Dwatery ocean

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Abstract

In this paper I raise a difficulty for Joseph LaPorte's account of chemical kind terms. LaPorte has argued against Putnam that H_2O content is neither necessary nor sufficient to fix the reference of the kind term 'water' and that we did not discover that water is H_2O. To this purpose, he revisits Putnam's Twin Earth story with the fictional scenario of Deuterium Earth, whose ocean consists of 'dwater', to conclude that we did not discover that deuterium oxide is (a kind of) water (usually called 'heavy water'). Instead, according to LaPorte, by including deuterium oxide in the extension of the term 'water', we simply refined our vague use of the term 'water'. But we *could* have decided to exclude deuterium oxide from the extension of the term 'water'. Let us call this the thesis of semantic stipulation.

I raise two problems for LaPorte's Deuterium Earth story. First, I show that 'dwater' (i.e. deuterium oxide not as a kind of water) does not have the same scientific credibility of 'heavy water' (i.e. deuterium oxide as a kind of water). Second, I argue that for the thesis of semantic stipulation to go through one would need to show that 'dwater' is semantically on a par with 'heavy water'. Namely, one would need to show that 'dwater' is a projectible kind term, capable of supporting inductive inferences. But, in fact, it is not, because the term is vulnerable to an unwelcome Goodmanian scenario, unless one surreptitiously reintroduces some Putnamian assumptions about D_2O content being necessary and sufficient to fix the reference of the term.

1. Introduction

In *Natural kinds and conceptual change*, Joseph LaPorte[1] puts forward an innovative view of natural kind terms, according to which the use of such terms is vague. Following a well-known linguistic tradition, he calls the hidden vagueness in the use of a term, which is later exposed as our knowledge grows, 'open texture'.[2] Natural kind terms are then subject to meaning-change over time, whereby meaning-change should not be understood as synonymous with conceptual-change of the Kuhnian type, but instead as

[1] Joseph LaPorte, *Natural Kinds and Conceptual Change* (Cambridge: Cambridge University Press, 2004).

[2] Op. cit., 97.

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precisification of kind terms with open texture. LaPorte combines precisification with a Kripkean defence of the rigidity of kind terms. Any kind term rigidly designates the same kind in all possible worlds, although the extension of the kind term in question may change from one world to another, and even within the same world before and after a scientific revolution. Since there is an element of semantic stipulation as to how we refine the use of a vague kind term, LaPorte takes kind terms as rigid *de jure*, but not *de facto*.[3]

Under the Kripke–Putnam view, rigidity accomplishes the other important job of getting kind terms hooked up to their referents. For example, the term 'water' refers to whatever possesses some *underlying properties and relations* that – empirically discovered – guarantee sameness of kind to paradigm water. But LaPorte argues that this is instead the role of the causal theory of reference and not of rigidity, and accuses Putnam of conflating the two.[4]

Against Putnam's causal theory of reference, LaPorte maintains that possessing underlying properties and relations does not guarantee sameness of kind to paradigm samples. For example, being H_2O is neither necessary nor sufficient for being water; nor did we discover that water is H_2O. On the contrary, if confronted with XYZ we might conclude that 'XYZ is water'; or vice versa, if confronted with H_2O having unusual characteristics, we might conclude that 'Some H_2O is not water'.[5] LaPorte concludes that the kind term 'water' is vague and changes its meaning over time, so that XYZ is neither clearly in nor clearly out of the extension of the term until a decision is made by speakers to include or exclude it. Such stipulation on behalf of speakers would amount to a precisification of the term; it would not be a scientific discovery. To illustrate this point, LaPorte revisits Putnam's Twin Earth story with the fictional scenario of Deuterium Earth.[6] The story is functional to LaPorte's point that scientists *stipulated* that deuterium oxide (D_2O), i.e. one of the most relevant isotopic varieties of water, is *a kind of water* (usually called 'heavy water'). But they *could* have chosen otherwise, and they would not have been wrong in doing so, anymore than we are right in including deuterium oxide in the extension of 'water'. Let us call this the thesis of semantic stipulation.

LaPorte's argument draws on the mixed nature of the liquid that we normally call 'water'. Naturally occurring water is not 100%

[3] Op. cit., 47.
[4] Op. cit., 43.
[5] Op. cit., 93.
[6] Op. cit., 104–107.

