Opened March 1, 2024
Version July 16, 2024
Small edits, December 29, 2024. April 8, June16, 2025.
Major revision initiated, August 4, 2025
Draft completed August 20, 2025
Edits, September 2, 27, 2025
October 2, December 24, 2025

Chapter 12

Small-e empiricism Defined and Defended[1]

1. Introduction

The fundamental idea motivating empiricism is that experience has the unique capacity to inform us of contingent facts of the world. We have seen in the first part of this volume how this motivating idea was expressed historically in various versions of empiricism. None, I believe, is fully adequate to the way that present science engages with the world. The goal of this work is to develop an updated version of empiricism that is well adapted to the successful methods of science. This chapter will articulate the doctrine of small-e empiricism and defend it. Its goal is to give a more precise expression to the vaguer idea of the privileged status of experience.

The principal ways that small-e empiricism amends existing conceptions of empiricism have already been explored in earlier chapters, especially in those that develop a concept of experience well adapted to modern science. These ways are collected in two general amendments that are developed more fully in Section 2 below. The core doctrine of small-e empiricism is developed in Section 3 and is:

> *Science is empirical.* The propositions of experience provide inductive support for the truth of the contingent propositions of science; and the inductive support of experience is the only means of providing support for these contingent propositions.

The case for this version of empiricism is laid out in Sections 4 to 7 in two steps. Sections 4 and 5 develop the easier part of the case: that the resources admitted by small-e empiricism do have the capacity to lend support to the truth of contingent propositions of a science. This capacity

[1] I thank Jim Brown for helpful discussion on several parts of this chapter.

follows from the fact that experiential processes provide physically continuous connections with the systems of interest. The second more difficult step, developed in Sections 6 and 7, is that experience is the *only* way to provide secure support for the contingent propositions of science. This is indicated by the fact that no other mode has succeeded. More precisely, successes enjoyed by other modes are retrospective. They affirm results in a science only after these results have been secured empirically. That their failure is expected follows from the absence in the ontology of science of channels connected to the systems of interest in the world through which these other modes could operate.

Section 8 affirms that small-e empiricism conforms with the long-standing tradition in empiricism of excluding from science propositions that cannot be given inductive support in experience. It does not, however, endorse the extreme view of the logical positivists that such propositions are meaningless or the falsificationists' project of seeking a demarcation criterion for science.

Section 9 describes the importance of empiricism for the process of scientific discovery. These processes are slow and incremental and, as new steps are taken, they require the reliable guidance that only empirical evidence can provide. Chapter 10 sketches briefly how the relations of inductive support that are central to small-e empiricism relate to beliefs. An informal guide is provided by Hume's maxim that beliefs should be proportioned to the evidence. Section 11 outlines how the concerns of the venerable rationalism-empiricism debate expand well beyond the narrower ones of small-e empiricism.

In preparing the defense of small-e empiricism in this chapter, I found myself unexpectedly charting new territory. It may well be that I have been inattentive in my reading or have failed to appreciate what I have read. However, my impression is that the long tradition of writing on empiricism has almost everywhere failed to give a sustained, well-structured argument for empiricism as a general doctrine. In its place, there are strong assertions of the primacy of experience and perhaps details of how specific results are supported by experience. More generally, most writing on empiricism has been in the Big-E tradition; and that tradition is skeptical. It is anti-inductivist and committed to strict limits on what experience can give us. Hence a primary goal of argumentation in Big-E Empiricism is to sustain pessimistic conclusions that contradict small-empiricism and cannot be employed here.

2. An Empiricism for Science

The version of empiricism developed in this volume differs in many important ways from existing versions of empiricism. These differences respond to my enduring concern that empiricist thinking has largely failed to keep up with the accelerating developments in science over the last few centuries. Small-e empiricism seeks to be a serviceable empiricism adequate to the actual practice of empirical science. It arises through several changes to the existing formulations of empiricism.

The first change recall that empiricist writing of the seventeenth and eighteenth century formulated its doctrines in terms of human cognition and mental states. The project was both epistemological and early attempts at formulation a science of psychology. Since we now have a distinct science of empirical psychology, empiricist writing in philosophy can narrow its scope to the epistemic issues that arise once investigations have passed beyond the specifics of mental states. Chapter 5 relates how present empirical philosophy has largely failed to separate itself from the centrality of human cognition. The remedy, described in Chapter 8, is to engage with experience at the stage at which it is given propositional expression, such as when it is reported in the scientific literature.

The authority of experience derives from its connection through continuous physical processes with the systems of interest. In earlier eras of science, this direct connection was provided by human sense organs. As a result, older work defined empiricism in terms of human sense organs. As described in Chapter 9, scientific instrumentation now surpasses human sensory powers, so that small-e empiricism includes instrumental sensing in the concept of experience.

The second change to traditional writing in empiricism is to abandon the inductive skepticism of Big-E Empiricism. The Big-E version divides experience, which is taken to be veridical, from results derived from it. These latter are not veridical and serve only as intermediates in relating experiences to experiences. Small-e empiricism accepts that the inductive support of a result, even if fallible, is support for the truth of the result. Accordingly, as described in Chapter 10, small-e empiricism discards the ever-troublesome, strict district division of Big-E Empiricism between veridical experience and the instrumental results derived from it. In its place, experience enters small-e empiricism as a continuous physical process whose stages are successively more remote from the system of interest.

Here small-e empiricism follows the conception of "empirical science" that has become a routine notion in the larger science literature. Its evolution and present state were surveyed in Chapter 6, where it was summarized as:

> *Scientists' conception of empirical science*. Science consists of observational and experimental reports and further results inferred from them. The observational and experimental reports are the empirical evidence indispensable for science.

The scientists have simply shed the inductive skepticism of Big-E Empiricism and did so likely without realizing the skeptical heritage of the adjective "empirical." In this regard, in my estimate, the scientists have been better philosophers than we philosophers.

3. Small-e empiricism

Chapter 7 reviewed several attempts from the early to mid-twentieth century to capture the core commitment of empiricism in a principle of empiricism. They were grouped into three general versions. Each of them, the chapter reported, fails adequately to capture the core commitment of small-e empiricism. A new formulation is needed that implements the changes indicated in the last section. The formulation of small-e empiricism is:

> *Science is empirical.* The propositions of experience provide inductive support for the truth of the contingent propositions of science; and the inductive support of experience is the only means of providing support for these contingent propositions.

Here, as indicated, "*experience*" designates a continuous physical process that connects with the system of interest in the world. The stages of the process closer to the system of interest physically condition the state of the stages further from these systems. Thus, light from a distant comet propagates to a terrestrial telescope where it forms a photographic image.

The "*propositions of experience*" describe the states of these stages and express how these stages reflect the relevant features of the systems of interest. Inductive support proceeds in the opposite direction to the conditioning relations. The propositions describing stages more remote from the system of interest provide inductive support for those describing stages closer to the system of interest. The propositions describing the photographic image of the comet, for example, inductively support propositions concerning the position of the comet when the photograph was taken.

In a subsequent stage of investigation, the propositions describing the various stages of the experiential process then inductively support more general propositions in the science. The propositions determined photographically of the position of the comet at particular times inductively support a proposition describing its continuous trajectory at more times.

This formulation does not specify the strength of the support provided by experience. That strength can vary. It will be noted in the section that follows that, fortunately, experience has been able, historically, to provide strong support for a wide range of sciences. Whether such strong support can be secured depends on which experiences are available to us. We can readily conceive of cases in which sufficient experience is not presently available and may never be. For example, novel discoveries in particle physics are limited by the energies attainable in particle accelerators. Processes that require much greater energies may remain outside what present accelerators can provide. Discoveries in an archeological site may be forever precluded if some disaster obliterates the site.

