Realism, Reference, & Possible Worlds: the Approach via Modal Logic

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Introduction

This article offers a critical review of various current debates between realism and anti-realism in epistemology and philosophy of science. In particular, it focuses on the claim of some philosophers – chief among them Saul Kripke and the early Hilary Putnam – that modal logic (i.e., the branch of logic concerned with matters of necessity and possibility) provides strong support for a realist approach to these issues.

I begin by discussing Kripke's arguments for the existence of *a posteriori* necessary truths or those that have to be discovered through some process of scientific enquiry but which none the less hold as a matter of necessity in any world physically congruent with our own. This claim is backed up by Hilary Putnam's famous series of 'Twin-Earth' thought experiments designed to make the case for modal realism, that is, the idea that certain names (prototypically natural-kind terms like *gold, water, acid, lemon or tiger*) have their reference fixed across all 'possible worlds' by just what it is to be an entity of just that kind. Thus the reference-fixing may be in virtue of its molecular constitution (*water* = H_2O) or its subatomic structure (*gold* = 'the metallic element with atomic number 79'). Likewise *acids* have the property 'proton-donor' which defines their reference more precisely than earlier descriptions like 'corrosive' or 'apt to turn litmus-paper red'.

In the same way *tigers* and *lemons* are distinguished by reason of their possessing certain distinctive genetic or chromosomal features, rather than through descriptive attributes such as 'striped, carnivorous, and fleet-footed' or 'yellow of skin, with a white rind, and bitter in taste'. Those features belong to them essentially and did so even at a time when nobody possessed the relevant scientific knowledge. Their usage was therefore 'truth-tracking' or 'sensitive to future discovery', rather than failing to refer altogether or – as the rival (descriptivist) account would entail – involving so disparate a range of imputed properties that we cannot think of early users as referring to the same kind of thing. This approach also claims to resolve the problem with anomalous items such as unripe (green) and sugar-saturated lemons or fleet-footed, striped, and carnivorous creatures that just happen *not* to be tigers.

What the Kripke/Putnam approach thus provides is a means of conserving fixity of reference across large (even radical) episodes of scientific theory-change. However – I argue – this benefit is lost if one follows a thinker like David Lewis in asserting the *reality* of all those 'possible worlds' where things are conceived to differ with respect to certain distinctive (e.g., micro-structural) features that define what it is to be a thing of that kind in the world that we actually inhabit. According to Lewis, this claim is on a par with the realist view of mathematical statements (about numbers, sets, classes, etc.) as referring to a realm of abstract, mind-independent objects which are none the less real for our having no means of perceptual or epistemic access to them.

Yet the result of adopting a Lewisian modal-realist ontology is to blur certain crucial distinctions, as between the order of *a priori* or trans-world necessary (e.g., logical and mathematical) truths and those which obtain as a matter of *a posteriori* necessity in that particular world – our own – where water is H_2O, gold has the atomic number 79, tigers and lemons have a certain genetic-chromosomal structure, and so forth.

That is to say, modal 'realism' of this type entails the acceptance of a massively expanded ontology whereby – as W.V. Quine puts it – there is just no distinguishing, in point of truth, between statements which quantify over such diverse items as centaurs, Homer's gods, mathematical sets and classes, and brick houses on Elm Street. This despite Quine's outlook of radical empiricism and his well-known objections to modal logic as a source of needless philosophical confusion. My article thus puts the case for modal realism as a domain-specific approach that involves different orders of truth-claim as regards mathematics, the physical sciences, and other areas of discourse. It also points out some of the shared problems with a descriptivist approach that opens the way to a doctrine of wholesale ontological relativity across shifting scientific paradigms and a Lewis-type 'many-worlds' modal conception that likewise tends to blur such basic distinctions. I conclude that modal logic is a powerful resource in the realist's philosophical armoury but one that requires exceptionally careful handling if its application is not to produce unwanted ontological commitments.

I

Kripke is known chiefly for the arguments advanced in his book *Naming and Necessity* where he proposes a causal theory of reference as against the once prevalent descriptivist theory descending from Frege and Russell (Kripke 1980; also Frege 1952; Russell 1905). According to the latter we pick out referents (objects or persons) through a cluster of descriptive attributes which serve to specify and hence to individuate just those uniquely designated objects or persons. Thus, to repeat, people once referred to *gold* under some such description as 'yellow, ductile metal that dissolves in nitric acid', whereas now it is defined (for scientific purposes) as 'metallic element with atomic number 79'. Or again: when we refer to a historical individual such as *Aristotle* we do so by applying certain salient descriptions such as 'pupil of Plato', 'tutor of Alexander', 'author of *The Poetics*, the *Prior Analytics*, etc.'

