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Realism, Progress and the Historical Turn

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Abstract The contemporary debate between scientific realism and anti-realism is conditioned by a polarity between two opposing arguments: the realist's success argument and the anti-realist's pessimistic induction. This polarity has skewed the debate away from the problem that lies at the source of the debate. From a realist point of view, the historical approach to the philosophy of science which came to the fore in the 1960s gave rise to an unsatisfactory conception of scientific progress. One of the main motivations for the scientific realist appeal to the success of science was the need to provide a substantive account of the progress of science as an increase of knowledge about the same entities as those referred to by earlier theories in the history of science. But the idea that a substantive conception of progress requires continuity of reference has faded from the contemporary debate. In this paper, I revisit the historical movement in the philosophy of science in an attempt to resuscitate the original agenda of the debate about scientific realism. I also briefly outline the way in which the realist should employ the theory of reference as the basis for a robust account of scientific progress which will satisfy realist requirements.

Keywords Scientific realism · Historical turn · Reference · Truth · Scientific progress

1 Introduction

The contemporary debate between scientific realism and anti-realism is conditioned by a polarity between two opposing arguments. At one pole, scientific realists argue that the success of science is best explained by the approximate truth and genuine reference of theories. At the other pole, anti-realists appeal to the falsity and failure of reference of

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previously successful theories as the basis for the pessimistic induction on the history of science. This polarity has skewed the debate away from the problem that lies at the source of the debate.

From a realist point of view, the historical approach to the philosophy of science which came to the fore in the 1960s gave rise to an unsatisfactory conception of scientific progress. One of the main motivations for the scientific realist appeal to the success of science was the need to provide a substantive account of the progress of science as an increase of knowledge about the same entities as those referred to by earlier theories in the history of science.[1] But the idea that a substantive conception of progress requires continuity of reference has faded from the contemporary debate.

In this paper, I revisit the historical movement in the philosophy of science in an attempt to resuscitate the original agenda of the debate about scientific realism. To this end, I focus upon the conception of scientific progress that emerges from the historical movement. The leading lights of the historical school—T.S. Kuhn, Imre Lakatos and Larry Laudan—all proposed models of scientific theory change. All three of these theorists of scientific change addressed the topic of scientific progress. But, as we shall see, none of their accounts of scientific progress can satisfy a scientific realist who seeks a robust account of such progress. For none of the accounts show how later scientific theories lead to progress in the sense of providing an increase of truths known about the same entities to which earlier theories referred.[2]

2 From the Historical Turn to Scientific Realism

As is well-known, the philosophy of science underwent a historical turn between the late 1950s and the mid 1970s. Traditional empiricist philosophy of science tended to adopt a monistic conception of scientific method, and to favour formal investigation of the relation between theory and evidence. In the 1950s, a number of factors led to a shift of focus and approach. Gestalt psychology, Wittgensteinian philosophy of language and historical studies of scientific change fostered a new understanding of science. Rather than the exercise of a fixed and universal method, science was seen as an evolving process undertaken in a variety of circumstances. The method and practice of science were seen to vary from epoch to epoch, theory to theory, perhaps even culture to culture. The language of science was subject to variation, as the concepts it embodied were refined and displaced in the course of theoretical change. Even the sensory experience of scientists seemed to depend upon the theoretical and conceptual frameworks through which scientists perceive the world.

In short, proponents of the historical philosophy of science sought to understand science as a human activity conducted in shifting historical circumstances. Science is not a mechanical rule-governed activity to be studied by formal means. It is an activity conducted by human agents situated in real historical conditions. Scientists pursue their

[1] A glance at some representative contributions to the realist literature in the 1970s and early 1980s reveals a clear concern with continuity of reference. See, for example, Newton-Smith (1981, p. 161), Putnam (1975, p. 197) and Smith (1981, pp. 2, 7).

[2] My use of the term 'entity' may suggest that the discussion is couched in terms of reference to theoretical entities which constitute objects. But the term 'entity' may be understood in a liberal manner, so that the term may apply to structures as well as objects. Thus, if, as some recent structural realists suggest, structures rather than objects exist at a fundamental level, then I would be happy for structures to count as the entities to which realistically interpreted theories refer.

scientific work in particular intellectual contexts, physical settings and social environments. In light of this, the techniques of the historian of science were to replace those of the formal logician or confirmation theorist.