These cases should not be an occasion for an excess of pessimism. Time and again, claims that some domain lies beyond possible experience have been proven wrong. A well-known instance is Auguste Comte's then highly plausible assertion in his 1835 *Cours de Philosophie Positive* that we cannot know the chemical composition of the Sun. Within a few decades, Norman Lockyer had found novel spectral line in sunlight that subsequently proved to be due to a new element, Helium, that was discovered first in the Sun.[2]

Because of its close affinity with empiricism, the account of inductive support intended is supplied by the material theory of induction, as developed in my works elsewhere (2021, 2024). One of its results (2024, Ch. 2) is that there are self-supporting inductive structures and that these are instantiated by mature sciences. That is, the empirical evidence for a mature science is sufficiently rich that it alone is sufficient to provide inductive support of sufficient strength to secure the stability of mature sciences.

In requiring that experience is the "*only means of providing support,*" the sorts of support considered are quite general. They include any mode that purports to establish the truth of contingent propositions. The requirement does allow intermediates. These may be other propositions that do not themselves count as propositions of experience; or even those that may

[2] For details, see Hearnshaw (2010).

appear to be non-inductive modes of support. The "*only means*" requires that *ultimately*, whatever the intermediate may be, the support it provides can be traced back to the inductive support derived from experience.

An example of this sort of mediation is the derivation of a fundamental law of a science from a Platonic principle that the true law must be the simplest conceivable mathematically. We shall see below that Einstein hoped that this principle would lead him to the basic laws of his unified field theory. Small-e empiricism requires that this principle is either ineffective or, if it does yield results, its success depends on a tacit or even explicit foundation of the principle in experience.[3]

4. The Adequacy of Experience

The first part of the case for small-e empiricism is an argument in three parts for the first clause of the doctrine as stated above:

> "…The propositions of experience provide inductive support for the truth of the contingent propositions of science; …"

It is developed in the following three subsections. In brief, experience has a privileged authority to provide this support. Inductive inference is a medium capable of delivering that support. We have good empirical grounds for the reality of the experiential processes and thus their capacity to inform us.

4.1 The Authority of Experience

Experience enjoys a special privilege in its capacity to inform us of contingent propositions in science. That privilege does not derive from any special capacity of human sense organs or of human mental processes. Rather, as has already been noted in Chapter 9, its privilege derives from its constitution as a continuous physical process that is connected with the systems of interest. This foundation in a direct access to the system of interest gives its deliverances an unmatched priority in any dispute.

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[3] See my *Material Theory of Induction* (2021, Ch.6), for an account of how productive simplicity requirements are really veiled references to support from background facts. Small-e empiricism asserts that these background facts are ultimately supported solely by experience.

There are many, familiar examples of the exercising of this authority. It was doubted, as we saw in Chapter 9, that biology could admit such an anomalous animal as a platypus, a duck-billed mammal. Once a specimen was secured, examined and found not to be a hoax, experience had established these doubts cannot be sustained. In the late nineteenth century, two views of electrodynamic action persisted. In one view, the electromagnetic effects arose through unmediated action at a distance but came retarded in time. In the other view, the action propagated as waves as required by Maxwell's electromagnetic theory. Heinrich Hertz (1893, Ch. VII) presented powerful evidence for Maxwell's wave view by using a spark detector to map out the distribution of the nodes and peaks of standing electromagnetic waves in space and then, similarly, to reveal further their properties such as their finite speed of propagation. Hertz's spark gap detector probed and revealed the waves by connecting directly with them.

4.2 The Power of Inductive Inference

Experience enters the scientific literature in the form of propositions that describe various stages of the experiential processes. That these propositions correctly reflect the properties of the system of interest is established by relations of inductive support. That a proposition describing the system of interest does so correctly is supported inductively by propositions describing nearby stages in the experiential process. These last propositions are supported inductively by those at farther stages; and so on.

Hubble's determination of the recession of the galaxies, as described in Chapter 10, illustrates these relations of inductive support. First, consider the stages of the experiential processes. Hubble (1929, p. 169) reported the velocities of recession of some galaxies as "available." They are made available through continuous physical processes that begin with the emission of light from these galaxies. This light is modulated into distinct frequency lines that are characteristic of the luminous material in the galaxy. Those frequency lines are shifted toward the red as the light propagates towards us through expanding space. The light, arriving at a terrestrial observatory, is split into its component frequencies and recorded in a spectrogram. Further optical instrumentation then measures the magnitude of the shift in the frequencies of the spectral lines.

Each of these stages is given propositional expression, such as in the paragraph above. Inductive support proceeds in the direction opposite to that of the light propagation. The propositions describing stages farther from the system of interest, the remote galaxies, provide inductive support for those closer to the galaxies, until support is provided for the propositions that the galaxies are receding at the velocities indicated. For example, the spectrogram is an image of lines on a photographic plate. The proposition recording the spacing of the lines supports inductively the corresponding distribution of frequencies of the light received. That an entire suite of known lines is found shifted by the same amount in the spectrogram of some specific galaxy inductively supports the proposition that the light as emitted carried the unshifted lines. That there was uniform shift then supports the proposition that the galaxy receded with a velocity suitable to produce the shift.

Once support for propositions describing the system of interest has been secured, those propositions can then provide inductive support for further propositions in the wider science. For example, the propositions asserting a velocity of recession of the observed galaxies inductively supports the proposition of a velocity of recession of the remaining galaxies for which red shift was not measured.

That inductive inferences play such an important role in connecting experience with the further results of science means that the connections are necessarily fallible. The fallibility is controlled by the process of "winding back," described in Chapter 10. It allows us to reaffirm the correctness of an inductively supported result or to correct erroneous judgments of support. Such corrections were needed in the case of Hubble's assessments of distances to the galaxies. Winding back though his experiential processes, it was found that his erroneous distance estimates arose from mistaken assumptions about Cepheid variable stars.

Inductive inference has the capacity to provide strong inductive support for the contingent propositions of science on the evidence of experience. Whether such support can be provided depends on the strength of the evidence experience provides and, perhaps, our persistence in pursuing suitable experiences. It turns out, as is well-known, that this capacity for very strong support has been realized multiply in our science, both in sciences past and in our present sciences. For science after science, it is a routine exercise to display the empirical evidence that supports it. It is not that the science is, in a loose, general sense, supported as a whole. Rather, that overall support consists in the fact that each individual proposition of central importance to the science is well-supported by experience.

4.3 The small-e empiricists' Ontology

Experience has a privileged place in small-e empiricism. It provides inductive support for further and deeper truths of the world. These deeper truths that reach well beyond experience specify the small-e empiricists' ontology. The physical processes of experience are themselves a part of the ontology of science and subject to affirmation by empirical investigation. This gives small-e empiricism a self-supporting character. It allows experience to inform us of the contingent propositions of science; and those contingent truths in turn support the efficacy of experience in informing us of these contingent propositions.

This ontology reaffirms the privilege and authority of experience. Consider experiences derived from human sense organs. Galileo's observation of patterns of light and dark on the moon can be taken as veridical since there really are such patterns on the moon's surface and their configuration is imprinted on the light that propagates from the moon, through Galileo's telescope to his eye. The ears of listeners in Mauritius in 1883 really did hear the eruption of Krakatoa. The sound was carried by real acoustic sound waves from an event nearly two thousand miles away. When Marsh reported a garlic-like smell in the context of his test for arsenic, molecules of arsine were really present in the arsenic coated glass of his apparatus and were really carried by diffusion to his nose.

The same consideration applies to instrumental experiential processes. Radar detection succeeds because there really are electromagnetic waves propagating from the target to the radar receiver. X-ray crystallography can reveal the structure of DNA since there really are X-rays diffracted by the molecule's crystalline structure. Gravitational waves detected by LIGO can inform us of distant gravitational cataclysms since there really are such waves. Chromatographic analysis of the components of some sample works because, within the device, the different components really do diffuse at different rates, allowing their sequential detection.