Hence Frege's cardinal dictum that 'sense determines reference', i.e., that in so far as such proper names refer it must be in virtue of our grasping the relevant descriptive criteria. On the contrary, Kripke maintains: the reference of *gold* was fixed by an inaugural 'baptism' or act of naming, and has since held firm despite and across all subsequent changes in our knowledge concerning its nature, identifying features, physical properties, micro-structural constitution, or whatever. Otherwise – on the descriptivist theory – every time that we made a new discovery about gold we should have to say (absurdly) that 'gold is not gold', since our previous beliefs had turned out false or inadequate, and it was just those beliefs that had fixed its reference. Or again: if we discovered that Aristotle had *not* in fact been a student of Plato, tutored Alexander, authored the *Poetics*, etc., then we should have to say 'Aristotle wasn't Aristotle'. Rather, what allows us to avoid this absurd consequence is the Kripkean causal theory of naming and necessity whereby 'Aristotle' refers to just that historical individual who was so named and whose identity was fixed – necessarily so – at his

moment of conception. (More exactly: at the moment when his father's sperm fertilised his mother's egg.) So likewise: had George W. Bush not become US President as a result of the controversial 2001 election – had there been a recount of the Florida vote, let us say, and the Supreme Court not decided against it by upholding the official outcome – then he would still have been the selfsame George W. Bush despite this significant change of descriptive attribute.

In the case of natural-kind terms like *gold* the argument works in a similar way: what the term picks out is just that substance (i.e., the element with atomic number 79) which received its name through an initial act of baptism and that has always since then been designated 'gold'. Thus the term referred to the identical stuff even when nobody knew about atomic numbers and when people had to make do with rough-and ready descriptive attributes. From which it follows that they were always wrong in mistaking fool's gold (iron pyrites) for the genuine item despite its superficial resemblance. What made them wrong was (1) the necessity that 'gold' should refer to *gold* in any conceivable world where the substance thus named possessed just that kind of uniquely distinctive microstructure, and (2) the linguistic 'chain' of transmission whereby its reference had been preserved through every shift in its associated range of descriptive criteria (Kripke 1980).

On the strength of this argument Kripke advances some far-reaching proposals with regard to modal logic, that is, the branch of logic having to do with matters of possibility and necessity. In brief, he makes a case for the existence of *a posteriori* necessary truths – like those about the atomic constitution of *gold* or the genetic-chromosomal identity of *Aristotle* - which are neither analytic, i.e., true-by-definition, nor *a priori*, that is to say, self-evident to reason, but which none the less hold necessarily in any world where their referents exist or once existed. (See also Linsky [ed.] 1977; Schwartz [ed.] 1977; Wiggins 1980.) Thus gold *cannot but* be that kind of stuff in all worlds physically compatible with ours in respect of their constituent natural kinds while Aristotle *cannot but* have been just that individual in all worlds where his identity was fixed by the self-same act of conception. And of course one could multiply similar examples, such as *water* having the molecular structure H_2O just in virtue of its being water, or acids being proton-donors just in virtue of their being acids, or tigers possessing a certain chromosomal make-up since that is what constitutes the membership-condition for any creature that belongs to the species 'tiger' (Putnam 1975a, 1975b, 1975c).

Of course these criteria haven't always applied since 'water' was once defined vaguely as the kind of stuff that fell as rain, filled up lakes, was liquid under normal ambient conditions, boiled or froze at certain temperatures, possessed certain useful cleansing properties, etc. In the same way our knowledge of acids advanced from 'acid = corrosive to certain metals, sour-tasting in dilution', etc., to 'acid = having the property of turning litmus-paper red', to 'acid = proton-donor'. Nevertheless the term 'acid' may be held to have referred to the same natural kind despite and across all these changes of descriptive paradigm, just as 'tiger' has continued to pick out the same animal species whether vaguely defined as a 'large, fast-running, cat-like creature with stripes' or with reference to its chromosome structure.

In this respect – so the argument goes – such names are 'truth-tracking' or 'sensitive to future discovery' (McCulloch 1995). That is to say, their usage at any given time

might always turn out (now as in the past) to be based on a limited or partial knowledge of just what it is – scientifically speaking – that constitutes the kind in question. Very often it is a matter of superficial appearances, as in the case of 'gold = yellow, ductile metal' (which would also encompass iron pyrites) or – perhaps the most famous example – 'whale = large, water-spouting fish'. However this gives no reason to conclude (with the strong descriptivists or paradigm-relativists like Thomas Kuhn) that shifts in the range of identifying criteria from one theory or classificatory system to the next can at times be so drastic as to break the referential chain of transmission and leave us at a loss to compare theories in point of their descriptive accuracy or causal-explanatory power (Kuhn 1970; also Quine 1961a). What leads philosophers to adopt this surely desperate position – i.e., the thesis of radical 'incommensurability' between paradigms – is their acceptance of Frege's cardinal precept that 'sense determines reference' along with the idea (which Frege sharply rejected) that the sense of any given term can only be specified in relation to the entire language, discourse, or received body of knowledge within which it plays a role (Frege 1952; also Dummett 1978). Thus scientists working before and after some major episode of theory-change must be thought of quite literally as inhabiting 'different worlds', or worlds that contain a whole different range of objects, properties, causal powers, micro-structural features, and so forth.

