

Pragmatism, Perennialism, and the Physics of Ignorance

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Abstract: Investigations of the foundations of quantum field theories have suggested (at least to me) the thesis that theory specification has a pragmatic dimension: strategies for equipping physical theories with content, if sensibly pursued, eventuate in contents indexed not only (or not just) to the way the world is, but also to our aims in using our theories and the circumstances we use them in. This essay assesses a “fundamentalist” response to the move to pragmatize theoretical content. The apparent appeal of the move, the fundamentalist response claims, derives from transient artifacts of the present incomplete state of physics. Fundamental physics, the response continues, can be properly understood if only it’s understood as representing the way the world is. Anyone who thinks otherwise has paid too much attention to incomplete and unfundamental sciences! Of course, none of the physics we have right now is genuinely fundamental. To directly assess the fundamentalist response, we need to know things of which we are ignorant—the future of science, the nature of fundamental physics. Here, I undertake an indirect assessment, by developing two reasons to predict that future scientific theories, including theories of “fundamental physics,” will continue to be best understood as possessing pragmatized content.¹

§1. Introduction

Working on the foundations of quantum field theory (QFT) has convinced me that the best way to make sense of a successful physical theory is *not* to afflict upon it a single fixed interpretation that equips it once-and-for-all with an univocal content presenting the theory’s picture of *the* way the world is. The best way to make sense of a physical theory is rather to associate with that theory a galaxy of interpretations, with different interpretations supporting its application in different circumstances. Thus I support a pragmatist thesis about the interpretation of physical theories. That thesis is: strategies for equipping physical theories with content, if sensibly pursued, eventuate in contents indexed not only (or not just) to the way the world is, but also to our aims in using our theories and the circumstances we use them in (see §4 for more and Ruetsche 2011 for much more). Here I try to defend the thesis against the criticism that its appeal, such as it is, derives from resting too much weight on the transient frailties of developing science. Really fundamental physics, the criticism goes, will admit a single, satisfying, and univocal interpretation that makes sense of all its applications. The content of really fundamental physics, the criticism concludes, lacks a pragmatic dimension.

The essay proceeds as follows. §2 offers an account of what pragmatist approaches to philosophy of science *are*, that my view about the interpretation of physical theories counts as an instance of them. The account contrasts pragmatist approaches with what I call *perennialist* approaches, and along two axes. One axis concerns the expected shape of an adequate philosophical analysis; the other axis concerns methods appropriate to articulating an analysis of that shape. §3 argues that pragmatist *methods* honor an important methodological norm that perennialist methods flout.

¹ For desperately-needed feedback on early drafts, I am obliged to Holly Anderson, David Freeborn, Christopher Mitsch, Paul Teller, Jingyi Wu, and participants in the 2017 PragMapps workshop at the University of Pittsburgh.

Pragmatist methods enjoin close attention to concrete details and specific applications. Paying such attention to members of a family of theories including QFT, §4 motivates the pragmatists thesis that the best way to understand those theories indexes their contents to contingent circumstances. §5 addresses the “perennialist’s apology”, which is the criticism that this and similar pragmatist theses are artifacts of the incomplete and imperfect condition of the bits of science pragmatism engages. The perennialist’s apology rests on a prediction: the future of science will deliver fundamental theories unsullied by pragmatized content. §5 offers two reasons to bet against this prediction. §6 distills morals for perennialism, pragmatism, representation, and realism.

§2. Pragmatism and Perennialism

One way into our topic, “pragmatic approaches to philosophy of science,” is to ask: what other approaches are there?—and, how are pragmatic approaches different from these? (A theme to be developed presently is the methodological value of having alternatives in view.) A bit of mid-20th philosophical currency—“perennial philosophy”—affords a useful counterpoint:

Of the philosophical phrases which have come into popular use during the XXth century, perhaps none is more curious than “perennial philosophy” or, in its more common Latin form *philosophy perennis*...*Philosophia perennis* is a philosophy which endures; its truth is considered to persist from generation to generation, long after ephemeral philosophical fads and fashions come and go. (Schmitt 1966, 505)

From the vantage of perennial philosophy, we’re asking same questions Socrates did or a sentient alien might; these questions have (upto incidental local variations) the same answers; the answers reflect the way the world is. We may not yet have identified those answers, but they’re what philosophy should be aiming for.

The perennialist’s understanding of the *aim* of philosophy has implications for its *method*. The very possibility of perennial philosophy rests on the hope that the resources invoked in constructing answers to philosophical questions are available to all comers, regardless of their socio-historical location or peculiarities (e.g. “fads”) pertaining thereto. The hope has a comforting consequence. If local contingencies don’t matter to how a philosophical question is answered, philosophy is a project to which contingent ignorance is no impediment. What you don’t know about how the world *actually* is can’t hurt you, qua perennial philosopher.

What can help you? Resources available to all who inquire are resources appropriate for perennial philosophy. They might include (1) rationality (narrowly understood as an automatic endowment of inquiring creatures, not as something you grow into, given enough work undertaken in the right circumstances); (2) logic and mathematics; (3) metaphysical considerations (where these are fixed and universal). For investigations, like the present one, into science, another appropriate resource for the perennialist might be (4) methodological considerations, where these are anchored in a fixed and immutable Nature of Science.

It's noteworthy that (1) expresses a substantive view about the nature of rationality, and casting (2-4) as perennial resources presupposes substantive views about how rationality so construed functions in the fields of mathematics, metaphysics, logic, and science. For instance, metaphysical considerations are suitably general perennial resources if metaphysics consists in synthetic *a priori* statements which can be discerned by exercises of pure reason—but not if “metaphysics” is shorthand for a set of answers to Carnapian external questions. Put another way, (2-4) are expressions of the view that logic, mathematics, metaphysics, and philosophy of science are examples of perennial philosophy. These inquiries *can* be adeptly pursued without appeal to “adulterating” considerations that are artifacts of contexts of inquiry, and *if* successfully pursued will issue answers to philosophical questions that abstract away from such concreta. Although nothing's stopping the perennial philosopher from lavishing attention on messy contingencies, it follows from how she understands her endeavor that lavishing attention on messy contingencies will do nothing to promote it.

One way to hear “pragmatist” is as an alternative to “perennial.” Even if the pragmatist philosopher poses questions similar to those posed by the perennial philosopher (and this remains to be seen), she countenances answers of a different shape, requiring for their construction resources unnecessary for perennial philosophy. The pragmatist entertains the possibility that answers to apparently perennial questions *could be* indexed to contingent circumstances contributing to the local conditions in which those questions are raised. And she has a correlate interest—one arguably motivating a variety of philosophical question absent from the perennialist's radar screen—in understanding how and why the indexing of answers to local conditions occurs. Thus the pragmatist philosopher of science puts features *not* common to all who inquire to philosophical use. Examples of these features include our aims and desires, the current state of technological and theoretical resources, what Longino calls contextual values—and all the ways considerations like the foregoing influence how we use theories.