5. Inductive Hesitations

Inductive inference is an essential part of the argument for the adequacy of experience within small-e empiricism. There is a long-standing tradition of skepticism about inductive inference. This skepticism is, in my view, untenable. My texts (2021, 2024) have sought to provide a sound foundation for inductive inferences. They argue that inductive inferences are warranted by background facts, where the warrant resides in the meaning of these facts.

Someone can simply refuse to accept a well-warranted inductive inference. They are free to do so, but to do so is simply to be irrational. For to be rational is just to conform with the dictates of an applicable logic.

In the example in my (2021, Ch.1), Curie's inductive inference to the crystallographic properties of Radium Chloride were warranted by a fact, Haüy's principle. The meaning of the principle is what justifies her inference. To deny the inference is tantamount to denying Haüy's principle.

Further discussion of the rationality of inductive inference is given in the following chapter. Below I respond to some hesitations about inductive inference that are more precise than a mere mistaken sense of discomfort and malaise with inductive inference.

5.1 Is Induction from Experience Sufficient?

This hesitation doubts that experience alone can provide sufficient evidence to secure inductively our mature sciences. The supposition is that empirical considerations alone provide only a part of what secures our mature sciences. The remainder, it might be supposed, is some sort of non-empirical metaphysics. My earlier work on inductive inference has been concerned precisely with this worry. I argue that mature sciences are supported entirely inductively by experience, without the need for further non-inductive supplements. The character of the support lies in a massive structure of mutually supporting propositions spread throughout a science. That is, if we identify any proposition in a mature science, we can trace its inductive support to other propositions; and the support for those to still others until the supporting network has spread over large parts of the science. Norton (2024, Ch.2, §§5-7) summarizes the case for this conclusion, whose elaboration is found in later chapters of the 2024 work.

5.2 Are Non-Inductively Founded Concepts Essential?

This is a more precise version of the last concern. It identifies the missing, non-empirical metaphysics with concepts that are supposed essential to the formation of a science. The best-known version of this idea is Kant's eighteenth-century proposal concerning concepts like space, time and causality. They are not, he asserted, inherent in things-in-themselves. They are provided by our means of perceiving the world. This general Kantian orientation has been very influential and has reappeared repeatedly in the writing of later thinkers.

The great appeal of Kant's proposal and later versions that followed is that they eliminate inductive risk. Kant feared that mere experience cannot assure us of the irrefutable truth of

Euclid's geometry. He sought to secure its inerrancy by removing central propositions of Euclid's geometry from the realm of facts in the world. The problem with Kant's proposal is that his assured certainties fail. Geometry, as we soon learned in the nineteenth century, need not be Euclidean; and, as we learned in the twentieth century, is not exactly Euclidean. Kant's assurances about the certainties of causation have failed similarly.[4] Our subsequent history of securing factual, contingent truths prior to experience has fared no better. We saw in Chapter 3 that the idea that there are no synthetic, a priori truths was a core commitment of the logical positivist movement.

In their place, small-e empiricism asks that factual generalizations of a type appealing to by Kant and Kantians should be introduced tentatively as hypotheses that are to be vindicated by further empirical analysis. Accordingly, Kant's pronouncements on the necessary geometric properties of triangles have been replaced by empirically supported, non-Euclidean results in general relativity.

Versions of Kant's proposal became popular in the nineteenth century as an objection to a bare form of enumerative induction. In his *Philosophy of the Inductive Sciences*, Whewell (1847, p. 36) introduced the notion of the "Colligation of Facts" as essential to the forming of generalizations. According to it, as he put it, "Facts are bound together by the aid of suitable Conceptions." These concepts are not merely induced from experience, but arise (again in Whewell's formulation) "[when by] an act of the intellect, we establish a precise connexion among the phenomena which are presented to our senses." Chapter 2, §13, above reported how similar sensibilities supported a skepticism over the power of inductive inference alone. Henry Sidgwick, we saw, averred that "I think it impossible to establish the general truths of the accepted sciences by processes of cogent inference on the basis of merely particular premises."

These concerns are sustainable in so far as they impugn a bare notion of enumerative induction. A collection of facts that merely affirms many instances of "this *A* is *B*" is insufficient to sustain the generality "all *A*'s are *B*." Fortunately, actual scientific practice does not use this unsustainable, bare form of enumerative induction. Inferences of this form are narrowly circumscribed by whether there is a specific warranting fact available. That fact in turn must be

[4] See Norton (2003)

supported, ultimately, empirically, thereby ensuring that the reasoning draws only on experience. As an example, Curie's 1903 generalization was supported by Haüy's principle, which was in turn supported empirically by lengthy investigations in the nineteenth century.

5.3 What about THE problem of induction?

A more serious form of inductive skepticism is provided by Hume's problem of induction. In its modern guise, it asserts that no general rule for inductive inference can be justified. Such efforts at justification are either circular or trigger an infinite regress. The problem cannot be formulated within the material theory of induction since that theory employs no general rules for inductive inference. Norton (2024, Ch. 6) argues for the failure of efforts to recreate such vicious circularities or harmful regresses within the material theory of induction.

6. The Exclusivity of Experience

Section 4 above argued for the adequacy of empirical investigations to secure the evidence for our science. This adequacy is compatible with a weaker form of empiricism in which experience suffices to establish the contingent facts of a science, but leaves open the possibility of other modes of establishment. In this weaker version, we might accept that some specific, contingent result can be established empirically by arduous observational or experimental work. But we might also allow that the same result could be secured with less effort by, for example, a thought experiment whose formulation does not already tacitly include the result. Might there be some other, as yet undiscovered mode that equals or betters the performance of empiricism, we are left to ask.

The second clause of the statement of the core doctrine of small-e empiricism precludes this weaker form of empiricism. It asserts

> "… and the inductive support of experience is the only means of providing this support."

Establishing this exclusivity presents a greater challenge than merely establishing the adequacy of experience. For the latter is already apparent in the millennia of successes of empirical investigations in science. To establish this exclusivity of experience, we must now consider not just occurrent modes of investigation but speculation about the possibility of other modes; and then argue for their failure.

This section and the next summarizes the case for this exclusivity of experience. The first element of the case is the simple fact of history that no other successful mode has been found. Their enduring failure has been masked by the fact that their successes are retrospective. That is, they succeed only with results that have already been established empirically. Otherwise, they turn out to be repeatedly and reliably in error.

The second element is the opacity of these other modes. We are to suppose that they succeed in informing us of the world while having at best a thin account of how they do so. This contrasts with empiricism's success. It provides a detailed and well-supported account of the experiential processed that give us access the world. Small-e empiricism's ontology has no place for the channels required by the other modes. Their failure is expected. This opacity means that these other modes have no internal resources to correct failed predictions. They can only say that their Platonic vision was clouded or that they had misunderstood how a metaphysics of simplicity is implemented in the world. These other modes must repeatedly defer to empirical affirmation of their result and, if there is a conflict, the empirical result will be favored.

6.1 The Failure of Known Alternatives: Successes are *post hoc*

A simple historical fact already gives us good reason to think that no other mode can succeed. We have tried over millennia to find such a mode, but without success. This is, I believe, the result of a survey of other modes. All of them that I have been able to identify have failed. These alternatives can be grouped loosely into three types, with some overlap between them. They are:

Platonic insight

Innate or intuitive ideas

Oracular revelation

Recounting the details of the failure of the individual modes requires a lengthier exposition and, for this reason, has been postponed to the following section.[5] Here, however, the main conclusion is easily stated. None of these alternative modes has been successful.

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[5] Blum (2021) provides an analysis of John Wheeler's 1950s non-empirical physics. Blum (p. 219) diagnoses its failure as deriving from its "lack of empirical input," in conformity with the analysis given here.

