July 2, 2013

A Material Dissolution of the Problem of Induction

John D. Norton[1]

Department of History and Philosophy of Science

Center for Philosophy of Science

University of Pittsburgh

http://www.pitt.edu/~jdnorton

In a formal theory of induction, inductive inferences are licensed by universal schemas. In a material theory of induction, inductive inferences are licensed by facts. With this change in the conception of the nature of induction, I argue that the celebrated "problem of induction" can no longer be set up and is thereby dissolved. Attempts to recreate the problem in the material theory of induction fail. They require relations of inductive support to conform to an unsustainable, hierarchical empiricism.

1. Introduction

The problem of induction is a demonstration that there can be no justification for any rule of inductive inference. Take the enumerative rule that lets us infer from all past A's being B that the next A will be B. Should we say that the rule has always worked well enough, so we should expect it to work in this new case? That would be circular, for we would be applying the enumerative rule to itself. Should we say that it must be a good rule, for that is the best explanation of its past successes? That is, should we justify the enumerative rule by invoking another rule: that we should infer to the best explanation? How do we justify that new rule?

---

[1] I am grateful to Jim Bogen for comments and for first suggesting that I apply the material approach to the problem of induction; for much stimulating discussion from Peter Achinstein, Thomas Kelly and John Worrall at a symposium at PSA 2008; for discussion by the Center for Philosophy of Science Reading Group, April 12, 2010 (Natalie Gold, Slobodan Perovic, Wolfgang Pietsch, Susan Sterrett, Tad Szubka); and from Anil Gupta.

Might we say that this new rule has passed multiple severe tests, where it would have failed if it were a poor rule? That is, might we justify the rule of inference to the best explanation by yet another rule of severe testing?

Our peril is now apparent. We justify each rule of induction by calling up another rule of induction. Each step requires a new rule. We cannot call upon a rule that has already been used, for that would make the justification circular. We must keep finding new rules. There is no end. We have triggered an infinite regress. The difficulty is readily created, yet it is so hard to escape that it has become the paradigm of an intractable philosophical problem.[2]

The purpose of this paper is to suggest that the problem can be escaped. While the problem of induction requires few assumptions, there is one that is not usually challenged. It is that inductive inference is governed by universal rules and that the valid inductive inferences are picked out as those that conform to these universally applicable schema. If this assumption is discarded, then, I will argue here, the problem can no longer be set up; it is dissolved. This assumption is discarded if we move from a formal theory of induction to a material theory of induction. In a formal theory of induction, valid inductive inferences are distinguished by their conformity to universal templates. In a material theory, inductive inferences are warranted by facts.

This change makes all the difference to the problem of induction. In a formal theory of induction, the problem of justifying some particular induction becomes the intractable problem of justifying the universal rule or template to which it conforms. If one adopts a material theory of induction, one no longer separates factual content from the rules of inductive inference. The problem of justifying some particular induction is replaced by the straightforward task of justifying the facts that warrant it. That replacement, I shall argue, so alters things that the traditional problem of induction can no longer be set up.

Elliott Sober (1988, Ch.2) has independently recognized that a material approach to induction derails the standard argument for the skeptical conclusion that induction is unjustifiable. Samir Okasha (2005) has described and compared Sober's and my analyses. They, however, think the general problem remains unresolved. Sober, Okasha and others writing more

---

[2] While the problem is often labeled "Hume's problem of induction," my concern is limited to the modern version of the problem as described in Section 3. No Hume exegesis is attempted.

recently (John Worrall and Thomas Kelly) maintain that the material approach succumbs to a different version of the regress. The common concern is that, when we trace back the chains of facts warranting further facts, we eventually end in a starting point too meager factually to support inductions of any real scope. The whole inductive project cannot get started.

This concern, I will argue here, depends on a tacit and unwarranted assumption: that the relations of inductive support among facts are organized in a strictly hierarchical structure. That is, the simplest facts of experience reside at the lowest level. We use inductive inference to add new, higher layers of fact of greater generality. Crucially, we demand that the facts of each new layer can only be warranted by those lower down.

That is the wrong picture and responsible for the mistaken conclusion that there is a regress problem for the material theory of induction. In mature science, the warranting relations cross over in many directions defying any strict hierarchy. There is no point in the structure at which we are allowed access only to some meager facts of experience. We always have other facts from elsewhere to call upon and justify our inductive inferences.

How might such a structure be erected? One way is with the use of hypotheses. We may propose some fact provisionally and use it to warrant an inductive inference. We have an obligation to return and provide inductive support for the provisional hypothesis. If we are thorough in securing support everywhere—as I believe is the case in mature science—then we end up with a structure in which every warranting fact is supported by other inductive inferences in a highly connected, massively tangled structure. Such massive interconnectedness suggests an intriguing idea: once the relations of inductive support are all in place, we have an inductively self-supporting structure. That structure is mature science.

The next section will briefly sketch the material theory in order to preclude the common[3], *mistaken* reading that the theory asserts that all induction is really deductive. The next two Sections 3 and 4 will set up the traditional problem of induction for a formal theory and show how the corresponding set up fails for a material theory of induction. Section 5 will then review attempts to resurrect the problem of induction for material theories. These attempts will be sharpened into two objections. First, an historical-anthropological objection plays out in our real

---

[3] That is, it is common amongst sympathetic colleagues who have undertaken informally to explain to me why the theory is wrong.

history; it fails because it relies on highly speculative historical fables (Sections 6-7). An empirical objection plays out in the logical space of justification. It fails because it depends on the dubious presumption that experience can be captured propositionally in a way that does not already require inductive knowledge; and because it relies on the narrowly hierarchical version of empiricism sketched above. (Sections 8-10). Sections 11 and 12 will sketch a non-hierarchical account of relations of inductive support, illustrated by the analogy to support relations in towers and arches.

2. Material Theory of Induction

In a formal theory of induction, valid inductive inferences are distinguished by their conformity to universal templates. They may be simple, such as the template that licenses an inference from some past A's being B to the conclusion that all A's are B. Or they may be more complicated, such as the requirement that degrees of inductive support conform to the probability calculus.