Here are two examples contrasting perennial and pragmatist approaches to the philosophy of science:

- “Naturalistic” metaphysicians and Carnap on ONTOLOGY. For Tim Maudlin,

Metaphysics is ontology. Ontology is the most generic study of what exists. Evidence for what exists, at least in the physical world, is provided solely by empirical research. Hence the proper object of most metaphysics is the careful analysis of *our best scientific* theories (and especially of fundamental physical theories) with the goal of determining what they imply about the constitution of the physical world. (Maudlin 2007, 104)

Maudlin casts “what exists?” as a perennial question, and urges us to obtain an enduring answer by means of “careful analysis” of fundamental physics. By contrast, Carnap insists that, in the happy circumstance that we encounter a successful scientific framework,

we have to face ...an important question; but it is a practical, not a theoretical question; it is the question of whether or not to accept the new linguistic forms. The acceptance cannot be judged as being either true or false because it is not an assertion. It can only be judged as being more or less expedient,

fruitful, conducive to the aim for which the language is intended. Judgments of this kind supply the motivation for the decision of accepting or rejecting the kind of entities. (Carnap 1950, xx).

For Carnap, “what exists?” has different answers in different circumstances, answers which aren’t aptly judged to be right or wrong, only more or less appropriate. Both the articulation and the assessment of answers requires attention to local contingencies.

- Mackie and Woodward on CAUSATION. On the perennial hand, we have Mackie’s once-and-for-all analysis of an event’s cause as an insufficient but nonredundant part of an unnecessary but sufficient condition for that event. On the pragmatist hand, we have Woodward’s descriptive cum evaluative investigation of what sorts of causal reasoning we engage in, with what aims, and also (given the foregoing) what methodologies are appropriate ones for causal reasoning (Woodward 2016). (CAUSE is a concept running through a number of sciences. But similar contrasts can be drawn with respect to concepts central to specific sciences—for instance, gene or species or mass or pathology.)

These perennialist/pragmatist pairs dramatize a contrast between *what theories represent* and *how we use theories*, a contrast central to how many pragmatists understand their projects.² Huw Price distinguishes

between what we might call a metaphysical stance with respect to a vocabulary—a stance which takes the primary question to be whether the claims distinctive of the vocabulary are *true*—and a genealogical or anthropological stance, which is interested in why creatures like us come to employ the vocabulary to begin with. (2007, 25)

—and chronicles the perils of adopting the former. Woodward also sees an alliance between pragmatist approaches and skepticism about representation:

Historically, many pragmatists have been skeptical about (or hostile to) ‘representation’ as a useful concept for understanding how language and other sorts of activities such as scientific theorizing works, at least when representation is understood, as it often has been, in terms of notions like mirroring, picturing, correspondence and the like. (2016, 9)

I however will try to resist skepticism about representation, at least in its starkest form. I don’t take “what theories represent” and “what theories are for” to lie on opposite sides of a methodological fault line. Focus on one aspect needn’t preclude focus on the other. After all, a theory’s representational capacities could have *something* to do with its patterns of and aptness for use, and our aims in applying it could shape its representational capacities! Pragmatists can care about representations, too, provided they express that care by attention to the uses to which representations are put. What is more, paying attention to representation may give pragmatists and perennialists (avowedly concerned with representation) common points of reference. And

² E.g. Teller 2012 issues a plea, inspired by the consideration of scientific practice, to move beyond an old-fashioned notion of truth conceived in terms of literal, precise and accurate representation.

this could help us all navigate the tangle of considerations for and against pragmatist and perennial approaches to science.

It's important to distinguish *pragmatist methods* from *pragmatist theses* about the upshots of those methods. Pragmatist methods pay philosophically informed attention to local circumstances and concrete examples. Pragmatist theses concern the results of such investigation, and contend that local contingencies matter substantially to philosophical analyses. Consider a putatively perennial analysandum *X*. A pragmatist thesis concerning *X* is that analyses of *X* keyed to the various habitats in which *X* functions defy a common perennial analysis. By contrast, the perennial philosopher expects a univocal analysis untethered to local accidents, and accordingly sees little cost in pitching her investigations at Theory *T*, or laws of nature as such, or science conceived in full abstraction. For she regards variations in concrete instantiations of each of these abstractions to be devoid of philosophical interest. A metaphor capturing this methodological difference depicts the perennial philosopher surveying an expanse of garden plots from the lofty heights of a hot-air balloon, a perspective which can obscure ground-level differences between those plots. The pragmatist, by contrast, is covered with dirt and down in the weeds.³

If pragmatist theses are true, *pluralism* is an anticipated consequence of adhering to pragmatist methods. Against the backdrop of perennial expectations that concept *X* is unitary, if accounts of *X* indexed to different contexts assume forms that defy a common analysis, pluralism about *X* results.⁴ However, and this will be important soon, pluralism is not a *necessary* consequence of applying methods of inquiry appropriate to pragmatism. For it's possible that for some values of *X*, the many analyses crafted of *X* in its many natural habitats share a core structure that passes muster as a perennial analysis of *X*, that is, an account unadulterated by contextual considerations, of what *X* is, an account of enduring validity. In this case, following the pragmatist methods of examining concrete cases results in a unitary analysis congenial to the perennialist.

Obviously it would by my lights be ironic if the analysandum "pragmatism" admitted a unitary analysis. I don't mean the foregoing as a definitive account of conditions necessary and sufficient for philosophical approaches to count as instances of pragmatism. I offer it because it both suits and explicates my present purposes. One of these, prosecuted in the next section, is to argue that pragmatist methods adhere to a norm that perennialist methods flout.

³ In a friendly dig at Arthur Fine, Ruetsche (2015) calls these grubby engagements with ground-level plots "locavore" methodologies.

⁴ Some examples: for pluralism about genes, see Waters 2006; for pluralism about the ontology of biology, see Mitchell 2003. It's a bookkeeping matter whether to count this sort of fragmentation as a single concept admitting multiple analyses or as the discovery that what we regarded to be a single concept turned out instead to be many concepts. However the books are kept, the philosophical surprise for the perennialist remains.