We can summarize here the way in which we find these other modes to fail. The failures may not be apparent immediately since the proponents of these other modes can claim successes. Their successes do not vindicate the modes, since they have been retrospective or *post hoc*. That is, they are able to assert, subsequent to empirical discoveries, that their modes affirm the discoveries. When we already know the answer, it is all too easy to convince ourselves that this is just what our favored non-empirical mode would tell us. When these modes offer results that go beyond what has been established empirically, their failures are frequent and sustained.

6.2 Empiricism Only Has the Capacity to Self-correct

Perhaps this dismissal of these other modes as merely *post hoc* is too hasty. Their proponents can concede that their modes have failed sometimes. However, they might say, this is no fatal error since the same is true of empirical methods. We have many cases of sciences that enjoyed strong empirical support but later proved to fail. The most important examples arise when try to apply a science in domains beyond those in which their evidential support is found. The familiar example is Newtonian mechanics. It fails when we consider motions with speeds close to that of light (special relativity); extremely intense gravitational fields (general relativity); large cosmic distances (relativistic cosmology); and the very small (quantum theory). All modes, including the empirical, fail sometimes.

There is a difference, however, that distinguishes empirical methods as singularly successful. Empirical methods have within them the means to correct their errors. When an experiential result errs, if enough information on the experiential process is available, we can locate precisely how the error arose through the "winding back" recounted in Chapter 10. In 1610 and the years following, Galileo misidentified the rings of Saturn. He reported that the planet has lobes or even "ears."[6] We now know that the misinterpretation resulted from the inability of Galileo's early telescope to resolve Saturn's rings.

The corrections are possible on a larger scale, when there are revolutionary changes in a science. Empirical methods tell us what is best supported by the evidence then available. That qualification allows that further evidence may require revisions to what is best supported. That sort of revision is possible and perhaps even expected when new evidence is drawn from new domains remote from those already explored. The familiar example is again the failure of

[6] As recounted in Shea (1998, pp. 223-24).

Newtonian mechanics. It was revealed by empirical investigations that probed extreme domains, as sketched above.

The other, non-empirical modes do not have the means internally to provide for and explain the failures. They rely on empirical investigations to alert them to the problem. When an error is found, they can only say that their Platonic vision was clouded or their intuitions misread. They must just concede the error. Perhaps they can then find *post hoc* how their methods might vindicate the new theories found empirically. They are intrinsically unreliable.

6.3. The small-e empiricists' Ontology Precludes Other Modes

From the perspective of small-e empiricism, the unreliability of these other modes is quite expected. The ontology of small-e empiricism circumscribes the ways that we can access systems of interest in the world. They are restricted to those that are identified as experiential processes here. Claims of other modes are unsupported by this ontology. Their successes, it follows, are fortuitous or covertly guided by what experience has already affirmed.

We are used to the ontology of science refuting claims of alternative modes of access to the world. A version of astrology asserts that the specific positions of celestial objects at the moment of a person's birth correlates in profound ways with that person's future. Astrophysics has identified the repertoire of interactions between these celestial objects and occurrences on earth. There are some connections. The connection between the positions of the Moon and Sun and ocean tides is well-known. However, that repertoire is so sparse that it precludes the correlations asserted by this version of astrology.

Sortilege is a form of divination that seeks signs of future events in the outcome of simple physical processes like cards dealt from a shuffled deck (Tarot), the configuration of cast sticks (I Ching) or the results of die casts (divination in the ancient Greek world). Modern mechanics affirms that all these processes are effectively random. To someone with a modest knowledge of mechanics, the belief that the outcomes of these processes correlate with future events requires a willful credulity. It is especially so given that the full details of the mechanical process that produces the results are so fully exposed as to assure their effective randomness.[7]

[7] Norton (2022, §4.3, §5.2) provides more details of these forms of divination within an analysis of notions of chance outside probability theory.

For our purposes, the main result in the empirical study of sense perception is that its ontology powerfully restricts the range of sense experiences we humans can have of the world. The ontology precludes a parapsychology that proposes further modes of sense experience. These further modes include telepathy, which proposes an addition channel of communication between minds, and clairvoyance, through which agents have the ability to "see clearly" in way that goes beyond the five senses. To someone who accepts the ontology of senses supplied by mainstream psychology, the notion of "ESP," extra-sensory perception, is an oxymoron.

6.4 The Priority of Experience

In the light of the considerations so far make, it surely is futile to harbor the hope that some as yet undiscovered alternative mode may appear. Were such a mode to be found, we have reason to believe that it would be subordinate to empiricism.

The reason is that empiricism enjoys a priority over all other modes in that the results of any other mode is overruled if they contradict experience. No matter how erudite a mode's assurance that there can be no duck-billed platypus, its failure is assured when a specimen emerges. Such overruling has been a frequent occurrence in the history of science. A few examples, in addition to those in earlier sections, illustrate it.

Johannes Kepler, in his 1596 *Mysterium Cosmographicum*, described a geometric construction in which the five Platonic solids were nestled between six spheres. The sizes of these spheres matched the orbits of the six planets then known. This Platonic recovery of the orbital size and number of planets fared poorly under the subsequent empirical discoveries of more planets and the existence of an asteroid belt between the orbits of Mars and Jupiter.

Modern physics supplies many examples of how intuitions have been overruled by new, empirical discoveries. Einstein's 1905 special theory of relativity conflicted with long-standing presumptions about time. It entailed that whether two spatially separated events are simultaneous depends on the inertial frame of reference in which their timing is judged; that moving clocks are slowed; and that observers in relative motion will judge each other's clocks to have slowed. These results are now treated as elementary facts to be learned by any student of physics. When

Einstein proposed them and for many to the present day, they so contradict intuitive expectations as to make them inadmissible.[8]

Quantum theory provides a more extreme example. According to its standard interpretation, atomic processes are indeterministic: the full specification of the present state allows only a probabilistic determination of future states. Particles may interact non-locally, that is, with processes whose speed of propagation exceeding that of light; and atomic states can be non-separable, that is, they need not be fixed by properties assigned to a single event or even small neighborhood in spacetime. Einstein himself was repelled by these features and remarked:[9]

> It seems hard to sneak a look at God's cards. But that he plays dice and uses 'telepathic' methods (as the present quantum theory requires of him) is something that I cannot believe for a single moment.

There is no converse priority. Other modes of investigation cannot overrule experience. This asymmetry is so familiar that it has been encoded in Thomas Huxley's much-repeated riposte of 1870. It concerned the empirical refutation of Buffon and Needham's theory of "Xenogenesis" (as Huxley called it) for the creation of life (1870, p. 402):

> But the great tragedy of Science—the slaying of a beautiful hypothesis by an ugly fact—which is so constantly being enacted under the eyes of philosophers, was played, almost immediately, for the benefit of Buffon and Needham.

In more recent times, no matter how greatly our intuitions rebel against the odd results of quantum theory, that rebellion alone is no match for empirical support. If these odd results are to be overturned, it will be through further empirical investigations.

7. Illustrations of the Failure of non-Empirical Modes of Investigation.

7.1 Platonism

The history of Platonism in science is one of retrospective successes and prospective failures. This is already evident in the earliest applications of Platonic ideas. A matter theory

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[8] See Marder (1974) for a survey of just a small portion of the immense literature that unsuccessfully challenges special relativity.

[9] In a letter to Cornelius Lanczos, March 21, 1942, Einstein Archive, 15-294; As translated in Dukas and Hoffmann (1979, p. 68).

plays an enduring role in the cosmology of Plato's *Timaeus*. Plato, speaking through his character Timaeus, supposes that the elements of matter are each made up of particles too small to be seen by us (Plato, 1888, p. 201). Plato is then able to recover the four elements, earth, air, fire and water, that were then supposed to form the basis of all terrestrial matter. He achieved this by finding (p. 191)

> …the four fairest bodies that could be created, unlike one another, but capable, some of them, of being generated out of each other by their dissolution …

Plato reassures us that this is no idle play, but a serious attempt at finding the true theory of matter. He continued the above quote with[10]

> … for if we succeed in this, we have come at the truth concerning earth and fire and the intermediate proportionals.

