is not necessarily the intrinsic unnaturalness of the Higgs that is most troubling, but rather the immediate prospects of destabilisation when its kind is proliferated in nature, its kind being zero-spin scalar bosons, construed as elementary. Except for the Higgs boson, all particles of the SM – and thus all known fundamental particles – either have spin ½ fermions (e.g., electrons, quarks and leptons) or spin 1 bosons (e.g., gluons, and photons). By contrast, the Higgs particle as zero spin and, as said, is scalar and therefore quadratic which generates several radical problems: the radical fine-tuning, but more. The disturbing fact about such a large cancellation is that the bare mass of the Higgs is a *free parameter* (a variable which cannot be predicted or constrained by the model), thereby it entails what is sometimes called an ansatz- an assumption or simply a guess; the reason why nature would have fine-tuned it to almost exactly the interaction mass is unexplained, hence it is "unnatural". In short, the Higgs boson is sensitive to high energy; it destroys decoupling, and thereby threatens the autonomy of HEP and the stability of the SM. And we cannot on pain of failing a contemporary Copernican test, think there are no other scalar bosons.

Here's the thing to notice: The fact that the SMHM seems to be realized in nature despite physicists' strong reservations against it may have a seemingly very paradoxical consequence: that physicists would ultimately have to develop a much more radically new approach to elementary particle physics than if new physics beyond the SM had been discovered (such as supersymmetry) This requires a profound change of ideas concerning particle physics. From this perspective, the physicists' classification of the SMHM as *ad hoc* may have verbalized their resistance against such profound change. HEP is in a right old pickle.

A stunning example of this is pickle is the following: If you bash two particles together hard enough, their energies become so concentrated at the collision point that they'll form a black hole, yet colliding particles with even higher energy produce a bigger black hole. Contrarily to the prevailing paradigm, then, *higher energy does not provide shorter lengths*; indeed, the reverse is the case. Black holes (and quantum gravity) upend the expected relationship between high energies and short distances. In so doing, they challenge the Neo-Democritean worldview that has a brainwashing effect on the many fields it has infected with *physics envy* (or *physics emulation*).

The crisis of naturalness reveals the ideology motivating its construction. Indeed, head of research at the Large Hadron Collider at CERN, contends that the increasingly patent 'unnaturalness' of the Standard Model is obliging physics to write a *Summa contra naturalitatem* on its way to a 'post-naturalness era'. The collapse of naturalness under the weight of the empirical evidence suggests that the scientific enterprise has reached a crisis in two senses. *The first sense is negative*: The supposed Master Science (high-energy physics) finds itself at an impasse due to a still-dominant 'degenerative research programme' owing more to a Neo-Democritean ideology than to the actual data. *The second sense is more hopeful*: Science is on the verge of a 'phase transition' (e.g., liquid to gas) thanks to the emergence of a new, regenerative paradigm exemplifying the Platonic 'art of weaving' mentioned earlier. As one physicist puts it, '[t]here is a quake rumbling through the core of physics. Suddenly, apparently unrelated areas appear to show an eerie capacity to fertilise each other,' the sign of a genuine 'un-particle physics' entailing a '*Platonic perfection*'.

To aid the delivery of this unparticle physics, I develop a *bespoke version of renormalisation group theory* (RG), which is central to my entire effort. The RG method is one of the most successful theoretical devices employed by physicists for modelling and understanding macroscopic phenomena. Put in drastically brief terms, renormalisation entails a ground-breaking technique that *washes out irrelevant (micro) details* so as to retain only that which really matters, *as when we squint to get a better view of an object*. It is often said in the literature that such a procedure renders analysis tractable–allowing us to get our heads round what is otherwise intractable–beyond enumeration or counting. I argue that this assumption is wrong. What RG actually reveal is that the understanding of the micro as a kind of absolute first principle is erroneous. In a sense RG is not about coarse graining, or zooming out, as some maintain, but rather zooming in, fine graining, in terms of what is relevant and therefore, in fact, real, given the target system.