In a material theory (Norton 2003; 2005, pp. 25-31), inductive inferences are warranted by facts. A simple example illustrates this central idea. We can infer inductively from the evidence that some samples of the element Bismuth melt at 271ºC to the universal conclusion that all samples melt so. The warrant is a fact about chemical elements:

Generally, all samples of one element agree in such physical properties.

The "generally" accommodates the existence of allotropes of elements, which typically differ in their physical properties. Without this qualification, the inference would be deductive. The qualification gives the inference an inductive character. In accepting the conclusion, we take the inductive risk that this element has no allotropic forms that would have a different melting point. As result, the inference is ampliative, even with explicit adoption of the warranting fact as a premise. *The material theory does NOT assert that all inductions are enthymemes, that is, deductive arguments with suppressed premises.*

The general fact about elements cited above functions both as a factual statement and a warrant for an inference. We are familiar with this dual function in deductive logic. There, the fact "If A then B." also functions as a warrant for a deduction from A to B. Here we have an inductive analog. The fact "Generally, such and such." warrants the inductive inference to "such and such." In the deductive case, there is some latitude in precisely how the "if…then…" is understood. (Is it understood truth functionally? Relevantly?) The latitude is far greater in the inductive case, for the import of the crucial word "generally" is quite vague and highly context specific. If one is of a probabilistic turn of mind, one will want to interpret the "generally" as qualifying the ensuing assertion as one of high probability. To my mind, that is a contrived reading when applied to a system, the chemical elements, that has roughly 100 instances only. The chemists' use of the term is qualitative and more hesitant.[4]

This example illustrates the material theory of induction. According to that theory, all inductive inferences are warranted by facts.[5] Since these facts are contingent, there are no universal warrants. No system of inductive logic holds universally; each holds only in the limited domain in which the warranting facts are true.

3. Setting Up The Problem Of Induction

If we are ever to hope to make progress with the problem of induction, it is essential that we give it a precise formulation.[6] Too often, discussions of the problem bleed off into other problems attached to inductive inference, such as Hempel's raven or Goodman's grue problem, and then further into a vague foreboding that inductive inference is philosophically problematic in all its aspects. That sort of malaise is irresolvable. One cannot hope ever to demonstrate that inductive inference is free of all woes, including those as yet unimagined.

For present purposes, I shall take inductive inference to mean ampliative inference, a notion that is broader than the enumerative inference against which the problem of induction is leveled in the older literature. I shall take the problem to be a particular, brief demonstration of the impossibility of justifying any rule of inductive inference. It is summarized by Salmon (1966, p. 11; Salmon's emphasis) as a dilemma with deductive and inductive horns.

---

[4] For an analysis of a comparably vague term, "likely," see Norton (2011, Section 3.1.2).

[5] This last claim is supported in the places already cited by displaying the factual warrant that underwrites inductive inferences of many different types. For further examples, see Norton (2010).

[6] The literature on the problem of induction is enormous and it is impossible to survey the many different responses. A recent, noteworthy contribution that provides an entry to the literature is Howson (2000).

> Consider, then, any ampliative inference whatever… We cannot show *deductively* that this inference will have a true conclusion given true premises. If we could, we would have proved that the conclusion must be true if the premises are. That would make it necessarily truth preserving, hence, demonstrative. This, in turn, would mean it was nonampliative, contrary to our hypothesis….
>
> At the same time, we cannot justify any sort of ampliative inference *inductively*. To do so would require the use of some sort of nondemonstrative inference. But the question at issue is the justification of nondemonstrative inference, so the procedure would be question begging…

Salmon's second, inductive horn leads to a circularity ("question begging"). This second horn could equally be developed as a fatal infinite regress, as does Popper (1959, p. 29) when he formulates the problem in terms of justifying the principle of induction:

> …the principle of induction must be a universal statement in its turn. Thus if we try to regard its truth as known from experience, then the very same problems which occasioned its introduction will arise all over again. To justify it, we should have to employ inductive inferences; and to justify these we should have to assume an inductive principle of a higher order; and so on. Thus the attempt to base the principle of induction on experience breaks down, since it must lead to an infinite regress.

4. The Set Up Fails For A Material Theory

Is there a corresponding problem for a material theory of induction? Straightforward efforts to replicate the problem in a material theory fail.[7] Justifying an inductive inference in a material theory amounts to justifying the material facts that warrant the inference. We can confront this warranting with the dilemma at the core the problem of induction.

In the deductive horn, we would seek a deductive justification of a warranting material fact. Since the material fact is true only contingently, its truth cannot be demonstrated by purely deductive means. It cannot be a truth of logic.

---

[7] The discussion that follows elaborates briefer remarks made in Norton (2003, §6; 2005, pp. 30-31).

Since the path to justification is blocked in the deductive horn, we must seek it in the inductive horn. Can a warranting, contingent fact be justified inductively? In the case of a formal theory of induction, this horn of the dilemma yielded a circularity or an intolerable infinite regress. In a material theory, the warranting fact is, by supposition, distinct from the conclusion of the inductive inference. So there is by supposition no circularity. However we do expect that the warranting fact is itself justified. For the inductive inference is only valid in so far as the warranting fact is true. So if we are to be assured that an inductive inference is valid, we must also be assured of the warranting fact. The need for that assurance triggers the regress. For we learn the warranting fact by further inductive inferences, which in turn have their own distinct warranting facts; and so on.

In the case of a formal theory of induction, the analogous regress is immediately harmful and obviously unsustainable. The difficulty was already illustrated in the Introduction above. To avoid circularity, we did not justify the enumerative rule with the same rule. Instead we sought justification in the rule of inference to the best explanation; and we justified that rule by the rule of severe testing. Perhaps we can find another rule to justify this last rule; and perhaps yet another rule for the next, even as this extended chain of justification looks increasingly suspect. However our supply of rules is limited and the appetite of the infinite regress unlimited. Our fate is sealed. We cannot re-use a rule in an effort to keep justifying our original rule, for that reduces the justification to a circularity. We cannot abandon justification or we leave our original rule without completed justification.

