Meta-Incommensurability between Theories of Meaning: Chemical Evidence

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Attempting to compare scientific theories requires a philosophical model of meaning. Yet different scientific theories have at times—particularly in early chemistry—pre-supposed disparate theories of meaning. When two theories of meaning are incommensurable, we must say that the scientific theories that rely upon them are meta-incommensurable. Meta-incommensurability is a more profound sceptical threat to science since, unlike first-order incommensurability, it implies complete incomparability.

Meta-Incommensurability between Theories of Meaning: Chemical Evidence[1]

The incommensurability of different theories is widely held to be a serious obstacle to epistemic progress; belief in first-order incommensurability between scientific theories is often characterized as a form of skepticism that needs refuting. Theories of reference remain the best way to make sense of what incommensurability really means for scientific knowledge and, while they provide a useful philosophical tool for identifying incommensurability, this approach brings to light a new problem. A type of meta-incommensurability exists at that level—incommensurability between different theories of meaning.

This is a potential problem for many sciences and a real one for chemistry since different chemical theories may demand wholly incompatible theories of reference just to understand how each describes the world. If

1. Earlier versions of this paper were presented at the Incommensurability 50 conference at the National Taiwan University in June 2012 and at the Australasian Association of Philosophy conference at the University of Wollongong in July 2012. I would like to thank the audiences at these conferences (including Paul Hoyningen-Huene in particular) and two anonymous referees for *Perspectives on Science* for their helpful feedback. I am also grateful to Jordi Cat, William Newman, Kyle Stanford, Alex Levine, Noretta Koertge, and Robin Hendry for enlightening discussions on and around this topic.

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no common theory of meaning can be found, those scientific theories must be said to be second-order incommensurable.

This phenomenon is noteworthy for two reasons. Because recognition of meta-incommensurability allows us to say a priori that two scientific theories are first-order incommensurable. And because this second-order incommensurability is an even more profound epistemic problem since, unlike standard incommensurability, it implies that the scientific theories in question are completely incomparable at the first order.

1. Varieties of Incommensurability

Thomas Kuhn and Paul Feyerabend each claimed that rival scientific claims are not perfectly comparable (Feyerabend 1962; Kuhn [1962] 1996). They borrowed the term "incommensurable" from mathematics, where it means that two quantities have no common measure (e.g., irrational numbers and rational ones).

The idea that scientific theories may be incommensurable was stated most succinctly by Feyerabend:

> [Two theories are incommensurable if] … the main concept of the former … can neither be defined on the basis of the primitive descriptive terms of the latter, nor related to them via a correct empirical statement. (1962, p. 74)

The same notion was employed by Kuhn when he used the word "incommensurable" to explain how scientists on either side of a revolution could rationally disagree about the successes and failures of their competing positions:

> … the proponents of competing paradigms will often disagree about the list of problems that any candidate for paradigm must resolve. Their standards or their definitions of science are not the same … ([1962] 1996, p. 148)

> Within the new paradigm, old terms, concepts, and experiments fall into new relationships one with the other. The inevitable result is what we must call, though the term is not quite right, a misunderstanding between the two competing schools … ([1962] 1996, p. 149)

Many people have interpreted these claims as a form of relativism (Doppelt 1978; Siegel 1980; Sankey 2000). Kuhn, in particular, denied these charges quite vigorously (Kuhn [1973] 1977, [1983] 2000), hence it is worth noting that incommensurability of scientific theories does not mean that they cannot be compared *at all*, any more than mathematical incommensurability does (D'Agostino 2014). Sometimes it is obvious that the predictive power of one scientific theory is much better than another, namely, when the phenomena to be described are clearly defined.

W.V.O. Quine made an analogous claim about the indeterminacy of translation, asserting that multiple translations of a given sentence are always possible:

> [M]anuals for translating one language into another can be set up in divergent ways, all compatible with the totality of speech dispositions, yet incompatible with one another. In countless places they will diverge in giving, as their respective translations of a sentence of the one language, sentences of the other language which stand to each other in no plausible sort of equivalence however loose. (1960, p. 27)

The difficulty is not that the manuals are elusive; the problem is in establishing that a purported manual is completely satisfactory.

