Durham University

Insights

Institute *of* Advanced Study

Science and Everyday Life: Water vs H_2O

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Volume 3 2010 Number 23

ISSN 1756-2074

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SCIENCE AND EVERYDAY LIFE: 'WATER' VS 'H_2O'

'Water' is common to both scientific and vernacular language, and so is a good example with which to explore the disputed relationship between them. Does vernacular usage defer to science, so that water must be H_2O? If so, then for centuries the folk might apply the term to something that science may discover not to be water. Or may vernacular usage properly resist scientific reform, because it embodies a quite distinct body of knowledge and classificatory interests? In that case things that are not H_2O may rightly continue to be called 'water.' Call these options deference and difference: I argue that difference presupposes the basic adequacy and coherence of the vernacular usage. In the case of 'water' that adequacy and coherence is missing unless the term tracks H_2O content.

Introduction: Science and Everyday Life

In this paper I would like to consider what kind of relationship there is between scientific and vernacular uses of the word 'water,' concentrating on two opposed models which I will call 'deference' and 'difference.' To raise the question of what relationship there is *between* scientific and ordinary language presupposes that they are distinct, yet it is not immediately obvious why they should be: scientists are people, and their technical discourse must have its origin in the colloquial. Though scientific concepts are refined and often highly abstract, they are honed for the description of the very same world in which everyday life takes place. J. B. S. Haldane made just this assumption in his short educational sketches for the *Daily Worker* (collected in Haldane, 1941). In one striking example (pp. 53–5), he fills in some background to a recent explosion in an ammonia factory, explaining how compressed gases may cause explosions, also discussing ammonia the substance, its toxicity, its presence in the outer planets and its possible role as an alternative to water in an extraterrestrial chemistry of life. At one point he asks 'What is ammonia?' but continues 'If you buy a bottle labelled "ammonia" at the chemist's, you do not get a pure substance, but a solution of ammonia in water' (p. 53). Haldane does not actually say what ammonia is until later: it consists of '1 atom of nitrogen united into a molecule with 3 of hydrogen' (p. 54). So the assumption that motivates all of Haldane's sketches – that science investigates the same world as that in which everyday life takes place, and that its discoveries can deepen our understanding of both the commonplace and the extraordinary – is underwritten by a presumption that a practical category (ammonia, a cleaning fluid) and a scientific category (NH_3) are linked, and that the scientific category determines the extension of the practical one. Containing ammonia the substance (NH_3) is what makes ammonia the cleaning fluid the particular cleaning fluid that it is.

Water is an even more ancient and ubiquitous feature of human life. Perhaps because of this, it has also had a constant role in the history of what might broadly be called science: from Thales' appeal to it as a universal explanatory principle, through Aristotle's inclusion of it as one of the four elements, Lavoisier's discovery that it is a compound of oxygen and hydrogen, to the fruits of modern science collected into a seven-volume work on its structure and properties (Franks, 1972–1982). So, predictably, it is at the centre of the philosophical literature on the relationship between scientific and ordinary language. In other papers (Hendry, 2004, 2005, 2006, 2008, 2010a, 2010b), I have claimed, responding to the arguments of Joseph LaPorte among others (2004), that within chemistry substances are individuated by their microstructural properties, and that the identification of the relevant microstructural properties constituted a discovery rather than a conceptual innovation (see also LaPorte, 2010). In those earlier papers I concentrated just on chemistry and its historical development, sidestepping the issue of the relationship between chemical and other language.

Deference and Difference

In this section I will set out two models of that relationship. Firstly there is *deference*, in which ordinary language is a 'first approximation' to scientific investigation, which will (eventually) uncover the deep structural features of things that make them what they are. Secondly there is *difference*, in which folk classification is governed instead by independent human interests that are typically practical rather than epistemic, and may or may not line up with scientific classification.

