Scientific Progress Without Justification

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Abstract: According to some prominent accounts of scientific progress, e.g. Bird's *epistemic account*, accepting new theories is progressive only if the theories are justified in the sense required for knowledge. This paper argues that epistemic justification requirements of this sort should be rejected because they misclassify many paradigmatic instances of scientific progress as non-progressive. In particular, scientific progress would be implausibly rare in cases where (a) scientists are aware that most or all previous theories in some domain have turned out to be false, or (b) the new theory was a result of subsuming and/or logically strengthening previous theories, or (c) scientists are aware of significant peer disagreement about which theory is correct.

1. Introduction

Most would agree that science is one of – if not *the* – human endeavor in which we've made the most progress in the past few centuries. But what makes us so sure that the various changes that have occurred in science are genuinely progressive? *What is required for scientific progress?*

Philosophical accounts of scientific progress contain different answers to this question. These accounts purport to tell us both what is, and what isn't, required for scientific progress. In this paper, I will be concerned with a particular requirement that is implied by some such account and not others. Roughly, this requirement holds that the acceptance of a new theory counts as progressive only if the theory is epistemically justified. Such a requirement is explicitly and enthusiastically endorsed by some in the debate about scientific progress (e.g. Bird 2007, Park, 2018, Needham 2020). Others have rejected such a justification requirement as unnecessary or unmotivated (e.g. Rowbottom 2008, Niiniluoto 2014, Cevolani and Tambolo 2013, Dellsén 2016).

This paper argues in favor of the latter position. My arguments will not rely heavily on our pre-theoretic intuitions about whether we would be inclined to use the term 'progress' to describe some hypothetical episode in science. Rather, I'll attempt to identify a wide range of paradigmatic cases of scientific progress in which epistemic justification is lacking. Denying progress in these cases would not just be counterintuitive, but also go against various truisms about scientific methodology and imply that there is much less progress in science than most of us have previously thought. Thus, in brief, I hope to be moving beyond clashing intuitions about hypothetical cases, and instead provide a different type of argument against the justification requirement on scientific progress.

2. Scientific Progress and Epistemic Justification

What are accounts of scientific progress accounts of? What is the question to which an account of scientific progress is supposed to be the answer? In what follows I take the central question of scientific progress to be this:

> What type of cognitive change with respect to a given phenomenon *X* constitutes a (greater or lesser degree of) scientific improvement with respect to *X*?

For reasons of space, I will not defend my focus on this question here. I will, however, clarify three key phrases therein.

The first clarification concerns the phrase 'type of cognitive change'. This is meant to cover, *inter alia*, the process of *adopting* a new theory about some previously untheorized phenomenon, and the process of *replacing* one theory with another.[1] Different accounts of scientific progress will disagree on exactly what types of adoption/replacement are required for scientific progress, e.g. whether the adoption of a new theory requires coming to *know* the contents of the new theory. Here and in what follows, the term 'theory' should be interpreted very broadly, so as to count any type of scientific representation – including hypotheses, models, and natural laws – as 'theories'.

[1] It is also meant to cover other types of cognitive changes, such as discarding a (mistaken) theory, discovering a new phenomenon, and developing a new explanation for a familiar phenomenon using an extant theory. But for current purposes we can set such cases aside and focus on cases of adopting/replacing theories.

A second clarification concerns the term 'constitutes'. It is a truism that there are many ways for science to progress – even cognitively, i.e. with respect to its theories (representations). For example, there is surely a sense in which scientists make progress as they collect more evidence or develop new formalisms. These are all forms of progress… in a sense. But I say that we should distinguish these from the type of progress that occurred, for example, when J.J. Thomson's plum pudding model of the atom was replaced with Ernest Rutherford's nuclear model. The difference is that the former type of progress (e.g. collecting evidence) is progress *because and in so far as* it helps to achieve the latter type (e.g. improving atomic models). By contrast, the latter type of progress counts as progress regardless of whether it leads to some other instances of progress. To mark this distinction, I say (following Bird 2008, 280) that some improvements *promote progress*, whereas others *constitute progress*. It is the latter that accounts of scientific progress are accounts of.

A final clarification. In the question above, I use the term 'improvement' instead of 'progress' to emphasize two related points about our topic. The first is that accounts of scientific progress are not attempts to analyze the term 'scientific progress' as it is used either in common parlance or scientific practice. Even if there was no such term in our languages, there would remain the question of what types of cognitive changes we should count as improvements on what came before. So the underlying philosophical question is not about language, and certainly not about the word 'progress'. A second reason to use 'improvement' rather that 'progress' is to emphasize that accounts of scientific progress are unmistakably *normative* – not mere descriptions of scientific practice or the history of science, but partly prescriptive claims about how science ought to proceed (cf. Niiniluoto 2019, §2.2). In evaluating accounts of scientific progress, we thus need to think long and hard about whether the normative implications of each account are, all things considered, desirable.