It is extremely rare to see anything that looks like an explicit translation manual between scientific theories. But Quine's solution resembles the actual practices of scientists far more than any translation manual could. Quine suggests that we "need [a] *background language* to regress into. The background language gives the query sense, if only relative sense; sense relative in turn to it, this background language" (1969, p. 49). The background language need not be formal, the regress may be launched simply by asking, 'In what sense?' of the term.

The concepts of incommensurability and indeterminacy of translation do differ.[2] Kuhn claims that a faithful translation is *a fortiori* impossible because meaning cannot be fully preserved. Conversely, Quine denies that there is any objectively true meaning "beyond what is to be gleaned from overt behavior in observable circumstances" (Quine 1987, p. 5). This indeterminacy is for Quine a choice between equally accurate translations, since many sentences may be consistent with the gestures and utterances to be translated.

What Quine suggests we step back into is another natural language, spoken by all those trying to communicate. (This is natural for Quine, since he believes that reference is tantamount to usage.) Any attempt to overcome incommensurability through the creation of a translation manual by comparing theories point by point assumes that the sentences to be translated have a meaning that one may succeed or fail to fully communicate. That is, attempts at commensuration of scientific theories amount to

2. I owe the following distinction to Sankey (1991a) and am grateful to an anonymous reviewer for bringing this article to my attention.

a version of Quine's regress into a background language where the background language employed is a philosophical theory of meaning.[3]

This paper argues that one reason such an attempt to commensurate theories in this way might fail is an inability to find an appropriate background language. Being aware that not all epistemic agents speak the same language, it is unsurprising that there may not always be a common background language to regress into. Similarly, we should not suppose that regress to a common theory of meaning will always be possible.

To appropriate Quine's suggestion in order to evaluate the commensurability of scientific theories, there is just one auxiliary assumption necessary: When we treat scientists as epistemic agents, we must take their statements to have meanings that are not accidental. That is to say, in order to apply his maneuver to attempt a solution to incommensurability, we must deny Quine's deliberate conflation of meaning with reference and attribute a semantic model of meaning to scientists. I shall argue that scientists are sophisticated epistemic agents and, as such, we should not resort to non-semantic models of denotation, which would be to give up on meaningful understanding of any scientific theory not our own.

2. Direct Reference

In order to understand the problems involved with scientists trying to communicate across theoretical divisions, we need to first have a theory of just what is happening when each of them tries to communicate *within* their paradigm, only then can we say whether or not communication can succeed across significant barriers.

It is widely supposed that science deals with natural kinds as its stock-in-trade. This assumption is well supported for the modern physical sciences. Unlike certain theoretical abstractions, for a natural kind we admit that, "the properties which distinguish it do not grow out of one another, and cannot therefore be set forth in words, even by implication, otherwise than by enumerating them all: and all are not known, nor are ever likely to be so" (Mill [1872] 1974, bk 1, ch. VIII, § 4).

Hilary Putnam used the baptism of natural kinds as part of his theory of meaning (Putnam 1973, 1975, [1970] 1975); he explains how lay speakers' connection to the natural kind is a causal one:

> … we assign to the tokens of a name that I utter whatever referent we assign to the tokens of the same name uttered by the person from

3. In most cases it has been a causal theory of reference (Kitcher 1978; Nola 1980; Kitcher 1982; Kuhn [1982] 2000; Sankey 1990, 1991b; Lewowicz 2011). The cogency of this approach has already been called into question for both causal and descriptive theories of meaning (Bishop and Stich 1998); see below, §6.

> whom I acquired the name (so that the reference is transmitted from speaker to speaker, starting from the speakers who were present at the "naming ceremony," even though no fixed description is transmitted) … (1975, p. 246)

Linguistic "labor" is divided between experts and laypersons, where experts do have an empirical method of identifying the natural kind.