Deference

In the 1970s, Hilary Putnam developed a model of the meaning of scientific terms to set against the consensus view that had emerged from the aftermath of positivism (see Putnam, 1975, pp. 235–8). The consensus view was that the meaning of a scientific term is determined by its place in a broader context, including theoretical, experimental and ontological principles. One consequence of this – semantic incommensurability – was made explicit by Thomas Kuhn (1970, Chapter X) and Paul Feyerabend (1962): there have been revolutions in the history of science so profound as to involve change in its underlying concepts, and therefore change in the meaning of central theoretical terms. It follows that if there are revolutions of this kind in the history of science, its development cannot always be regarded as a cumulative process. Even if successive scientific theories use the same words (such as 'atom,' 'electron,' 'mass' or 'water') this does not imply that successive generations of scientists are delivering a series of insights about a fixed subject matter (whether atoms, electrons, mass or water). The retention of the words masks the fact that they express different concepts. Incommensurability also precludes us from regarding successive generations of scientists as being in genuine disagreement with each other, if there is sufficient conceptual change between them. Aristotle, for instance, did not harbour the false belief that water is an element: he had different concepts. It also presents serious difficulties for the view that Lavoisier discovered that water is a compound of hydrogen and oxygen, despite having false beliefs about both elements (see Hendry, 2010a).

Putnam responded to incommensurability by attempting to uncouple the meaning of a term from its broader scientific context and, more generally, from the knowledge or beliefs of its users. According to Putnam, the reference of a natural-kind term would be relatively independent of background belief, because it attaches to its referent directly, like a proper name. Take 'water,' or 'gold.' For Putnam, samples of these substances would be picked out by ostension or description (e.g. 'the stuff that flows in rivers and falls from the sky as rain,' or 'the stuff the King's crown is made of'). The term will apply to whatever else shares the sample's underlying nature: in the case of gold, this is having atoms with a nuclear charge of 79 atomic units; in the case of water it involves being composed of H_2O molecules.

The account makes two important kinds of presupposition. Firstly there is externalism, which is the idea that the contents of someone's thoughts – for instance, the fact that they are thinking (and talking) about *water* – may be determined by facts of which they are unaware: the relevant facts are external to their epistemic perspective. Externalism itself presupposes that the relevant facts exist and that they exist independently of their being known. It is to that extent committed to some form of realism about them. In the case of water, Putnam presumes that what makes something water is its composition, which may be unknown both to historical scientists and laypeople. But *what* makes it the case that chemical composition is what makes something water, rather than its appearance (for instance)? That is where the second assumption comes in: according to Putnam, 'water' is a natural-kind term, and as such, it is used in a particular way that involves deference to science (he calls this a 'socio-linguistic hypothesis' (1975, p. 144)). Someone who uses the word 'gold' may have some idea of what gold looks like, but will typically lack the expertise to tell it apart from other things it resembles (like fool's gold). So in using the term they intend it to apply to things that *experts* would identify as gold. But science has determined that having atoms with a nuclear charge of 79 atomic units is what makes something gold, so deference makes this the criterion for being gold even in a layperson's usage.

Typical speakers of English may be ignorant of what chemists regard as the underlying nature of gold, but intend their use of the word to pick out just what chemists would regard as gold, that is whatever possesses its underlying nature (having atoms with a nuclear charge of 79 atomic units). Applying this model in an obvious way to 'water,' the word in its standard usage picks out samples of stuff which are predominantly composed of H_2O molecules. In short, water *is* H_2O. Since chemists determined this only in the nineteenth century, it counts as a discovery. In what follows I will leave aside many of the objections to this model that turn on its essentialist and externalist commitments (see Hendry, 2010a), and, by considering an alternative, will focus just on its deferential account of the relationship between scientific and ordinary language.

Difference

John Dupré has long opposed the scientific essentialism of Putnam's account (Dupré, 1981, 1993). Dupré is a pluralist about classification, pointing out that there are many informal systems of classification associated with practical, non-scientific activities such as cookery and gardening. These systems of classification are, he argues, autonomous: they are governed by different interests and should not be expected to defer to science. For instance, from a biological point of view tomatoes are fruit, whereas culinary classification would group them with vegetables, along with other salad ingredients. Interestingly, Dupré combines pluralism about classification with realism about kinds: he does not deny that there are real divisions in nature: rather he thinks that there are many, and that the practical or epistemic purposes of various crafts and sciences make different kinds of division salient.