Moreover, we cannot talk of scientific 'progress' in this regard since the very criteria for what *counts* as an advance in knowledge are themselves relative to this or that paradigm and hence incapable of adjudication from some standpoint of objective (paradigm-transcendent) truth. (For further discussion see Laudan 1977; Lipton 1993; Rescher 1979.) Besides, as Quine famously argued, observations are always to some extent 'theory-laden' and theories always 'underdetermined' by the best empirical evidence to hand (Harding [ed.] 1976). In which case scientists can always save a cherished theory by pleading observational error, perceptual distortion, the limits of precise measurement, etc., or alternatively save some striking empirical observation – where it comes into a conflict with a well-established theory – by making suitable adjustments elsewhere in the overall 'web of belief'. At the limit (as with certain well-known problems in the field of quantum mechanics) this might even entail some revision to the ground-rules of classical logic such as bivalence or excluded middle. (See Quine 1961a; also – for a range of views on this topic – Gibbins 1987; Haack 1974; Norris 2000; Putnam 1983.) However there is something decidedly suspect about an argument that leaves no room for such basic normative conceptions as those of good observational warrant or accordance with our best theoretical beliefs as judged by the standards of valid logical (e.g., hypothetico-deductive) inference.

Hence a main attraction, for some, of the Kripkean 'new' theory of reference: that it offers a means to avoid this unpalatable upshot of wholesale paradigm-relativism or 'incommensurability' across different theories, languages, or conceptual schemes. For if reference is fixed independently of any descriptive criteria that happen to apply from one to another paradigm then we can perfectly well explain how a term like 'electron', once introduced through the inaugural act of naming, continued to specify the same referent despite some otherwise radical revisions to its range of defining properties or imputed characteristics. (See especially Putnam 1978.) Thus pioneer usages – like that of J.J. Thomson – were descriptively and theoretically wide of the mark when assessed against our present (quantum-based) understanding, as indeed was Niels Bohr's 'planetary' model of electrons orbiting the nucleus before he

abandoned that model in favour of a quantum-theoretical approach (Bohr 1934, 1958). Yet it is still the case that we can speak of Thomson, Bohr and others as referring to a certain kind of subatomic entity – the *electron* – and also as having come up with different, more-or-less adequate theories and descriptions concerning it. For what the Kripkean account of reference-fixing entitles us to claim is that Thomson set this process in train through an inaugural act of naming ('let us call "electron" the kind of thing that would explain these otherwise mysterious phenomena') and that the name then stuck – referentially speaking – despite its radical redefinition with the advent of quantum mechanics.

Thus philosophy of science can be saved from its own sceptical devices by acknowledging (1) that descriptive attributes don't go all the way down, (2) that early usages are 'sensitive to future discovery', and (3) that in the case of genuine (as opposed to empty or fallacious) object-terms their reference is preserved across even the most revolutionary episodes of theory-change. That is, the term 'phlogiston' now survives as nothing more than the name for a non-existent stuff that once figured (along with 'dephlogistated air') in a false theory of combustion while the term 'oxygen' has retained its referential good standing since we have adequate grounds to suppose that oxygen really exists and provides the best explanation of just what occurs in that process. This despite the fact that Priestley and Lavoisier – proponents of the two rival theories – conducted experiments that proved each correct by his own theoretical lights and which could arguably serve (on descriptivist grounds) to support Kuhn's case for the paradigm-relative nature of scientific truth-claims. However such ideas will appear less plausible – in fact decidedly *outré* – if one adopts the alternative Kripkean approach and takes it that the reference of genuine (as distinct from factitious or illusory) natural-kind terms is truth-tracking and fixed by their referring to entities of just that sort.

Other instances are more problematic since they offer some leeway for reconstruing the object-terms or ontological commitments of an earlier theory in keeping with subsequent advances in scientific knowledge. Thus pre-Einsteinian talk about the 'ether' – the pervasive, intangible substance that was thought to explain the passage of light and other forms of electro-magnetic radiation throughout the universe – can be taken as co-referential with post- Maxwellian talk about the 'electromagnetic field'. (See especially Psillos 1999; also Aronson, Harré and Way 1994; Leplin [ed.] 1984). Although the ether was shown not to exist as a result of the Michelson-Morley experiments still there is a case (so the realist might argue) for applying this retroactive principle of charity or for treating such talk as descriptively void but referentially on the right track. And again, while Black's 'caloric' hypothesis turned out to involve a false supposition – i.e., the existence of a likewise intangible fluid medium whereby to explain thermal conductivity and related phenomena – still it can be shown to have played a crucial part in developments that led to the theory of specific heat (Psillos 1999). In these cases – the latter especially – any Kripkean approach would need to be qualified so as to incorporate at least some elements of the rival (descriptivist) account. Otherwise, of course, there could be no explaining how two distinct terms with different senses and with a role in radically different physical theories might none the less be construed as referring to 'the same' (or at least to strongly analogous) kinds of physical phenomena. Indeed some philosophers have put the case for viewing the Kripkean approach not so much as an ultimate solution to problems thrown up by the Frege-Russell approach but rather as a theory which

allows – and requires – some additional descriptivist component (Evans 1982; also Schwartz [ed.] 1977). Still they would mostly argue that Kripke's account is one that goes far toward resolving those problems and that it offers the best way forward not only for debates in philosophical semantics but also for epistemology and philosophy of science.