Now, there are many accounts of scientific progress – many accounts, that is, of what type of cognitive change constitutes a scientific improvement. But four such accounts have been most prominent in the recent literature (see Niiniluoto 2019, Dellsén 2018b). *The truthlikeness account* holds that scientific progress consists in increasing the truthlikeness, i.e. the verisimilitude, of accepted theories (Popper 1963; Niiniluoto 1984, 2014). *The functional account* holds that progress consists in decreasing the number and/or importance of unsolved problems, by solving or eliminating existing problems without generating new ones (Kuhn 1970; Laudan 1977). *The* *epistemic account* holds that progress consists in accumulating knowledge in science, i.e. in adding to the stock of scientific knowledge (Bird 2007, 2016). Finally, *the noetic account* holds that scientific progress consists in increasing understanding of natural phenomena (Dellsén 2016, 2018c). For each of these accounts, there is an achievement that lies at its heart (respectively: truthlikeness, problem-solving, knowledge, understanding). It is possible, of course, to develop each of these accounts in different ways depending on precisely how one defines each type of achievement.

In this paper, I will focus on a feature of the epistemic account that distinguishes it from most versions of the other three accounts. According to epistemological orthodoxy – endorsed by proponents of the epistemic account (e.g. Bird 2007, Park 2017) – a known proposition must have a certain kind and degree of normative support, called *epistemic justification*. Roughly, epistemic justification (or simply justification) is what must be added to a true belief in order for it to constitute knowledge.[2] So, roughly speaking, the epistemic account implies that adopting or replacing a theory cannot count as a scientifically progressive unless the new theory is epistemically justified; otherwise, the new theory would fail to count as knowledge.[3] Call this *the justification requirement*.

Is epistemic justification also a requirement for progress on other accounts? Some have argued or assumed that understanding should be taken to entail epistemic justification or even knowledge (e.g., Sliwa 2015, Khalifa 2017). In my view, this is a mistake (Hills 2016; Dellsén 2017, 2018a; see also Lawler 2016). Hence, in contrast to Bangu (2015), I take it that the most plausible version of an understanding-based account does *not* require justification for progress. Similarly, although proponents of the truthlikeness account sometimes write as if justification is essential to science as a whole and therefore to scientific progress (e.g., Niiniiluoto 2014, 76; 2017, 3299-3300), this does not follow from the official statements of their accounts. Finally, the functional account clearly does not require progressive theories to be epistemically

[2] Depending on one's theory of justification, one may also take it to be necessary to add a special condition that rules out Gettier-cases. We won't be concerned with Gettier cases below, however, so I'll ignore this complication in what follows.

[3] I say 'roughly speaking' because a proponent of the epistemic account might argue that the new theory could still count as progressive if it merely *implies* a (previously unknown) proposition that becomes known. In that case, only the implied proposition needs to be epistemically justified. This maneuver arguably has problematic consequences for the epistemic account – for example, it implies that the introduction of any number of falsehoods still counts as progressive provided that a single unknown proposition becomes known in the process. For simplicity's sake, however, I do not take issue with it in what follows.

justified either. Indeed, the functional account distinguishes itself from all other accounts in not even requiring factivity for scientific progress – neither the problems nor their solutions must be grounded in reality in order for the 'solutions' to such 'problems' to count as progressive (see, e.g., Laudan 1977, 16).

It is important to understand that accounts which do not *require* justification for progress may still find an important role for the scientific practice of making observations, gathering data, presenting arguments, debating the plausibility of theories, and accepting or rejecting theories based on whether they meet certain epistemic standards. By the lights of any factive account of scientific progress, e.g. the truthlikeness account or the noetic account, these *justificatory activities*, as I shall call them, will be integral to the progress of science – not because they are *constitutive* of progress, as per the epistemic account, but because they *promote* progress. Indeed, justificatory activities promote progress to an extent that is hard to exaggerate. In their absence, scientific progress would be a matter of pure guesswork, and should occur only in those rare instances in which we happen to chance upon a correct theory. Because of justificatory activities, however, science is perhaps the most successful enterprise in the history of humankind.

So the point of disagreement between the epistemic account and other factive accounts (e.g. the noetic and truthlikeness accounts) is not about *how important justification is* to progress. Proponents of these accounts can all agree that justificatory activities are of the greatest importance to scientific progress. Rather, the difference concerns *how justification is important* to progress. On the noetic and truthlikeness accounts, its importance is *instrumental:* justification is an important means to making scientific progress. On the epistemic account, by contrast, justification is constitutive of progress: it's a necessary condition for knowledge, the accumulation of which is identified with progress.

What type of arguments might be provided for or against a justification requirement on progress? Thus far, the most prominent arguments that have in fact been put forward have tended to appeal to *intuitions* in a very direct way. In particular, Bird's influential argument for favoring his epistemic account against the truthlikeness account is that, in certain hypothetical cases, requiring justification for progress "accords with the verdict of intuition", while not doing so "conflicts with what we are intuitively inclined to say" (Bird 2007, 66).[4] A number of philosophers have contested Bird's intuitions about these cases and/or presented cases in which, it is claimed, our intuitions point in the other direction (Rowbottom 2008; Dellsén 2016). Moreover, empirical investigations into the folk concept of progress have at best delivered ambiguous results (Mizrahi and Buckwalter 2014; Rowbottom 2015, 103).