Yet very few members of the linguistic community have direct causal access to the kind, nor even epistemic access to the full concept:

> Today it is obviously necessary for every speaker to be able to recognize water (reliably under normal conditions), and probably every adult speaker even knows the necessary and sufficient condition "water is H_2O"… (Putnam 1975, p. 228)… this does *not* mean that knowledge of the fact that water is H_2O is being imputed to the individual speaker or even to society. It means that (*we* say) the extension of the term "water" as *they* (the speakers in question) use it is *in fact* H_2O. (Putnam 1975, p. 269)

So, while this is certainly a causal connection, for most speakers of the language these are social causes only—reference borrowing.

It is important to note here that it is crucial that causal theories of reference use natural kind terms when describing the entities of scientific theories. It might be suggested that a non-kind structure could be compatible with Putnam's criterion whereby an expert must be able to distinguish one substance from other superficially similar ones. This is not what Putnam had in mind, since his example of twin-water is clearly about two different natural kinds. Moreover, Putnam also incorporates ostension and the causal chain back to a baptism event as necessary components of the concept. Since Putnam says explicitly that the "stereotype" of a kind used by lay speakers is not the whole concept, the only way for the causal chain to work is if lay speakers are referring to tokens of the type denoted by experts (lay speakers' intensions would not suffice).

In the 1770s and 1780s massive changes took place in French chemistry making it the one period in the history of science when baptism of natural kinds really happened. Up until the generation immediately preceding the Chemical Revolution, chemists (particularly in France) had continued to pay lip-service to the Aristotelian elements while building their systems on more tangible chemical agents.

The Chemical Revolution axiomatized this expectation that the chemist who identifies an element must have a causal relation to it, through laboratory analysis. In the preface to his famous textbook, Lavoisier writes:

> … if we apply the term *elements* or *principles of bodies,* to express our idea of the last point that analysis is capable of reaching, then all the

> substances that we have not yet been able to decompose are for us elements. ([1789] 1864, p. 7)[4]

With Lavoisier's definition in place, a chemist who successfully decomposes a substance previously believed to be simple will baptize any new natural kinds. That is to say, reference can only be fixed *a posteriori* by failing to decompose the substance further. Furthermore, the Chemical Revolution was an era of renewal with respect to reference fixing; it was the first time that causal access to elements was assumed. Lavoisier and Guyton's team coined natural kind terms and rebaptized known substances, using the new systematic names for compounds and—more importantly—using the names of elements to denote natural kinds.

The style of reference borrowing introduced was also quite Putnamian. By communicating her findings with her peers, a chemist who succeeds in decomposing a substance into new, simpler components forges a causal chain that transforms the chemical community into a linguistic community for the new natural kind.[5] Thus, by giving an empirico-pragmatic definition of an element together with a system of nomenclature, Lavoisier's *Elements of Chemistry* enabled all chemists to act as Putnamian experts:

> … only a few adult speakers could distinguish water from liquids which superficially resembled water. In case of doubt, other speakers would rely on the judgement of these "expert" speakers. (Putnam 1975, p. 228)

Robin Hendry argues that Lavoisier was invoking a specifically Lockean theory of denotation, wherein a minimal description must be given alongside ostension (2005, 2010).[6] The presence or absence of supplementary

4. All translations of Lavoisier are my own.

5. The social structures necessary for this Putnamian style of reference borrowing were already in place well before the Chemical Revolution ensured that reference fixing applied to natural kinds. Learned societies (e.g. the Royal Academy of Sciences of Paris and the Royal Society of London) made reference borrowing quite efficient with their journals and corresponding memberships. But this was not always the case: throughout the Middle Ages most alchemical texts were written in a type of code based on mythological metaphors that served to limit the size of the alchemical community to a few meritorious adepts, a tradition continued by a few chemists as late as the 1660s (Newman 1996).