II

These claims are widely contested – not least by adherents to the 'old' descriptivist paradigm – but have all the same exerted a powerful influence on recent philosophical debate. In particular they have led to a revival of causal realism (i.e., the claim that certain kinds of object necessarily and of their very nature possess certain properties, dispositions, or causal powers) for which a main source is the Kripkean treatment of issues in modal logic.

Other thinkers – Putnam chief among them – have shown more willingness than Kripke himself to press the argument in this direction. Thus Putnam has proposed a number of ingenious thought-experiments designed to bring home the realist point that meanings 'just ain't in the head' (Putnam 1975a, 1975b, 1975c; also Norris 2002a). That is to say, what fixes the truth-conditions for our various statements concerning the physical world is not the range of descriptive criteria by which we pick out objects of this or that kind but rather the existence of just such objects with just such uniquely identifying structures and properties. The best-known case has to do with a space-traveller from Earth to Twin- Earth who finds, on arrival, that everything looks the same as back home, including the existence of large quantities of water which fills up the lakes, falls as rain, boils and freezes at identical temperatures, etc. The only difference is that – unbeknownst to him – Twin-Earth 'water' (as referred to by the natives) has the molecular constitution XYZ, rather than H_2O.

So when the traveller exclaims with evident delight 'Lots of water around here!' he must surely be thought to have got it wrong – to have been misled by superficial or phenomenal appearances – since the stuff in question is *not* the kind of stuff that he and other Earthians standardly (correctly) refer to as 'water'. And of course the scenario can be turned around by supposing a traveller from Twin-Earth to visit Earth and likewise misidentify Earthian 'water' as just the same stuff that exists in such abundance back home, unaware as he is – not having performed the requisite chemical analysis – that this stuff is in fact H_2O and not XYZ.

There are many variations on a kindred theme in the recent literature, some (like Putnam's) designed to refine, extend, and reinforce the basic realist point while others – as I have said – adopt a more qualified approach by attempting to accommodate certain arguments from the descriptivist quarter. Then again, philosophers like Tyler Burge have argued that there is no reason in principle to restrict the Kripke-Putnam approach to natural kinds such as tigers, acids, gold, water, or electrons (Burge 1979). For the same considerations should apply just as well to artefacts or objects that don't occur naturally but which, none the less, have their reference fixed through an inaugural act of naming and thereafter passed down through a communal 'chain' of transmission that ensures a sufficient degree of continuity despite any shifts in their range of descriptive criteria.

This is not to say – crucially – that the correct usage of such terms depends on the individual speaker's possessing an expert or scientific grasp of what it is that uniquely identifies the object concerned. Thus the traveller to Twin- Earth is deceived by appearances *whether or not* he happens to know that Earthian water has the molecular structure H_2O. What makes him wrong about its Twin-Earthian counterpart is the fact that there are some experts back home – physicists or chemists – who do possess that kind of expert knowledge and to whom the wider community defers should any question arise with regard to anomalous cases such as 'heavy water' or borderline (say, highly polluted or otherwise non-standard) samples of the kind. Putnam calls this the 'linguistic division of labour' and takes it to explain how someone – like himself – who has problems in distinguishing beech-trees from elms can none the less deploy those terms with a good degree of referential assurance (Putnam 1975a, 1975b; also 1988: 22-6). That is, any issue with regard to their correct usage could always be resolved (if need be) by appealing to the relevant specialist, i.e., arborological sources.

No doubt there is a sense in which arguments of this sort require that the basic position be modified so as to acknowledge the reference-fixing role of those various descriptive attributes or criteria that effectively decide what should count as expert opinion. All the same that position is by no means undermined since it still provides the best means of explaining how elms and beeches – or Earthian and Twin- Earth 'water' – can indeed be picked out as distinctive kinds whose salient (or kind-constitutive) features are those implicitly referred to when speakers use the terms in question. Thus Putnam's not knowing how to tell the difference between the two sorts of tree is made up for by the fact of his knowing that others know, just as – from a chronological perspective – we can claim that people were referring to such things as *gold, water, acids,* or *electrons* at a time when even the most expert sources could not have provided an adequate account of their constituent structures or properties. To this extent the 'linguistic division of labour' is the equivalent, in synchronic terms, of the idea that such early usages should properly be viewed as 'truth-tracking' or 'sensitive to future discovery' (McCulloch 1995).