The most stunningly successful tools of physics in the last 100 years (e.g., renormalisation) necessarily 'avoid physics' in order to work. By 'avoid,' I mean: They explain physical phenomena by means of theoretical devices that remain at a certain distance from the reality the phenomena reveal. Take the boiling of a kettle: In order to explain this phenomenon, physics assumes the *idealised thermodynamic limit* ∞, the actual attainment of which would entail an infinity *of molecules* that our kettles *can't* possess. The point is that physics approaches *every* phenomenon by means of models displaying such physics-avoidance; 'effective idealisations' belong to physicists' daily bread (hence their increasing reliance on purely abstract objects such as quantum fields). I return to this later. Indeed, physics consists mainly in effective field theories, mentioned already, they work, but they aren't true, including, as said, the Standard Model, shockingly for any would-be Pharaohs. But rather than taking this situation as proof of scientific anti-realism, I approach it as an indication that any truly realistic science has to have an 'apophatic' character: Like so-called 'negative theology' in the Christian tradition, I argue, physics gets at nature *more* by saying *what nature is not* than by trying to capture nature's plenitude in some simplistic concept. And, crucially, all such endeavours are generatively aporetic, and never-ending, even in eternity, what St Gregory of Nyssa calls *epectasis*, and Aquinas concurs, arguing that given the nature of the creature the ontological distinction and distance will remain and continue in heaven. And physics is moving towards such a high stakes, endlessly sophisticated game. As one physicist puts it, theoretical physics is the 'science of the invisible, as a *modern form of theology*'. Fittingly, then, *apophasis* is an important methodological tool in an effort to free science from the Neo-Democritean yoke – in the direction of *a web of strategies, methods, and disciplines*, all of which embrace the aporetic nature of knowledge and of existence.

In order to free mental or imaginative space for such an approach, engaging with the vanguard of scientific literature draws out the significance of four patterns that are observable everywhere in the natural world. The first of these is the so-called 'tyranny of scales' which precludes the postulation of any absolute, basic unit, level, or method. A telling example is that of the so-called 'handshaking model' increasingly deployed by cutting-edge science (especially nanoscience). In the scientific context, handshaking means the mobilisation of multiple inconsistent or conflicting models in an effort to generate a more adequate account of the target phenomenon through a Venn Diagram-like overlapping 'handshake.' For example, computational modelling in the study of nanosized solid-state materials employs three different inconsistent models from three different conflicting levels: continuum mechanics, classical molecular dynamics, and quantum mechanical models. Such handshaking puts methodological 'flesh' on the idea of weaving mentioned already. Multiscale analysis is prevalent in what is tellingly termed active matter. In short, active matter is an umbrella term used to refer to systems whose components are self-propelled and thus out of thermal equilibrium, and which often, as a consequence, are able to generate collective, directed action like flocking and swarming. Analysing active matter requires multiscale analysis, from bottom-up to top-down to middle-out. "Middle-out" modelling strategy arises when rather than attempting to model the system bottom-up, one starts at intermediate (mesoscopic) scales where systems exhibit behaviours distinct from those at the atomic and continuum scales. One then seeks to upscale and downscale to gain a more complete understanding of the multi-scale system.

I argue for Middleism: Facts 'below' and 'above' the middle level – facts about particles and galaxies -depend on facts involving entities at the central, and therefore *more* 'fundamental,' middle level. 'The quantum revolution requires us to demote the status of microphysical entities. We should reverse the usual understanding of emergence: it is microphysical phenomena that emerge from the more fundamental domain of chemistry, thermodynamics, and solid-state physics, not vice versa'.

A second major patternis 'universality,' namely, the fact that many physical systems with radically different microscopic compositions share the same critical exponents (which are in general *irrational numbers precluding dimensional analysis*): counter intuitively, Water, nickel, and iron are all in the same universality class. Third, there is the ubiquitous phenomenon of 'scale-invariance': For example, (1) Fractals (the self-similarity of which display spatial scale invariance- say, measuring the coastline of Britain); (2) Flickeror pink noise which is interpreted as footprint of complexity, entailing temporal scale invariance; (3) Power laws manifest scale invariance in the size and duration of events in the dynamics of the system. Incidentally, a *power law* is a relationship in which a relative change in one quantity gives rise to a proportional relative change in the other quantity. Take the analysis of earthquakes, which is *completely indifferent to physical scale* because it applies a *power law* that remains the same at every scale. Flicker or pink noise exemplifies scale invariance but it also manifests universality, as it is indifferent to material constitution, insofar as it occurs in countless domains, form the brain and heart to DNA, music and the economy. Consequently, the ubiquity of flicker noise is one of the oldest puzzles of contemporary physics and science in general, but one that resonates with criticality, more generally, whether in our kettles or the cosmos itself, which is the fruit of phase transitions.