Despite this independence, scientific and non-scientific classification may become entangled, even though deference to science is typically 'philosophically unmotivated' (Dupré, 1999, p. 461). In the past, whales counted as perfectly good fish, because 'fish' meant something like a sea-dwelling animal with a characteristic shape. Thus Moby Dick was both a fish and a whale, as was the great fish that swallowed Jonah. Educated people now typically exclude whales from the fish on the grounds that they are mammals, a fact that the OED reflects with a more restrictive definition of 'fish' as 'cold-blooded vertebrates with gills' (p. 466). This is not because whales have been discovered by science to be non-fish: neither 'whale' nor 'fish' is the name of a particular biological species, and neither corresponds to a well-formed higher taxon (pp. 462–7). In short, biology does not really take a view on either category: 'What a fish is is not the sort of thing a scientist (except, perhaps, a linguist) could find out' (p. 467). But if 'folk once believed that whales were fish' and now they do not, they must have been 'duped into changing that belief for bad reasons' (p. 465). Moreover, Dupré argues that biology itself is not unified from a taxonomic point of view, with various parts of that science employing quite different species concepts based on morphology, phylogeny or membership of a breeding community (1993, Chapter 2). This further undermines the idea that one taxonomic system should be regarded as privileged.

Now there are disanalogies between chemical substances and biological species: for a start, the very same category names (witness 'water' and 'ammonia') are firmly in use in both scientific and vernacular contexts. Secondly, chemistry is taxonomically more unified than biology: the International Union of Pure and Applied Chemistry (IUPAC) agreed on a definition of the element names in terms of nuclear charge in the early twentieth century, and in IUPAC's current systematic nomenclature for chemical substances, molecular structure provides the sole basis for naming (see Thurlow, 1998, and Hendry, 2006, 2008). Nevertheless, the question arises whether there are folk classifications of chemical substances that cut across the scientific categories, and if so whether, like the folk-biological categories, they should be regarded as being 'on a par' with them (Dupré, 1999, p. 462). This possibility presumes a number of things about the folk classifications in question: that they embody coherent ways of thinking about their subject matter, and that the corresponding kind-terms have reasonably determinate extensions. However, the opponent of pluralism should not apply these requirements in a question-begging way: that is, by requiring essentially that the folk-classification should not disagree with science. The defects should be internal.

Barbara Malt (1994) and Noam Chomsky (1995) have argued precisely that vernacular usage of 'water' does not track H_2O content. Malt asked a sample of undergraduate students to judge the H_2O content of a range of liquids that are called 'water' (e.g. tap water, bottled water, etc.), and of a range of liquids which are not (e.g. tea, saliva, coffee, etc.). Although the waters, were judged on average to contain more H_2O than the non-waters, she found it significant that the students allowed waters to contain significant amounts of non-H_2O (up to a third), and judged many liquids with high H_2O content (e.g. tea and coffee) to be non-waters. She also asked them to judge how typical these liquids were as water: here again there was some correlation between typicality and judged H_2O content, but also important were use (drinking water was the most typical), location (in a house, or perhaps a bottle) and source (coming from a tap). Malt concluded that her data were inconsistent with Putnam's assumption of what she calls 'psychological essentialism' (Malt, 1994, p. 64), which is roughly the idea that chemical composition alone determines whether or not a particular liquid is water. The other factors – function, location and source – should not be dismissed as 'quick and dirty' procedures for identification: rather they are 'involved in the concept of water' (p. 65).