§3. In praise of pragmatist method

Here's a suggestion, foregrounded in some of the feminist science literature but broadly relevant to the epistemology of science: in science, there's an epistemic value that operates at the level of methodology. In a slogan, the value is: don't silence evidence. In more detail, the value exhorts the scientist investigating a space of hypotheses to pursue protocols that enable the emergence of a wide range of evidence relevant to distinguishing between those hypotheses. An example of an experimental protocol defying this value might be an investigation of gender experiences that uses a survey instrument requiring respondents to identify themselves as either men or women (with no other option). Such a protocol makes it difficult for evidence of human experiences that don't fit neatly into that dichotomy to register. But those experiences are evidence relevant to hypotheses about gender experience.

Anderson (2004) is a sustained discussion of another example: research addressing whether divorce is damaging for women. Researchers adhering to an experimental protocol employing 'objective' gauges of well-being, such as household income, concluded that divorce is damaging, citing such evidence as the lower household income divorced women typically have compared to the household incomes they had when they were married. A salient consideration obscured by the researchers' protocol is the possibility that less money could conduce to greater well-being if after divorce women have *more control* over their household income. Although this possibility is instantiated by many women after divorce, it emerges only through research protocols (like those followed by a team of investigators led by the psychologist Abby Stewart) that broaden the conception of well-being in way that allows research subjects to contribute testimony about the impact on that commodity of "objective" measures. Dubbing the epistemic virtue upheld by Stewart's team "fruitfulness," Anderson explains why it matters:

One research design is more fruitful than another, with respect to a controversy, if it is more likely to uncover evidence supporting (or undermining) all, or a wider range of sides of the controversy. ...For example, the conception of divorce as loss, presupposing a negative evaluation of divorce, will be able to guide research toward discovering the negative but not the positive features of divorce. By comparison, the Stewart team's value-laden conception of divorce as involving both loss and opportunities for growth is more epistemically fruitful, relative to controversies about the overall value of divorce, in that it allows us to uncover evidence bearing on both the pros and the cons of divorce. (2004, 20)

One might worry that the fruitfulness norm has limited bite insofar as "relevance" is keyed to hypotheses under investigation. Often, failures to meet a fruitfulness-like methodological norm—failures to register salient evidence—are only visible as such in retrospect, once hypotheses emerge which might have been supported by evidence suppressed by the protocols failing to meet the norm (see e.g. Hrdy 1986). That doesn't make the norm totally toothless in practice, though – there's no practical impediment to using the norm to fault protocols suppressing evidence for *hypotheses already on the table*.

Pragmatist and perennialist approaches to the philosophy of science are already on the table, as are their allied research designs of (respectively) grubbing in the dirt and lofty aerial survey. The fruitfulness norm has traction. And it favors the pragmatist research design, which enjoins close attention to ground-level practices. It is only through such attention that philosophically salient differences between those practices—evidence supporting pragmatist theses—might come into focus. But so might emerge evidence supporting the sorts of univocal analyses anticipated by the perennialist. Perfectly general accounts should, after all, apply to all instances. And so ground-level investigation of specific theories stands to confirm perennial accounts. Pragmatist methods are fruitful. Perennialist methods, however, are not: if there are insights to be had at the ground-level which are not accessible from the hot air balloon, engaging science only from the perspective of the hot air balloon blocks the entry of those insights into evidence. Lofty disregard for specifics is a research design that violates the fruitfulness norm. Fortunately, for the perennialist, it's also a research design that's optional. Given her aims, she has no reason to get down in the weeds. But it's not incoherent for her to do so.

§4. A Case for Content Pragmatized

The Perennialist's Apology

Adhering to fruitful pragmatist research designs, I'm going to examine some concrete bits of science afforded by linear and interacting QFTs, hailed by many as “fundamental” physics. Fundamental physics merits examination in this context due to a special role it often plays in debates over pragmatist and perennial approaches. That role is to underwrite a dialectical maneuver I'll call “the perennialist's apology”. I'll explicate the apology before turning to the concrete examination of QFTs.

“Fundamental” physics is so-called because it is imagined to be a complete and autonomous guide to what the physical world is at base like (cf. the quotation from Maudlin on pg xx). No legitimate question of physics is left unanswered by fundamental physics, and there are no exogenous empirical facts in virtue of which fundamental physics governs as it governs. Properly understood, fundamental physics discloses the whole truth about the physical world. Fundamental physics may be the last bastion from which perennial philosophers might defend their aim at univocal and abiding philosophical analyses from pragmatist affronts. Pragmatists confront the perennialist with case studies supporting pragmatist theses to the effect that analysands (gene, or aggression, or cause) should be understood in different ways in different contexts. In response, perennialists might issue

THE PERENNIALIST'S APOLOGY. *Of course*, you're going to encounter suggestive messiness if you fixate on evolutionary biology or causal reasoning in the social sciences. Those disciplines are not only superficial hodgepodes but also superficial hodgepodes rife with direct or analogical significance for the human condition — so hodge-podes of exactly the sort upon which one would expect “pragmatist” considerations to intrude. In those disciplines there is both opportunity and motive for such intrusion. There is opportunity because there is no fundamental way the biological or social world is, leaving room for interests,

goals, and so on, to shape the way we take those worlds to be. There's motive because those are *our* interests, goals, and so on, and they're reinforced by allowing them to intrude. By contrast, there is a way the *physical* world is. That way has nothing to do with our needs, desires, tastes, or limitations. A clear-eyed and rigorous interpretation of fundamental physics, unadulterated by consideration of faddish contingencies, will reveal that way. And an adequate philosophy of science will recognize the importance of this—and so foreground realism, representation, “getting the ontology right”, both in itself and as a success condition for other varieties of scientific achievement, such as explanation, modeling, etc.

It is in keeping both with pragmatist method and with the spirit of fruitfulness to assess the perennialist's apology by examining a putatively fundamental physical theory in search of its unadulterated and univocal account of what the world is like. Next I relate the results of just such an investigation.

Interpreting QM_{∞}

Starting with the perennial question of what apparently fundamental physics represents, (Ruetsche 2011) develops and defends a pragmatist position in the general philosophy of science. The book argues that engaging with the foundations of QFT motivates a way of thinking about the content of physical theories that challenges perennialist expectations. On this way of thinking, physical content is not rigidly fixed once and for all by an uncompromising exoskeleton of theoretical law. Rather, although constrained by a looser set of constitutive theoretical principles, physical content is to a certain extent the creature of the aims, needs, and limitations of theory-users. What it is *in full detail* to be a QFT varies as function of the circumstances in which the theory is applied, and varies in response to our aims and our background knowledge, our scientific aspirations, our broader explanatory commitments, our technical resources. The best way to make sense of QFT is to pragmatize its content.