This particular regress has a noxious character. We are only a few steps into the regress and we are rapidly depleting our small stock of rules of inductive inference. Worse, given the fragile character of each rule of induction, applying one rule to justify another even once is precarious. Are we really comfortable explaining the rather spotty success of the enumerative rule by saying it is good rule, as opposed to being a poor rule that sometimes mimics better inductive practices? Can we really affirm that the rule of inference to the best explanation has passed multiple severe tests, when we find it hard to specify precisely just what it is to explain? Repeatedly using one rule of induction to justify another quickly becomes fanciful.

Matters are quite different in a material theory. We ask what justifies the warranting fact. The answer will be some further familiarity of our science or knowledge. We ask what justifies that and we are offered further familiarities. In science, the resulting regress may well simply amount to tracing back through the history of science of the origins of the propositions forming the science. Or, more realistically, each new generation of textbooks rewrites the history so as to make the evidential case more cogent and streamlined. More likely, it will be that sanitized, ahistorical case that we will trace out. What warrants our inference from the melting point of a few samples of an element to all samples of the element? It is the fact that chemical elements are *generally* uniform in their properties. And why do we believe that? We now know that elements are constituted of large numbers of atoms, all of the same type laid out in the same way microscopically, so that all samples of the same element are microscopically identical, mostly, and so have the same physical properties. In turn we know these facts from investigations in chemistry that have identified which substances are the chemical elements; and from investigations in physics that have mapped out the atomic structure of each element. And so on.

We have triggered a regress. It is an exploration through science that expands its compass the farther it is traced. However, it is quite unlike the regress of rules triggered by a formal theory of induction. It is not fanciful. It is real and well-documented. Indeed it is even mundane. There are open questions about it. Since each fact draws on many others for inductive support, the compass will grow exponentially and could quite possibly embrace all of science. Is that the revealing of a fatal circularity in the inductive grounding of science? Or is it, as I am inclined to believe, merely a manifestation of the inductive solidity of all science? As long as we consider mature science, we cannot tinker with one part without triggering a collapse everywhere. Skepticism about evolution in biology, eventually requires us to call into question received views in geology, the radiochemistry used in dating artifacts and rock, the time scales of big bang cosmology and the further theories that undergird them all.

In sum, a replication of the argumentative structure that visits the problem of induction upon formal theories of induction fails to yield a clear-cut problem for a material theory. That failure is my principal ground for claiming that a material theory of induction evades the problem of induction.

5. Attempts To Resurrect The Problem

Can it really be that easy? I believe it can. The task is not to show that a material theory of induction is immune to all challenges; that is an impossible demand. The task is merely to show that this particular challenge fails. And it does. What was a short, sharp and decisive demonstration of a fatal difficulty for a formal theory of induction becomes inconsequential when replicated for induction, materially conceived.

Nonetheless, many are likely to share my initial sense of foreboding when dealing with a regress. As we proceed farther back in the regress, we have less general facts. That seems threatening to an account of inductive inference that uses facts to warrant inductive inferences. Can that sense of foreboding be translated into a precise problem? Here are some attempts to do it.

Elliott Sober's (1988, Ch.2) analysis of simplicity contains an account of inductive inference similar to the material theory. He writes (p.59):

> …I shall suggest that every non-deductive inference from observations to hypothesis must involve substantive assumptions about the world. When we infer tomorrow's sunrise from the ones observed in the past, an additional assumption is involved; the same is true when we infer that tomorrow's bread will nourish from the fact that the bread we ate in the past has done so.

Sober is at pains to assert that the additional assumption will generally be different in each case, thereby precluding some general principle of uniformity serving to power inductive inference. The fact of this difference blocks what he identifies as Hume's argument. However Sober still arrives at the skeptical conclusion. He notes later of the regress at issue here (p.66, Sober's emphasis):

> As we pursue these questions of justification—pushing farther and farther back for the "ultimate" assumptions that underlie our empirical beliefs—will we eventually reach a stage where an empirical belief that is not strictly about the here and now is sufficiently supported by current observations, taken all by themselves? That is what the Principle of Empiricism demands. But here we see empiricism in conflict with the thesis about confirmation: If hypothesis H and observation statement O are not deductively related (they are logically independent), then O confirms or disconfirms H only relative to a background theory T. The third term *never* disappears…
>
> If Hume required that we show how present observations all by themselves provide reasonable support for our predictions, retrodictions, and generalizations, he was right to conclude that they do not. The thesis that

> confirmation is a three-place relation sustains Hume's skeptical thesis, but not the argument he constructed on its behalf.

Sober (1988, p.68, his emphasis) defines the "Principle of Empiricism," mentioned above, as:

> [T]hat beliefs about the future must be justified in terms of present observations *alone*."

It leads to a terser statement of problem (p. 68):

> Present experience is no guide to the future, except when it is augmented with contingent assumptions about the connection of past to future.

Samir Okasha (2005, p.250) has also objected along similar lines, responding critically and with some justice, to the brevity of my earlier accounts:

> Norton's attempt to show that the regress is not infinite is not especially convincing. He says that some chains of justification 'may just terminate in brute facts of experience that do not need further justification' ([Norton, 2005, p. 668]). But if this is so, it is hard to see what motivates the thesis that every inductive inference needs to be licensed by some material postulate or other; indeed, the claim that 'brute facts of experience' may terminate the regress of justification is tantamount to a denial of that thesis. It cannot be true that inferences from observed to unobserved always require additional empirical assumptions and that 'brute facts of experience' can justify conclusions about the unobserved on their own.

John Worrall's apprehensions are similar. He writes (2010, p. 746):

> However, if we follow this backward direction, we clearly meet what seems to be an insuperable problem: the accreditational buck, it seems, has to stop somewhere: it can't be an infinite chain (or, rather, tree since more than one nonphenomenal premise will usually be involved in any 'demonstrative induction,' and perhaps there will be more than one way of accrediting a given theory by this method). Even if we were to think, following Hume's thought experiment, of the starting point being Adam making some initial observation, we know that nodes in the tree must contain, at some stage, universal claims – and so we would still have to account for some initial act (or acts) of generalization. And given that we want each node to be justified, we would seem to be back at the same old problem.