6. This is not implausible since it is well known that Lavoisier was influenced by the *abbé* de Condillac, himself a devotee of Locke (Albury 1972; Bensaude-Vincent 2008) and this does seem a fair characterization of Lavoisier's aims early in his career when refuting phlogiston theory. Indeed, even at the peak of his success Lavoisier says, "the idea must depict the fact" (Guyton de Morveau et al. 1787, p. 13). Yet his aims at that point were to create a language that would serve as an "analytic technique" and avoid giving false

descriptions need not concern us here since two different natural-kind-based theories of reference will normally be commensurable, i.e. the scientific theories invoking these rather similar theories will be meta-commensurable (see below, §5).

3. Descriptive Theories of Reference

Direct reference theories like Putnam's are not the only approach to meaning. Scientists denote the furniture of the world—they mean the things they say—in different ways. The history of science bears this out and we need different styles of reference to make sense of the diversity of styles of human understanding.

The other major approach to understanding reference is the definite description model, favored by Gottlob Frege and Bertrand Russell. It works by parsing complex propositions into three more precise and transparent ones, for example:

"The father of Charles II was executed" becomes

- There exists some *x* such that *x* was the father of Charles II
- This *x* was executed
- There is only one such *x* (Paraphrase of Russell 1905, p. 482)

Each of these claims can then be assessed separately for its truth or falsity.

The fact that it allows us to make sense of entities that we no longer believe exist makes the definite description model of denotation particularly useful in the history of science. By setting aside the fact that the scientists of that period were mistaken when they asserted that entities such as the luminiferous aether existed, the descriptivist model allows philosophers and historians to appreciate the internal coherence of an antiquated science. Definite descriptions are highly flexible in that they denote whatever fits the description, if anything. But the lack of rigid designators in this approach makes definite descriptions antithetical to proper names and natural kind terms. There is no need for a baptism moment (even metaphorically) as it is the semantic value of the description that does the reference fixing.

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impressions, that is to show how the new chemistry should use nomenclature to express the relationship between compounds and their constituent parts. Nevertheless, Lavoisier's shift towards Greek names (e.g., "the matter of heat and of fire" became *caloric* under the new nomenclature and, well before Lavoisier's alliance with Guyton, "vital air" became *oxygen*) suggests that he was relatively unconcerned with the transparency of the particular names of simple substances by the later part of his career. Whatever the case may be, pinpointing every aspect of Lavoisier's practice is not necessary, since my thesis rests only on the claim that by his generation chemists were using a natural-kind-based theory of reference.

Furthermore, the evidence suggests that this was the theory of reference used up until the early modern period, especially in chemistry. The definite description model works surprisingly well for certain chemical entities that do not lend themselves to a natural kinds interpretation.

Aristotle's four elements are in a sense defined by their characteristic properties. He recognizes that this could lead to some confusion with the everyday substances that go by the same names and explains what he really means:

> The simple bodies are indeed similar in nature to them, but not identical with them [the elements]. Thus the simple body corresponding to fire is fire-like, not fire; that which corresponds to air is air-like; and so on with the rest of them. (1991, 330b22f)

The same goes for alchemy. Paracelsus famously developed a system where chemical properties were reducible to a combination of three principles—mercury, sulphur and salt; the principles of fluidity, inflammability and solidity respectively. Although the mercury principle was named after the liquid metal, the *principle* is a theoretical abstraction. This principle is often described as "sophic" mercury to distinguish it from ordinary quicksilver; likewise sophic salt is not the same as the condiment and sophic sulphur is something far less tangible than common brimstone.