In my view, however, the most important weakness in Bird's argument is its direct appeal to our intuitive inclinations as grounds for rejecting or accepting accounts of scientific progress. In light of the normative nature of the question of scientific progress, it is more appropriate to consult our *reflective judgments*, e.g. regarding whether there are robust aspects of scientific practice and methodology that make more or less sense on one account as opposed to another. This is the approach I take in the following three sections. I will argue that there are important categories of cases in which the justification requirement (and thus the epistemic account) delivers verdicts about scientific progress that are not just counterintuitive in hypothetical cases, but also go against truisms about scientific practice, scientific methodology, and the success of science.

3. Progress and Turnover

To introduce the first problem for the justification requirement on scientific progress, consider first a well-known argument, *the pessimistic meta-induction* (see, e.g., Poincaré 1952/1905; Hesse 1976; Laudan 1981). The simplest version of this argument infers by enumerative induction from the empirical premise that most successful theories that were accepted in the past have turned out to be false, to the conclusion that currently accepted theories will probably turn out to be false as well. For our purposes, it is worth noting that if this argument were successful, it would not so much establish that current theories are in fact false (since they *might* yet be true by pure chance, for example); rather, it would establish that we are *unjustified in believing* that they are true. Current theories might *be* true, but they would not be *known* to be true.

[4] In one of Bird's cases, we are asked to consider René Blondlot's claim to have observed 'N-rays', a type of radiation supposedly similar to X-rays. N-rays do not exist, so Blondlot must have somehow hallucinated or fabricated his experimental results. It follows that Blondlot's claims about N-rays are unjustified. Now suppose N-rays did exist, so that Blondlot's claims were true by pure luck. In that case, says Bird, it is still intuitively wrong to say that Blondlot's discovery constituted progress (Bird 2007, 67).

There are various convincing responses to the pessimistic meta-induction, both to this simple form of the argument and to more sophisticated variants (e.g., Roush 2010; Fahrbach 2017). However, there is a key thought behind the pessimistic meta-induction that remains unchallenged (and rightly so), viz. that, *in principle*, a sufficiently dismal track record regarding our past efforts to theorize about some phenomenon might undermine one's justification for believing current theories. If one knows that scientists in some discipline have in the past consistently produced and accepted radically false theories about some topic, and that one's epistemic situation has not changed significantly for the better since this last occurred, then surely this would undermine one's justification for believing the discipline's current theories on the topic. After all, the disciplines's poor track record would serve as a kind of higher-order evidence that the first-order evidence in favor of the theory is in fact misleading or insufficiently probative. The upshot is that even a theory for which scientists have produced plenty of (first-order) scientific evidence might fail to be justified – either at all, or to the extent required for knowledge.

What implications does this have for the justification requirement on scientific progress? Consider a discipline whose track record thus far regarding some specific phenomenon is sufficiently poor. That is, the discipline has produced and accepted so many theories about this phenomenon that have turned out to be radically false by our current lights that its current theories about the phenomenon would fail to be epistemically justified, even in cases where the first-order evidence for its theories would otherwise make them justified. Thus, by virtue of its track record alone, the discipline would be unable at present to accumulate knowledge by adopting new theories about this phenomenon, for the justification for any such theory would immediately be undermined by the discipline's poor track record. Given the justification requirement on scientific progress, the new theory would therefore contribute nothing to scientific progress – no matter how much more accurate the new theory is, no matter how much understanding it would produce, no matter how many problems it would solve (and so on for other potential necessary conditions for scientific progress).

This implication is more than just counterintuitive. It means that scientists who are seeking to maximize their contribution to scientific progress should look backwards to the history of their discipline before deciding whether to work on one phenomenon rather than another. Specifically, they should try to ascertain whether their discipline's track record would undermine justification for future theories, including the yet-to-be-discovered theories they themselves hope to contribute to their field. These scientists should avoid studying phenomena on which past theorizing has been radically mistaken, since there would be no hope of making progress on such topics according to the justification requirement. The methodological implication of the justification requirement in these cases is thus, to put it bluntly, to avoid research on topics that would require groundbreaking research – research that goes against all previous theories about the phenomenon in question – and instead to focus on researching phenomena for which our past and current theories are already on the right track.

It is here that the normative nature of the concept of scientific progress comes to the fore. As I emphasized in the previous section, we should choose between different accounts of scientific progress based not on whether the theories or their implications accord with 'what we are intuitively inclined to say'; rather, we should consider whether such accounts agree with our reflective normative judgments. In this respect, an account of scientific progress is no different than a theory in normative ethics, which should be accepted or rejected based on whether we are prepared, on reflection, to accept its normative implications. So what is our considered normative judgment about whether our account of scientific progress ought to imply that it would be impossible for scientists to make progress regarding phenomena on which the relevant discipline's track record is sufficiently poor? Or, equivalently for our purposes, what is our considered judgment about whether progress-seeking scientists should avoid groundbreaking research of the type described above?