Thomas Kelly has objected on similar grounds. To give it a sharper formulation, he separates out the commitment of the material theory that grounds the problem. A material theory, he urges (2010, p.760), must be committed to

> Prior Knowledge: In order to learn a fact by induction, one must have prior knowledge of the material fact that licenses the induction.

He then turns to "E," which he defines to be the totality of our knowledge immediately before we acquired our first piece of inductive knowledge. He continues:

> Suppose that we try to take a first, minimal step beyond E. Again, intuitively, this proposition will be our first piece of inductive knowledge…My worry is that, given that the only empirical knowledge that one has at the point is observational knowledge and its deductive consequences, there would not be anything suitable around to play the role of material postulate.

After examining these remarks and their fuller texts, it becomes clear that there are actually two distinct concerns being raised in connection with the termination of the justificatory regress. One is an "historical-anthropological" objection and the other "empirical." They are elaborated and rebutted in the following sections.

6. The Historical-Anthropological Objection

The regress in this objection plays out in time.[8] When we trace back the history of how humanity actually acquired inductive knowledge, we come to the moment of the first induction. It is a specific event that must arise for some particular human. No material fact is then available to warrant this first induction. For all such warranting facts must make more general assertions in some fashion if they are to license inductive inferences from the specifics of particular observations of the here and now to the more general. The problem of induction returns for the material theory in the inability of our inductive enterprise ever to start historically.

To illustrate the worry, we need only imagine an Adam, still bereft of any inductively grounded knowledge, emerging from his cave. Presumably, he can come to know that, as general matters, which are the substances around him that are good to eat, that ascending heights is

---

[8] I have labeled this "anthropological" since this events envisaged must predate recorded history and their study belongs more to anthropology than history of science.

dangerous, as are certain insects, that thunder follows lightning and that day follows night. Yet he cannot come to know these as generalities by induction from the particulars of his experience if he does not already have knowledge of more general scope to serve as the warranting material postulates.

7. Why It Fails

If this concern is to be the analog of *the* problem of induction for a material theory, then it has become a frail and feeble echo of its former self. For the original problem lay in enmeshing formal approaches in a sharp and decisive predicament. The historical-anthropological objection rests on imagining a wildly fictitious scenario, our distant forebears at the moment of their first induction inference. We simply cannot know that there ever was such a moment or, more generally, just what sort of cognition took place in the heads of our forebears, when they supposedly knew only what sense experience could deliver by deductive inference. Here I agree with Worrall's own rejoinder (2010, p.748):

> The whole idea of reconstructing our knowledge from bottom up in this way is surely a chimera. Surely these justificatory trees grow back into the mists of time to the dawn of homo sapiens, and surely well beyond.

Since the historical fable seems to arise quite commonly in objections to the material theory, it is worth specifying a little more precisely just why it is a fable.

The principal difficulty is the presumption that our present modes of disciplined reasoning persist essentially unchanged into the heads of our remote ancestors. They were, no doubt, always engaging cognitively with the world. But what is implausible is that they recognized, let alone maintained cleanly, the distinctions that are fundamental to the historical-anthropological objection. Our forebears would have amassed a body of belief. But would their cognition have been so regimented as to enable delineation of the introduction of new thoughts by inference as opposed to introduction by hunch, speculation, misconception, authority, hearsay, reliable or distorted memory? If that distinction is dubious, then distinguishing inferences further into deductive and inductive is even more dubious, as is the idea of a moment in which all beliefs are derived solely by deduction from experience.[9]

Taking this alternative picture seriously amounts to creating a counter-fable. How might it proceed? As time passes and our forebears learn more of the world, more modern categories of reasoning would begin to solidify, until we meet with the writers of antiquity who codify modes of logic essentially familiar to us. Prior to this time, it would be impossible to set up the historical-anthropological objection because there is no problematic moment of the first induction. After that time, it is too late to set up the objection. Sufficient of what we now label as inductive knowledge would have accrued for induction now to be quite possible.

Thomas Kelly quipped to me light-heartedly that the inductive regress resembles the problem of the chicken and the egg: which came first? The analogy is apt in this regard. If we seriously trace back the generations of chicken and egg, we will find fowl biology slowly changing, de-evolving, until the ancestral life forms are no longer readily distinguishable as chicken and egg. We thereby avoid the paradoxical termination of a chicken unhatched from an egg or an egg unlaid by a hen.

Did inference really develop this way? We can only speculate. However the range of possibilities is sufficiently varied as to admit plausible scenarios in which the historical-anthropological objection fails. The essential point is that any positive account of the cognition of our distant forebears is speculation. My plausible counter-fable should not be taken any more seriously than that of a primitive Adam bereft of any inductive knowledge.

This discussion calls to mind the many viewpoints and long standing debates of epistemology.[10] I do not think that the response to this historical-anthropological objection requires commitment to a particular view. To take one extreme, consider a foundationalist who would hold in this case that beliefs in general, contingent propositions are grounded through

---

[9] In addition, we should be skeptical of the very idea of direct sense experience, expressible in a language in which distinctions as refined as that between induction and deduction are possible. This issue will be taken up in a later section under the Sellar's "myth of the given."

[10] As with the problem of induction, the relevant literature in epistemology is enormous. For an entry into it, see Moser (2002), especially Goldman (2002), Fumerton (2002), and Bonjour (2002).

induction on the non-inferentially known foundation of experience. The foundationalist analysis could not be applied until explicit notions of justification had been developed and applied; until then, our primitive forebears' cognitive commitments would not count as knowledge.[11] In contrast with the foundationalist's internalism, one might consider an externalist-reliabilist, who would allow that our ancestors' cognitive commitments can count as knowledge as long as they are brought about by a reliable process. Here we might consider our Adam's belief that sweet things are good to eat and heights dangerous. It is not far-fetched to imagine that biological evolution might be the process in this case, for babies already have a liking for sweet things and an aversion to heights. This sort of externalism gives a ready account of how an Adam might already know general facts of the type needed to warrant his first, explicit inductive inference.