The historical turn gave rise to a variety of distinctive problems and projects in the philosophy of science.[3] Of most relevance in the present context was a project initiated in T.S. Kuhn's book, *The Structure of Scientific Revolutions*. This is the project of developing a historically adequate model of scientific theory change. Kuhn sought to characterize the development of science in terms of a sequence of stages, from the emergence of paradigm-based normal science, through crisis and revolution, to the acceptance of a new paradigm and return to normal science. After Kuhn, first Imre Lakatos, and later Larry Laudan, proposed alternative models of theory change, which were intended in various ways as improvements on Kuhn's account.

The three models of science have much in common. All depict scientific activity as based on enduring theoretical structures which provide a conceptual and methodological framework for ongoing research. All three models allow a role to be played in scientific change by methodological factors of a broadly traditional nature.[4] However, methodological considerations are to be understood within the context of all-embracing change that extends beyond change of theory. In the context of such profound change, the transition between theories brings with it a new conceptual apparatus and changes to the problem-solving agenda as well as alteration in the methodology of science itself.

The historical turn in the philosophy of science provides important background to the emergence of scientific realism in its contemporary form.[5] From a realist perspective, the historical school failed to provide a satisfactory account of progress in theoretical science. For historical models of theory change fail to portray scientific progress as an increase in knowledge about a common domain of entities to which earlier theories referred, and about which later theories provide more extensive knowledge. This rationale for scientific realism has disappeared from the realist's agenda while attention has focused upon the opposition between the success argument and the pessimistic induction. In this paper, I describe those elements of historical models of theory change that underlie the problem situation out of which contemporary scientific realism emerged.

I will begin with a detailed discussion of the elements of Kuhn's theory of scientific change that are of most relevance to the question of progress (Sect. 3). I shall then provide a less detailed discussion of the relevant aspects of Lakatos's (Sect. 4) and then Laudan's (Sect. 5) models of theory change. Next I will offer some remarks about the question of whether scientific progress is cumulative or non-cumulative in nature (Sect. 6). Then I will explain how the views of progress of the historical philosophy of science fail to provide an adequate account of progress (Sect. 7). Finally, I will comment upon how this criticism of the historical turn reflects a realist standpoint in the philosophy of science, and indicate the direction in which development of a realist account of progress is to proceed (Sect. 8).

[3] Some of the major themes to emerge from the historical turn in the philosophy of science include the theory-dependence of observation, the incommensurability of theories, methodological change and the underdetermination of theory by evidence.

[4] In the case of Kuhn, of course, this was not clear until the clarification of his methodological views in the postscript to the 2nd edition of *The Structure of Scientific Revolution*s and *The Essential Tension*.

[5] This is not by any means to suggest that contemporary scientific realism emerged solely as a response to the historical turn. An equally important aspect of the emergence of scientific realism involves the rejection of the logical empiricist partial interpretation account of the meaning of theoretical terms in the late 1950s and early 1960s.

3 Paradigm Change

In *The Structure of Scientific Revolutions*, T.S. Kuhn provided an account of science according to which science as it is ordinarily practiced by scientists, "normal science", is based on a widely accepted theoretical framework which he called a "paradigm".[6] Such paradigm-based normal science is disrupted at intervals by revolutionary episodes in which the reigning paradigm is displaced by a competing candidate for paradigm. The contrast between normal and revolutionary science yields a contrast between two forms of scientific progress. In normal science, progress is largely cumulative. But progress in normal science differs markedly from the discontinuous change characteristic of scientific revolutions.

3.1 Normal Science

Progress in normal science consists in the steady growth of solutions to normal scientific puzzles. Kuhn distinguishes between empirical and theoretical puzzles. The empirical aspect of puzzle-solving may be seen from three kinds of empirical puzzle between which Kuhn distinguishes. The first kind of empirical puzzle is the determination of significant facts, e.g., stellar positions, specific gravities, wave lengths, etc. (1996, p. 25). The second is the measurement of effects predicted by paradigm, which enables comparison of paradigm with empirical data (1996, p. 26). The third is the articulation of paradigm by extending it to new phenomena. Articulation of the paradigm includes its application or extension with respect to facts to which it draws attention, such as the determination of empirical laws and precise values of constants, e.g. the gravitational constant (1996, p. 27).

In addition to empirical puzzles, normal science addresses puzzles of a theoretical nature. Theoretical puzzles divide into categories similar to the kinds of empirical puzzles that I have just described. On analogy with the first kind of empirical puzzle, Kuhn notes that predicting valuable factual information on the basis of a theory constitutes a theoretical puzzle for normal science (1996, p. 30). However, a more important kind of theoretical puzzle reflects the need to compare theory with observation. This requires that predictions be derived from theory in order that they may be tested, e.g. the implications of Newtonian dynamics with respect to gravitational attraction between planets (1996, p. 32). As for the third kind of puzzle, articulation of paradigm, Kuhn sees a close connection between empirical and theoretical aspects of such puzzles. The extension of a paradigm to novel empirical phenomena requires that parallel developments be undertaken at the theoretical level (1996, p. 33).