There are a number of things the scientific essentialist might say here. The first is that the title of Malt's widely-cited article ('Water is not H_2O'), though arresting, is not borne out by the contents. (Perhaps that title is irresistible when one wishes to argue against essentialism about chemical kind terms: see Weisberg, 2006.) 'Water is not H_2O' suggests that water is something else, whereas the following facts are quite clear from Malt's results: that being H_2O is the only *chemical* requirement that is relevant to being water; that it is the only requirement of any kind that is necessary to being water (Malt acknowledges this (1994, p. 66)); and that the other relevant conditions she mentions (function, location and source) are fleeting, contingent and apply only to particular types of water. I think that these facts make being H_2O uniquely relevant to being water. So water is H_2O even in the vernacular, although some other factors may affect how closely a particular sample is judged to be stereotypical. All this is consistent with Putnam's analysis. A second essentialist response is that something does not become water merely by being called water: perhaps we need instead to understand why some things that are water are not called water, and why some things that are called water are not water (see Abbott, 1997). For instance, substances that are mostly water may fall under some more salient kind (such as babies, who are mostly water). Conversely, substances that are called 'water' as a whole may contain significant amounts of other chemical substances (for instance dissolved impurities). This is not because they magically *become* water by being included among a far greater amount of H_2O, but is rather because the sample as a whole is mostly water (i.e. H_2O), and falls under no other more salient kind. This kind of response needs to be stated carefully if it is not to beg the question in favour of scientific essentialism, but in what follows I will argue that it is broadly correct. How do we argue that some things that the common folk call water are in fact not water (and vice versa), except by appeal to science? That would be question-begging, so instead I will critically examine the conception of water that is embodied in Malt's empirical results. If that conception is confused or incoherent, there is an internal reason to defer to the scientific conception. In the next section I will address precisely that possibility.

Against Humpty Dumpty

Defenders of the difference model attempt to identify the extension of a folk category via linguistic evidence alone, contrast its extension with that of some scientific counterpart and conclude that the folk category is independent of the science. This makes two substantive assumptions: one is that the speakers of a natural language are authoritative about the extension of the kind terms they know how to use; the other is that kind terms in use have an extension. These assumptions are substantive because we cannot just assume that the competent speakers of a language collectively constitute Humpty Dumpty, whose words mean precisely what he chooses them to mean.

The defender of Putnam's scientific essentialism will reject the first assumption because on Putnam's account, speakers of a language use its kind terms to describe a world of which they have incomplete knowledge, and a complete account of classification and the meaning of natural-kind terms must take into account this wider context. Hence the argument against Putnam's model based on the linguistic evidence is question-begging. It must assume that ordinary speakers are authoritative, which is just to assume the falsity of externalism, to which Putnam is committed (see Chomsky, 1995, for explicit argument against externalism).

The second assumption, that the 'folk-concept' of water has an extension, is false because the intuitions that Malt extracts from the linguistic evidence are collectively inconsistent. If so, then the category has no extension. Consider two ways in which a substance name (e.g. 'that is water,' 'that is ammonia,' and 'that is gold') can be applied. The attribution may apply to a sample as a whole, or merely to a component of it. The first usage is in evidence in Malt's study in what she interprets to be uses of the names of types of water (e.g. 'bottled water' or 'river water'). One might see these rather as samples of water differentiated by their location or source, but let us leave that aside: the point is that the category 'water,' she assumes, is applied to whole samples even when it is recognised that they are not 100% H_2O. It would seem (and Malt takes it that way) that the impurities (i.e. the non-H_2O parts) are being called water. The second sense is in evidence in Malt's study in assessing uses of the phrase 'X is only partly water' (Malt, 1994, p. 62). Another example of this usage applies to non-liquids: we may ask how much water there is in the human body (it is widely known that the percentage is high), or how much water has been added to some ham (a lower percentage is evidence of higher quality ham). Interestingly, application of 'water' in this sense is clearly independent of its use, location and source. It is also independent of the display of the external characteristics of liquid water (e.g. transparency, potability, etc.). The key point, however, is that in this usage, stuff that is not H_2O does not become water merely by being mixed with H_2O. But this is inconsistent with what is assumed in the other use of 'water.' So we are dealing with at least two folk categories: water-as-such and water-in-a-mixture.