H_2O. For example, ocean water contains also a small percentage of deuterium oxide (of the order of 0.015%, upon LaPorte's indication), without counting percentages of other isotopic varieties (such as tritium oxide, oxygen-18, etc.), as well as salt and gold, among other substances. Following a strategy already deployed against Barbara Abbott's[7] Putnamian defence of water being H_2O, LaPorte[8] tacitly uses the mixed nature of any ocean water sample as an argument against the claim that H_2O content is necessary and sufficient to determine the reference of the term 'water'.[9]

In this paper, I object to LaPorte's Deuterium Earth story on two main grounds. First, scientific history belies LaPorte's intuitions as to why the Earthlings would have good reasons for not counting the Deuterium Earth's ocean liquid as *a kind of water*. Second, if we take LaPorte's view seriously, an unwelcome Goodmanian scenario may arise. In Section 2, I briefly review LaPorte's Deuterium Earth story and conclude that for the thesis of semantic stipulation to go through, one would need to prove that 'dwater' (as the Earthlings dub the Deuterium Earth's liquid) is a vernacular kind term on equal (scientific and semantic) footing with 'heavy water'. Or better, one would have to prove that the two options:

(A) D_2O is not a kind of water (let us call it 'dwater', as the Earthlings call it)
(B) D_2O is a kind of water (let us call it 'heavy water', as the Earth scientists call it)

are on a par, and in particular that option (A) is a live option with equal semantic status and scientific credibility as option (B). But I contend that it has neither. In Section 3, I show that option (A) does not have the same scientific credibility of (B), because D_2O does bear after all the *same microstructural-kind* relation to what we ordinarily call 'water'. In Section 4, I show that option (A) does not

7 B. Abbott 'A Note on the Nature of "Water"', *Mind* **106** (1997), 311–9.
8 See J. LaPorte, 'Living water', *Mind* **107** (1998), 451–5.
9 Under a Putnamian view, being H_2O is a necessary and sufficient condition for being water insofar as the threshold of impurities is lower than 20% (see H. Putnam, *Representation and Reality* (Cambridge, Mass.: MIT Press, 1998), 31). But LaPorte (1998), op. cit. note 8, has attacked this claim by noting how a cutoff at 20% is not sufficiently fine-grained a net to determine the reference of the term 'water'. By trading on the fact that the content of the Great Salt Lake in Utah contains twenty-eight percent impurities, LaPorte concludes that a jellyfish, a tomato, and an infant would count as 'water' in virtue of containing fewer impurities than the lake in Utah.

enjoy an equal semantic status with option (B) either, because for 'dwater' to be a genuine kind term, it would have to be projectible, i.e. it would have to support successful inductive inferences. But, as it happens, the term is non-projectible and vulnerable to an unwelcome Goodmanian scenario. In Section 4.2, I present a series of possible responses to the Goodmanian scenario and I conclude that none of them successfully evades it.

2. LaPorte on Deuterium Earth

LaPorte's thesis of semantic stipulation derives its compelling force from his apt variation of Putnam's Twin Earth story. LaPorte presents us with the fictional scenario of Deuterium Earth visited by the Earthlings in 1905.[10] The space travellers land on Deuterium Earth equipped with samples of various biological and chemical substances from planet Earth, which they soon begin to compare with the substances populating Deuterium Earth. The water-like liquid that fills the ocean, and that looks *prima facie* identical to the Earthlings' sample of water from planet Earth, reveals soon some dissimilarities even before molecular testing is done: no fish or aquatic plant can live in it and its boiling and melting points differ from the ones of water.

The Earthlings dub the non-better-identified microstructure PQR and find also traces of PQR in their own ocean-water sample from planet Earth (in the order of 0.015%). 'Eventually, through sophisticated testing',[11] the Earthlings find out that the water-like liquid consists of hydrogen atoms, whose mass is greater than the mass of ordinary hydrogen atoms, because of one neutron (in addition to the proton) in the nucleus. In honour of Deuterium Earth, they call the new element 'deuterium'.

The Earthlings learn from the Deuterium Earthlings that an explosive weapon was built with deuterium and that the explosion caused a whole island to vanish.[12] No such bomb is known to the Earthlings. Thus, in the light of all these differences, the Earthlings decide to dub the water-like liquid that fills the ocean on Deuterium Earth 'dwater', so as to distinguish it from 'water'.