3.2 Scientific Revolutions

In normal science, progress consists in the cumulative solution of puzzles that arise in the context of the reigning paradigm. But paradigm-based puzzle-solving does not continue forever. The puzzle-directed activity of normal science is periodically disrupted by revolutionary upheaval in which the paradigm is rejected in favour of a competing paradigm candidate.

[6] In response to criticism, Kuhn clarified the notion of paradigm by introducing a distinction between the paradigm as disciplinary matrix and the paradigm as exemplar (Kuhn 1996, pp. 181 ff.). Much recent discussion of Kuhn emphasizes the interpretation of paradigm as exemplar. However, in the context of the models of scientific theory change proposed within the historical school, it is the more embracing disciplinary matrix version of paradigms that is of primary relevance.

Kuhn allows that the anomalies which beset the old paradigm, and give rise to revolution-inducing crisis, may be resolved by the new paradigm which takes over the field. This tends to be one of the main factors which persuades scientists to convert from one paradigm to another (1996, p. 153). A considerable amount of the problem-solving capacity of the earlier paradigm must be preserved by the new paradigm (1996, p. 169). But, despite the resolution of anomalies and significant retention of puzzle-solving capacity, it remains difficult to show that progress is the unequivocal result of paradigm change. This is because, as Kuhn says, "there are losses as well as gains in scientific revolutions" (1996, p. 167). In the transition between paradigms some of the old puzzle-solutions obtained under the previous paradigm are lost in a process that is sometimes described as 'Kuhn loss'.

The situation is aggravated by an additional factor. According to Kuhn, competing paradigms are incommensurable with each other. This is a further source of discontinuity. As characterized in *The Structure of Scientific Revolutions*, there are three components of the incommensurability of paradigms. (1) Paradigms differ with respect to the standards they employ and the problems they address. (2) Alternative paradigms employ different systems of concepts, giving rise to variation of meaning between paradigms. (3) The perceptual experience of scientists is so influenced by paradigm that adherents of competing paradigms perceive the world differently.[7] Of these three components, it is the second that is presently of most relevance. Because of profound difference in conceptual apparatus, scientific revolution is characterized by semantic discontinuity between paradigms. This affects not only the sense, but also the reference of the terms used by paradigms. The result is that paradigms may not even refer to the same things, so that there is a discontinuity of reference in the transition between paradigms.

In light of the loss of problem-solving ability and referential discontinuity between paradigms, one might well wonder whether there may be progress through scientific revolutions. Kuhn explicitly addresses this question in the last chapter of *The Structure of Scientific Revolutions*, as well as the 'Postscript—1969'. He is at pains to deny that progress in science is to be characterized in terms of truth. He suggests instead that:

> … we may… have to relinquish the notion, explicit or implicit, that changes of paradigm carry scientists and those who learn from them closer and closer to the truth… (1996, p. 170).

In the 'Postscript', Kuhn adds:

> A scientific theory is usually felt to be better than its predecessors not only in the sense that it is a better instrument for discovering and solving puzzles but also because it is somehow a better representation of what nature is really like. One often hears that successive theories grow ever closer to, or approximate more and more closely to, the truth. Apparently generalizations like that refer not to the puzzle-solutions and the concrete predictions derived from a theory but rather to its ontology, to the match, that is, between the entities with which the theory populates nature and what is "really there." Perhaps there is some other way of salvaging the notion of 'truth' for application to whole theories, but this one will not do. There is, I think, no theory-independent way to reconstruct phrases like 'really there'; the notion

[7] In his original discussion in *The Structure of Scientific Revolutions*, Kuhn presents the idea of incommensurability as involving these three dimensions. In later work, he restricted the notion of incommensurability to the semantic sphere. For further discussion, see Sankey (1993).

> of a match between the ontology of a theory and its "real" counterpart in nature now seems to me illusive in principle…. (1996, p. 206).

Thus, Kuhn denies that progress between paradigms is to be thought of in terms of successive approximation to truth. In place of a truth-oriented conception of progress, Kuhn suggests we should think in evolutionary terms.