Natural kinds are types, no more or less than the collection of all their tokens. Conversely, principles are "ideal substances, real in the sense that they existed in matter, but not real in the sense that they could be handled and observed" (Boas 1958, p. 86). Because all these principles are more like forms than like everyday materials, the definite description model just works. If we take the claim "The sulphur principle is found plentifully in metals," we get:

- There exists an x such that x is the sulphur principle
- This same x is found plentifully in metals
- There is only one such x

This is a far more faithful reading of what these early-modern chemists believed they were dealing with than any model involving natural kinds could hope to provide.[7]

7. Imposing a Russellian order in this way can be very helpful, since mediaeval alchemy is notoriously obscure. Indeed, it is unclear whether Paracelsus and his followers would say that their principles were more like the substantial forms in Aristotle's hylomorphic view or more like an *eidos* in Plato's transcendental realm. Traditionally, historians of chemistry have supposed the former (Boas 1958, p. 86) but recently Ursula Klein has argued for the latter (Klein and Lefèvre 2007); Klein's interpretation is not uncontroversial, cf. Newman 2008. If the Platonic intention is correct, applying the Russellian model of denotation

4. Changing Conception of Elements

It may be worth looking for translation manuals between those theories that use the same theory of reference. The fact that most alchemists and early-modern chemists continued to pay lip-service to Aristotle's elements while using chemical principles suggests that they believed their theories to be compatible with Aristotelian natural philosophy. Paracelsus' sophic mercury, sulphur and salt are defined by the properties of fluidity, inflammability and solidity in much the same way that Aristotle's elements were defined by their qualities. Hence it comes as no surprise that alchemical theorists would try to show how these principles could be (theoretically) reduced to the Aristotelian elements. It is not necessary to believe that any commensuration schema would ultimately be successful in order to see that this approach is a priori plausible for the theories in question. In the case of competing systems of hypostatical principles we do need to work through the steps to see if they are commensurable as scientific theories because we cannot say a priori that they are not. They are commensurable at the meta-level because they use the same theory of reference.

Lavoisier takes an ostensibly sympathetic tone in his "Reflections on Phlogiston" when he says of G.E. Stahl's phlogiston theory of combustion—"Indeed, nothing was more natural than to say that combustible bodies inflame because they contain an inflammable principle" (Lavoisier [1783] 1862, p. 624). But he is actually attacking Stahl's antiquated theory of reference—what Lavoisier really wants is for his audience to see phlogiston as a concept just as hollow as the "dormitive virtue" that Molière famously mocked for being true *sui generis*.[8] If one were to interpret terms like "dormitive virtue" through a causal theory of reference, both reference fixing and reference borrowing would have to take place without a real act of ostension. This would be next to useless since it would not aid scientists in gathering information about the many other properties of the natural kind and further empirical investigation would be necessary to show that a single natural kind was responsible for the phenomenon in question.[9] More to the point, while we might admit that the term "dormitive virtue" can be taken to *denote* the

highlights a significant metaphysical difference between hypostatical principles and natural kinds. The third point that comes out of a definite description is not all that interesting when it says, "Charles II had only one father" or even "There is only one present King of France." But for chemical principles this does more work: instances of a chemical principle are, on this reading, identical.

8. Molière's *The Imaginary Invalid* suggests that Aristotelians fail to explain anything when they ascribe opium's ability to put people to sleep to its possessing a *vertus dormitiva* (1673, troisième intermède).

9. Lavoisier applied the causal theory of reference to chemical entities that were given more descriptive names earlier in his career, which turned out not to refer in the way the

morphine contained in opium, that is not the *meaning* of the term. To use a semantic theory of meaning in such as way would be a misuse.

5. Competing Theories of Meaning

Different theories of meaning can themselves be incommensurable. Since scientific theories employing disparate theories of meaning have no common measure, they can never be first-order commensurable and are furthermore completely incomparable in meaning.