In my view, scientists should not avoid this type of research, and, consequently, we should conceive of scientific progress in way that doesn't require justification. On the contrary, it is precisely on the topics where we believe previous theories to be radically mistaken that we need scientists to do more research in order to replace previous theories. Indeed, it is worth noting that various major science funding agencies, such as the National Science Foundation (NSF) and the European Research Council (ERC), have recently adopted policies that are meant to steer scientists towards 'transformative' research, which is likely to disrupt existing scientific paradigms, and away from 'safe' research that merely builds upon previous theories and results (see Stanford 2019). The justification requirement on scientific progress implies, implausibly, that these policies are likely to hinder scientific progress, because the 'transformative' theories that scientists are being encouraged to develop would imply that previous theories are radically mistaken, which in turn would undermine, via the route sketched above, the justification for the newly developed theories.

4. Progress and Unification

I turn now to a second problem for the justification requirement on progress, which has to do with the subsumption of several previous theories under one 'unified' theory.

The problem I have in mind is closely analogous to the so-called *preface paradox* (Makinson 1965; see also Christensen 2004). Suppose I wrote a long book containing a number of distinct factual claims $P_1,\ldots,P_n$. I have fact-checked each claim, so I'm justified in believing each P_i. But am I justified in believing the conjunction of these claims, $(P_1\&\ldots\&P_n)$? Surely not, since that amounts to being justified in believing that my book is completely error-free (an amazing feat, which I have absolutely no reason to think I am fortunate enough to have accomplished). Indeed, it seems that I would be justified in believing that $(P_1\&\ldots\&P_n)$ is false, and that I might accordingly say or imply as much in the preface to my book ("the errors herein are all mine"). Several lessons have been drawn from this type of case. One of the least controversial such lesson is that justification is not closed under conjunction: one can be justified in believing a number of claims and yet fail to be justified in believing their conjunction (even when one is also justified in taking the latter to follow logically from the former).

This failure of justification to be closed under conjunction can be effortlessly explained on the assumption that justification requires some minimum of probability (where 'probability' may be given any standard interpretation, e.g. in terms of rational degrees of confidence). For any two propositions, P_1 and P_2, neither of which entails the other, it is a theorem of the probability axioms that the probability of $(P_1\&P_2)$ is lower than the probability of each of P_1 and P_2. *A fortiori* for longer conjunctions of non-entailing propositions. It follows that conjoining non-entailing propositions will, sooner or later, result in a conjunction whose probability is as low as you like.[5] So if being justified in believing P requires that the probability of P exceed some threshold

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[5] Well, almost: it will never get to 0 unless one of the conjuncts is a contradiction or contradicts the rest of the conjunction.

$t > 0$ (e.g. 90%), then a conjunction of justified claims may not itself be justified. In other words, justification would not be closed under conjunction. Indeed, it is not hard to see that failures of justification closure are rather commonplace on this picture, even for maximally short conjunctions (and *a fortiori* for longer conjunctions). For example, if we set the probability threshold for justification at $t = 90\%$, and assume P_1 and P_2 to be probabilistically independent, then justification fails to be closed under conjunction even when P_1 and P_2 each have 94% probability.

So much for the preface paradox. Now consider the scientific practice of subsuming theories about the same phenomenon under a 'unified' theory that entails all of the subsumed theories. The example with which I will operate here concerns various gas laws that were proposed and accepted in the 17th, 18th, and 19th centuries, relating two or more quantities of a gas:

- *Boyle's Law*, discovered in 1662, holds that for a given gas sample at a fixed temperature, pressure (P) is inversely proportional to volume (V): $P \propto 1/V$.
- *Charles's Law*, discovered around 1780, holds that in a given gas sample with fixed pressure, volume is proportional to temperature (T): $V \propto T$.
- *Avogadros's Law*, discovered in 1811, states that for fixed temperature and pressure, volume is proportional to the amount of gas molecules in the sample, measured in moles (n): $V \propto n$.
- *The Ideal Gas Law*, first formulated in 1834, subsumes all of these laws, and much else besides, under one equation: $PV = nRT$ (where R is a the universal gas constant).

Now, it is not hard to see that the Ideal Gas Law entails each of Boyle's Law, Charles's Law, and Avogadros's Law, and that none of the latter (or indeed their conjunction) entails the former. Thus it is plausible that at some point in history, e.g., just after the Ideal Gas Law was proposed in 1834, these theories constituted a case in which justification fails to be closed under conjunction. After all, each of the three subsumed laws, i.e. Boyle's, Charles's, and Avogadros's, were presumably justified at some point when the Ideal Gas Law failed to be so, for the simple reason that there are many more ways for the Ideal Gas Law to be false than for each of Boyle's Law, Charles's Law, and Avogadros's Law to be false. Put in terms of probability, the probability of the Ideal Gas Law is necessarily a great deal lower than the probability of each of the three subsumed laws.