According to this line of thought, later paradigms are further along in an evolutionary sequence than earlier paradigms. The developmental process from one paradigm to the next is, Kuhn writes:

> … a process of evolution *from* primitive beginnings – a process whose successive stages are characterized by an increasingly detailed and refined understanding of nature. But nothing that has been or will be said makes it a process of evolution *toward* anything… We are all deeply accustomed to seeing science as the one enterprise that draws constantly nearer to some goal set by nature in advance. But need there be any such goal? Can we not account for both science's existence and its success in terms of evolution from the community's state of knowledge at any given time? Does it really help to imagine that there is some one full, objective, true account of nature and that the proper measure of scientific achievement is the extent to which it brings us closer to that ultimate goal? (1996, pp. 170–171)

Kuhn does not spell out his evolutionary notion of progress in detail. But the tendency of the line of thought is clear enough. Rather than model the notion of progress on the idea of discovering an increasing amount of truth about an underlying reality, progress occurs if a later paradigm is more highly evolved than the paradigm that it replaces. This means that the later paradigm is better adapted to its environment than its predecessor in the sense that it resolves the anomalies which undermined its predecessor, while retaining much of the former paradigm's puzzle-solving ability.

4 The Methodology of Scientific Research Programmes

Generations of students have been introduced to the philosophy of science by way of the conflict between Kuhn's theory of paradigms and the falsificationist methodology proposed by Karl Popper. Where Popper taught that in science nothing should be protected from criticism, Kuhn seemed to suggest that progress is made precisely by exempting theory from refutation.

In a bold synthesis, Lakatos proposed a methodology of scientific research programmes, which combines elements of Popper's falsificationist methodology with Kuhn's model of theory change. According to Lakatos, scientific research programmes provide a basis for research over a sustained period of time in a manner analogous to a Kuhnian paradigm. The central components of a research programme form a "hard core" which is immune to change throughout the life of the programme. A "protective belt" of auxiliary hypotheses surrounds the hard core and is subject to modification in different versions of a programme. Unlike Kuhn, Lakatos does not suppose that science is dominated by a single research programme. It is instead characterized by competition between alternative programmes. Moreover, it is possible to undertake comparative evaluation of competing research programmes on an objective basis. Such comparative evaluation is based primarily on the extent to which work in a research programme proceeds in a progressive manner.

By contrast with Kuhn's evolutionary metaphor, Lakatos characterizes progress in terms of the prediction of novel facts. Progress within a research programme is defined for historically connected series of theories, i.e. theories which share the same hard core:

> Let us take a series of theories, T^1, T^2, T^3,… where each subsequent theory results from adding auxiliary clauses to (or from semantical reinterpretations of) the previous theory in order to accommodate some anomaly, each theory having at least as much content as the unrefuted content of its predecessor. Let us say that such a series of theories is *theoretically progressive (or 'constitutes a theoretically progressive problemshift')* if each new theory has some excess empirical content over its predecessor, that is, if it predicts some novel, hitherto unexpected fact. Let us say that a theoretically progressive series of theories is also *empirically progressive (or 'constitutes an empirically progressive problemshift')* if some of this excess empirical content is also corroborated, that is, if each new theory leads us to the actual discovery of some *new fact*. Finally, let us call a problemshift *progressive* if it is both theoretically and empirically progressive, and *degenerating* if it is not. (1978, pp. 33–4).

It is implicit in Lakatos's discussion of progress within a research programme that each member of a research programme grows out of an earlier member of the programme.[8] If a later theory T^2 replaces an earlier theory T^1 in the research programme, T^2 must contain all the unfalsified content of T^1. Given this, and that T^2 is only deemed progressive if it is also empirically progressive (i.e., has confirmed novel predictions), there is a clear sense in which the later theory T^2 does progress over the earlier T^1. For T^2 contains all that is correct in T^1, but it goes beyond T^1 by successfully predicting new facts which T^1 does not predict.

The condition of containment which applies to earlier and later members of the same research programme does not carry over to the transition between successive research programmes. Rival research programmes are incompatible with each other, so they do not explain phenomena in the same way. A research programme cannot contain the content of a rival programme in the sense of containing precisely the same explanations of phenomena as the rival programme contains. However, Lakatos does say that when a research programme surpasses a rival with respect to progressiveness, and as a result comes to replace it, the superseding research programme should *explain* the previous success of the programme that it replaces (1978, p. 69).

This means that if an earlier research programme successfully predicted an event, or explained some phenomenon, the later research programme should explain or predict it too. If this occurs, while the later research programme would not contain the earlier research programme, it would account for all that the earlier research programme did. As before, this seems a clear sense of progress, since the later research programme explains all that is explained by the earlier one, *and* goes beyond it by virtue of confirmed excess empirical content over its rival.