The "fairest" bodies are the five Platonic solids, four of which are then associated with the terrestrial elements as (p. 199):

fire—tetrahedron
air—octahedron
water—icosahedron
earth—cube

With this association, Plato had recovered retrospectively why there were just four terrestrial elements. The awkwardness that there are actually five Platonic solids is escaped by associating the remaining solid, the dodecahedron, with the cosmos as a whole (p. 197).

That this was a serious theory of matter is affirmed further by Plato's extensive use of the theory to accommodate, retrospectively, known properties of matter. The narrative recovers at some length, page after page, many of the familiar properties of terrestrial matter. These properties include how matter behaves under melting, flowing, cooling and solidification (p.213) and how the matter theory accommodates the interactions of matter with living organisms, such as the origin of the sensations of colors (pp. 247-53). The accommodations are easily formulated and, to an adherent of Plato's theory, likely plausible. For example (p. 291):

[10] This appears to be an early instance of inference to the best explanation.

> Fire is composed of finer particles than any other element, whence it penetrates through water and earth and air and whatever is composed of them, and nothing can keep it out.

So much for the retrospective successes. They just return properties of matter already evident in experience. The account fares poorly prospectively, that is predictively. In assigning the fifth Platonic solid, the dodecahedron, to the cosmos, it mistakenly predicts that the matter of the heavens is unlike terrestrial matter. Plato's narrative includes a rudimentary theory of elementary transformations. Fire, air and water are intertransformable since their primary shapes are composed of triangles. No such transformation is possible for earth since its primary shape, the cube, is composed of squares. For example (pp. 203-205), if the particles of water are divided by fire or air, they may recombine into various combinations fire and air. Earth, divided by fire, can only return to earth (p. 203).

It is hard to know what to make of these predictions, since there is considerable ambiguity in associating the four elements with substances we now know. The carbon of a diamond, the hardest of all minerals, if set upon by fire and air, resolves into something entirely gaseous, carbon dioxide. Is this a transformation forbidden by Plato's theory of earth to air? In all this ambiguity, one thing is certain: Plato's analysis failed to make definite predictions that conform with later empirical results.

It is tempting to dismiss these failures as inevitable at such an early stage of the development of science. Is it not just unkind but anachronistic to expect anything better? My point, however, is that this pattern persists to the present. For their entire history, attempts at Platonic insights succeed retrospectively and fail prospectively. Einstein provides a more modern example. His early work in physics conformed with empiricist expectations. It depended on an astute sense of the import of experimental results. After his completion of the general theory of relativity in the mid 1910s, he shifted towards a mathematical Platonism that found its fullest expression in his Herbert Spencer Lecture, delivered at Oxford on June 10, 1933.[11] There he proclaimed (1933, p. 274):

> Our experience hitherto justifies us in believing that nature is the realization of the simplest conceivable mathematical ideas. I am convinced that we can discover by

[11] For further historical details, see Norton (2000) and van Dongen (2010, Ch. 2).

> means of purely mathematical constructions the concepts and the laws connecting them with each other, which furnish the key to the understanding of natural phenomena.

Even more striking is Einstein's explicit acknowledgment (p. 274):

> In a certain sense, therefore, I hold it true that pure thought can grasp reality, as the ancients dreamed.

Just as Plato sought the fairest shapes for his elements, Einstein now sought the mathematically simplest expressions for the fundamental laws of physics. The retrospective successes were immediate. Einstein could claim that versions of Maxwell's electrodynamics and his own general theory of relativity conformed with this Platonism (p. 274):

> The physical world is represented as a four-dimensional continuum. If I assume a Riemannian metric in it and ask what are the simplest laws which such a metric can satisfy, I arrive at the relativistic theory of gravitation in empty space. If in that space I assume a vector-field or an anti-symmetrical tensor-field which can be derived from it, and ask what are the simplest laws which such a field can satisfy, I arrive at Maxwell's equations for empty space.

This new outlook was then supposed to prove itself prospectively as the secure guide to his unified field theory. The program proved sterile prospectively. Einstein toiled in vain for over two more decades in the search for his unified field theory up to his death 1955.

These are only two episodes within a long-standing tradition that ascribes a mathematical structure to the world. It encourages the idea that mathematical explorations are a fertile means of learning about the world, in advance of experience. As a general matter, the successes of these means are retrospective. They provide no basis for concluding that mathematical investigations are a means of discovery of facts of the world, *prior to experience*. For further discussion, see Norton (2000, Appendix D; 2024, Ch7, §7.4)

To preclude any misunderstanding, I have no doubts about the value and even necessity of mathematical descriptions of physical facts and mathematical formulations of physical theories, once their factual content has been discovered empirically.

One further example is a striking illustration of the purely retrospective success of a priori reasoning. In the 1930s, the eminent physicist, astronomer and cosmologist, Arthur Eddington, created an expansive theory intended to unify cosmological and quantum scale phenomena. It was developed as a purely deductive theory. Eddington (1936, p.5) introduced it as "I think it will be found that the theory is purely deductive, being based on epistemological principles and not on physical hypotheses." Eddington argued that, by considering large number coincidences and other factors, he could deduce the Hubble constant, which measures the rate of recession of the galaxies. He wrote (1933, p. 94):

> According to the argument here developed we can calculate by pure theory what ought to be the speed of recession of the spiral nebulae. … Since certain small factors in the formulae are at present left in suspense, there is a temporary indefiniteness; but we can say provisionally that the result is between 500 and 1000 km. per sec. per megaparsec.

Eddington then emphasized how this recovery of a result up to then only found by laborious astronomical measurements was a striking confirmation of his theoretical analysis.

> No astronomical observations of any kind are used in this calculation, all the data being found in the laboratory. Therefore when we turn our telescopes and spectroscopes on the distant nebulae and find them to be receding at a speed within these limits the confirmation is striking.

Where Eddington found this a striking confirmation of the powers of his purely theoretical reasoning, it is apparent to us that it is yet another illustration of how a priori reasoning can only recover results retrospectively, but not prospectively. For Eddington's value of the Hubble constant of "between 500 and 1000 km. per sec. per megaparsec" just happens to agree with the value that Hubble had found observationally in his 1929 work. We saw in Chapter 10, Section 7, that Hubble's value for the constant was roughly an order of magnitude too large. Eddington's analysis was only as successful as the retrospective results to which he was, perhaps unwittingly, adapting his reasoning.

7.2 Innate or Intuitive Ideas

That we know facts in the world through some prior, innate or intuitive faculty of the mind has, traditionally, been denied by empiricists. This denial forms the starting point and guiding theme of Locke's (1689) *Essay Concerning Human Understanding*. Chapter II is entitled "No Innate Principles in the Mind." Locke's denial is more expansive than that needed for a scientific empiricism, for Locke's concern extends beyond mind independent facts in the world to mental states such as the experience of colors.[12]

That we have some innate or intuitive sense of mind-independent truths of nature has an enduring presence. The most familiar instance is Euclid's foundation for geometry. He based it on a short list of postulates and axioms, whose truth were supposed self-evident. Here is how the founding postulates of Euclid's geometry were introduced in the first English edition of Euclid's *Elements*, Billingsley (1570).[13] They are…

> … certain general sentences, so plain, & so perspicuous, that they are perceived to be true as soone as they are uttered, & no man that hath but common sence, can, nor will deny them.

The axioms—"common sentences" for Billingsley--were introduced with similar assurances:

> … certaine general propositiós, commonly known of all men, of themselves most manifest & cleare, & therfore are called also dignities not able to be denied of any.