A small amount of mathematical physics frames the argument for pragmatizing content. Start by some contrasts between theories of classical physics and quantum theories. In the simplest case of a single particle of mass m traveling in one dimension, classical physics specifies the particle's state by assigning it precise position and momentum values. All its other properties are functions of these values — the particle's kinetic energy, for instance, is its momentum squared, divided by $2m$. Hence, the particle's classical state enables us to predict the values of all other physical properties with probability 1. Interrelations between these properties reflect the laws and symmetries of the theory; a mathematical object known as the *Poisson bracket* expresses these interrelations.

Now, the quantum theory of our particle: its state is a vector in a vector space; position, momentum, and other properties correspond to mathematical objects called operators on that vector space. The state vector fails to fix the values of nearly all of these properties. Instead, via a recipe known as the Born Rule, the quantum state defines a probability distribution over possible values of quantum properties. For a given pair of properties, there is typically the following sort of tradeoff: the more accurately the state vector predicts the value of one property,

the less accurately it predicts the value of the other. A mathematical object known as the *commutator bracket* sets the terms of this tradeoff. The commutator bracket also structures the collection of quantum properties in a way that reflects the quantum theory's laws and symmetries.

Their manifest differences notwithstanding, there are striking similarities between quantum and classical theories. At the core of each resides a structuring of physical magnitudes, enforced by the Poisson bracket in the classical theory and by the commutator bracket in the quantum theory. This suggests a recipe that, given a classical theory, produces a quantum theory based upon it and known as the classical theory's *quantization*. This *Hamiltonian quantization recipe* asks the aspiring quantum mechanic to take the Poisson bracket between the classical position and momentum magnitudes, and try to find a vector space on which act a pair of operators satisfying a commutator bracket of the same form. The aspiring quantum mechanic thereby constructs a vector space *representation of the canonical commutation relations* (or CCRs) defining the quantum theory she seeks. That quantum theory is *the* quantization of the classical theory she started with. Embarking from a representation of the CCRs, she can readily construct the remainder of her quantum theory. Casting the operators furnishing the representation as quantum mechanical position and momentum magnitudes, she can take products and linear combinations of them to build a host of other quantum magnitudes standing to one another in functional and nomic relationships. With this collection of quantum magnitudes at hand, she can define a family of quantum states as those that assign well-behaved probabilities to possible values of those magnitudes.

So far, so good. But what if it were possible, starting from the *same* classical theory *T*, to follow this Hamiltonian quantization recipe to construct *different* quantum theories? Then we wouldn't really know which of those were '*the* quantization of *T*.' That supposedly precise physical theory would be at best ill-defined and at worst inconsistent!

The Stone-von Neumann theorem is a mathematical result assuring us that unsettling non-uniqueness does not afflict products of the Hamiltonian quantization—provided that recipe embarks from a classical theory for a system with finitely many degrees of freedom (finitely many particles moving in finitely many dimensions, say). No matter how different a pair of representations of the CCRs quantizing such a theory might seem superficially, those representations will always prove to be notational variants on one another. They'll agree about what's physically possible, as well as about what structures of properties physical possibilities instantiate. When a classical theory is suitably finite, the Stone-von Neumann theorem attests, its quantization is essentially unique.

Classical field theories aren't suitably finite. They concern systems like fields, systems whose states are specified (in the most straightforward case case) by assigning a number (the field's amplitude) to each point of space. Since there are infinitely many points of space, a field has infinitely many degrees of freedom. We can still follow the Hamiltonian quantization recipe to quantize a classical field theory. We obtain a quantum field theory. But not a unique one. Outside the scope of the Stone-von Neumann theorem, there are infinitely many apparently physically distinct ways to quantize a given classical field theory. Distinct quantizations can differ on such

physically basic questions as what particles are, whether they exist at all, and if they do, whether it's possible to have only finitely many of them.

With good old-fashioned ordinary quantum mechanics, we at least know what vector space structure a theory has. (We just didn't know how to make sense of it!) With QFTs and other quantum theories addressing infinite systems (all of which I gather under the heading QM_∞), there are uncountably many rival vector space structures, affording infinitely many apparently physically distinct representations of the CCRs defining each theory. Each representation gives rise to a quantization that seems qualified to serve as that QFT. Such rampant non-uniqueness raises a host of foundational question: what is a quantum theory? What criteria of identity apply to such theories?⁵ What does it really takes to be a quantum state or a quantum property? ...And: how should we frame and adjudicate answers to questions such as the foregoing?

Two broad strategies of response to the non-uniqueness suggest themselves immediately. The *privileging strategy* identifies the QFT with a unique physically significant vector space representation of the CCRs. Rival representations are dismissed by the privileging strategy as mathematical artefacts without physical significance. The *abstraction strategy* identifies the QFT with structure common to *all* representations of the CCRs. Features parochial to particular representations are dismissed by the abstraction strategy as superfluous mathematical structure without physical significance. Ruetsche 2011 examines uses to which theories of QM_∞ are put, in the hopes that a winning interpretive strategy, a strategy that makes the most sense of the most uses, will emerge. Such an examination is maximally hospitable to the prospects for fundamentalism/realism. Those positions ask us to believe the world is the way fundamental physics says it is. A winning interpretive strategy would not only tell us what we believe when we believe this, but also *why* we should believe it. Our belief explains the myriad successes of the theory we're interpreting, and thereby enjoys tremendous abductive support. A winning interpretive strategy equips the theory both with unpragmatized content and reason to endorse that content.

The fundamentalist hope for a winning interpretive strategy are dashed, or so Ruetsche 2011 contends. Theories of QM_∞ are used in many contexts—particle physics, cosmology, black hole thermodynamics, solid state physics, homely statistical physics —, and with many aims — to model, explain, predict, and guide the development of future physics. An interpretive strategy that secures one aim in one context may frustrate another aim in another — or even in the same — context. Some examples: The privileging strategy has purchase in standard particle physics, where the symmetries of a particularly simple spacetime (Minkowski spacetime) furnish principles for selecting a privileged representation, one which sustains a fundamental particle notion. However, some aspects of standard particle physics, such as the “soft photons” involved in certain scattering experiments, escape the reach of the privileged representation—but can be modeled by discarded representations. Moreover, significant explanatory agendas invoking

⁵ Questions about *what theory to interpret* can be distinguished from questions about *how to interpret* a fixed theory—with perennialist and pragmatist answers available, arguably independently, to questions of each sort. This is an important subtlety I suppress in the text, which treats the questions at hand as questions about how to interpret a fixed theory.

particles can't operate within a single privileged representation. Cosmological particle creation is an example. Accounts of this phenomenon deploy rival representations to describe the universe at different epochs in its history. And there are in QM_{∞} other explanatory agendas — embracing symmetry breaking, phase transitions, superconductivity, the dynamics of an expanding universe—that invest a variety of representations with physical significance. The privileging strategy would block these explanatory agendas.