Admittedly, whether this particular case counts as one in which justification closure fails will depend on historical details of the case that I would not presume to know for certain. Was the Ideal Gas Law already justified in 1834? And were all of Boyle's Law, Charles's Law, and Avogadros's Law definitely justified at that time? If the answer to the first question is 'yes', or if the answer to the second is 'no', then this case does not exemplify the failure of justification closure. In that case, we'd have to look elsewhere for an historical example to illustrate the point, or imagine a nearby possible world in which Boyle's, Charles's, and Avogadros's were justified at some point when the Ideal Gas Law failed to be so. No matter. The philosophical point here is that we can surely find – or, failing that, imagine – some case in which previous theories $T_1,\ldots,T_n$, which are individually justified, are subsumed under a 'unified' theory T_U, which fails to be justified due to its having a (much) lower probability than any of the previous theories $T_1,\ldots,T_n$.

The problem with all of this for the justification requirement is that, in such a case, the step from accepting each one of the subsumed theories, $T_1,\ldots,T_n$, to (also) accepting the subsuming theory, T_U, would not count as progressive – even when all theories involved would otherwise qualify for making progress. For example, according to the justification requirement, the formulation and acceptance of the Ideal Gas Law might very well (depending on the details mentioned above) not have been progressive when it was formulated in 1834, even if the discovery of each of Boyle's Law, Charles's Law, and Avogadros's Law constituted progress. This implication is hard to swallow, since the discovery of the Ideal Gas Law seems paradigmatic of scientific progress. Indeed, it seems to be precisely because the Ideal Gas Law subsumes several previously accepted gas laws that it contributes so much to progress. More generally, the justification requirement entails, implausibly, that progress-seeking scientists should avoid subsuming previous theories under a unified theory in cases where justification is not closed under conjunction. That can't be right.

5. Progress and Disagreement

A third and final problem with the idea that scientific progress requires epistemic justification concerns the relationship between progress and disagreement in science.

In recent epistemology, there has been much interest in *peer disagreement*. Two or more agents count as 'peers' in the relevant sense just in case they are (roughly) equally well informed with respect to a given proposition, and (roughly) equally competent reasoners with regard to that proposition. A much-discussed question has been how (if at all) one should modify one's beliefs upon encountering disagreement from someone one recognizes as one's epistemic peer. A bewildering number of views on this issue have been defended, most of which entail that, in one way or another, the parties to a peer disagreement should 'conciliate', i.e. move closer to the opinion(s) of those with whom they disagree. The 'should' here is *epistemic*: it concerns how an agent would have to modify their beliefs in order to ensure that they remain epistemically justified after becoming aware of the disagreement. So most of the views on offer hold that a revealed peer disagreement undermines the relevant agents' justification for their initial beliefs.

Although much of the discussion about peer disagreement appeals to idealized cases, many of the lessons from these discussions apply to real disagreements in science.[6] Most scientists working in the same field have access to roughly the same evidence (because they share their results in a systematic way), and they are roughly equally competent in reasoning from that evidence (because they are selected based on similar competencies, and receive a similar type of training). So while not all scientists within a field will be 'peers' in the strictest sense of the term, there is reason to think that what's true of disagreement among peers will largely be applicable to disagreement among scientists within the same field. And although the parties to scientific disagreements tend to be groups of multiple scientists as opposed to individual agents, this also is no obstacle to learning from the peer disagreement debate, at least not when the groups of scientists are of comparable sizes (as in a 47/53% split, for example).

Now consider a garden-variety scientific disagreement that arises and evolves over time. Initially, a theory T_1 is overwhelmingly accepted by the scientists working in the relevant field. Then, at some later time, a rival theory T_2 is proposed, where T_2 is superior to T_1 in whatever way is required for progress (e.g. by being more truthlike). Slowly but steadily, T_2 wins over the proponents of T_1; moreover, new

[6] A common complaint about the peer disagreement debate is that it deals only with a very idealized form of disagreement, so that little if anything can be learned from it about more realistic cases. This complaint is largely based on a confusion. No one is suggesting that we should simply extrapolate from idealized to realistic cases, as in some sort of enumerative induction from a single case. Rather, the point of focusing the debate on idealized cases is to home in on the factors that might be relevant to whether, and how, a disagreement undermines epistemic states such as justified belief. Once we have discovered what those factors might be in a controlled situation in which others factors have deliberately been eliminated, we can locate those factors in more realistic cases, where several other factors will be at play as well.

generations of scientists tend to favor T_2 over T_1, so that T_2 grows in popularity "one funeral at a time". Eventually, T_2 becomes overwhelmingly accepted, just as T_1 had been previously. But this process does not happen over night; it's gradual. So there is a period of time, Δt, during which proponents of T_1 and T_2 are of comparable sizes. During Δt, those on either side of the T_1/T_2 divide can look over to the other side and see that the number of fellow scientists who disagree with them is about as large as the number of those who agree.

Now consider whether proponents of either theory, T_1 or T_2, would be justified in believing their preferred theory during Δt. Without further information about the case, it's impossible to give a definitive answer. But one thing that can be said definitively is that, according to most views of peer disagreement (i.e., any conciliatory view), one of the factors that is relevant to determining whether these beliefs are justified is that there is so much disagreement within their field. Specifically, their awareness of this widespread disagreement on T_1/T_2 would undermine their justification for believing whichever of T_1 and T_2 they in fact believe.