Another iteration of the same challenge to the Neo-Democritean paradigm is proffered by 'small-world network analysis', which also deflates, indeed dismantles the importance of size. A network is a collection of nodes and edges that are connected in certain ways; it is characterised by high clustering and short path lengths, and a graph is a mathematical description of such a network. Importantly, it is topological – therefore non-causal – in nature. Topology is sometimes referred to as rubber sheet geometry, the study of properties of spaces that are invariant under any continuous deformation. Since many biological systems can be modelled as networks, i.e. they have many interconnected elements that can be considered as nodes and edges; this approach clearly has enormous explanatory potential. This fact is even more significant given the sheer microphysical diversity of systems, e.g. the same topological explanatory pattern can be used to explain the robustness of the brain, a computer network, an ecological community, a protein interaction network, and so on.

We should come to the conclusion that size is both colloquial and parochial, the demystification of which is a necessary step to the generation of new, more creative modes of thinking that in turn ministera death-blow to the hitherto dominant dogma that the smaller an entity is (or the higher its energy), the greater its importance. William Blake's *Auguries of Innocence*, Leibniz and his mite (insect), and John Donneand his flea, are all correct.

Fourth, as the MIT physicist Wen points out, while all materials are made of the same three components – *electrons, protons, and neutrons*, they come in many different forms (solid, liquid, conductor, insulator, superfluid, and magnet, to name but a few) requiring patterns of organisation known in the literature as '*orders*'; many of these are *intertwined,* for example, in high-temperature superconductors. To repeat, if everything is made from the same stuff, from where does difference come? In a sense, all matter is a question of criticality and order, as is nature and the cosmos, which is Greek for order, and this leaves decomposition with hindmost. Here we begin to approach a radical, at least culturally speaking ressourcement of Plato.

That being the case, a legion of philosophical theses, which were lauded, and sniffily assumed as obvious, were resting, if not on outright error, on radical incompleteness and myopia, being conjurations of a frigid imagination: Competitive dualisms are evidence of such barrenness: From reduction and emergence, to material/immaterial, realism and non-realism, freedom and determinism, nearly all of philosophy of mind, especially the infamous exclusion problem of Kim's, which is but a parochial puzzle and nothing more, and not to mention that cultural shibboleth the brain, which simply does not exist as it is usually presented in the construction of false questions: that big marble or atom in the skull. I do, however, appreciate the neurologist, Charles

Sherrington's, back in the 1940's, characterising of what some term the brain as *an enchanted loom, replete with shuttles that weave patterns*.

As the vanguard of physics makes its belated return to Plato, up ahead, this is easier to notice if we realise that in certain contexts less is more, and as Nobel laureate Philip Anderson famously said, more is different: Less particles, or indeed their absence, for they are now construed as agitations of quantum fields, that pop in and out of existence, and not a set of marbles, as it were; rather it is the 'unparticle physics' that comes to the fore, and in so doing throws into question how the above philosophical questions were formulated, indeed contrived.

Physics is at is most exotic – though I would argue that exotic, as with spooky action at a distance, is in the eye of the beholder, but when matter is confined (especially in 2-dimensions), and thermal energy suppressed or dampened, allowing otherwise unnoticed states of matter to become conspicuous, and such states are the 'orders' mentioned already; that are global in nature, being generated and driven by topology and not composition – cutting stuff into smaller and smaller bits will do little else than mislead, blinding one to phenomena. To repeat, topology describes global properties of a system that are preserved under continuous deformation and are independent of specific coordinates.

A wonderful example is that of the Factional Quantum Hall effect, which is itself a step beyond the profound theories developed by the Landau; there, it was symmetries and their breaking that accounted for different orders of matter, and their transitions. FQH occurs when electrons are driven into an extreme quantum corner by confining them to two dimensions, cooling them down to very low temperatures, and exposing them to a strong magnetic field. The term FQHE does not refer to a single observation but encompasses a myriad of non-trivial states and phenomena. The Fractional Quantum Hall effect manifests topological order, and with that, factional charge and thereby quasi-particles (anyons or compressed fermions, for example). Such topological order entails ground state degeneracy which simply means that a single energy level generates many different states (an inverted form of multiple realisation, or so I argue). As said, rather than symmetry and its breaking, crucially FQH arises from long-range entanglement, and thereby global behaviour.

Borrowing form Wen again, we can use dancing to gain an intuitive picture of topological order. Each boson moves around by itself and doing the same dance, while in a fermion superfluid, fermions dance around in pairs and each pair is doing the same dance, whilst topological order is described by a global dance, *where every particle (or spin) is dancing with every other particle (or spin) in a very organized way.*

One of the main reasons to call such phases topological is the fact that the ground state degeneracy depends on the topology of the surface on which the system is defined: the surface becomes the content, not the old-fashioned notion of parts, so to speak. The priority of surface leads us back to the notion of confinement, and the fecundity of 2-dimentions. 2-dimensionality is more exotic, I contend, because more potentiality is present, unspent, and confinement squeezes this potentiality allowing it to weave its magic, what one physicist called: *Many-Body Quantum Magic*. However, I argue that it not quite accurate to say that 3-d is less exotic, after all potentiality has actualised itself in an amazing 3rd dimension, which we have domesticated. Leaving that aside, as Plato tells us:

> Weaving is the art of making (nearly) two-dimensional cloth out of three-dimensional wool, while the statesman weaves possibly thick "human material" into a two-dimensional cover.