What is more, according to Kripke, it is a matter of *a posteriori* necessity that this should be the case, that is, a necessary truth about *gold, water, acids,* or *electrons* that they possess just those structures or properties that they do in fact possess, whatever the range of differing descriptions applied to them since way back when the terms were first introduced (Kripke 1980). This would also apply to terms such as Twin-Earth 'water' if we suppose the possible world in question to be one where certain natural kinds do in fact (necessarily) possess a whole range of quite distinct atomic, molecular, or genetic features. However it is crucial to Kripke's argument – at least from the realist standpoint – that we have to draw a line between logically possible worlds, i.e., those that we are able to conceive or postulate without contravening some trans-world necessary axiom of logical thought, and worlds wherein the range of possible departures from our own is subject to various specified physical constraints (Bradley and Swartz 1979; Kripke 1980; Schwartz [ed.] 1977; Wiggins 1980). For without this distinction there could be no warrant for the basic Kripke-Putnam claim, i.e., that *a posteriori* truths about the way things stand with respect to natural kinds (or this-world operative laws of nature) are also necessary truths in so far as they could not be otherwise in any world physically compatible with ours.

As I have said, such arguments have not gone unchallenged by philosophers within the analytic community. They are stoutly opposed by a sceptic like W.V. Quine who regards modal logic as a needless liability, rejects all talk about 'possible worlds' as a piece of sheer metaphysical indulgence, and adopts a naturalised (physicalist) epistemology that finds no room for such extravagant ideas (Quine 1971a, 1971b; also 1969). On the other hand they are taken to the limit – and beyond – by a modal logician such as David Lewis who argues for the literal reality (as distinct from the merely hypothetical or counterfactual existence) of all those logically possible worlds that fall within the limits of rational conceivability or which don't involve any pair of contradictory propositions (Lewis 1986; also 1973). Thus, for Lewis, there is an endless plurality of worlds in which every contingent this-world truth is negated, so that (for instance) Julius Caesar didn't in fact cross the Rubicon, or kangaroos weren't in fact equipped with heavy tails which prevent their unfortunate tendency to topple forward at every step. These worlds are just as 'real' as our own but non-actual (and hence, to us, epistemically inaccessible) since they just happen not to be the world that we actually inhabit.

On this view we should think of 'actual' by analogy with deictic or token-reflexive terms like 'I', 'here', 'now', or 'today', that is say, terms which necessarily involve some reference to a given speaker at a certain time or place of enunciation. So just as there are manifold times and places that lie beyond our first-person indexical grasp so likewise there are numerous alternative worlds whose reality is in no way affected by the mere fact that they have not been actualised in our own experience or that of persons who share our particular world. To suppose otherwise – so Lewis suggests – is the kind of parochial prejudice that must ultimately lead to downright solipsism or the refusal to credit any reality other than that which we are able to cognise from our own spatiotemporally restricted viewpoint. He also points out that if we want to be realists about mathematics then we shall have to accept that there exist certain abstract objects and associated truth-values of which we can indeed have knowledge even though they belong to a realm that by very definition cannot be accessed by any quasi-perceptual means of epistemic contact. (For further discussion see Alston 1996; Hale 1987; Katz 1998; Soames 1999.) And since mathematics is the best (most secure) kind of knowledge we possess there must surely be a place for Lewis's real but non-actual worlds together with numbers, sets, classes, and other such abstract entities. Thus we should not be over-impressed by any argument on common-sense (actualist) grounds that rejects the reality of all those possible worlds and, along with them, the only conception of mathematics that doesn't reduce to some form of shifty conventionalist or fictionalist doctrine.

Lewis is a brilliantly gifted exponent of what remains – as I have argued at length elsewhere – an exorbitant and hugely implausible hypothesis backed up by all manner of ingenious argumentation (Norris 2000). It is one that has its origins in Leibniz – the progenitor of possible-worlds talk as a device for spelling out the implications of modal logic – and which might be taken to find support (albeit from an equally exorbitant quarter) in the 'many-worlds' interpretation of quantum mechanics (Leibniz 1972; Deutsch 1997; DeWitt and Graham [eds.] 1973). However Lewis-style 'realism' is a far cry from the arguments advanced by Kripke and early Putnam with regard to the fixity of reference across all worlds compatible with ours in the relevant (e.g., physical or historical) respects. That is to say, it exploits a certain strategic blurring of the Kripkean distinction between trans-world necessary truths such as

those of logic and mathematics and truths that hold good as a matter of *a posteriori* necessity, i.e., in virtue of the way things stand with regard to our actual world.

The former have to do with statements that *could not possibly* have been falsified no matter how the laws of nature lay or how events turned out in our particular world while the latter have to do with statements whose truth-value is determined – and their reference fixed – by just such intra-mundane laws and events. In short, what is distinctively *realist* about modal realism of the Kripke/Putnam type is its insistence on drawing such a line and thereby preventing the tendency of thought to stray over into worlds of counterfactual supposition which acknowledge no constraints on the capacity of reason to conjure up any range of alternative 'realities' subject only to certain basic logical axioms, e.g., that of non-contradiction. For this leads to such a downright profligate ontology – such an endless multiplicity of worlds all enjoying the same ontological status – that it tends to undermine the kinds of counterfactual-supporting argument ('had x not occurred, then neither would y; therefore x was a causal factor in y') that play a central role in scientific, historical, and other sorts of causal-explanatory reasoning (Hawthorn 1991; Mackie 1974; Salmon 1984).