Thirty years elapse: it is the year 1935 when the Earthlings at last return to planet Earth, bringing with them samples of substances

[10] Op. cit. note 1, 104–107.
[11] Op. cit., 105.
[12] Op. cit., 106.

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from Deuterium Earth. When confronted with the ocean-sample of 'dwater', the scientists on Earth respond disappointingly that it is not a new liquid but just a chemical variety of water, made up by the hydrogen isotope, which they had coincidentally called 'deuterium' to distinguish it from protium (i.e. the hydrogen atom, whose nucleus consists of one proton only). LaPorte draws the following moral from the story:

> What do I think this story shows? I think it shows that we did not *discover* that deuterium oxide is water. Hence we did not discover that water is identical to H_2O. We could have concluded that some H_2O (the variety that is D_2O) is not what we had been calling 'water', as our space travellers concluded. I think the decision that just H_2O made with protium bears the *same microstructural kind* to the majority of what we called 'water' would have been no less acceptable a conclusion than that H_2O bears the key relation. We cannot say that our space travellers were just flat wrong in concluding that D_2O is not what they had been calling 'water' and that we are just plain right in concluding that it is.[13]

In sum, 'water' is a kind term with open texture and it is a matter of semantic stipulation whether we decide to include or not deuterium oxide in its extension. We could have gone either way. Or, so LaPorte argues. This is what I call the thesis of semantic stipulation.

Alexander Bird[14] attacks LaPorte on this specific point by noting how chemistry is the science of substances, and that although the space travellers might have been right in not counting D_2O as water, their reasons were practical rather than chemical: 'if you want to know what a substance *is* rather than what it will do to your body or whether you can make a fusion bomb from it, you turn to a chemist'.[15] Moreover, Bird draws attention to the use of vernacular kind terms as opposed to natural kind terms and to Putnam's division of linguistic labour to conclude: 'the claims about open texture are most plausible concerning vernacular terms that appear to be natural kind terms. But important identity statements in science are

[13] Op. cit., 107, 110.

[14] A. Bird, 'A posteriori knowledge of natural kind essences: a defence', *Philosophical Topics* **35** (2007), 293–312.

[15] Op. cit. note 14, 299. See also A. Bird, 'Discovering the essences of natural kinds', in H. Beebee and N. Sabbarton-Leary (eds) *The Semantics and Metaphysics of Natural Kinds* (New York: Routledge, 2009), 128.

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not just those that conjoin a vernacular kind term with a scientific one'.[16]

I follow up on Bird in arguing against LaPorte that it is *not* the case that we could have gone either for the Earthlings' option of not including D_2O in the extension of water, or for the Earth scientists' reverse option. In other words, it is not the case that the two options are on a par, i.e. that whether or not D_2O is a *kind of water* is ultimately a matter of semantic stipulation. My line of argument departs from Bird in two respects: (1) I think that LaPorte is after all correct in claiming that the Earthlings' reasons for taking D_2O not as a kind of water are ultimately of chemical (as opposed to practical) nature; and (2) I also think that LaPorte is correct in stressing the importance of vernacular kind terms with open texture for scientific claims (in particular, I am thinking of the role of vernacular kind terms for inductive inferences, as opposed to theoretical identity statements).

Whilst I concede these two points, I do not think they jointly license the thesis of semantic stipulation. For the thesis to be defensible – out of the seemingly compelling force of the fictional scenario – we need to assess whether the Earthlings' conclusion that D_2O is not *a kind of water* but instead a new chemical substance (called 'dwater') stands up scientific and semantic scrutiny. In the next two Sections, I cast doubt on both.

The two points are related. For 'dwater' to have the semantic status of a genuine kind term, it would have to be projectible: i.e., it would have to support successful inductive inferences. But I am going to argue that the term is either non-projectible; or its projectibility depends ultimately on facts about the D_2O content of the new liquid as an *isotopic kind of water*. I must then first show that facts about the D_2O content of Deuterium Earth's ocean liquid underwrite the conclusion that it is an *isotopic kind of water*.