These postulates and axioms then provided sufficient basis for the deductive recovery of the geometry found by practical measurement. In so far as these postulates and axioms are self-evident, prior to experience, they implement an alternative to empiricism.

As we all know, the self-evidence of Euclid's founding principles proved fragile. In the 19th century, alternative geometries were discovered as physical possibilities, in contradiction with Euclid's postulates. In the 20th century, Einstein's general theory of relativity established that our actual geometry deviated from that of Euclid. The axioms proved similarly fragile. The cardinal measures in Cantor's transfinite set theory required a denial of Euclid's axiom "Every whole is greater than his part."

The pattern set by Euclid has been replicated throughout the history of our science. Once a new science is established from experience, its foundations are scrutinized to find its simplest and most appealing formulation. The result is often presented as establishing the necessity of the

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[12] Here Locke's empiricism intersects with issues that are properly subject to empirical investigation in psychology. Whether we are born with an innate capacity to recognize faces remains, I believe, a subject of debate in modern psychology.

[13] Billingsley's edition is unpaginated. The quoted passage follows the statement of the first postulate, called by Billingsley "peticions or requestes."

particular science. The foundation is judged to be so natural as to be self-evident and thus knowable prior to experience, if only we had taken the trouble to conceive it.

Olivier Darrigol's, *Physics and Necessity* (2014) is a capacious inventory of such attempts, drawn from work over the last five centuries. Its 390 pages recounts examples from mechanics, prior to Newton, in Newton's time and in the later development of classical mechanics, in geometry, in spacetime theories, in numbers and mathematics, in classical field theories and in quantum mechanics. There are so many examples that I assert only with slight hesitation that *all* of them are *post hoc*. Empirical investigations have done the work and they are now wise after the fact.

Kant's epistemology is perhaps the most familiar example of this approach in philosophical writing. He successfully recovered retrospectively key physical elements of the new Newtonian science. Most prominently, he gave an absolute assurance of the eternal security of Euclid's geometry. That was a lesser challenge when that eternal security was already the default expectation. His plumbing of intuition through the postulation of the synthetic a priori proved to have meager prospective powers when developments in geometry and physics in the 19th and 20th centuries overturned Euclid's geometry empirically.

7.3 Conceivability

The modern incarnation of innate or intuitive ideas in the philosophical literature is conceivability. It is vested with great powers. Most prominently, what is conceivable reveals to us what is metaphysically possible. Whether conceivability truly has such powers remains a matter of great debate in the philosophical literature. In their introduction to a collection of papers on the topic, the editors, Tamar Gendler and John Hawthorne, after some preliminaries, lay out a challenge to be pursued in in the volume (Gendler and Hawthorne, 2002, p. 6):

> While these clarifications dispel a certain amount of confusion, they do little to resolve an obvious puzzle: on the face of it, the idea that conceivability is a guide to metaphysical possibility is extremely problematic. According to current orthodoxy, metaphysical possibility can neither be reduced to, nor eliminated in favour of, linguistic rules and conventions; it constitutes a fundamental, mind-independent subject-matter for thought and talk. Given this picture, it is rather baffling what sort of explanation there could be for conceiving's ability to reveal its character. It seems

> clear that the causal explanation for the reliability of perception is unsuitable here- and it is profoundly difficult to see what to put in its place.

In my view, the challenge is devastating and unanswerable and the remainder of the volume struggles to meet it. The problems have already been rehearsed in Gendler and Hawthorne (2002) and elsewhere (Norton, 2022a)), so only brief mention of them is needed here.

The supposed relation of conceivability to metaphysical possibility is fatally troubled on both sides. First, take conceivability. It is untroubling, in so far it merely affirms logical compatibility or restates something well founded in experience. If it seeks to do more, however, the notion is too inchoate to serve the weighty role attributed to it. The well-known difficulty is that it is often as easy to conceive some result as to conceive its negation. The relation would then tell us that the result is both metaphysically possible and metaphysically impossible. We can also conceive results known assuredly to be false.[14] The optimistic response is to undertake a convoluted quest for just the right, restricted form of conceivability that would escape the plethora of troubling counterexamples. The more realistic response—my view—is to accept what should have been obvious from the start. Conceivability is just too inchoate a notion to serve the weighty ends sought. There is even a tinge of magical thinking to it: if I truly believe it so in just the right way, then it is so.

The notion of "metaphysical possibility" is similarly troubled. It is defined poorly by suggestive metaphors, commonly concerning limitations on the powers of fictional gods. Metaphysicians struggle to find any cogent instances. Or so I have argued in Norton (2022a, §12). It seems to me to be a fiction invented by metaphysicians. The literature on metaphysical possibility looks like tomes on the biology of unicorns. There might well be many, learned treatises debating whether unicorns are ruminants. They must come to nothing since no amount of learned debate can wrestle anything factual from such an invention of fiction.

Thought experiments have provided a convenient vehicle for proponents of the three modes above: Platonism; innate or intuitive ideas; and conceivability. Superficially, through a thought experiment, we seem able to learn contingent facts by mere introspection without empirical investigations. That is just what each of these modes purports to provide. Elsewhere in

[14] In my mind's eye, I see a neo-Pythagorean who, after millennia and a computer's assistance, has finally found a ratio of enormous whole numbers equal to the square root of two. Eureka!

this volume, I argue that thought experiments only provide the illusion of non-empirical access to contingent facts. A closer analysis—one that I have defended for roughly four decades—shows that thought experiments are merely picturesque arguments. They can only licitly deliver contingent truths if those truths are the conclusions of cogent reasoning in the thought experiment from suitably rich, contingent premises that may or may not be explicit in its set up.

7.4 Oracular Revelation

In this last mode, deep truths of the world are supposed to be revealed through the pronouncements of an enlightened person or the writings within a sacred text. The veracity of the revelations is supported by a narrative that may draw on divine interventions or by some other mystical authority. Since I doubt that these sorts of revelations are now taken seriously as modes of discovery in science, only a few brief remarks are needed here, lest I advance invidious critiques. The content delivered by these modes, once again, conforms with what was retrospectively already accepted ideas at the time of their formulation. They provide little prospectively. Creation narratives, for example, typically conform with what are plausibly the best guesses of then contemporary peoples. If the narratives provide medical advice, they are again reflections of common ideas and often notable for their omission of what are now rudimentary elements of public health policy.[15]

7.5 "Non-empirical theory assessment"

Richard Dawid has written about (2013, *passim*) "non-empirical theory assessment" and (2022, p. 61) "non-empirical confirmation."[16] One could be forgiven for assuming that these terms connote a challenge to empiricism.[17] Dawid's account turns out to be the reverse. It is a resounding endorsement of the strength and reach of empirical evidence. This is evident from Dawid's initial account in his paper. His concern (2006, §2) there was to dispute what he called

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[15] A popular riposte is that ancient health guides would have done well to advise "boil water!"

[16] Dawid (2022, p. 61) then replaced this last term with one he deemed more specific: "meta-empirical confirmation."

[17] Chapter 6 recounts the strong negative reaction that arose after publication of Dawid (2013) and was expressed in the workshop, "Why Trust a Theory? Reconsidering Scientific Methodology in Light of Modern Physics," held in Munich in December 2015.

the "'scientific underdetermination principle," which asserts a limitation on the reach of evidence by assuming that there are always competing scientific theories, adequate to the empirical data. Using the example of string theory, Dawid argued that the existing empirical evidence in particle physics was *already* powerful enough to determine string theory without the need for novel empirical evidence that addresses string theory specifically. This followed from further considerations, such as the lack of viable alternatives to string theory, a parallel to the development historically of the standard model of particle physics and the internal coherence of string theory. In characterizing his account as identifying "purely theoretical theory confirmation," Dawid (2006, p. 319) was careful to qualify the claim with a footnote recalling the importance of observational support:

> This, of course, includes indirect empirical support, that is, those observations that have led to the prior set of theories from which the theoretical scheme in question has been construed.