In sum, I endorse no particular historical-anthropological fable about how we acquired our early inductive knowledge of the world. All that is needed for me to deflect the historical-anthropological objection is to establish that it is grounded in speculative fables and that there are equally credible competing fables, such as the one derived from externalism, that does not enable reconstruction of an analog of the problem of induction.

Once we take the historical aspect of this historical-anthropological objection seriously and labor through the ensuing analysis, it becomes plausible that the historical aspect of the objection is really incidental. It might well be just a convenient parable whose deeper goal is to formulate an objection that is fully expressible in terms of the logical relations in our present knowledge. I turn to that objection.

8. The Empirical Objection

The regress of this empirical objection is atemporal; it plays out in the logical space of our present justifications. As empiricists, we expect all our empirical knowledge to be grounded in experience. But pure experience, absent any general knowledge, provides no material postulate strong enough to allow induction to proceed to generalities beyond immediate experience. So, the objection asserts, the material theory entails that induction is possible only if we deny

---

[11] The following sections will take up the issue of whether such an approach runs into difficulties.

empiricism and, by means other than induction from experience, introduce knowledge of contingent facts that transcend the deductive consequences of our experience.

To illustrate this worry, consult a modern ephemeris for a complete record of all the observed positions of the morning star and the evening star. We should like to infer that one star becomes the other and that the one object—Venus—persists in intermediate positions, even when those positions are obscured from our gaze by the earth or the sun. The relevant induction requires supposition of a material fact about the continuity of motion of celestial objects. Such a supposition cannot be located in any purely observational fact in astronomy or elsewhere. The material theory of induction does not permit the induction to proceed from purely observational premises.

Might we escape by recalling that celestial objects are Newtonian masses governed near enough by Newton's laws of motion and gravitation? They entail that these masses trace out continuous trajectories, which is just the material fact needed. Calling up Newton's mechanics breaks the no-prior-inductive knowledge presumption, for Newton's mechanics was itself learned inductively from particular facts about bodies and their motions. If we replace Newton's mechanics by these particular facts, the problem returns. We have no material facts of a sufficiently general character that can license inductive inferences to the intermediate, unobserved positions of the morning and evening star.

This empirical objection fails, I maintain, since its cogency requires a commitment to two quite narrow presumptions in epistemology both of which are dubious. The first is that it is possible to separate out the purely experiential propositions that can be known without prior inductive knowledge. The second is a strict, hierarchical construal of empiricism, a kind of naive inductivism.

9. Why It Fails: The First Presumption

That we can separate out purely observationally or experientially based knowledge independently of our larger conceptual system is a fiction Wilfrid Sellars (1956) denounced famously as the "myth of the given." Our present purposes do not require a full development of Sellar's critique. Rather, all that is needed is to cast doubt on the narrower idea that there are propositions that capture experience without the prior requirement of inductive knowledge. For experience must first be expressed propositionally if it is to figure in inductive or deductive reasoning; and the empirical objection requires such propositions as the supposed starting point of inductive and deductive inferences.

My narrower version[12] of Sellars' point begins with the idea that language is unable to provide a mode of expression for our experiences that does not already presume general knowledge of the type provided by induction. Take for example, the proposition "The ball is red." For this proposition to be understood, one must have a prior conception of both "ball" and "red." Neither is simple. A ball is, most crudely, a roughly spherical object of any size, so that an understanding of the term "ball" requires enough background knowledge of geometry to know the difference between a sphere, cube and cylinder and the physical possibilities afforded by them. A common connotation of "ball" is of a rigid or elastic body, which presumes some knowledge of the elastic properties of materials. A functional property of "ball" is that it can roll if pushed, thereby presuming an understanding of both kinematical and dynamical notions. Finally, a connotation is that balls are involved in games, presuming some knowledge of game play in human society. Similar demands are made for understanding the predicate "red." Minimally it requires the ability to classify, even if only hesitantly, which of the infinite range of colors in the color manifold are appropriately labeled "red." We would not say someone with normal vision understands "red" if they are unable to pick a red ball from a pink one or a violet one, when asked.

Perhaps the example is poorly chosen and we should seek to express pure experience with terms less context-dependent than "ball" and "red". Might we replace the proposition with "This thing [pointing] is the same color as that thing [pointing]." This translation is, in the end, no simpler. How are we to know just which portions of the world are picked out by the pointing unless we have a general understanding of the default designations of terms like "this thing" in similar contexts? And understanding just which aspects of the two things are same when they agree in color is every bit as complicated as understanding "red."

Might we escape by seeking an artificial language? Might we take pure experience to be expressed, for example, in the glowing diode or inked line traced by a chart recorder attached to some sensor? The same problem returns. For the glowing diode or inked line has no meaning until it is interpreted. That process requires a general sort of inductive knowledge. We need to

---

12 Developed very briefly in Norton (2003, p. 668).

know, for example, that the inked line is connected by some physical process to the physical magnitude of interest and that the connection is such that increases and decreases in that magnitude correspond to deflections in the inked line.

The parable of Adam in his cave was intended to conjure up a notion of induction-free, propositional knowledge. The parable failed not just because it relied on a fantasy history, but because of the impossibility of induction-free propositional knowledge in the first place.

10. Why It Fails: The Second Presumption

We may want to set this difficulty aside. Perhaps we may seek to revive the old notion of a distinct observational and theoretical vocabulary in science;[13] and we may conjecture that the sort of inductive knowledge needed to give meaning to simple experiential propositions is quite narrow. Then the empirical objection is revived through the supposition that theories more remote from experience employ a theoretical vocabulary (e.g. "electron," "nucleotide") that, supposedly, appears in none of the general knowledge native to the observational domain. It follows that the inductive knowledge native to the observational domain cannot provide the material postulates that warrant inductions to these more remote theories.