To be sure, some of the explanatory agendas undermined by the privileging strategy are supported by the abstraction strategy. But only some of them. Among the “surplus” properties the abstraction strategy deprives of physical significance are the order properties that distinguish between the distinct phases in a phase transition, as well as the properties that enable us to make sense of the dynamics of mean field models. So there are worthwhile physical projects promoted by each strategy, worthwhile projects frustrated by each strategy, and worthwhile physical projects frustrated by both strategies.

A winning strategy for interpreting QM_{∞} has failed to emerge. Does it follow that we don't understand QM_{∞} ? On the contrary, or so I would contend. Noticing the failure — noticing that equipping a theory of QM_{∞} with constitutive CCRs leaves open a host of interpretive questions, questions which can be and in practice are answered in different ways in different contexts of aim and application— *is* understanding QM_{∞} .

Focussing on the fully rigorous theories of mathematical physics afforded by QM_{∞} , regarding them as possible representations of the way the world is, articulating those representations in order to exploit standard realist arguments to justify belief their accounts of the physical world — in short, operating in a manner that seems maximally hospitable to finding perennial answers to perennial questions — I conclude that theory specification has a pragmatist dimension. Strategies for equipping physical theories with content, if sensibly pursued, eventuate in contents indexed not only (or not just) to the way the world is, but also to our aims in using theories and the circumstances we use them in.

§5. Future Physics?

More apologetics

Although based on consideration of clean and precise theories of physics, the foregoing move to pragmatize theoretical content is subject to a variation on perennialist's's apology. Clean and precise though they may be, the perennialist might venture, the theories of QM_{∞} I consider are not final physics and they are not fundamental physics. They are ephemeral and imperfect stopgaps. Final physics, when we have it, won't be prone to or compromised by the constrained ambiguity I suggest afflicts present theories of QM_{∞} .

There is very obviously potential here for a dialectical impasse. Confronted with the perennialist's apology, pragmatists might object that the posited fundamental theory underwriting

the apology is nowhere near to at hand. Even bracketing the perennial sticking points of consciousness and the direction of time, the physical theories currently available can't account for most of the gravitational sources in the universe; confining attention to the sorts of matter they can account for, they can't explain why that matter predominates over antimatter and they can't unite gravity with the forces that fall under the quantum mechanics of the standard model. (And that's just the start of their shortcomings.) Perennial philosophers may remain unmoved by these observations, and invoke future theories they can imagine but not produce, theories whose supposed features will neutralize pragmatist conclusions.

The only way I can see to navigate the impasse is to find grounds for expectations about future theories. While such grounds will inevitably be defeasible (or Nobel-prize worthy), the projects of developing and defeating them are liable to render the perennial and pragmatist theses more contentful, as well as to clarify what's at stake in choosing between them. So: what, in spite of our current ignorance, can we reasonably expect for the future of putatively fundamental physics?

There are forcefully articulated positions in the literature defending the antifundamentalist prediction that putatively fundamental physics will never reach a state of univocal completion. This is one way to read Wilson on the ubiquity of physics avoidance (2018) and Cartwright on the untidiness of nature (1999). Wilson develops natural histories of concepts in applied mathematics; Cartwright considers the diverse methodologies of many sciences to evoke the metaphysics of a dappled world. What I'm going to try to do here is mount a *different* defense of the antifundamentalist prediction, a defense that concedes as much as I can bear (and possibly more than is reasonable) to fundamentalists and other perennialists.

So although I'm personally attracted by dappled world metaphysics – I like the idea that the world is fundamentally untidy – I'm going to grant both that there's a univocal fundamental way the world is and that there's a possible scientific theory – I'll call it *T!* – that completely and adequately captures that way. Believing *T!*, you'd be believing the truth. In the face of lessons pragmatists would draw from ephemeral science, the perennialist's apology asserts that a wholly perennial natural philosophy would result from properly analyzing *T!*. So understood, the apology incorporates an undischarged promissory note to the effect that *T!* admits an unadulterated, univocal analysis congenial to the aims of perennial philosophy. I'm going to grant that too: I'm going to grant that *T!*'s myriad applications can all be sustained by a single, unambiguous account of what the world is like, according to *T!*.

What I'm going to try to add to the debate are considerations from the past and present of science that support a prediction and a claim. The prediction is that *T!* does not lie in the future of science. The claim is that successful present science is no guide to *T!*. I mean the prediction and the claim to suggest (although they fall a long way short of establishing) that conjuring *T!* and its pristine interpretation won't help us understand the ongoing human effort that is science. Conceding the conceptual possibility of perennialist natural philosophy, I'm nevertheless predicting that it will never pass muster as a *philosophy of science*.

The Jungle Red in Tooth and Claw

As a defense against the pragmatist charge that the content of QFT has a pragmatic dimension, the perennialist's apology conjures a final fundamental theory $T!$ whose content needn't be pragmatized to make sense of its empirical success. $T!$'s unpragmatized content is simply and straightforwardly a representation of how the world is.

I doubt that the future of human science will comprehend $T!$. Here I defend the anti-fundamentalist prediction that science will never stabilize to a univocal final theory whose content is best understood as unpragmatized. I can't offer conclusive support for the prediction. (Nor can fundamentalists offer conclusive support for the prediction that $T!$ waits in the offing. Short of producing $T!$, I'm not sure what would count.⁶) But I can offer support for the antifundamentalist prediction in the form of a commentary on a notorious metaphor from van Fraassen's *Scientific Image*. He is countering the realist's contention that the approximate truth of established scientific theories is the best explanation of their remarkable success:

I claim that the success of current scientific theories is no miracle. It is not even surprising to the scientific (Darwinist) mind. For any scientific theory is born into a life of fierce competition, a jungle red in tooth and claw. Only the successful theories survive—the ones which in fact latched on to actual regularities in nature. (van Fraassen 1980, 40)

My commentary is that the sort of semantic indecision that enables QM_{∞} to admit a variety of interpretations is an underappreciated scientific virtue. Scientific theories whose contents are pragmatized exhibit, in the range of interpretations they admit, a resource of constrained adaptability. Admitting different interpretations in different contexts, QM_{∞} is equipped to compete in the scientific jungle red in tooth and claw—to meet the demands, many and varied, a living scientific theory faces.⁷

The commentary inspires a prediction, one that can be falsified by the future of science. The prediction is that because pragmatized content is a scientific resource, successor theories will share with QM_{∞} the feature that no single interpretation emerges as the best. To do the work the perennialist's apology demands of it, $T!$ must be free of constrained ambiguity. So put another way, the prediction is: $T!$ won't be among the sequence of successor theories. Semantic indecision isn't a passing frailty of present science but a critical strength of science as humans practice it.