3. Why 'dwater' does not have the same scientific credibility as 'heavy water'. The Deuterium Earth story continued

In this Section, I show that the Earthlings are in fact wrong in thinking that D_2O is not a kind of water. Facts about the D_2O content of Deuterium Earth's ocean liquid underwrite its nature as an isotopic *kind of water*; and there are reasons – I think – for resisting LaPorte's conclusion that some H_2O (for example, the D_2O variety

[16] Bird 2009, op. cit note 15, 135.

of it) is not what we have been calling 'water'. Let me continue the Deuterium Earth's story where LaPorte's one ends, following this time the historical records about the discovery of deuterium, and the ensuing scientific debate.

It is the year 1935. The Earthlings have at last returned to planet Earth after more than thirty years field-work on Deuterium Earth. They present a jar of Deuterium Earth's ocean liquid to the Earth scientists, who upon investigation conclude that it is not a new liquid but just a new kind of water that they have themselves recently discovered and independently called 'deuterium oxide' or 'heavy water' (the first is the scientific kind term, the second is the vernacular kind term).[17] Lots of things have happened in the scientific world since the Earthlings left planet Earth in 1905 – the Earth scientists explain to the Earthlings.

'To start with, in 1919 the isotopic constitution of elements became well-known. The term "isotope" was originally used by Frederick Soddy to designate chemically non-separable varieties of the same element, whereby in the case of heavy radioactive atoms the differences in atomic weight did not give rise to observable chemical differences. But the use of the term has changed since (despite Soddy's acrimonious defence of the original meaning): now (i.e. in 1935) the term "isotope" is ordinarily used to indicate atoms with the same nuclear charge but different atomic weight'.

'This leads us' – as the Earth scientists hasten to explain to the Earthlings – 'to the rather delicate issue of finding a suitable name for the new liquid, following up on the discovery in 1931 of the hydrogen isotope containing a neutron in addition to the proton, by three American scientists.[18] Urey discovered the new isotope by evaporating liquid hydrogen at low temperatures, and examining the resultant spectral lines. His discovery followed of one year the discovery of two other isotopes of oxygen (i.e., ^{17}O, ^{18}O in addition to the known ^{16}O), on the basis of a measured discrepancy for the hydrogen atomic weight'.

[17] Henceforth I use the vernacular kind term for the purpose of comparing it with the Earthlings' vernacular kind term 'dwater' under the assumption that both Earthlings and Earth scientists would agree in using the scientific kind term 'deuterium oxide' to refer to D_2O, but they would diverge in the use of the vernacular kind term to stress their divergent opinions as to whether D_2O is or is not a *kind of water*.

[18] Urey, H. C., Brickwedde, F. G., Murphy, G. M. 'A Hydrogen Isotope of Mass 2', *Physical Review* **39** (1932), 164–165.

The Earth scientists continue their report to the Earthlings: 'The choice of a name has proved rather difficult and it has been the subject of lively discussion. *The Times* of 9 December 1933 announced in a column the discovery of "heavy hydrogen" as a "a new kind of water", which has escaped discovery hitherto only because of its very small quantity in nature compared to ordinary hydrogen, and whose presence in ordinary water would significantly alter the ability of water to support life. The search for a suitable name was open and an entire meeting of the Royal Society was dedicated to it on 14 December 1933'.[19]

'At the meeting, Soddy, the father of isotopy, refused to consider this element as an "isotope" on the ground that it defied his original meaning of "isotope", reserved – as it was – to *chemically non-separable varieties* of the same element.[20] But other physicists were of a different advice. Lord Rutherford, for example, retorted to Soddy that the term "isotope" was now extended to include chemically separable elements having the same nuclear charge and different mass, and he himself proposed the name "diplogen" for the new element. "Diplogen", meaning in Greek *double*, found some enthusiastic reception among the scientists present at the meeting, because, in the words of Sidgwick, "the interesting thing about it is not that it is the second lightest particle….[but rather] that it is double the first one".[21] Moreover, since the atomic volume and atomic number are the same as the hydrogen, the physical properties of this substance would not differ much from those of hydrogen, to the point that – as Dr Aston reported at the meeting – Prof. Bohr preferred to call it simply "hydrogen" since its atomic number was 1 and it was not a new element. Yet, there are some noticeable differences in the chemical behaviour of the new element, especially its rate of diffusion and chemical reactions, which were duly reported at the Royal Society meeting'.