One could certainly object to this revival of the empirical objection by impugning this clean division of our language and knowledge into observational and theoretical parts. However I will accept the division temporarily in order to expose the second dubious presumption on which the empirical objection rests. It depends upon an untenably strict construal of empiricism. According to it, knowledge is properly empirically grounded only if its warrant can be traced back fully to purely experiential propositions in a rigid, inductive hierarchy.

This hierarchy starts with observational propositions; above them come propositions inferred from the observational by induction; then further propositions inferred from them; and so on. The hierarchy is structured by distance from observation: one inference from it, two inferences from it and so on. Or if we cannot identify definite layers, there is at least a notion of inductive distance, with some propositions inductively closer and others more distant from observation.

[13] As, for example, Hempel (1965, §2).

The essential restriction is that an inductive inference can only draw upon propositions inductively closer to observation than the inference's conclusion. This restriction is the basis of Sober's "Principle of Empiricism" and is also, I believe, the essential content of Kelly's "Prior Knowledge" commitment, both quoted in Section 5 above. The acceptance of this restriction underwrites the empirical objection. Applied to the first induction beyond the observational realm of the here and now, it tells us that this induction can only draw on propositions closer to observation. None of those are sufficiently general to warrant this first induction; hence the induction is unwarrantable.

We should wonder how such a narrow view of empiricism could enter, tacitly or otherwise, into our deliberations. It is, in effect, suggested by a simple, nineteenth century inductivism in which the fundamental laws of science emerge in a single induction from a sufficiently large collection of observations. Mill (1872, Book II, Ch. VIII), in his famous methods, for example, allowed that one could infer inductively that *A* causes *a* if we find *a* always subsequent to *A*. More narrowly, Mach (1986) urged that scientific laws were really just economical summaries of experience, thereby effectively doing away with induction.

While we may doubt that science ever was that simple, all illusions that it is so were shattered by the emergence of theories of modern physics such a general relativity and quantum mechanics in the early 20th century. These theories, as Einstein repeatedly insisted, are not recovered by simple induction from experience. As early as 1918, he protested, with a little overstatement, that "there is no logical path to these [fundamental] laws" but that nonetheless "in practice the world of phenomena uniquely determines the theoretical system." (Einstein, 1918) If we are to believe, as empiricists surely must, that our modern theories have good empirical credentials, then our empiricism cannot be this strict hierarchical variety.

Indeed, closer reflection suggests that this hierarchical variety of empiricism never was viable. Rather, in grounding our theories in experience, relations of inductive support routinely cross in a way that makes the hierarchy unsustainable. A simple example arises in Newtonian gravitation theory. When we infer inductively from the observed positions of Venus to the elliptical orbit that fits them, we select an ellipse from all possible curves, on the warrant of Newton's inverse square law of gravity that entails that planets orbit in ellipses. Yet Newton's law can have the benefit of inductive support from the very ellipses whose fitting it warrants. Take as a datum that planets do orbit the sun in what are, to very good approximation, re-entrant ellipses. In one of the lesser-known but most brilliant inferences of his *Principia*, Newton (1729, Book 1, Prop. 45, Cor. 1) demonstrated that, from this datum, one could infer to the inverse square law of gravity. Any deviation in the exponent of the force law from two would be revealed as a failure of re-entrance and the extent of the deviation could be computed numerically from the extent of the failure.

11. Non-Hierarchical Empiricism

11.1 The Tower and the Arch

If we eschew this hierarchical form of empiricism, how are we to conceive the grounding of our science in experience? A simple metaphor solidifies the picture urged here. According to hierarchical empiricism, scientific knowledge is like a tower: it must be constructed by starting at the bedrock of experience and inductively stacking the stones, one on top of another, until the edifice is complete. Each stone is supported only by those beneath it, that is, by those closer to bedrock. In a more realistic picture, the edifice of science is like a stone arch or masonry dome or even an elaborate medieval cathedral, with many smaller arches and vaulted ceilings. Each of the stones gain structural support from stones elsewhere, both above and below it.

A stone high in an arch, for example, cannot fall because it is supported by the stone beneath it *and* the stone above it. Without support from the stone above it, the first stone would slide off and fall. This account repeats for the next higher stone. Ultimately the support for each stone derives from many stones both above it and below it; and then from the entirety of the stones in either side of the arch. (See Figure 1.) Remove one stone and the arch falls. This principle of diffused support applies in the more complicated case of vaulted ceilings. Each stone in the ceiling is supported by the totality of the stones, locked together.

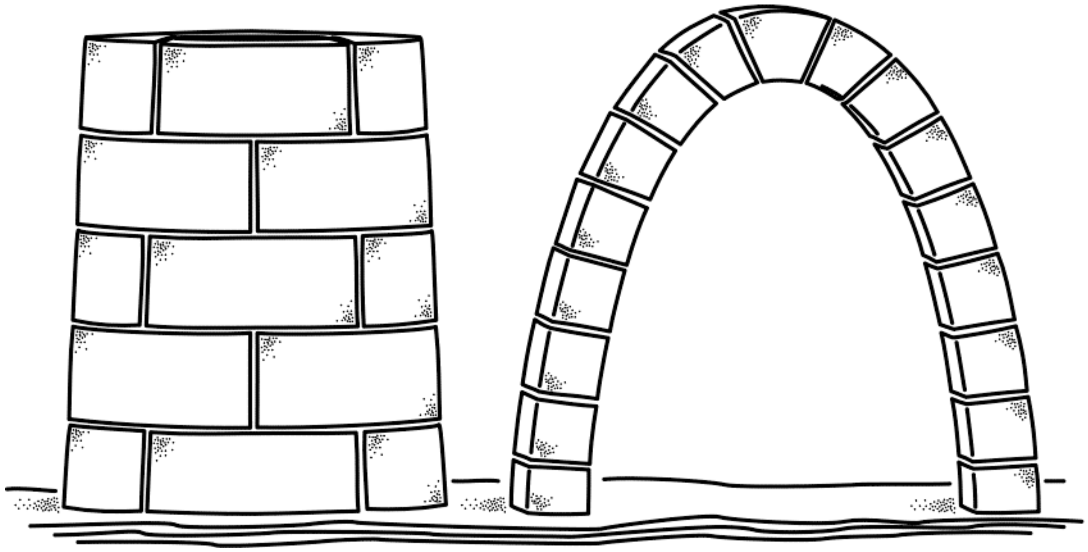

Figure 1. A tower and an arch

The important fact is that these structures cannot be built merely by stacking stones. If we merely stack its stones, an arch would fall well before its keystone was inserted. However, if one has a completed arch, dome or cathedral, one can affirm that each stone is in fact properly supported and that this support eventually traces down to the ground.