Similar qualifications appear in Dawid (2013, p. 3):

> While these arguments can be called non-empirical in a certain sense, they are nevertheless rooted in observation and may be understood in terms of an extension of the conventional horizon of observational input.

And again (2013, p. 38):

> The term "non-empirical" clearly does not imply that no observation or no empirical data has entered the argument.

Rather, empirical evidence is distinguished as data that can be predicted by the theory, whereas non-empirical evidence provides support without being predicted by the theory.

8. Science is Empirical

8.1 Preclusion of Empirically Inaccessible Propositions

One of the notable and most familiar consequences of traditional empiricism can be summarized in the slogan used above, "Science is empirical." More expansively, empiricism asserts a blanket exclusion from science of contingent propositions that, by their construction, can never be inductively supported by experience.

Small-e empiricism retains this exclusion. A form of it, congenial to small-e empiricism, arises through the following question. Are there sciences of such a peculiar nature that they elude empirical support, that is, they elude inductive support by experience? Small-e empiricism entails that such bodies of propositions do not constitute a science in the sense of being a well-systemized and well-supported collection of contingent facts.[18] It is easy to formulate empirically inaccessible, contingent propositions that at least superficially appear to belong within a science. Such propositions preclude, by supposition, inductive support by experience, which is the *only* means through which they could be supported, according to small-e empiricism. Hence, they must remain an unknowable speculation, to put it kindly, or a fanciful hunch, if we are less kind.

For example, in a highly speculative cosmology, we might posit alternative universes that make no physical contact with our universe and whose physics is stipulated to be so different from ours that we cannot apply results recovered in our universe to these other universes. The contingent propositions of such a cosmology are excluded from science in virtue of their lacking the possibility of empirical or any other form of support.

8.2 The Logical Positivist's Meaninglessness is Too Strong

In a severe formulation, such empirically inaccessible propositions were the favorite target of the logical positivists. In his "The Elimination of Metaphysics Through Logical Analysis," Carnap (1931, p. 237) offered the example of propositions concerning Hans Driesch's neo-vitalist "entelechy." It is an animating spirit whose understanding cannot be provided in physical terms. Logical positivists, such as Carnap, used their verifiability principle to denounce such propositions as meaningless metaphysics. Their elimination was a major goal of the logical positivist movement and a defining characteristic of the empiricism of the Vienna Circle.

Small-e empiricism also deprecates such metaphysics, but not by the Draconian resort of judging them to be meaningless. That reduces them to something comparable to an uncommunicative grunt or drool. Propositions about alternative universes and life spirits are not completely meaningless. Although they may not meet the standard of a refined philosophical account of meaning, they have a meaning at the level of informal discourse. Ordinary language users understand more from such propositions than is conveyed by a grunt or a drool, even if

[18] Mathematics is sometimes described as a science to reflect its rigor and precision. It is not a science in the sense indicated here since its propositions are not contingent facts.

they may be unable to articulate fully the state of the world portrayed. Small-e empiricism simply remains silent on such propositions. They do not lie within the scope of the sciences.

8.3 No Demarcation Criterion

This preclusion of empirically inaccessible propositions from science is not intended to provide a demarcation criterion for science, such as promoted by Karl Popper with his criterion of falsifiability. The problem with such criteria is that they replace delicate matters of degree with oversimplified, absolute declarations. This body of work, a criterion will proclaim, is science; that body is not. Familiar declarations of this type are detrimental since they are too cheap and too open to misuse. A dubious enterprise can concoct scenarios, even if fanciful and remote from realization, in which its propositions could accrue empirical support or empirical falsification. The enterprise is thereby ennobled as "science." This is so even if its propositions are irresponsibly speculative; its empirical support is meagre; or if its propositions are falsified.

What matters is not whether some body of propositions is labeled "science" or not, according to some philosopher's definition. What matters is the body's strength of empirical support. We prize those that enjoy the strongest support for the fact of this support. For then we have good reason to accept the propositions; and, if we are rational, we should do so, no matter how the label "science" has been distributed. For more discussion, see Norton (manuscript).

9. Empirical Discovery

9.1 Discovery and Justification are Intertwined

The doctrine of small-e empiricism, as articulated and defended so far, applies to the justification of the contingent propositions of a science. It makes no assertion directly about the process of discovery. If, however, we pay attention to how successful scientific discoveries are actually made, we find that a close engagement with experience is an essential element in successful discovery processes. Science is empirical in both discovery and justification.

This follows from fact that discoveries in science are not made in one momentous act of insight in which a profound truth of science springs forth fully formed in an instant. Rather discovery in science occurs through a gradual exploration that has many intermediate steps and many intermediate results. To succeed, the exploration must be controlled repeatedly by checks on whether it is heading in the right direction. Whether these intermediates are doing so is a question of justification that requires a reliable mode of justification. It follows that discovery and justification are intimately intertwined. The prospects for successful discovery are greatly enhanced if the mode of justification employed is reliable, that is, is empirical. The prospects are poor for a discovery process whose checks are guided by a mistaken mode of justification.

We have seen an example in Section 7 above of how a poor mode of justification can compromise a discovery process. Einstein's quest for a unified field theory was guided by the mistaken supposition that the truth of a physical theory is revealed by its great simplicity. This supposition replaced what had been the distinctive characteristic of Einstein's earlier successes: he was guided by his extraordinary ability to see the deeper import of experimental results. When that guide was replaced by the guide of simplicity, Einstein's search ceased to be productive.

That the incremental character of scientific discovery is not generally recognized results at least in part from the need for commentators to provide terse and simple accounts of discoveries in science. There are, to be sure, moments of extraordinary discovery in science that do leave us in awe of a scientist's intellectual prowess. However, I fear that the creative powers of the scientist's pure intellect are commonly exaggerated. An abbreviated history of discovery is easier to narrate if the many, messy steps of the real events are collapsed into a heroic tale of inscrutable genius. My sense from my work in history of science is that our *unfettered* imagination is rarely productive in science. Rather, what appears in summary as great leaps of the intellect are, in reality, the slow accretion of many small advances; and, crucially, those small advances are powerfully constrained by experience. Here are some examples.

9.2 Examples of Discovery Processes

Einstein's discovery of special relativity is justly celebrated as a premier instance of extraordinary intellectual creativity in science. It is precisely because of my admiration for his work that I have studied closely how he came to his discovery. The core conceptual innovation was the relativity of simultaneity. If we compare Newton's Absolute Time with Einstein's relativity of simultaneity in a single step, it is a breathtaking leap. Einstein, however, struggled for seven or more years with problems in electrodynamics before he hit upon the idea. As I have reconstructed in some detail in my Norton (2004), Einstein had become convinced on empirical grounds of the principle of relativity and sought a way to implement it in a modified electrodynamics. After all his efforts had failed, he realized, in an historic moment of insight, that the relativity of simultaneity solved the problem. Here Lorentz' theorem of corresponding states provided the mathematical expression of the result needed. Einstein merely had to connect the spatially dependent time coordinate of the theorem with the true time measured by clocks. Lorentz' theorem was in turn a consequence of Maxwell's empirically well-founded electrodynamics.