It might be objected that it is the goal of a theory of reference to account for the denotations of all rational agents. The theory of definite descriptions and the causal theory are the two best established accounts of meaning but we have seen that neither is quite comprehensive. In recent years alternative theories of reference have been suggested that attempt to incorporate the strengths of each of these disparate approaches in a single theory (Sankey 1994, §2.6 "A Role for Descriptions"; Psillos 1999, ch.12; Soames 2002). But this is beside the point: even if one were to believe that a particular theory of reference were far and away superior to all others, this superiority can only lie in such virtues of the theory as clarity and robustness. One must not be tempted to say that a particularly unambiguous and elegant theory of reference is the one correct model of *meaning*. We must take a stronger intentional stance towards epistemic agents by admitting that the meanings of their utterances may take different forms, for example if a scientist's metaphysical views lead her to describe substances in terms of principles, a natural-kind-based theory is not the way to interpret the meaning of her statements.

Let us suppose that Bertrand Russell extended his model of denotation to substances as alchemists did. Russell's statements about water made here on Earth would have exactly the same extension as those made by Hilary Putnam. On the other hand, if these two philosophers were to travel together to Twin Earth, we would need to take their distinct theories of meaning into account before we could say whether any of their statements are true or false. Because Putnam means H_2O when he says "water," upon his arrival on Twin Earth his utterances of "Water is H_2O" would still be true, yet his observation that "That is water" would be false (Putnam 1975, p. 223f). Conversely, when Russell says "water," he means *the colorless, tasteless liquid that fills oceans, lakes and rivers (in varying degrees of purity)*. Thus all Russell's statements that

name suggested. For example, oxygen was first conceived as the principle of acidity; now we know that the natural kind baptized "oxygen" by Lavoisier is not the cause of acidity in general (and the most general theory of acidity we currently have invokes pairs of electrons, not any natural kind). For this reason Robin Hendry suggests that we describe such concepts as "chemical syndromes" (2005, p. 34).

include "This is water" are true, whereas if he were to muse that "All water is H_2O" while on Twin Earth, that would be false according to his meaning.

When we consider the descriptive theories of reference laid out by Frege and Russell, we find that they are readily inter-translatable. Likewise, Putnam's model is similar enough to Kripke's for them to be often conflated.[10] Thus we can distinguish two "meaning paradigms"—definite description and direct reference. Causal direct reference theories can only make sense of scientific theories that employ natural kind terms.[11] Even highly technical and sophisticated versions are based on similar assumptions[12] do not allow for denotation of transcendental forms and their participants. Hence definite descriptions are how we should understand most theoretical entities belonging to scientific theories that do not invoke natural kinds, especially when they are characterized as universal principles.

These theories of meaning are incommensurable because natural kind terms (and proper names) are direct designators; these are fundamentally different from definite descriptions—different kinds of concept, not merely different in scope or degree. If one were to compare two purely extensional theories of reference[13], one might well try to commensurate their first-order subsidiaries by comparing the entities in the world that they purport to denote. Yet all the theories that concern us here are semantic theories, theories of meaning. One might *attempt* something similar by interpreting the meaning of a common word, such as "water," first with a natural-kind-based theory by counting out all the tokens of H_2O in the world, then with a descriptive theory by noting the existence of all bodies sufficiently watery to deserve the name. No matter how great an overlap one found with such an approach, this would not be a way to commensurate these theories of meaning, since in both cases one neglects the *sense* of the word.[14] Furthermore, there

10. E.g. (Nola 1980; Read and Sharrock 2002); for the distinction, see (Putnam 1990; Hacking 2007; Hendry 2010).

11. That is to say, when applied to the natural sciences. Certainly, Kripke's model is designed to work just as well for proper nouns and Ian Hacking has developed a theory of "human kinds" for the social sciences (Hacking 1995).

12. E.g., the notion of partial denotation allows a single term to refer to multiple natural kinds (Field 1973; McLeish 2006).

As it happens, we do need this sort of maneuver to maintain a compatibility between Lavoisier's pragmatic stance towards elements and treating them as natural kinds, since many of those substances were later decomposed, e.g. the boracic radical was shown to be a compound of boron and oxygen.