In order to home in on how this affects scientific progress, let us consider a variation of the cases described above in which each scientist's first-order evidence for which of T_1 and T_2 they believe is just barely sufficient during Δt to make them epistemically justified (i.e. justified to the extent required for knowledge) in believing T_1/T_2. In such cases, the justification-undermining effect of the disagreement would prevent scientists from being epistemically justified in believing either of T_1 and T_2 during Δt. Of course, the T_1/T_2-disagreement's potency to block epistemic justification in this way would disappear once the disagreement abates, i.e. once T_2 starts to become significantly more popular than T_1. But for some period of time when the disagreement is sufficiently evenly split, i.e. during Δt, the relevant scientists would not be epistemically justified in their beliefs about T_1 and T_2.

Now consider what this means for scientific progress if we impose a justification requirement. If justification is required for progress, the disagreement during Δt would not just prevent scientists from being justified in their beliefs regarding T_1/T_2; it would also prevent their beliefs regarding T_1/T_2 from contributing towards scientific progress in the way they otherwise would (e.g., through constituting accumulated knowledge). Thus whereas we might have thought that the gradual replacement of T_1 by T_2 before, during, and after Δt was simply a case in which there was gradual progress as an increasing number of scientists came to accept a superior theory,[7] the justification requirement implies that the disagreement during Δt blocks any of the progress with respect to T_1/T_2 that would otherwise occur during that period. Moreover, given that scientists' beliefs regarding T_1 were (barely) epistemically justified before Δt, the justification requirement implies that there is a sudden drop in progress at the beginning of Δt. It's as if disagreement casts a paralysing spell that temporarily destroys previous progress on the topic and blocks any further progress during the period. This spell is then lifted when the disagreement has abated sufficiently so as to no longer undermine justification as it once did (see Figure 1 for a simple illustration).[8]

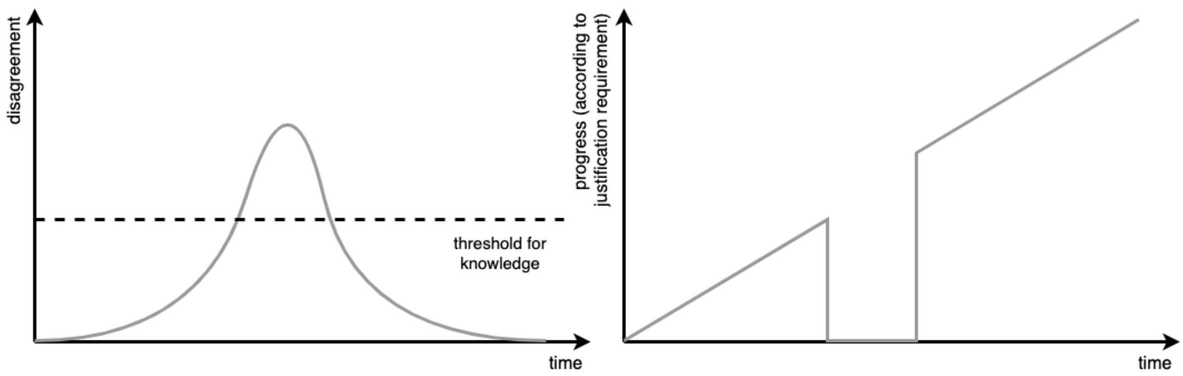

Figure 1: A simple illustration of how disagreement would temporarily block progress according to the justification requirement.

To see just how absurd these consequences of the justification requirement are, it may be helpful to apply them to an historical case. In the 18th and early 19th century, the dominant theory of the nature of light was Isaac Newton's 'corpuscular' theory, according to which lights consisted of tiny particles emitted from light sources. Newton's theory went mostly unchallenged until Augustin-Jean Fresnel's formulation of a transverse wave theory in 1815-1818, according to which light consists of waves that oscillate in a direction perpendicular to its movement. Fresnel's theory enjoyed considerable empirical success shortly after it was formulated. For example, the theory correctly predicted that a bright spot would appear at the center

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[7] I am assuming for simplicity that T_2 is superior to T_1 in other respects (e.g. by being more truthlike). If not, e.g. if T_1 is superior, then this would be a case of scientific regress, but the argument in the main text would apply *mutatis mutandis*.

[8] Note that the issue here is not the epistemic one that we wouldn't *know* – or be *justified* in our beliefs about – whether we are making progress on the relevant phenomenon during Δt. Rather, the issue is that, according to the justification requirement, there wouldn't *be* any progress on the relevant phenomenon during Δt.

of the shadow formed by shining light from a single source on an opaque disc. This and other convinced some scientists, especially Fresnel's French compatriots, that his theory was correct in the early 1820s. At the same time, many other scientists, especially Newton's British compatriots, remained skeptical of Fresnel's theory and loyal to Newton's. During the latter half of the 1820s, however, Fresnel's theory grew steadily in popularity, even in Britain, and by the 1830s there were few supporters of Newton's theory left on the scene.