Indeed there is a sense in which Lewis's extravagant hypothesis comes close to Quine's likewise extravagant doctrine of ontological relativity, that is, his idea that the objects or entities posited by different conceptual schemes are as many and various as the schemes themselves, and extend all the way from brick houses on Elm Street to numbers, sets, classes, centaurs, and Homer's gods (Quine 1961a, 1969). As I have said, Quine takes a dim view of modal logic since it seems to involve unacceptable consequences, such as that if it is a necessary truth that '9 is greater than 7' then it is also a necessary truth that 'the number of planets is greater than 7'(Quine 1971a: 20-21). Yet of course the latter is a contingent fact about the way things stand in our particular corner of the universe while the former is a truth-of-definition accordant with the rules of elementary arithmetic. In which case – he argues – we should stick to the first-order predicate calculus and eschew the kinds of misconceived modal reasoning that lead to such unfortunate (logically repugnant) results.

However this objection can be turned back – on the Kripke/Putnam modal realist account – by distinguishing the order of transworld necessity that applies to certain truths of logic and mathematics from the order of *a posteriori* necessity that applies to certain truths about the physical world that we actually inhabit. Moreover we can thereby resist Quine's conclusion that there is simply no difference, in point of 'reality', between the various sorts of object that have figured as posits in various (e.g. common-sense, mathematical, scientific, religious, or mythical) conceptual schemes (Quine 1961a). For one could argue that this pyrrhic conclusion is forced upon him – in large part – through Quine's refusal to apply just the kinds of reality-preserving modal distinction that would allow a more adequate treatment of metaphysical, ontological, and epistemological issues. And besides, his point about the number of planets – that modal locutions run into trouble when it comes to distinguishing necessary from contingent truths – is one that sits awkwardly with Quine's dependence on modal distinctions by way of enforcing just that logical point.

That is to say, there is a sense in which modal logic – contrary to received opinion – has a fair claim to be more basic to the process of rational (truth-preserving) argument than the first-order predicate calculus on which Quine supposedly builds his case. For

that case cannot hold up except on the assumption that there exist necessary truths (like those of mathematics) and contingent truths (like that concerning the number of planets) which have to be distinguished on pain of falling into gross philosophical error. Thus:

> [g]iven that logic is concerned . . . with formulating principles of valid inference and determining which propositions *imply* which, and given that the concepts of validity and implication are themselves modal concepts, it is modal logic rather than truth-functional logic which deserves to be seen as central to the science of logic itself . . . . From a philosophical point of view, it is much sounder to view modal logic as the indispensable core of logic, to view truth-functional logic as one of its fragments, and to view 'other' logics - epistemic, deontic, temporal, and the like - as accretions either upon modal logic (a fairly standard view, as it happens) or upon its truth-functional component. (Bradley and Swartz 1979: 219)

All the same these advantages are thrown away if modal realism is pushed to the point, as in Lewis's theory, where it invites the Quinean charge of sheer metaphysical extravagance by maintaining the existence of all those non-actualised but equally 'real' (since logically possible) worlds. Indeed – as I have said – this argument comes out pretty on a par with Quine's idea that what is real *just is* what is 'real' (within a given conceptual scheme) for all that we can possibly know, judge, or ascertain.

To be sure, Lewis has a strong case when he recruits mathematics in support of his modal-realist claim that there must be truths – such as those pertaining to various logically possible worlds – that go beyond anything knowable by means of perceptual acquaintance or epistemic contact. To reject this claim is to end up in the position of sceptical or anti-realist thinkers who declare that 'nothing works' in philosophy of mathematics since we can *either* have a notion of objective (recognition-transcendent) truth that places it forever beyond our epistemic reach *or else* a conception of mathematical knowledge that equates truth with our best methods of proof or verification. (See especially Benacerraf 1983; also various contributions to Benacerraf and Putnam [eds.] 1983 and Hart [ed.] 1996.) In which case we should have to conclude that there exist a great range of well-formed but as-yet unproven theorems – like Goldbach's conjecture that every number is the sum of two primes – that are neither true nor false since we lack (and might never produce) an adequate proof procedure. Or again, we should find ourselves driven to endorse the surely absurd conclusion that Fermat's Last Theorem was likewise devoid of an objective truth-value during the three centuries of intensive work before Andrew Wiles came up with his celebrated proof. More than that: we should be quite at a loss to explain just what it was that rendered previous attempts inadequate and that might yet conceivably turn out to reveal a flaw in Wiles's reasoning.

III

Of course Lewis's argument would count for nothing with those, like Michael Dummett, who take an antirealist view of mathematics and other areas of discourse (Dummett 1978, 1991). On their account there is no making sense of the claim that statements can possess an objective truth-value quite apart from our capacity to find it out by some empirical or formal method of verification.