13. E.g., Mill [1872] 1974, bk 1, ch. II, §5, or more recently Quine 1987, p. 5.

14. Philip Kitcher's model suggests that a context-sensitive theory of reference would allow us to specify a set of entities such that each token of a term refers to one member of the set (even when it is uncertain which member of the set is being indicated) (1978, p. 527). But for this approach to make any sense, all members of that set must be the same

is no way (apart from approximation) to find an equivalent between tokens of a type and participants in a form.

Once we recognize this meta-incommensurability[15], it becomes clear that it is a priori impossible for a scientific theory relying upon definite descriptions to be commensurable with one using natural kinds. This is necessarily so, since the aim of both theories of reference is to provide an account of sense or intension and they do so in fundamentally different ways. The possibility that the extension of Lavoisier's simple substance *sulphur* might coincide with Paracelsus' *sulphur* principle, for example, is irrelevant to questions of meaning.

Like other forms of incommensurability, incommensurability between theories of reference does not imply that these theories cannot be compared at all. But, if theories of reference are our only means of cashing out the true meaning of the scientific theories' claims about the world (or at least about certain entities, such as natural kinds), then second-order incommensurability does imply a fortiori complete incomparability of those scientific theories.

A major assumption of the present argument has been that scientists know what they mean; this implies the possibility that different scientists use (or in the past have used) different models of reference. This can be true in two connected ways: The sorts of entities their scientific theories invoke might be incompatible with a certain theory of meaning. Thus, simply by using a particular scientific theory, the scientist commits herself to a particular theory of reference, whether wittingly or not.

Or, purely intensionally, a scientist would normally have definite ideas about what would count as a real-world instance of one of her theoretical entities. This may be incompatible with certain theories of meaning. The reference-theoretical commitments of practicing scientists are rarely explicit, so I do not mean to suggest that their scientific works contain fully fleshed-out meta-theories of meaning. Scientists need not be part-time philosophers but we might hope that a scientist, beyond merely using technical terms correctly, could explicate the meanings of her claims by specifying what they do and do not entail (through Socratic dialogue with a philosopher, if

kind of thing, e.g. persons or natural kinds. To throw disparate entities into the same disjunction (e.g., allowing that "mercury" could refer to common quicksilver or the hypostatical principle of metallicity) might preserve the extension of a term across scientific revolutions but such a solution would fail to preserve the sense of the word.

15. Although we do not use the term in the same way, I believe the phenomenon I describe here is on the same level as the notion of meta-incommensurability that Eric Oberheim and Paul Hoyningen-Huene have already described (see below, §6). My claims here are parallel to and completely independent from theirs, so I do not shy away from using the same word.

necessary). Or, at the very least we should hope that a scientist could identify an alternative theory of reference as not what she means when she talks about the world.[16]

6. Scepticism and Progress

While meta-incommensurability is a greater epistemic threat than traditional first-order incommensurability, examining the relationship between theories within a given model of reference can give us increased confidence in the potential for diachronic commensurability.

Meta-incommensurability does not imply that theories of reference cannot be compared; we can give reasons why invoking natural kinds is a better way to undertake certain sciences than Platonic forms. In practice, it could turn out that many modern scientific researchers cannot give even minimally coherent explanations of what they mean when they use certain natural kind terms. This would be a worry but not devastating for those using a Putnamian causal theory, so long as they could point us to an expert in their field who could. This would show that they are participating in a linguistic community where these terms do have meaning. Perhaps the worst case scenario would be if the originator of the new theory were the only one who says something explicit about how these new terms mean what they mean (rather than just providing a set of examples or a method of verification). The history of science sometimes looks like this but plenty of scientists are more than minimally reflective. They need not even have come up with the theory of reference—we have seen how Lavoisier enabled other chemists to create linguistic communities just by applying his definition of an "element" to their empirical discoveries—they just need to believe, "This is what I mean by 'element'."[17]

Incommensurability between philosophical positions that happen to be meta to scientific theories has already been noticed by Eric Oberheim and Paul Hoyningen-Huene (1997). Their argument centers on the meta-incommensurability that arises between realist and anti-realist philosophies

16. Most of them will not have thought through every aspect of their epistemic and ontological commitments, so it would probably not be possible to determine whether each particular scientist favours, for example, Putnam's causal theory over Kripke's. But it should be straightforward to question a contemporary scientist and establish whether she assumes a causal or descriptive theory of denotation. Likewise, if historians can find enough primary source discussions (in prefaces and refutations of others' work), a sensitive reading can give us an insight into what earlier scientists' commitments were.