[8] I simplify somewhat for expository purposes. At this point in the text, Lakatos speaks only of a "problemshift" and "series of theories" rather than using the term 'research programme' as such. The notion of progress is defined before Lakatos introduces the idea of a research programme. But Lakatos explicitly comments that the notion of a problemshift is to be replaced by that of a research programme (1978, p. 34, fn. 2).

5 Research Traditions

In *Progress and its Problems*, Laudan proposed a model of scientific theory change that is in many respects similar to the models of Kuhn and Lakatos. He introduces the notion of a research tradition, which differs from a Lakatosian research programme primarily in virtue of having an evolving hard core.

Laudan proposes a model of scientific rationality based on the idea that science is a problem-solving enterprise. According to this model, scientists act rationally if they accept the research tradition which has the highest problem-solving effectiveness, though they may *pursue* a less effective but promising tradition which has a high rate of problem-solving success. To compute problem-solving effectiveness, Laudan introduces a taxonomy of scientific problems. *Empirical* problems are empirical facts in need of explanation. They are *unsolved* if no research tradition solves them, *solved* if solved by one or more tradition, *anomalous* for a given research tradition if unsolved by it but solved by a rival. *Conceptual* problems are either *internal* difficulties to do with imprecise or incoherent formulation of concepts, or logical inconsistency; or they are *external*, in which case they involve a conflict with well-established theories or traditions, methodological views, or non-scientific world-view.

Laudan's account of scientific progress is based on his idea of problem-solving. Progress occurs if there is an increase in the level of problem-solving between theories or research traditions. More exactly, Laudan defines problem-solving effectiveness as follows:

> …the overall problem-solving effectiveness of a theory is determined by assessing the number and importance of the empirical problems which the theory solves and deducting therefrom the number and importance of the anomalies and conceptual problems which the theory generates… (1977, p. 68).

Given that solving problems is the aim of science, progress in science is to be characterized in terms of progress towards that aim, i.e., in terms of increased problem-solving effectiveness over time. Progress between theories in a research tradition requires "an increasing degree of problem-solving effectiveness" (1977, p. 68). In the long run, a research tradition is progressive if it shows an overall increase in problem-solving effectiveness.

As for progress between research traditions, the same measure is employed. One research tradition is more progressive than another if it has a higher measure of problem-solving effectiveness than the other. And, in general, if one research tradition displaces another, the displacement constitutes progress towards the goal of maximal problem-solving if there is an increase in problem-solving effectiveness from one research tradition to the next.

For Laudan, unlike Kuhn, research traditions are not thought of as completely replacing one another in the manner of paradigms which govern periods of normal science. Thus, the question of whether there may be overall progress in science, given that it is broken by revolutionary change of paradigm, does not arise for Laudan. So the main issue with respect to progress is simply whether there is an overall increase of problem-solving effectiveness from one theory to another in a research tradition, and whether the existing research traditions continue to manifest increasing problem-solving effectiveness.

6 Cumulativity Versus Non-cumulativity

Before turning to the issue of realism, I wish to briefly comment on a theme that emerges in relation to alternative accounts of scientific progress. Some accounts are *cumulative* accounts of progress. Some are *non-cumulative* accounts.

Traditional empiricist models of science tended to adopt an incremental model of scientific growth, on which science advances by a steady build-up of factual knowledge. Such an account of progress is exemplified by the reductionist view of inter-theory relations favoured by logical positivism and empiricism.[9] Perhaps surprisingly, Karl Popper insisted that scientific progress is "conservative" despite being a process of conjectures and refutations. Popper emphasizes that a new theory must explain the successes of its predecessor (1981, p. 94).

By contrast with traditional empiricism, Kuhn and Laudan adopt non-cumulative accounts of scientific progress. Kuhn's evolutionary account of progress through scientific revolutions involves, not only a gain in problem-solving ability, but losses of some of the old problem-solving ability of the old paradigms. There are, Kuhn says, "losses as well as gains in scientific revolutions" (1996, p. 167). Given the losses, paradigm shift is non-cumulative, for to be cumulative there must be a complete retention of at least the empirical successes of earlier theories.

Laudan follows Kuhn in taking there to be both losses and gains in the transition between theories. He suggests that increased problem-solving effectiveness may occur even where there is a non-cumulative transition between theories due to Kuhn loss:

> Knowledge of the relative weight or the relative number of problems can allow us to specify those circumstances under which the growth of knowledge can be progressive even when we lose the capacity to solve certain problems. (1977, p. 150).

That is, we can judge there to be progress in respect of increased problem-solving ability, even where the ability to solve certain problems has been lost.