Other celebrated examples in modern physics follow this pattern. In the mid 1920s, quantum mechanics emerged in a roughly modern form. Its core innovation was the notion of a quantum state, be it represented by Heisenberg and Born's matrices or Schroedinger's waves. That this state would be the core of the new theory did not arise in the physicists' minds in an instant. It was the accumulation, in the quarter century preceding, of many small steps, each being driven further from classical conceptions by empirical consideration. Heisenberg's pivotal "*Umdeutung*" paper (1925) introduced his matrices explicitly as a summary of the empirically determined amplitudes for transitions in electron energies in a hydrogen atom. These amplitudes were in turn read from empirically measured emission spectra.[19]

10. Connection to Belief

Small-e empiricism differs from much of the literature on empiricism in making no essential use of notions of belief or knowledge. Where a more traditional empiricism might consider whether we should believe some proposition in science, small-e empiricism asks only after the inductive support provided for the proposition by experience. Its burden is only to specify the nature and extent of evidential support from experience for the contingent propositions of a science and how the requirement of inductive support from experience circumscribes the scope of such propositions. Here the analysis conforms with the primacy afforded to inductive inference over belief in my earlier works (2021, 2024) on the material theory of induction.

There is, however, an important connection to belief formation that lies outside the strict formulation of small-e empiricism. It comes *after* relations of inductive support have been

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[19] Einstein's discovery of general relativity is, with justice, taken as a supreme instance of a scientist's creativity. Even in this most extreme case, careful historical scrutiny shows how Einstein took many small steps towards the final theory, with each being powerfully controlled by empirical considerations. The story is too hard to summarize in a short paragraph. Some details are in Norton (2020).

established. That some contingent proposition is well supported inductively must have some further import or else the declaration is a mere curiosity of inductive logic. That further import concerns our beliefs and is provided by Hume's (1894, p. 110) celebrated maxim:

> A wise man, therefore, proportions his belief to the evidence.

In offering this maxim, I ignore Hume's inductive skepticism and suggest that the maxim be read independently of it. I read the maxim as directing us to accord belief in propositions according to the strength of their inductive support from the evidence of experience. There is no need for a scientific empiricism to elaborate. For that would enmesh scientific empiricism in debates that are best left to epistemologists. How should our beliefs be structured? Should they be organized as probabilities? How should evidential support be incorporated in them? Just when do those beliefs rise to the level of knowledge?

These are questions worthy of philosophical analysis. However, they have engendered vast, tangled and, in my view, inconclusive literatures. There is no need to encumber a scientific empiricism with these unresolved problems, when precise statements of small-e empiricism can be formulated without them.

The deepest reason for eschewing the analysis of beliefs, their interrelations and their modes of formation is this. Since beliefs are mental states, we should not expect armchair philosophical reflection to discern their natures. States of mind are properly the province of empirical psychology. Armchair speculation has proven over millennia to be incapable of anticipating the results of empirical investigations. This limitation is the reason, I believe, for the unsatisfactory character of much of present-day epistemology. It seeks results in an empirical science by relying merely on anecdotes and introspection, as opposed to the systematic empirical investigations that psychology requires if it is to be a science.[20]

[20] However, a later chapter will explore the *import* of small-e empiricism for these debates over the nature of knowledge.

11. The Rationalism-Empiricism Debate

11.1 The Seventeenth Century Debate

The issues raised in this chapter intersect with those of a classic debate in philosophy between empiricism and rationalism.[21] Conceptions of rationalism, prevalent in the seventeenth century, combine three modes discussed above: Platonic insight, innate or intuitive ideas and oracular revelation. Nelson (2005a, p.4) provides this characterization:

> Traditional rationalisms identify the intellect, the mind, or the rational part of the soul (or even the State) as of primary importance in receiving and holding knowledge. The corresponding objects of knowledge are then nonsensory, general, and unchanging or eternal.

The third, oracular revelation, arises through the theological entanglements of seventeenth century rationalism.

A more complete analysis of the exclusivity of experience may well require a full engagement with this debate. However, the literature on this debate is immense and well beyond what can be accommodated here. My feeling, however, is that much of this classic debate lies outside the issues directly relevant to the present concerns of scientific empiricism. The debate is largely—though not exclusively—focused on disputes arising among rationalists and empiricists in the seventeenth century. The debate readily mixes concerns we would now identify as scientific with others in theology that lie outside modern science. A major focus is the mental life of agents over such issues as whether and how certain notions can come to be conceived in the mind. These concerns are antecedent to those of scientific empiricism, whose starting point is experience once it has been formulated in mind-independent propositions.

11.2 The Example of Infinity

The differing views on infinity in the seventeenth century provide a mere glimpse of the concerns of this venerable debate. René Descartes (1641, pp. 25-37) famously employed the notion of infinity in his third meditation as part of his proof of the existence of God. He argued that we finite beings cannot independently form a concept of infinity. Our concept must be

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[21] Some sense of the reach of the debate from the rationalist perspective is supplied by the articles collected in Nelson (2005b).

caused within us by something external. Descartes then invoked a causal principle: "…that there must be at least as much reality in the total and efficient cause as in its effect." It followed, Descartes argued, that our concept of infinity was imprinted upon we finite beings by an infinite being. Elsewhere, in his *Principles of Philosophy* (1644, Prop. 26, 27; pp. 13-14), Descartes reserved the term "infinite" solely for God. We are instead to describe quantities that always admit of extension as "indefinite."

John Locke (1689, p. 67), in his *Essay Concerning Human Understanding*, regarded the mind as a blank sheet of white paper upon which experience writes. He was compelled to doubt that (pp. 62-63) "the infinitely wise God …should be supposed, to print upon the Minds of Men, some Universal Principles…" The notion of infinity was a special concern and discussed at length in Book II, Chapter XVII. His notion of infinity was similar to Descartes' indefinite. Infinities in "Space, Duration [of time], and Number," as he labeled them (p. 167), resided merely in their indefinite extendability. He denied that we could conceive of an actual infinity of space (p. 171, Locke's emphasis):

> … but to have actually in the Mind the *Idea* of a Space infinite, is to suppose the Mind already passed over, and actually to have a View of all those repeated *Ideas* of Space, which an endless Repetition can never totally represent to it: Which carries in it a plain Contradiction

These considerations are of immense importance in the history of philosophy and merit careful historical analysis. Now, centuries later, and with the benefit of the labors of many subsequent thinkers, the concept of infinity presents no foundational difficulties to the mainstream of present science. Its modern discourses no longer worry about whether a theology might require us to restrict the notion of an actual infinity solely to God. They do not fear that a mind conceiving an actual infinity is committing to a contradiction in requiring the mental act of completing something incompletable.

In present science, the concept of infinity is untroubling. Whether the interactions among bodies proceed infinitely fast is a matter of empirical investigations and is answered negatively by relativity theory. We ask of modern cosmology whether space is infinite in extent and whether time extends infinitely into the past and the future. We expect these questions to be answered empirically without any concern that merely to ask about infinity makes the questions illicit. We no longer fear infinity. Cantor's nineteenth century transfinite set theory has acquainted us with elaborate hierarchies of infinities that would surely have overwhelmed seventeenth century thinkers.

11. Conclusion

This chapter's goal has been to make the case for small-e empiricism. The single most important fact favoring it is that empiricism has an unmatched record of success in informing us about how the world is. Other modes have been tried, but they fail to match this record of success. Rather their successes, when they have them, are retrospective. They are wise after the fact, when empirical investigations have already shown the way. They have no prospective powers. Empiricism has a privileged authority. If some other mode offers a new result that contradicts experience, no matter how confidently, because it contradicts experience, the result is discarded.

Small-e empiricism is distinctive in being able to provide a detailed and well-supported account for why it succeeds where other modes fail. For, through small-e empiricism, we recover an ontology that shows us how the processes of experience connect reliably to the systems of interest in the world. Further, the ontology assures us, they are the only processes that do so. This ontology gives us an unmatched control of our scientific investigations. It allows us to specify in great detail, if we wish, just what supports any particular result in a mature science. If errors arise, we can examine the experiential and inferential processes that led to the error and determine precisely how the error arose and how to correct it. There is no correspondingly rich account for how other modes work. We have no details for processes that are supposed to connect, for example, what our deeper intuitions assure us must be so of the world, in so far as those assertions go beyond what empirical investigations already authorizes. The simple slogan is "Science is empirical."

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