Two unpack a little, in the three-dimensional world there are only two types of particles: „fermions," which repel each other, and „bosons," which like to stick together. A commonly known fermion is the electron, which transports electricity; and a commonly known boson is the photon, which carries light. In the two-dimensional world, however, there is another type of particle, already introduced, the anyon, appearing in strongly correlated quantum materials. As with the dancing, these don't behave like either a fermion or a boson in two dimensions, *exchanging identical particles twice is not equivalent to leaving them alone*. The particles' wave function after swapping places twice may differ from the original one; anyons have these unusual exchange statistics. By contrast, in three dimensions, exchanging particles twice cannot change their wave function.

This process of exchanging identical particles, or of circling one particle around another, is referred to by its mathematical name as 'braiding', weaving once again, which generates braided anyons. As mentioned, the currency of FQH is long-range entanglement and fractional charge or quasiparticles. And here's the rub: when we realise electronsare *indivisible* elementary particles, yet paradoxically a *collection* of them (e.g., anyons) can act as a fraction of a single electron, exhibiting exotic and useful properties. In clear terms, this issues a real challenge to our modernist, decompositional modes of thinking.

Other phenomena that echo these radical insights include the hexatic phase of matter that lies between the solid and the isotropic liquid phases in two dimensional systems of particles. Or a topological insulator, such as the kagome lattice, which is also 2-dimensional. Kagome is a Japanese word for a style of weaving for making baskets. Lastly, Fibonacci anyons, named after the famous sequence, and all manner of phenomena evident in graphene, as when it displays the FQHE. Many of the distinguishing features of graphene arise as a consequence of its honeycomb lattice structure, reminiscent of the Kagome basket, in particular, and weaving more generally.

What is worthy of note, as suggested, is the advent of duality, and the jettisoning of dualisms. Interestingly, electric-magnetic duality (EM duality) represents the first form of duality to be explicitly applied in twentieth century 'fundamental' physics. A famous example is that of wave/particle, of course. But others are more relevant here, especially with regard to Plato's move form 3-d to 2-dimensions. Central to the concept of duality is the presence of an equivalence relation between a pair of theories when they generate the same physics. As one physicist puts it, 'Under this equivalence, elementary particles in one theory may appear as composite particles in the dual theory, and vice versa. Thus, the distinction between elementary and composite particles can no longer be regarded as a fundamental'. Hence, *asymmetry can swap.*

The most notorious recent example is the AdS/CFT correspondence: anti--de Sitter/conformal field theory. This correspondence realises a holographic setting such that the physics of the system may be represented both by a theory defined in a *volume* enclosed by a *surface* and by another theory *defined on the surface* enclosing the *volume* (the physics of the system can be seen as being projected from the boundary of the volume). 'This suggests that quantum gravity should be described entirely by a topological quantum field theory in which all physical degrees of freedom can be projected onto the boundary'. Indeed, in loop quantum gravity, it is only at low energy that spin-networks manifest as '*weave-states*' in the world of classical geometry present or apparent. Space-time is, therefore, emergent from spin-network or *weave-states*.

Given recent history, in terms of the all-out war between high and low energy physics, which went all the way to the US Congress, and the subsequent iteration of internecine warfare in HEP – the String Wars, so-called, what is telling is that the seemingly abstruse theorising of string theory, and the just mentioned duality, are being brought to ground, insofar as after decades of funding, their application amounted to chatting at the bus stop with Godot. But patience was eventually spent, as was the money, and such theories were brought to bear on condensed matter physics as a tool box; thereby avoiding having to take up its P45.

Inasmuch as 'orders' with their exotic states of matter, universality, multi-scale analysis, and scale invariance, transcend particles – which is wise given the tenuous nature of their existence -transcending because they are topological, they also undercut the autonomy of the high-energy domain with its supposedly stand-alone particulate base. They show that particles alone cannot give us a *Theory of Everything*, but, at best, a *Theory of Everywhere*. And a 'theory of ubiquity' doesn't carry the purchase that ideologues of a more reductive framework require.