In contrast with Kuhn and Laudan, Lakatos adopts a cumulative account of progress. Within a research programme, there is total retention of the unfalsified content of each theory, so that all of the explanatory mechanisms are retained. When one research programme succeeds another due to overtaking it in respect of progress, it must explain the successes of the earlier programme. Both of these conditions provide for a cumulative build-up of empirical successes.

What is at issue between cumulative and non-cumulative accounts of progress? Laudan refers to R.G. Collingwood, who suggests that if there is loss rather than cumulative retention, it may be impossible to show that progress occurs.[10] This may explain the appeal of the cumulative idea of scientific progress. It is possible to determine that progress occurs if all the gains of an earlier theory are retained while further achievements are also made by a later theory. But if previous gains are lost in the transition to a later theory, it may no longer be clear whether any headway has been made. Without cumulative build-up, change

[9] This view of progress is nicely portrayed by Suppe (1977, pp. 53–56), who calls it "the thesis of development by reduction" (cf. Nagel 1961, pp. 337–345).

[10] According to R.G. Collingwood: "If thought in its first phase, after solving the initial problems of that phase, is then through solving these, brought up against others which defeat it; and if the second solves these further problems without losing its hold on the solution of the first, so that there is gain without any corresponding loss, then there is progress. And there can be progress on no other terms. If there is any loss, the problem of setting loss against gain is insoluble." (Collingwood, as quoted in Laudan 1977, p. 147.)

of theory may move one step forward and two steps back, rather than yield a forward progression.

This reason to favour a cumulative account of progress is primarily an epistemic point. It is a point about how to tell that progress has occurred in theory change. But my main concern in this paper is with the ontological and semantic dimensions of progress which turn on the continuity of reference between theories. Let us return to that issue.

7 The Failure of Historical Accounts of Progress

Let us now consider the conception of progress implicit in the models of scientific theory change proposed by the historical philosophy of science. All three of these accounts of progress lack a crucial element. They fail to mention growth in the truth known about an underlying reality.

Kuhn's talk of later paradigms occurring later in an evolutionary sequence explicitly avoids talk of progression toward the truth about the world's fundamental ontology. Lakatos's talk of corroborated excess empirical content allows for an accumulation of empirical truths known about observable phenomena. But it tells us nothing about whether such empirical progress involves progress in our knowledge about unobservable entities. Laudan's talk of increasing problem-solving effectiveness is primarily characterized in terms of empirical problems. Consequently, no conclusion may be drawn from his account of progress about whether successive theories or research traditions advance our knowledge about the directly unobservable things that underlie observable phenomena.

All three of these accounts of progress have much to be said in their favour. If later theories are more highly evolved, display increase of corroborated excess empirical content, or maximize problem-solving effectiveness, then without a doubt such theories represent significant improvements over their predecessors. Theories which exhibit these features contribute greatly to the growth of scientific knowledge.

But none of these accounts of progress provides a suitably deep sense of scientific progress. Scientific theories tell us a great deal about things that we can never observe directly by means of unaided sense perception. Old-fashioned physics told us that there were unobservable atoms and molecules that lie behind and explain observable phenomena. Later physics told us that atoms were made up of electrons, protons and neutrons, which explain the behaviour of atoms and molecules. Recent physics tells us about all sorts of other particles such as muons, mesons, neutrinos and quarks. If science is to progress in any genuine sense, then it must progress by finding out more and more about the unobservable entities like atoms and electrons and quarks that modern physics keeps telling us about. But none of the above accounts of progress provides an explicit account of progress in this sense.

All of the above accounts of progress are restricted to, or focus on, advances at the empirical level. They characterize progress in terms of empirical problem-solving, higher degrees of evolution, and excess empirical content. They tell us nothing about whether later theories provide us with more and more truths about unobservable things than earlier theories did. But no theory of progress that fails to do this can be a genuine account of progress in science. For any account of scientific progress which fails to account for increasing knowledge about unobservable reality fails to adequately account for one of the most striking and important features of theoretical change in modern science. Namely, science tells us more and more about entities that cannot be directly observed.

Instead of accounts of progress which avoid mention of truth at the theoretical level, a more robust account of the advance of theoretical knowledge of unobservable entities is needed. Such an account will require a notion of progress that is spelled out in terms of the reference on the part of the theoretical terms used by theories to theoretical entities (e.g., atoms, electrons, etc.), and an increase in truths, expressed by means of those terms, which are known about such entities. In brief, such an account of progress would have later theories providing us with more and more truths about theoretical entities than earlier theories provided us about those same entities.

8 The Standpoint of Realism

The objection that I have leveled against the account of scientific progress common to the models of Kuhn, Lakatos and Laudan is one that derives from the philosophical standpoint of scientific realism.