⁶ Well, I guess they could argue for something like Peirce's analysis of truth — but then they'd still be pragmatizing *something*!

⁷ A thought I lack space to develop here: there's a connection between the virtue of constrained ambiguity and the fruitfulness norm. Research designs that permit constrained ambiguity may allow evidence to register in a wider range of keys than would research designs that rigidly lock theories into unitary and perennial interpretations.

The Physics of Ignorance

The last section made a positive case for the anti-fundamentalist prediction that univocal final fundamental theory $T!$ does not lie in the future of science. This section considers, and seeks to defuse, a case that we *already* know some things about $T!$. The case rests on the claim that we have on hand resources for identifying which features our present successful theories share with $T!$. These features are *prima facie* candidates for representations of how the physical world is, and so suitable elements of perennial natural philosophy. The claim that we can, right now, identify features that will persist throughout the future of physics invokes what are known as renormalization group considerations.

A Puzzle About Perturbative QFT

Can we ever tell when our favored theories latch on to the way the physical world is? A position I'll call *renormalization group realism* is a (QFT-specific) strategy for articulating a realism evolved to resist the Pessimistic Meta-induction, a strategy rooted in a response to a foundational question about interacting QFTs. Identifying which aspects of our current theories *represent the world as it is*, this strategy promises to inoculate some theoretical contents against pragmatist encroachment.⁸

Whereas the mathematically tractable QFTs most amenable to the abstraction strategy discussed in the last section concern non-interacting quantum fields, the wage-earning QFTs making up the Standard Model of particle physics deal with interacting fields. The subsequent non-linearity blocks the standard construction of a fully explicit vector space representation for these QFTs. Physicists settle instead for a host of approximation techniques that succeed in extracting confirmable predictions from elements of the theoretical framework. The *perturbative* approach to interacting QFT frames many of these techniques.

In the perturbative approach, an interacting QFT that we don't understand mathematically is modeled as a slight modification of free theory that we do understand mathematically. Here, 'understand mathematically' means having an explicit space of solutions to the equations of motion defined by the theory's Lagrangian, and 'slight modification' means the full Lagrangian of the interacting theory is a sum of the Lagrangian L_0 of the free theory and a Lagrangian L_I , describing an interaction, multiplied by a coupling coefficient λ assumed to be small:

$$L_{tot} = L_0 + \lambda L_I \quad (1)$$

The ϕ^4 theory is the simplest case of an interacting QFT. It describes a self-interacting mass m scalar field theory, and its total Lagrangian is a function $L(\phi, m, \lambda)$ of that field ϕ , its mass m , and the coupling λ .

⁸ The position I'm calling renormalization group realism is a stock version of much subtler and thorough views presented in Fraser (2017, forthcoming) and Williams (2018, forthcoming). Wallace (2006) is an outstanding discussion of the foundations issues animating the view.

We don't know how to solve the equations of motion determined by the total Lagrangian. We do know that those determined by the free Lagrangian L_0 have solutions $\phi_0(x)$. Given the assumption that the coupling λ is small, it is reasonable to hope that solutions $\phi(x)$ for the total theory take the form of a *perturbative expansion* around free solutions:

$$\phi(x) = \phi_0(x) + \lambda\phi_1(x) + \lambda^2\phi_2(x) + \dots$$

If such solutions are brought under perturbative control, empirically significant quantities – for instance, n -point functions, which foster the calculation of S -matrix elements, which give probabilities for scattering experiments—can be derived.

(One!) problem physicists pursuing this program encounter is that *individual terms* in the perturbative expansion *diverge* (that is, become infinite). The ϕ^4 self-interaction of a mass m scalar field in d spacetime dimensions is an example. There, integrals like

$$\int_0^\infty \frac{k^{d-1}}{k^2+m^2} dk$$

(k momentum) crop up in individual terms of the perturbative expansions for quantities of empirical interest. Note that the integral ranges over *all* apparently physically reasonable values of momentum, from 0 to ∞ .

Physicists have evolved *perturbative renormalization* techniques to tame these disruptive infinities. The original problem that integrals like $\int_0^\infty \frac{k^{d-1}}{k^2+m^2} dk$ diverge, rendering the theory

empirically meaningless, has a fix known as “regularization.” A regularization procedure alters the troublesome divergent integral to make it finite. For example, a regularization procedure might impose an *ultraviolet cutoff*: instead of integrating over momenta from 0 to ∞ , truncate the

integral at some finite maximum value Λ_{UV} of momentum⁹: $\int_0^{\Lambda_{UV}} \frac{k^{d-1}}{k^2+m^2} dk$. The cutoff integral is finite, which cures the divergence.

But it introduces a new problem: now the theory is cutoff dependent! It doesn't reflect just how the world is, but also an apparently arbitrary choice of a limit of integration. The fix for this is called “renormalization.” The basic idea is to reparameterize, that is, rewrite the original Lagrangian in terms of new coefficients cleverly chosen so that as $\Lambda_{UV} \rightarrow \infty$, terms in the perturbative expansion at each order converge, and do so in such a way that cut-off dependence disappears. Brought home to the ϕ^4 theory, renormalization replaces our original total Lagrangian $L(\phi, m, \lambda)$ with a *renormalized* Lagrangian $L(\phi_r, m_r, \lambda_r)$ that's a function of masses, couplings, and fields (m_r, λ_r, ϕ_r) different from those (m, λ, ϕ) appearing in the original

⁹ An upper bound on momentum translates, via the deBroglie relations, to a lower bound on frequency; hence the nomenclature “ultraviolet”

Lagrangian. As long as the renormalized Lagrangian depends on only finitely many terms — that is, as long as it can be obtained by means of *only a finite number* of reparameterizations of quantities in the original Lagrangian—the physics it defines is humanly tractable. In this case, the theory is lauded as *perturbatively renormalizable*. Think of this as tamable by daredevil redefinitions and fancy calculational footwork. Typically, renormalized masses and couplings aren't supplied by calculations mediated by specific (and possibly inapt) renormalization schemes but *determined experimentally*.

We've taken enough on board to frame a puzzle about perturbative QFT. James Fraser puts it well:

The success of the perturbative approach is mysterious, I suggest, precisely because it dodges the question of what an interacting QFT is. ...[There is] an absence of any non-perturbative characterization of the system of interest. While I have argued that this does not render perturbative QFT incoherent it undercuts the possibility of telling a physical story which could explain its success. (Fraser 2017, 17-18)

The puzzle is: *Why does the technique of perturbative renormalization work so well?* Renormalization Group (RG) analyses suggest a solution.