Physics in recovery. Infinity in two directions, at least

First: String theories must compactify their many dimensions into 'bite-sized' artifice, just as holographic (gauge/gravity) duality explains the three-dimensional volume by the two-dimensional surface. Similarly, EFTs must posit a finite cut-off scale Λ so that condensed matter physics can operate, which it does by ignoring the infinities of high-energy physics. Renormalisation groups are the chosen mechanism for executing this procedure, one that extends to many regions of analysis (meteorology, for example). Here, infinity is reigned in.

Second: Importantly, the same logic reappears, but in the opposite direction, and it is ubiquitous in science in the guise of idealisation, mentioned already. For example, a thermodynamic account of phase transitions (e.g., water boiling or ice melting) involves indispensable non-analytic points (discontinuities), while, on the other hand, a statistical mechanical account (which is inherently continuous) of the same phenomena can only recover such points if the model systems are of infinite sizes (with finite density). 'The latter is an idealization of molecular thermo-systems that 'appears to cross over to the impossible.' This infinite idealisation in the form of the infinite (thermodynamic) limit $N \to \infty$, in which a new higher-level, non-fundamental theory (or model) is applicable, is essential and indispensable, so much so that it is not reducible to (e.g., derivable, deducible, or explainable from) a lower-level, and is thus emergent. The thermodynamic limit is ineliminable, otherwise the discontinuities (or nonanalyticity) that crucial phases manifest will be invisible, and all hope of recovery will be dashed. Any relaxation of this idealisation, and we reside in the night in which all cows are black, and the kettle fails to boil and fails not to. As the renowned physicist, Kadanoff sums it up: "The existence of a phase transition requires an infinite system. No phase transitions occur in systems with a finite number of degrees of freedom." There goes our cup of tea.

Every inquiry presupposes what Plato, in the *Republic*, calls an 'unhypothetical first principle' (*archêanupothetos*). This is also true of conventional physics, which endeavours to identify the first principle with an autonomous high-energy domain open to total mastery through a *Theory of Everything*. Once the factitious autonomy of high-energy physics collapses, however, a different first principle comes into view: the one Plato calls in the same dialogue 'the form of the Good.' On Plato's account, the Good is the generative source of both being and knowing that holds them together without eliminating their distinction. By the same token, the Good reconciles mystery and intelligibility, precise knowledge and open-ended wonderment. It is this reconciliation that clears the needed space for reconceiving science as a web of mutually reinforcing methodological strands, all of which are needed for an adequate account of nature.

For Plato, the arts are divided into those that combine or separate, spin or card. But the art of weaving is different: It does both, *combining union and difference*. Immanent analysis of high-energy physics (and of every other science) reveals something analogous to such weaving as an unavoidable feature of any honest scientific engagement with nature's complexity. The paradigm I've begun to outline here, renders this feature explicit in order to overcome the Neo-Democritean isolation of (would-be) levels of reality and discourse. The aim is a performative embodiment of Platonic weaving that brings to light the co-dependence of methods and disciplines (what Aristotle called 'subalternation').

Nature, it seems, loves to weave, and her predilection for universal patterns that play with and in the *same set of micro-entities* (*or a single energy level*) demonstrates that matter is not a static particulate base, but (to borrow terms from genetics) *totipotent* and *pluripotent* 'stem matter', our 'un-particle physics.' Insofar as it is a response to this call, the paradigm I propose here is a multi-pronged, flexible instrument for letting the findings of the sciences be what they are: *iconic revelations of the hidden faces of matter*, the very murmuring of creationas it echoes the logos, though which, for which, and in which it is held together: An inexhaustible 'potentiality' (*dynamis)* that mocks *Steady State Ideology* and reminds us that the completeness of this world's being is also its ever new arrival. It is what in the *Timaeus* is called the *khōra*, the space before articulated place (*topos*), before the logic of demarcation and difference, its lack of any positive characteristics, as well as the *khōra's* inability to be assimilated into the categories of either the ideal or the phenomenal.

To conclude on naturalness, philosopher of physics, David Wallace may well be correct: 'The longstanding failure of naturalness in cosmology and the Naturalness violation in particle physics have ramifications far beyond those specific and esoteric fields. Naturalness failure here undermines arguments for Naturalness anywhere, and calls out urgently for understanding. Rejection of Naturalness as a principle involves – one way or another – a far deeper and stranger shift in our scientific worldview.'

I leave you with W. H. Auden, *For the Time Being, Recitative*

> The miracle is the only thing that happens, but to you it will
> not be apparent,
> Until all events have been studied and nothing happens that you
> cannot explain.