Scientific realists hold that science affords knowledge of a mind-independent objective reality, including those areas of reality which are not directly observable by us. Scientific realists hold that there are absolute truths or objective facts about which our theories may be right or wrong, and that with the advance of knowledge we acquire a greater and greater fund of such truths about reality. Since our theories make claims about unobservable entities which may be true or false, and since the advance of science involves an increase of truth, for the scientific realist the issue of progress in science involves the question whether there is an increase of truths known about the unobservable entities postulated by theories.

Because the objection to historical accounts of progress depends on scientific realism it may appear to beg the question against the historical philosophy of science. But it seems to me that it is at precisely this point that the debate is joined. Those who advocate a realist account of progress appeal to the success of science to defend a realist account of the progress of science. Those who favour an anti-realist account of progress employ the pessimistic induction to argue against the realist view of progress.

The focus of the realism debate should not be whether the realist's success argument is more compelling than the anti-realist's pessimistic induction. The focus should be on the prospects for a robust account of scientific progress. The realist point is just that the historical models of scientific progress fail to deliver a sufficiently robust account of theory change which reveals the advance of science to constitute substantive progress at the level of theoretical knowledge about unobservable entities. A robust account of scientific progress must reveal the advance of science as an increase in the truth known about the unobservable entities postulated by theories. Such an account requires the continuity of reference between earlier theories and their successors. It requires that later theories tell us more truths than earlier theories did about the same entities to which earlier theories referred.

It is beyond the bounds of this paper to develop a robust account of progress in detail. Still, it is important to indicate the direction in which development of such an account may proceed. Because of the crucial role that is to be played by the notion of reference in a realist account of scientific progress, considerations in the theory of reference will loom large in any such account of progress. What is required is a theory of reference according to which reference may remain constant through significant variation in the descriptive content of theories. If reference is overly sensitive to description, reference may vary dramatically with change of theory, which would undermine a realist view of theoretical progress in science.

As has been widely recognized in the literature on semantic incommensurability and reference change, a classic Fregean description theory of reference is unsuited to the task of developing a realist account of scientific theory change. Because theoretical change gives rise to significant changes in the way in which the entities of science are described, a Fregean view of reference would entail significant variation in reference with change of theory. It is for this reason that realists were initially attracted to the causal theory of reference proposed by Putnam and Kripke, on which reference is determined at an initial naming ceremony in a non-descriptive fashion. On such a causal-theoretic approach, reference is not subject to variation with change of theory because it is not determined by the descriptive content associated with the theoretical terms employed by theory. The trouble is that the causal theory in its original form provides too strong a solution to the problem of reference change in science.

For the realist, it is important to show that there may be continuity of reference in the transition between theories. At the same time, it is equally important to allow that there may on occasion be change of reference.[11] It is also necessary to allow that theoretical terms introduced in science may sometimes fail to refer (e.g. 'phlogiston', 'aether'). In order to allow the possibility of change and failure of reference, the causal theory of reference must be modified in such a way that some descriptive elements enter into the determination of reference, as well as to grant a role to linguistic activity subsequent to original term-introduction in the determination of reference. If reference is determined both by causal relation between speaker and referent and by a description of the causal role played by the referent in producing observable phenomena, then it will be possible to allow that reference may occasionally change and that there may sometimes be failure of reference. At the same time, such a causal-descriptive account of reference allows that reference may survive variation in the descriptive content of theories.[12]

The causal-descriptive view of reference allows that reference may sometimes be subject to change. But provided that theoretical change does not fundamentally alter the characterization of the causal role of key theoretical entities, reference to such entities may remain constant throughout variation of theory.[13] As a result, earlier theories may refer to

[11] The point that there appear to be genuine cases of reference change within the history of science is well made with respect to the term 'electron' by Fine (1975).

[12] For a more detailed discussion of the causal-descriptive theory of reference and the problem of the discontinuity of reference, see chapters 2 and 5 of Sankey (1994).