Renormalization Group Considerations

This thumbnail sketch of RG approaches will associate a physical theory with a Lagrangian L , understood as a function of some list of fields and their spacetime derivatives. We might be especially interested in what that Lagrangian implies about phenomena accessible at some scale μ (e.g. an energy achievable in a particle accelerator)—what predictions the Lagrangian underwrites about experiments conducted at that scale. Introduce the notation L^μ for a Lagrangian, *taken as* governing phenomena at scale μ . L^μ is an element of a space I'll call T . T has the structure *Lagrangians* $\times$ *scales*—it's a space of various Lagrangians, understood as governing physics at various scales.

Where l is the energy scale accessible in our best particle accelerators and Λ is a *more fundamental* (i.e. higher energy) scale, an enticing element of T is a Lagrangian L^Λ governing higher energy physics underlying physics at “our” scale l . It is quite natural to be curious about what L^Λ implies about physics within our experimental reach. We can introduce a gadget $R_{l\Lambda}$ that acts on T to track the implication:

$$L^l = R_{l\Lambda} L^\Lambda$$

L^l is the *effective* (at scale l) Lagrangian induced by the underlying (at scale Λ) Lagrangian L^Λ . L^l encapsulates everything the underlying Lagrangian implies about physics at our scale. The family of transformations $R_{l\Lambda}$ acting on T , the family of transformations that encapsulate the

implications for effective physics at one scale of Lagrangians at underlying scales, constitutes the “*renormalization group*” (RG).

This framework suggests the following way of thinking about perturbatively renormalized QFTs: a renormalized Lagrangian obtained through “suspicious manipulations on formal power series” (Gawedzki 1986, 1280) codes a low-energy effective (at scale l) theory induced by (unknown) higher energy theories, and connected to them by an RG flow. Now suppose that the RG’s action on the space T containing our renormalized Lagrangian has the following features:

- *All* high energy theories flow to the *same* subspace of T —the subspace T_{eff}^l of effective (at l) theories.
- This *surface of attraction* T_{eff}^l is *finite dimensional*: only finitely many parameters are required to specify a Lagrangian in T_{eff}^l .

[i] would make the details of the underlying theory irrelevant to the shape of the effective theory: even if we’re ignorant of the finer points of higher-energy physics, we know in outline what signature they leave on physics at our scales. [ii] would ensure that that signature reduces to a set of experimentally tractable couplings, the parameters necessary to specify the element of T_{eff}^l that is the effective theory describing actual physics at scale l .

Effective theories residing in finite dimensional surfaces of attraction have the virtue that the contribution of unknown physics to physics at the scales we care about can be fixed experimentally, simply by measuring coefficients (masses and couplings and the like) defining the effective Lagrangian. Empirically successful perturbatively renormalizable interacting QFTs are widely regarded to be effective theories of exactly this sort:

It is a remarkable property of local QFTs that for a certain subset of theories, ...the low energy amplitudes can be parameterized by just a finite set of parameters—namely, those needed to locate the theory on the finite-dimensional attractive submanifold, and which can in principle be determined by making an equal number of independent experimental measurements. (Duncan 2012, 587)

Polchinski (1984) establishes one instance of the “remarkable property” Duncan celebrates. Polchinski considers a space of theories T consisting of Lagrangians that are polynomials in a 4 (spacetime) dimensional scalar field and its derivatives, and that take the form of the free Klein-Gordon field with *weakly coupled* interactions. He develops a precise definition of the RG map on that space, and shows that under the action of RG flow induced by this map, T has a 3 dimensional surface of attraction, where this surface is parameterized by couplings m^* (the effective mass), λ^* (the effective coupling) and ϕ^* (the effective field). This surface includes the perturbatively renormalized ϕ^4 Lagrangian we know and love!

Perturbative QFT’s real problem was: why should the approximation technique of perturbative renormalization work at all? What are the approximations approximations to? The answer

suggested by RG analyses is: perturbatively renormalized Lagrangians, astonishingly successful at applications to experimentally accessible regimes, are the effective Lagrangians for finitely renormalizable theories induced by physics underlying *physics at (experimentally accessible) scale l* . This underlying physics induces tractable effective theories because physics at scale l requires only finitely many renormalized parameters to specify. Put in terms of the RG apparatus: T_l^{eff} is finite dimensional and parameterized by the very variables perturbative renormalization techniques manipulate to tame unwieldy infinities. Despite not knowing the high energy details, we can completely specify the physics at scale l by *measuring* the finitely many couplings that locate the effective theory in T_l^{eff} . So we'll get the effective physics right even if our perturbative renormalization schemes are opportunistic and our cutoff procedures ill-understood.

Renormalization Group Realism

One strategy by which the realist might respond to the pessimistic meta-induction is *divide et impera*: distinguish aspects of our best current theories we can reasonably expect to persist in the face of theory change from idle theoretical wheels, and espouse realism about the distinguished aspects. For the strategy to amount to a move (rather than a promise or a bluff), the realist needs a way to pick out the distinguished aspects. The approach just sketched not only suggests a solution to the foundational puzzle about perturbative renormalization techniques. It also suggests a more precise *divide et impera* strategy than others currently on offer, a strategy undergirding a position I'll call *Renormalization Group Realism*.

Renormalization Group Realism acknowledges our most successful interacting QFTs to be merely effective. They succeed at experimentally accessible low energy scales because they approximate the implications higher-energy physics (at present unknown) holds for phenomena at those scales. Nevertheless, RG considerations enable us to identify features of these effective theories that are robust under variations in the underlying, unknown higher energy physics. These are features it is reasonable to expect to persist through future refinements of physics, features apt for a realism resistant to the pessimistic meta-induction, features in that sense perennial. They're features that promise to equip the physics we have now with unpragmatized content.

While I endorse the appeal to RG considerations as a resource in the project of making sense of QFT's empirical success, I also question whether the RG Realist strategy just outlined establishes a viable bulwark against attempts to pragmatize content. Here I'll argue that, cast as a response to the pessimistic meta-induction, RG Realism faces a dilemma. Either the strategy is merely a hopeful metaphor, or it's vulnerable to the antirealist maneuver of conjuring future physics that lies outside the space on which the RG acts. I'll try to drape the second horn in some historical credibility by casting Newton's LUG as an effective theory.