For the sake of the argument, let us suppose that Fresnel's theory is superior to Newton's in whatever way is required for a replacement of the latter by the former to constitute scientific progress. Suppose also that, at some point in the 1820s, the scientific community of optical physicists was sufficiently evenly split so that none, or at least relatively few, of them would have been epistemically justified in believing either theory according to most views of peer disagreement.[9] During this period, then, the justification requirement evidently implies that there was no, or at least little, scientific progress with respect to theories of light. Progress on the topic would have been blocked by the spell of widespread disagreement about which theory is correct. Once Fresnel's theory became sufficiently popular in comparison to Newton's – in the late 1820s or early 1830s, say – this lifts the spell so that scientific progress could again go back to normal.

Of course, a proponent of the justification requirement could respond by rejecting any view in the epistemology of disagreement on which peer disagreement has the capacity to undermine epistemic justification. There are two related issues with this response. First, it ties the plausibility of the justification requirement (and thus any account of scientific progress that incorporates it) very tightly to particular, minority views in the epistemology of disagreement. Although many views reject the idea that one loses all justification upon discovering that one is in a peer disagreement, there are much fewer views on which awareness of peer disagreement does not to any extent undermine one's justification for one's initial beliefs in a way that could prevent the belief from being epistemically justified in certain cases. Second, the few views that have been proposed on which disagreement does not undermine justification at

[9] Some of these scientists might have had relevant evidence that most other scientists lacked and/or been more competent than their average colleague, in which case they might not have been sufficiently close to being peers for their justification to be undermined by the disagreement.

all are arguably quite underdeveloped.[10] Indeed, it is noteworthy that one early proponent of such a view (Kelly 2005), later argued for a view on which some conciliation is often called for in cases of peer disagreement (Kelly 2010).

Better then, I say, to simply reject the justification requirement on scientific progress. Having done so, disagreement presents no obstacle to scientific progress. In a case where T_1 gradually loses out to T_2, there will come a time at which neither proponents of T_1 nor proponents of T_2 are justified in believing their preferred theory to be true, due to the widespread disagreement between them. While this puts working scientists in an epistemological conundrum regarding what to believe and pursue, it is no hindrance to scientific progress. If the replacement of T_1 by T_2 is otherwise progressive, e.g. in virtue of increasing truthlikeness or conveying more understanding, then this is simply a case of gradual scientific progress. No spell is cast, no progress blocked.

6. Conclusion

The justification requirement on scientific progress holds that in order for the adoption of a new theory to qualify as progressive, scientists must be epistemically justified in believing the new theory. I have argued against any such requirement by considering various commonplace scientific situations in which justification is undermined or absent. To deny that there is scientific progress in these situations is to condemn much of scientific practice as non-progressive.

[10] For example, Hawthorne and Srinivasan (2013) are often mentioned as defending a view on which conciliation is not called for in peer disagreements. But Hawthorne and Srinivasan do not really defend such a view as much as they simply assume it without argument in order to explore some of its consequences.

References

Bird, Alexander. 2007. "What Is Scientific Progress?" *Nous* 41: 64-89. https://doi.org/10.1111/j.1468-0068.2007.00638.x

Bird, Alexander. 2008. "Scientific Progress as Accumulation of Knowledge: A Reply to Rowbottom." *Studies in History and Philosophy of Science* 39: 279-281. https://doi.org/10.1016/j.shpsa.2008.03.019

Bird, Alexander. 2016. "Scientific Progress." In *The Oxford Handbook in Philosophy of Science*, ed. Paul Humphreys, 544-565. Oxford: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199368815.013.29

Cevolani, Gustavo, and Luca Tambolo. 2013. "Progress as Approximation to the Truth: A Defence of the Verisimilitudinarian Approach." *Erkenntnis* 78: 921-935. https://doi.org/10.1007/s10670-012-9362-y

Christensen, David. 2004. *Putting Logic in Its Place: Formal Constraints on Rational Belief*. Oxford: Oxford University Press. https://doi.org/10.1093/0199263256.001.0001

Dellsén, Finnur. 2016. "Scientific Progress: Knowledge versus Understanding." *Studies in History and Philosophy of Science* 56: 72-83. https://doi.org/10.1016/j.shpsa.2016.01.003

Dellsén, Finnur. 2017. "Understanding Without Justification or Belief." *Ratio* 30: 239-254. https://doi.org/10.1111/rati.12134

Dellsén, Finnur. 2018a. "Deductive Cogency, Understanding, and Acceptance." *Synthese* 195: 3121-3141. https://doi.org/10.1007/s11229-017-1365-4

Dellsén, Finnur. 2018b. "Scientific Progress: Four Accounts." *Philosophy Compass* 13: e12525. https://doi.org/10.1111/phc3.12525

Dellsén, Finnur. 2018c. "Scientific Progress, Understanding, and Knowledge: Reply to Park." *Journal for General Philosophy of Science* 49: 451-459. https://doi.org/10.1007/s10838-018-9419-y