[13] Here it is worth briefly illustrating the point by means of a concrete example. Throughout the history of thinking about atoms there has been significant variation in how the structure of the atom is described. The ancient Greek term 'atomos' (meaning uncuttable) was originally employed because it was thought that the basic constituents of matter must not be further divisible into more basic parts. The idea that atoms are indivisible endured well into the nineteenth century. Some nineteenth century authors such as Dalton used the term 'atom' in a way that may sometimes have referred to molecules (cf. Smith 1981, p. 108). By the end of the nineteenth and early twentieth century it was increasingly recognized that atoms themselves have component parts, first electrons, and later protons and neutrons. It seems unlikely that the modern term 'atom' refers to precisely the same thing as did the ancient term 'atomos', if indeed the ancient term referred determinately to anything at all. But it does seem plausible that there has been strong referential continuity between late nineteenth century use of the term 'atom' and contemporary use of the term. There has been significant variation in the way the structure of the atom is described in successive models of the atom from the Thomson "plum pudding" model, through the Rutherford-Bohr "mini-solar system" and later quantum mechanical models of the atom. If reference is determined by description, this episode in the history of the atomic theory would be marked by radical discontinuity of reference, given the variation in the description of the structure of the atom in the successive models. But this implication may be avoided on a causal-

the same entities that later theories refer to. Thus, it is possible for there to be continuity of reference through modification of theory in the course of the history of science. On the basis of an account of reference along the lines of the causal-descriptive view outlined above, I submit that the prospects are good for a robust account of the progress of science which may satisfy the realist demand for a substantive conception of progress at the theoretical level. There is no need to concede substantial ground to the anti-realist accounts of scientific progress which derive from the historical turn.

I shall conclude with a brief recapitulation of the argument of this paper. I have considered the accounts of scientific progress which emerge from leading figures in the historical movement in the philosophy of science. As we have seen, such accounts of progress fail to show how the advance of science may constitute genuine progress at the level of the theoretical entities discovered by science. But, from a scientific realist perspective, progress requires that there be genuine growth in knowledge about the unobservable entities that have been identified by theories. Such an account of progress requires a theory of reference according to which reference is not dramatically altered by change of theory. I have suggested that a modified causal theory of reference which allows causal role description to play a role in the determination of reference is what is needed to provide the realist with a suitable account of progress. Of course, it remains to be shown in detail that such an account of reference is in fact able to provide the realist with the sort of substantive progress at the theoretical level that accords with the realist vision of science. This is a job for future work, but it is a task that some realists have begun to undertake.[14]

References

Fine, A. (1975). How to compare theories: Reference and change. *Nous, 9*, 17–32.

Kuhn, T. S. (1977). *The essential tension*. Chicago: University of Chicago Press.

Kuhn, T. S. (1996). *The structure of scientific revolutions* (3rd ed.). Chicago: University of Chicago Press.

Lakatos, I. (1978). *The methodology of scientific research programmes, philosophical papers* (Vol. I). Cambridge: Cambridge University Press.

Laudan, L. (1977). *Progress and its problems*. Berkeley: University of California Press.

Nagel, E. (1961). *The structure of science*. London: Routledge & Kegan Paul.

Newton-Smith, W. H. (1981). *The rationality of science*. London: Routledge and Kegan Paul.

Nola, R. (2008). The optimistic meta-induction and ontological continuity: The case of the electron. In L. Soler, H. Sankey, & P. Hoyningen-Huene (Eds.), *Rethinking scientific change and theory comparison: Stabilities, ruptures, incommensurabilities?* (pp. 159–202). Dordrecht: Springer.

Popper, K. (1981). The rationality of scientific revolutions. In I. Hacking (Ed.), *Scientific revolutions* (pp. 80–106). Oxford: Oxford University Press.

Footnote 13 continued
descriptive account of reference. For, despite variation in description of the structure of the atom, there has been substantial continuity at the level of the causal role assigned to atoms as the basic building blocks of ordinary matter which join together to form molecules and play a role in chemical combination. To fully develop a causal-descriptive account of the stability of reference of the term ‘atom’, the description of the causal role of the atom must be articulated in further detail. In addition, details of the causal interaction between atomic physicists and the atoms on which they conduct experiments must also be investigated.

[14] To further develop the realist view of theoretical progress, case studies must be undertaken which illustrate and vindicate that conception of progress. A good example of the sort of case study I have in mind is Robert Nola’s study of nineteenth century work on the electron (Nola 2008). Though he works with a slightly different account of reference from the causal-descriptive account I have sketched, Nola argues for continuity of reference to electrons throughout the development and modification of the theory of the electron in the nineteenth century.

Putnam, H. (1975). *Mind, language and reality, philosophical papers* (Vol. 2). Cambridge: Cambridge University Press.

Sankey, H. (1993). Kuhn's changing concept of incommensurability. *British Journal for the Philosophy of Science, 44*(4), 775–791.

Sankey, H. (1994). *The incommensurability thesis*. Aldershot: Avebury.

Smith, P. (1981). *Realism and scientific progress*. Cambridge: Cambridge University Press.

Suppe, F. (1977). *The structure of scientific theories* (2nd ed.). Urbana and Chicago: University of Illinois Press.

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