We can use our old friend, unknown fundamental theory $T!$, to characterize what RG realism offers the perennialist. RG realism offers the perennialist a way to identify elements of present effective physical theory T that T shares with $T!$. *No matter what $T!$ is*, "robust" features of T , identifiable by appeal to RG considerations, will be retained its successors; these features are

reliable (albeit partial) guides to $T!$ and thus enduring (albeit partial) answers to the perennial question of what the physical world is like. But this is overstating what RG considerations can secure. RG considerations secure the persistence of “robust” features on the hypothesis that the space T of theories on which the RG acts includes $T!$. Existing RG results — of which Polchinski’s is an unusually explicit example — exploit carefully circumscribed spaces of underlying theories. Mathematical physicists recognize that the circumscription calls for circumspection:

Needless to say that we do not know how to solve [the RG equation] in general. *Some approximations are thus required.* ... the strategy consists in *solving the RG equation in a restricted functional space* and not as a series expansion in a small parameter. This is why we can hope to obtain non-perturbative results. ...Of course, *the quality of the result will depend crucially on the choice of space* in which we search for a solution. ...In all cases, *it is impossible to know whether we have missed some physically crucial ingredient by making one choice rather than another one.* (Delamotte 2007)

Even explicit RG results are only as reassuring as the space of theories on which the RG group acts is comprehensive. But that space incorporates assumptions about what kinds of interactions are possible and how to model them. And nature isn’t beholden to obey those assumptions. $T!$ could lie outside T and beyond the reach of the RG. If so, RG considerations can’t assure us that any part of present effective theory T reliably reflects either $T!$ or the truth about the physical world.

The RG realist faces a dilemma. Either the space of theories T on which the RG acts is explicitly specified, or it isn’t. If T is specified, the Pessimistic Meta-Induction retreats a level: skeptically relevant $T!$ s $\notin T$ undermine grounds for belief in T ’s representational success. If on the other hand, T isn’t specified, neither are reassuring RG results about which features of T are invariant under the details of the underlying physics.

A slightly different (and imperfectly analogous!) context supplies a concrete example of the epistemic dangers of overconfidence in the comprehensiveness of a theoretical space (see Wells 2015 and Ruetsche 2018 for the example developed). Cast Newton’s Law of Universal Gravitation (LUG) ($V(r) = \frac{GMm}{r}$) as a free theory residing in a space T of perturbative corrections. A generic member of this space takes the form:

$$V(r) = \frac{GMm}{r} \left[1 + \sum_{n=1}^{\infty} \lambda_n \left(\frac{r_0}{r} \right)^n \right]$$

LUG isn’t exactly true: famously, it fails to accommodate the perihelion advance of Mercury and other planets. However, other elements of T , e.g. the cubic correction $V_2(r) = \frac{GMm}{r} \left(1 + \frac{R_2^2}{r^2} \right)$, can save the observed phenomena of perihelion advance, provided finitely many free parameters are fixed by experiment.

Such reflection on the space T containing LUG and perturbative corrections thereto might inspire a kind of optimism: no matter what the details of underlying fundamental physics, its implications for physics at orbital radii we care about can be captured by a finite number of small empirically tractable corrections to LUG. In this sense, *LUG is approximately true*, and we can with confidence subscribe to those features of LUG's picture of the world that it shares with other theories in T . These include central gravitational forces acting instantaneously at a distance across Euclidean three-space.

But hindsight is 20:20, and in this case, pessimistic. The advent of General Relativity (GR) supports a starkly different commentary on LUG as an effective theory. The equations of motion determined by the cubic correction to LUG are low velocity, low eccentricity, large radius limits of the equations of motion arising from the Schwarzschild solution of the field equations of GR. GR does away with central forces acting instantaneously across Euclidean space. Reassuring considerations of features it shares with an apparently encompassing space of theories notwithstanding, *LUG gets things dead wrong*. Taking features of LUG "robust" under incorporation of higher-order corrections to represent how the world is, we would have been led astray.

The analogy, between RG realism and realism about what LUG shares with its space of perturbative corrections, is imperfect. Still this example should shake our faith in guides to the unpragmatized content of final fundamental physics that rely on examination of a supposedly complete space of possible theories. And it should do something else. It should help us to recognize a tension between research approaches framed by a posited "space of theories" (the T s on which the RG acts, the space of perturbative corrections to LUG, and string theory's "landscape" are all *prima facie* examples) and the methodological norm of "fruitfulness." Resolving to confront phenomena within the ambit of the space of perturbative corrections to LUG, physics would never have recognized anomalous perihelion advance as evidence for a theory, General Relativity, operating outside of that ambit.

§6. A pragmatist reappropriation

RG realism's robustness criterion picks out *some* content for endorsement. The last section questioned whether the content selected merited perennial endorsement as a reliable representation of how the physical world is. This section asks: if the robust content doesn't deserve perennial endorsement, what kind of endorsement does it deserve? My closing suggestion will be that the endorsement it deserves has a strongly pragmatist flavor.

Features of theories anointed as robust by RG considerations aren't thereby declared to be reliable representatives of fundamental physical reality. They aren't certified as real *tout court*. They are rather certified to be features that will persist as elements of theories *effective at scale l* , no matter what physics reigns at higher energy scales. Both the *scale-dependence* of the content endorsed by robustness considerations and their endorsement of that content as *effective* leave RG realism vulnerable to pragmatist reappropriation. A pertinent value for l when applying RG considerations is one that reflects the energies we can access experimentally. The content RG realism endorses is thus sensitive to our experimental reach, and liable to vary as our

technologies evolve. Indexing theoretical content to our present empirical and technological capacities is one way to pragmatize that content.

But RG realism harbors an even more dramatically pragmatic aspect. Contrasted with the sort of perennialism Maudlin's naturalistic metaphysics exemplifies, RG realism advocates a seismic shift in terms of theoretical endorsement. Whereas Maudlin celebrates physics qualified to inform metaphysics as "fundamental," RG realists hail our best QFTs as "effective." Rather than a compendium of nature's building blocks or a catalog of some ultimate supervenience base, an effective (at scale l) theory is a successful coping mechanism, a reliable means of organizing phenomena that manifest (at scale l). That is, effective theories abound in *pragmatic* virtue, with those elements of effective theories endorsed by the robustness criterion exhibiting the additional pragmatic virtue of probable continued utility. Whether effective theories are *true*, or harbor *genuinely referential* elements, where those accomplishments demand something more than the pragmatic virtues just enumerated — the answers to these questions don't influence the patterns of endorsement issued by RG realism. It could well be that RG realism is pragmatism in denial!¹⁰

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¹⁰ Elsewhere (Ruetsche, forthcoming), I question whether the attitude emerging from the RG Realist strategy should, on its own, be understood as realism. I argue that the commitments most clearly validated by the strategy are either commitments the anti-realist can live with outright, or commitments that the anti-realist can live with until and unless they are supplemented by something RG realists forswear: a Good Old Fashioned "Standard Interpretation" of QFT, an account of what sort of microworld is truly described/aptly represented by the theory.

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