Fahrbach, Ludwig. 2017. "Scientific Revolutions and the Explosion of Scientific Evidence." *Synthese* 193: 5039-5072. https://doi.org/10.1007/s11229-016-1193-y

Hawthorne, John and Amia Srinivasan. 2013. "Disagreement Without Transparency: Some Bleak Thoughts." In *The Epistemology of Disagreement: New Essays*, ed. David Christensen and Jennifer Lackey, 9-30. New York: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199698370.003.0002

Hesse, Mary. 1976. "Truth and the Growth of Scientific Knowledge." *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association, vol. 2*, 261-280. Chicago: University of Chicago Press. https://doi.org/10.1086/psaprocbienmeetp.1976.2.192385

Hills, Alison. 2016. "Understanding Why." *Nous* 50: 661-688. https://doi.org/10.1111/nous.12092

Kelly, Thomas. 2005. "The Epistemic Significance of Disagreement." In Oxford Studies in Epistemology, vol. 1, ed. Tamar Gendler and John Hawthorne, 167-196. Oxford: Oxford University Press.

Kelly, Thomas. 2010. "Peer Disagreement and Higher Order Evidence." In *Disagreement*, ed. Richard Feldman and Ted Warfield, 111-174. New York: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199226078.003.0007

Khalifa, Kareem. 2017. *Understanding, Explanation, and Scientific Knowledge*. Cambridge: Cambridge University Press. https://doi.org/10.1017/9781108164276

Kuhn, Thomas S. 1970. *The Structure of Scientific Revolutions*, 2nd edition. Chicago: University of Chicago Press.

Laudan, Larry. 1977. *Progress and Its Problems: Towards a Theory of Scientific Growth*. London: Routledge and Kegan Paul.

Laudan, Larry. 1981. "A Confutation of Convergent Realism." *Philosophy of Science* 48: 19-49. https://doi.org/10.1086/288975

Lawler, Insa. 2016. "Reductionism about Understanding Why." *Proceedings of the Aristotelian Society* 116: 229-236. https://doi.org/10.1093/arisoc/aow007

Makinson, David C. 1965. "The Paradox of the Preface." *Analysis* 25: 205-207. https://doi.org/10.1093/analys/25.6.205

Mizrahi, Moti and Wesley Buckwalter. 2014. "The Role of Justification in the Ordinary Concept of Scientific Progress." *Journal for General Philosophy of Science* 45: 151-166. https://doi.org/10.1007/s10838-014-9243-y

Needham, Paul. 2020. *Getting to Know The World Scientifically: An Objective View*. Cham: Springer. https://doi.org/10.1007/978-3-030-40216-7

Niiniluoto, Ilka. 1984. *Is Science Progressive?* Dordrecht: D. Reidel. https://doi.org/10.1007/978-94-017-1978-0

Niiniluoto, Ilka. 2014. "Scientific Progress as Increasing Verisimilitude." *Studies in History and Philosophy of Science* 46: 72-77. https://doi.org/10.1016/j.shpsa.2014.02.002

Niiniluoto, Ilka. 2017. "Optimistic Realism about Scientific Progress." *Synthese* 194: 3291-3309. https://doi.org/10.1007/s11229-015-0974-z

Niiniluoto, Ilka. 2019. "Scientific Progress." In *Stanford Encyclopedia of Philosophy* (Winter 2019 edition), ed. Edward N. Zalta.

Park, Seungbae. 2017. "Does Scientific Progress Consist in Increasing Knowledge or Understanding?" *Journal for General Philosophy of Science* 48: 569-579. https://doi.org/10.1007/s10838-017-9363-2

Poincaré, Henri. 1905/1952. *Science and hypothesis*. Repr. New York: Dover.

Popper, Karl R. 1963. *Conjectures and Refutations: The Growth of Scientific Knowledge*. London: Hutchinson. https://doi.org/10.1063/1.3050617

Roush, Sherrilyn. 2010. "Optimism about the Pessimistic Induction." In *New Waves in Philosophy of Science*, ed. P. D. Magnus and Jacob Busch, 29-58. New York: Palgrave MacMillan. https://doi.org/10.1007/978-0-230-29719-7_3

Rowbottom, Darrell P. 2008. "N-rays and the Semantic View of Progress." *Studies in History and Philosophy of Science* 39: 277-278. https://doi.org/10.1016/j.shpsa.2008.03.010

Rowbottom, Darrell P. 2015. "Scientific Progress Without Increasing Verisimilitude: In Response to Niiniluoto." *Studies in History and Philosophy of Science* 51: 100-104. https://doi.org/10.1016/j.shpsa.2015.01.003

Sliwa, Paulina. 2015. "Understanding and Knowing." *Proceedings of the Aristotelian Society* 115: 57-74. https://doi.org/10.1111/j.1467-9264.2015.00384.x

Stanford, P. Kyle. 2019. "Unconceived Alternatives and Conservatism in Science: The Impact of Professionalization, Peer-Review, and Big Science." *Synthese* 196: 3915-3932. https://doi.org/10.1007/s11229-015-0856-4