Thus Goldbach's Conjecture – along with a great many others unproven theorems – would fall into Dummett's 'disputed class' of statements that are neither true nor false, as distinct from merely undecidable according to our best, most advanced or sophisticated proof procedures. This conclusion follows logically enough if one accepts Dummett's anti-realist case for the impossibility of recognition-transcendent truths, that is, his idea that any 'gaps in our knowledge' must entail the existence of corresponding 'gaps in reality'. Furthermore it is one that in principle applies across each and every area of discourse from mathematics, logic and the physical sciences to history and ethics. Thus it excludes any modal conception, such as Lewis's, which embraces not only a realist outlook with regard to abstract entities like those of mathematics and the objective (even if unprovable) truth-value of statements concerning them but also a belief in the reality of all those non-actual yet logically possible worlds and their various constituent features.

Now there is a lot to be said, so the realist about mathematics might feel, for Lewis's robust attitude in this respect and his insistence that if anything is to serve as a guide in such matters then it had better be our grasp of just what is required in order to make good sense of mathematical truth-claims. Yet she might well balk at the further liability introduced by Lewis's outlook of intransigent realism with regard to possible worlds and his suggestion that the case for mathematical realism stands or falls with that for the reality (as distinct from the logical conceivability) of any and every such world. Here again there is a sense, as emerged in the comparison with Quine, that by taking so extreme or ontologically profligate a view Lewis runs the risk of drowning the realist baby in the metaphysical bathwater. At any rate his version of realism is far removed from the Kripke-Putnam emphasis on distinguishing contingent from necessary truths and – among the latter – those that possess analytic (transworld) necessity from those that hold as a matter of *a posteriori* warrant. Only thus can the realist hope to produce the kind of argument that would challenge the case for antirealism advanced by thinkers like Dummett, that is to say, an approach that treats every area of discourse as having no room for truth-apt statements whose objective truth-value transcends the limits of recognition or verification.

My own view – as should be evident by now – is that realism stands in need of such defence since we shall otherwise be wholly at a loss to explain a great many aspects of everyday as well as scientific knowledge and enquiry. Anti-realists often make much of the so-called 'argument from error', i.e., the claim that we can never be justified in asserting the truth of our current-best theories when we know that by far the greater proportion of scientific 'knowledge' to date has eventually turned out false, or else been shown (like Newton's theories of space-time and gravity) to possess only a restricted scope of application. (See especially Laudan 1981.) So why should we think that our own epistemic situation is in any way different from that which has prevailed up to now? However the realist can turn this argument around by remarking (1) that any talk of past errors presupposes our possession of other, more advanced or adequate truth-standards, and (2) that the recommended attitude of due humility concerning our present state of knowledge entails the supposition that we might yet be wrong according to (what else?) objective criteria of scientific truth and falsehood.

Thus the realist case is in no way compromised – and indeed much strengthened – by renouncing any claim to what Nicholas Rescher calls 'the ontological finality of science as we have it' (Rescher 1987: 61). Moreover there is the 'no miracles' argument which holds that we should always go for the least far-fetched or credibility-straining explanation, and should hence be sceptical of any approach – like anti-realism in philosophy of science – which would make it nothing less than a miracle that erroneous ideas should somehow have produced such a wealth of accurate predictive data and successfully applied scientific results (Boyd 1984; Putnam 1975c). In which case, according to Putnam, we have good reason to believe that 'terms in a mature scientific theory typically refer' and that 'laws of a mature scientific theory are typically approximately true' (Putnam 1975c: 290). This in turn goes along with the case for 'convergent realism' or the claim that even if our best theories so far have fallen short of the truth nevertheless they are demonstrably on the right track in so far as all the evidence points toward their having picked out a range of entities (such as 'molecules', 'atoms', and 'electrons') whose role is indispensable to further research. Thus science may be taken as converging on truth at the end of enquiry to the extent that its theories are increasingly borne out by the best evidence to hand (Aronson 1989; Aronson, Harré and Way 1994; Lipton 1993).

The anti-realist might readily accept all this and yet maintain – on prudential grounds – that we had much better treat atoms and suchlike as useful posits for the sake of upholding some empirically adequate theory, rather than leap to the premature conclusion that 'atoms' actually exist (van Fraassen 1980). To which the realist will once again reply that such objections miss the point since realism in philosophy of science is itself a candidate hypothesis to be judged – like scientific theories – on the strength of its explanatory virtues or its capacity to offer a plausible account of our knowledge of the growth of knowledge. That it does so better than rival hypotheses is a claim borne out by the above-cited range of arguments plus those various considerations from modal or possible-worlds logic which, as I have suggested, provide strong support for a causal-realist approach. That is, they explain how the reference of terms (including theoretical terms or names for 'unobservables' like atoms or electrons) is preserved across sometimes quite drastic episodes of scientific paradigm-change; how knowledge accrues through the discovery of ever more detailed micro-structural or depth-explanatory attributes; how theories can turn out wrong (or only partially valid) with the advent of later, more advanced or better corroborated theories; and again – most crucially for the realist – how the truth-value of well-formed statements or hypotheses might always transcend our present best knowledge or means of verification. In short, they offer strong grounds for maintaining that the burden of proof falls squarely on the anti-realist despite the current trend toward regarding anti-realism as something like a default position in epistemology and philosophy of science (Norris 2002b).