11.2 Inductively Self-Supporting Structures

My proposal is that the relations of inductive support in mature science form an analogous, non-hierarchical structure. Take any proposition in mature science. We will be able to display a rich and varied inductive case for it that draws on propositions in other parts of science. The inductive support is empirical in the sense that all relations of support eventually call upon facts of observation and experience, the bedrock in the analogy. However, the relations do not form a hierarchical structure. The support for a proposition will draw on propositions of generality both lesser and greater than it. However, just as no stone in the tower is unsupported, none of these propositions of greater generality will lack support.

What I have just described is an inductively self-supporting system of propositions. It is inductively sound in the sense that every proposition in it has good inductive support. It is self-supporting in the sense that all the propositions needed to provide that support are contained within the structure.

Multiple crossings over of support relations are a commonplace of science. It is quite visible in the interactions among different sciences, both in general and narrow propositions. Each science, for example, is confident that the general principle of the conservation of energy holds within its domain. It draws that confidence, in part, from knowing that energy conservation holds within the other sciences. At a more specific level, in a tradition extending back to Maxwell in the nineteenth century, chemists explain the viscosity of fluids through their molecular constitution. We now explain the anomalously high viscosity of water by its peculiar molecular constitution that sustains especially strong hydrogen bonding. Yet when Einstein established the reality of atoms and molecules in 1905 with his analysis of Brownian motion, he modeled the small corpuscles as suspended in fluid water. The viscosity of water on these small scales played an essential role in his analysis.

This sort of exchange of results between sciences is common and the results imported are routinely used in providing inductive support. There is no policing of the inductive support of each imported proposition to ensure that it, in turn, draws its support only from propositions of lesser generality. That would be neither practical nor desirable. What matters to the scientist importing the result is that the result is well-supported in its own science, even if part of its inductive support in turn derives from results in the first science.

11.3 A Role for Hypotheses

Once we are presented with such an inductively self-supporting structure, such as I believe we find in our science text books, it would be beside the point to object that the relations of support could not have been introduced sequentially from bare experience in the manner that hierarchical empiricism demands. We can affirm that each of its propositions is well supported; and that is enough. We need provide no rational reconstruction of how the structure was erected. It is no lesser a structure if it just materializes in a moment as a completed totality.

While we need not provide it, the analogy to the arch happens to provide a quite serviceable process for this rational reconstruction. How are arches, domes and cathedrals built in the first place? Their stones are supported initially by scaffolding. As each part became self-supporting, the scaffolding is removed until it is all gone and the structure is self-supporting.

The analog of a stone temporarily supported by scaffolding is the proposition introduced tentatively as an hypothesis or even conjecture. It may then be used, perhaps hesitantly, in the generation of inductive support for other propositions. However there is a positive obligation to return to it and provide proper support from other well-supported propositions. We expect that this process is completed in mature science. We may first proceed inductively with conjectures and hypotheses, supported by fragile wooden scaffolding. As the science matures, we return to them and replace the scaffolding with the masonry of proper inductive support.

It may seem that selecting this non-hierarchical empiricism is to favor a coherentist epistemology over a foundationalist. While a coherentist approach is clearly quite consonant with the non-hierarchical empiricism, it does not preclude foundationalism. What is precluded is a foundationalism that adheres to the inductive hierarchy sketched. What survives is a version of foundationalism that accepts that the inductive grounding of knowledge in experience need not be rigidly hierarchical.

12. Two Problems

There are two problems faced by this non-hierarchical form of empiricism and they will be sketched briefly here. I will argue that the circumstances they describe will arise, but that they present no obstacle to the material theory of induction or to the cogency of inductive inference in general.

First, we may wonder what assurance we have that the non-hierarchical structures of science are free of conjecture. In the arch analogy, how do we know that all the conjectural scaffolding has been replaced with stone?

We do expect any new science at its birth to mix conjecture with inductively well-supported propositions. As the science matures, the mix shifts away from conjecture. Einstein's adventurous 1905 conjecture of a localized quantum of light energy has now become the commonplace photon of modern physics. What we no longer expect is that all conjecture will be removed. That it will not is almost guaranteed by the eagerness of scientists to explore beyond the inductive reach of their evidence and by their creativity in imagining what that new territory beyond their inductive gaze may be like. Science is always growing. We should expect that its mature portions are built with the good inductive support of masonry; and we should expect that, as we visit its newest portions, we encounter propositions still supported by conjectural scaffolding. That is why the newest science is treated with the greatest caution.

Second, what assurance do we have of the uniqueness of the theoretical system developed? In the analogy, if the observational building foundations do not determine the configurations of each overlying layer of stone, may we not build many different structures on the same foundations?

In the context of a material theory of induction in which material facts are the warrant for induction, the different structures may well employ different local systems of inductive inference according to the fact within them. Indeed, that multiple systems of knowledge are possible seems to me a commonplace. We are used to distinguishing a scientific from a religious picture of the world, for example. Each invokes its own mode of inductive reasoning, since each employs a distinct base of facts that provide the warrants for its inductive inferences. That is just as the material theory predicts. An extreme example is the world picture of conspiracy theorists. Their alternative understanding of world events supports an alternative, contrarian inductive logic. In it, absence of evidence of government involvement in some public catastrophe is near certain proof of the perfection of the government's cover-up!