17. The majority of the names on Lavoisier's list of simple substances are very familiar, far more so than in earlier chemical texts. The reason we still talk about oxygen today is not simply because Lavoisier had the better first-order theory. The "staying power" of these names is because a thoroughgoing reform of chemical nomenclature coincided with an empirico-pragmatic definition of chemical element (Best forthcoming).

of science. Although analogous, the concerns discussed here apply even if both parties hold the same position with respect to realism.

Similarly, Michael Bishop and Stephen Stich (1998) have shown that arguments invoking theories of reference to interpret scientific theories cannot underwrite scientific realism nor can they prove the existence or non-existence of theoretical entities.[18] The present article considers similar flights to reference with the far more modest goal of meaningfully communicating across theories. This argument does more than present a further barrier to any who might overcome Bishop and Stich's challenge. The consequences here are more wide-ranging since this meta-incommensurability of meaning is a sceptical threat even to those who eschew metaphysics.

This article has argued that to do justice to the sense of the terms of scientific theories means utilizing the most apt theory of reference in each case. It does not follow that different theories of reference commit the epistemic agent to belief in the real existence of those theoretical entities, unless she is already committed to scientific realism. Furthermore, this article has not taken a position on the question of scientific realism. Descriptive and direct theories of reference are each compatible with a range of realist and instrumentalist interpretations[19]; it is the conjunction of a particular theory of meaning with a scientific realist position that entails belief in a specific ontology.

Nevertheless, to observe meta-incommensurability requires holding disparate theories of meaning simultaneously, which may seem to be at odds with scientific realism. Although pluralism about classification is traditionally associated with antirealism, Anjan Chakravartty (2011) has outlined a number of ways in which the scientific realist can be a taxonomic pluralist.

7. Conclusion

Whenever two scientific theories assume disparate models of reference, they are incommensurable at the meta level. This incommensurability of

18. They only demonstrate that this approach fails by showing that all such arguments to date contain a lacuna; nevertheless, the authors suggest that a cogent form may well be impossible – "since we have no idea how one would even begin to construct such an argument, and as far as we know no one else has ever tried, we are inclined to be more than a bit skeptical" (Bishop and Stich 1998, p. 40).

19. All except those particularly strong forms of scientific realism that specify both that we must interpret scientific theories literally and that "the world has a definite and mind-independent natural-kind structure" (Psillos 1999, p. xvii). These tenets together are incompatible with descriptive theories of meaning. Nevertheless, if we take the semantic stance to be more fundamental, we can simply strike out "natural-kind" from the metaphysical stance and retain a rather strong realism. A structural realist approach (e.g., Worrall 1989; Chakravartty 2004; Ladyman 2011) would be even more amenable.

meaning implies that they are also first-order incommensurable and completely incomparable. As long as philosophers (or philosophically inclined historians of science) can identify the theory of reference being used—even tacitly—we can say whether or not one scientific theory is commensurable with another at this meta-level. If they are using radically different theories of reference, they are incommensurable at that level and we need not go any further to ascertain whether they are first-order commensurable.

Meta-incommensurability is a potential epistemic obstacle for many sciences both historical and contemporary and a real problem for historians of chemistry who wish to compare Aristotelian or early-modern principle-based theories with later schools of chemistry that treat elements as natural kinds. Although meta-incommensurability is a greater obstacle to scientific knowledge than first-order incommensurability, the pluralism involved need not lead to epistemic relativism nor a scepticism towards scientific progress, since independent criteria can be given for the superiority of causal theories of reference over descriptive theories.

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