Now one might also ask what it is that determines which parts of a mixture are or are not water in this second sense. The only credible answer is whether or not they are composed of H_2O molecules. Why? One might take application of 'water' to the parts of a mixture to reflect a potential for that mixture to yield water on separation of its components (see Hendry, 2010b, for discussion and criticism of this and other macroscopic conceptions of chemical substance). But these dispositions are ungrounded unless explained by the presence of H_2O molecules. Otherwise we lose the distinction between water that is actually present in a mixture (in the form of H_2O molecules), and water that is merely present because it would result from chemical reactions that accompany the separation process (e.g. the denaturing of proteins on heating). Another example makes this vivid: how much water is present in hydrogen peroxide H_2O_2)? This substance decays vigorously on heating:

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

Through spontaneous decay, some water is always present in a sample of H_2O_2, but a dispositional conception of the water component would misidentify the amount if it failed to distinguish the water that is actually present from what would be generated by the decay of H_2O_2 as a result of the separation process (i.e. heating). Appealing to the presence of H_2O molecules is the only way I can see to make that distinction. Now the defender of difference might respond here that the usage of 'water' as a mixture-component is a philosophically unmotivated change to a perfectly adequate folk category, mirroring Dupré's commentary on the exclusion of whales from the category of fish. But this fails as a full defence of an independent folk category of 'water,' because then the concentration of the folk concept on surface characteristics is insufficient to motivate all uses of 'water.'

There are two other assumptions behind the project of identifying the classificatory concepts behind vernacular usage, which are more broadly questionable. One such assumption is that vernacular usage of kind terms embodies anything like a *system of classification* at all. Another is that, if it does embody such a system of classification, this system can be read directly off the linguistic evidence without any mediating selection or conceptual reconstruction. Why are these substantive assumptions? Because a *system* of classification is not merely a jumble of kind terms: presumably it aims at completeness for some domain, the extensions of its terms enter into set-theoretical relationships with each other (such as inclusion, exclusion, etc.), and its categories are connected by some kind of similarity relation which may either be theoretical (for instance, sameness of molecular structure) or phenomenological.

Scientific systems of taxonomy – those of chemistry, botany or zoology, for instance – have been honed over centuries, more or less consciously, in order that their kind terms really do form a system. For instance, in the 1780s Lavoisier and others introduced into chemistry a system of binomial nomenclature that remains in use today (consider for instance the names carbon dioxide, copper sulphate). This nomenclature was based on a project of identifying a complete list of the elements: 'based on' such a project because the system takes the the names of the elements as the elements of the binomial names. Such projects make substantive assumptions about their domains: in chemistry's case the assumptions are that there are indeed substances (the elements) out of which other substances are composed, but which are themselves composed of no other substances, and that composition in this sense is important in understanding chemical behaviour (it is). Eventually this system grew into the periodic table, a system of classification *par excellence* in that it was shown in the twentieth century to be exhaustive. So a system of scientific classification embodies a substantial amount of empirical knowledge and conceptual refinement: knowledge and refinement which it has acquired precisely with the aim of ensuring that the system is unified and coherent, in short that it makes some kind of sense of its domain. Now I do not mean to say that these systems develop in the abstract, or on their own: clearly they are the work of generations of people who teach each other, influence each other, who set up institutions including scholarly societies, university departments, and so on. This is what constitutes the reality of a scientific discipline as a historical entity. The same processes of knowledge-gathering and refinement, perhaps less formally and explicitly, have gone on in the practical activities invoked by Dupré (gardening, cookery, and so on), and are carried out by precisely analogous historical institutions. Now contrast this with the 'concept of water' that Malt attempts to extract from the linguistic evidence. Is there any reason to think that this evidence points to linguistic regularities that embody a coherent system of knowledge about the relevant domain (which in this case includes water)? No, and the mere noting of linguistic regularities fails to associate them with any particular set of knowledge or interests, apart from general human interest in having good stuff to drink. Association with interests (whether epistemic or practical) is surely a necessary prerequisite for any discussion of meaning.

In conclusion, there are two 'folk-concepts' of water. One, 'water as such,' can be understood as applying to things that are largely H_2O and fall under no more salient category. Application of the other ('water-in-a-mixture') is, I have argued, even more directly dependent on something being H_2O. Even in the vernacular, application of 'water' tracks H_2O-content closely. That should be no surprise, because identifying water as H_2O is one of the many fruits of chemistry's refinement of compositional thinking over three centuries. It makes sense to defer to it.

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Insights

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