The possibility of these multiple systems does not mean they are all correct. Just as valid deductive inferences require licit schemas, valid inductive inferences require true warranting facts. When two systems of inductive inference disagree, at most one is correct. At most one is using true warranting facts. When the competing systems do not intersect, it may be hard to discern if there is a problem. However the compass of active systems will grow. Initially, our ingenuity at numerology was the only real restriction on the formulae we could fit to the spectral lines discovered by nineteenth century spectroscopists in the colors of light emitted by electrified gases. That freedom diminished and disappeared when we learned how these spectral lines connect with the quantum properties of matter; and how these in turn must conform with the chemical properties of matter. If they are actively pursued, different inductive systems will eventually intersect in the same domain. When they do, one typically prevails. The contrarian inductive logic of the conspiracy theorist is rapidly revealed as delusional when applied in everyday life.

13. Conclusion

The problem of induction consists of the possibility of rapidly generating a circularity or pathological regress when we seek the justification of inductive inferences. That problem, I have argued here, is an artifact of the wrong conception of induction, a formal account of inductive inference. If we adopt the correct material account of induction, the problem is dissolved. The considerations that generated a circularity or pathological regress in the formal theory no longer do so in a material theory.

While I believe that dispatches the problem of induction, debate lingers over whether some analogous problem might trouble a material approach to induction. For seeking the justification of an inductive inference in science leads us to chains of justifying facts whose compass expands throughout science. The concern is that these chains might somehow end poorly. The view that they do end poorly depends, I believe, on an untenably strict, hierarchical form of empiricism. According to it, inductive support for a proposition can only be provided by already established propositions that are less general and closer to experience.

Whatever abstract appeal this form of empiricism may have, it is not the empiricism manifested in the practice of science. There we find a non-hierarchical empiricism, where relations of support are so tangled that no clear hierarchical structure can be found. The inductive cogency of the structure arises from the requirement that each proposition in it has strong inductive support, where the support for the proposition may be drawn from other propositions of generality both lesser and greater than it.

A system of propositions with this non-hierarchical structure of support cannot be generated by successive inductive inferences, each relying on already established propositions only. Its construction cannot be like that of a tower, whose successive courses of stones are laid in sequence. Rather it is like the construction of an arch or vaulted ceiling, in which some stones are supported by scaffolding that can only be removed when the remaining stones are in place. Then each stone is supported by other stones, both lower and higher than it in the arch.

Correspondingly a science may introduce some propositions provisionally as hypotheses and use them to support inductively other propositions. Their use, however, comes with the obligation that, eventually, proper support must be found for the hypotheses. The scaffolding must eventually be discarded. What results is a self-supporting inductive structure in which each proposition is supported inductively by propositions of generality lesser and greater than it. This use of hypotheses provides one way that an inductive project can get started and proceed beyond the strict limits of propositions known only in the here and now.

References

Bonjour, Laurence. (2002). *Internalism and Externalism* in Moser (2002, pp. 234-263).

Einstein, Albert. (1918). "Principles of Research," in *Ideas and Opinions*. New York: Crown, 1954.

Fumerton, Richard. (2002). "Theories of Justification," in Moser (2002: 204-233).

Goldman, Alvin I. (2002). "The Sciences and Epistemology," in Moser (2002, pp.144-176).

Hempel, Carl. (1965). "The Theoretician's Dilemma," in *Aspects of Scientific Explanation*. New York: Free Press, pp. 173-226.

Howson, Colin. (2000). *Hume's Problem: Induction and the Justification of Belief*. Oxford: Clarendon.

Kelly, Thomas. (2010). "Hume, Norton and Induction without Rules," *Philosophy of Science*, **77**(5), pp.754-64.

Mach, Ernst. (1986). "The Economical Nature of Physical Inquiry," in *Popular Scientific Lectures*, McCormack, T. J, (trans.), 5th ed., La Salle: Illinios, Open Court.

Mill, John Stuart. (1872). *A System of Logic*. 8th ed. London: Longman, Green, and Co., 1916.

Moser, Paul K. ed., (2002). *The Oxford Handbook of Epistemology*. Oxford: Oxford University Press.

Newton, Isaac. (1729). *Sir Isaac Newton's Mathematical Principle of Natural Philosophy and his System of the World*. Trans. Andrew Motte, revised Florian Cajori. Berkely: University of California Press.

Norton, John D. (2003). "A Material Theory of Induction." *Philosophy of Science*, **70**, pp.647-70.

Norton, John D. (2005). "A Little Survey of Induction," in *Scientific Evidence: Philosophical Theories and Applications*, Ed. Peter Achinstein, Baltimore: Johns Hopkins University Press: 9-34 on pp, 25-31.

Norton, John D. (2010). "There are No Universal Rules for Induction." *Philosophy of Science*, **77**(5), pp. 765-77.

Norton, John D. (2011). "History of Science and the Material Theory of Induction: Einstein's Quanta, Mercury's Perihelion." *European Journal for Philosophy of Science*. European Journal for Philosophy of Science. **1**, pp. 3-27.

Okasha, Samir (2005) "Does Hume's Argument Against Induction Rest on a Quantifier-Shift Fallacy?" *Proceedings of the Aristotelian Society*, 105, pp. 237-255.

Popper, Karl. (1959). *Logic of Scientific Discovery*. New York: Harper and Row.

Salmon, Wesley. (1966). *The Foundations of Scientific Inference*. Pittsburgh: University of Pittsburgh Press.

Sellars, Wilfrid. (1956). "Empiricism and the Philosophy of Mind," in *Minnesota Studies in the Philosophy of Science, Volume I: The Foundations of Science and the Concepts of Psychology and Psychoanalysis,* Herbert Feigl and Michael Scriven, eds., University of Minnesota Press, pp. 253-329.

Sober, Elliott (1988), *Reconstructing the Past: Parsimony, Evolution, and Inference*. Cambridge, MA: Bradford, MIT Press.

Worrall, John. (2010). "For Universal Rules. Against Induction." *Philosophy of Science*, **77**(5), pp. 740-53.