It is unlikely that sceptics will be won over by any amount of argument along these lines, whether through scientific case-studies designed to vindicate the claim of convergent realism or through the kinds of evidence that Putnam provides with his thought-experimental variations on the theme of naming, necessity, and natural kinds. Anti-realism is a doctrine so deeply bound up with certain ruling metaphysical preconceptions – most of all in Dummett's work – that it tends to adopt an across-the-board (no matter how logically nuanced) verificationist approach that treats such issues as largely irrelevant in comparison to its major thesis.

Nevertheless – I would argue – they are of the utmost importance if we want to get straight about basic questions like the role of mathematics in the physical sciences or how it can be that so seemingly abstract a branch of enquiry could have offered so much in the way of applied theoretical, predictive, and explanatory power. Thus, in Eugene Wigner's memorable words: '[t]he miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand or deserve' (Wigner 1960: 237). To which the anti-realist will standardly respond with some version of the sceptical dilemma, i.e., that we can either have a notion of objective mathematical truth that *ipso facto* transcends the utmost capacities of human epistemic grasp or a scaled-down conception whereby nothing counts as a truth-apt mathematical statement unless it lies within the compass of our knowledge or available proof-procedures (Benacerraf 1952). Yet this is no answer to Wigner's problem except in the scientifically and philosophically disreputable sense of treating that problem as one best shelved for want of any ready solution. What modal realism seeks to provide is an answer which respects the distinctive kinds of knowledge that pertain in the formal and the physical sciences and which also takes account of their distinctive relationship to issues of objectivity and truth. To this extent it offers a welcome alternative to the kinds of blanket anti-realist doctrine that have largely dictated the agenda of recent epistemological debate.

IV

Such arguments need to be worked out in detail with respect to those specific areas of discourse – from the formal sciences (such as logic and mathematics) to the various natural-scientific disciplines – where a realist approach will necessarily involve different kinds of ontological commitment. That is to say, it will require a good deal of specific fine-tuning as regards the existence of objective truth-values and the issue as to how this claim can be squared with the possibility of our acquiring knowledge concerning them. No doubt there are deep philosophical problems here, especially – as sceptics are quick to point out – in the paradigm case of mathematics where there might seem to be a flat choice between objective or recognition-transcendent truth and knowledge as a matter of provability by the best methods to hand (Hart [ed.] 1996).

All the same the sceptic will be hard put to argue against all the evidence to date that we should take a purely nominalist, instrumentalist, or fictionalist view of mathematical statements and treat their role in the development of physical theories as a kind of lucky fluke. More plausible – as some would hold – is the case for regarding such 'abstract' entities as numbers, sets, and classes as having to do with our acquired capacity for generalisation from the everyday experience of bringing objects under this or that system of counting or group membership. (For further discussion see Kitcher 1983; Maddy 1990.) Of course it remains for the realist to explain how a conception of this kind – classically adopted by empiricists like J.S. Mill – might be reconciled with the objectivist (e.g., Platonist or Fregean) view of mathematical truth as inherently transcending the limits of human cognitive grasp. Hence, as I have said, the pyrrhic idea that quite simply 'nothing works' in philosophy of mathematics since one can *either* have a plausible epistemic account on which 'truth' lies within the scope of human knowability *or* an alethic (objectivist) account on which – as it seems – knowledge must forever fall short of objective truth.

However it remains for the anti-realist to offer some convincing account of how one can adopt the view that 'numbers don't really exist' while assenting to the proposition that 'there are two prime numbers between 11and 19'. Or again, they will have a problem in making the case that all statements about elementary particles should be viewed as nothing more than useful (instrumentally efficacious) fictions while none the less declaring with the utmost confidence that 'the charge on every electron is negative'. What is clear – despite these philosophic qualms – is that one cannot make sense of the history of the physical sciences to date except on the assumption that mathematics has played a chief role in that history and hence that there must be some intrinsic (however elusive or conceptually recalcitrant) relation between mathematical truths and truths about the physical world. Wigner gives voice to the widespread sense of bemusement in this regard when he writes that 'the enormous usefulness of mathematics in the natural sciences is something bordering on the mysterious and [. . .] there is no rational explanation for it' (Wigner 1960: 223).

However his remark is less than helpful if taken – as sceptics would readily take it – to entail that no such explanation could ever in principle be had. After all, one need not be any kind of Pythagorean mystic or subscriber to Hegel's idealist doctrine that 'the real is the rational' in order to think that mathematics must have some explicable purchase on those various physical phenomena that it is able to describe, predict, or explain with such extraordinary power and precision. In my view the Kripke- Putnam approach via modal logic and the causal theory of reference offers a means of laying such sceptical doubts to rest by meeting them point-for-point across the range of current antirealist challenges.

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