'Although these isotopic species of water molecules are physically and chemically very similar', the Earth scientists continue, 'they give rise to divergences at the macroscopic level of thermodynamic properties such as temperature of maximum density, heat capacity, volume and compressibility. For example, the temperature of maximum density, that is the temperature at which $(\partial\rho/\partial T)_{\mathrm{p}} = 0$ is 3.98 °C at atmospheric pressure for H_2O, but becomes higher

[19] See E. Rutherford, et al., 'Discussion on heavy hydrogen', *Proceedings of the Royal Society* **A 144** (1934), 1–28.

[20] Op. cit note 19, 14.

[21] Op. cit, 6.

(of the order of 11.44 °C) for D_2O. Hence, the different melting and freezing points of the two liquids. Those macroscopic changes are due to the complex dynamics of liquid water, where both intramolecular vibrational modes and bending and stretching of the hydrogen-bonds and O–D bonds enter. And in biochemical reactions, replacing ordinary hydrogen with "heavy hydrogen" has far-reaching effects on the way living cells operate.'

'Until a year ago (i.e. 1934), ^{2}H still did not have a universally agreed name. Urey suggested "hydrogen two" for its nucleus and "pycnogen" for the element itself; Gilbert Lewis was in favour of taking ^{2}H as an element in its own right called "dygen", and called its nucleus "dyon". Eventually, Urey opted for "deuterium", upon suggestion of professors in the Dept. of Greek, and the name has now been universally accepted'.[22]

'It has also became clear', the Earth scientists point out, 'that given the very low percentage of "heavy water" contained in naturally occurring water, producing pure heavy water by electrolysis of ordinary water is a very difficult and expensive process. To produce one kilogram of heavy water, 50 tons of ordinary water have to be treated for one year, consuming 320.000 kilowatt hours, and, the output would still have a purity no better than about ten per cent'.[23] 'The first industrial scale production of heavy water has just opened in Vemork, Norway, a year ago (in 1934)', the Earth scientists continue, 'and scientists are all excited at the prospects of its possible applications in biochemistry, and even its possible therapeutic uses. We are still working on possible methods of estimating the quantity of deuterium in naturally occurring hydrogen, following up on the works of Drs. L and A. Farkas, but all the evidence points to a very low percentage which could potentially create problems when it comes to industrial scale production.'

Here the report of the Earth scientists to the Earthlings on heavy water ends, as of 1935. The following events are now history. The nuclear plant in Vemork was bound to play a key role in the nuclear race that eventually led to the production of the H-bomb.[24] During World War II and throughout the 1950s and 1970s, scientists explored a variety of methods for production of heavy water on industrial scale, the two main ones being distillation processes from water or hydrogen, and chemical exchange processes involving either

22 See P. F. Dahl, *Heavy water and the wartime race for nuclear energy* (Philadelphia: Institute of Physics Publishing, 1999), 29–30.

23 Op. cit note 22, 41.

24 See op. cit. note 22.

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water-hydrogen or water-hydrogen-sulfide. In both types of processes, the production of heavy water faced a serious challenge due to the very low deuterium-to-hydrogen ratio in nature.[25]

Ordinary water has indeed turned out to be a mixture of various isotopic varieties, such as $^{1}H_2^{16}O$, $^{1}H_2^{18}O$, $^{1}H_2^{17}O$, $^{1}H^{2}H^{16}O$. Isotopic variation is not normally regarded as relevant for the purpose of calculating physical properties of water because those properties do not vary much on a molar basis.[26] But it does become relevant when dealing with macroscopic, thermodynamic properties dependent on the atomic weight of the molecules.[27]

[25] In the words of Howard Rae, *Separation of hydrogen isotopes* (Washington, DC: American Chemical Society, 1978), 3, from Chalk River Nuclear Laboratories of Ontario (Canada): 'This very low value of the deuterium-to-hydrogen ratio in nature of about 150 ppm is the main factor responsible for the high cost of heavy water. It is necessary to process at least 8000 mols of feed per mol of product for all processes…Thus, the overall concentration ratio from feed to product is about 3×10^6. This means that hundreds of separative elements in series are needed to go from natural water to reactor grade heavy water.'

[26] F. Franks, *Water: a matrix of life* (Cambridge: The Royal Society of Chemistry, 2000), 19.

[27] Incidentally, this is one of the motivations for Paul Needham's suggestion that microstructural features should not be invoked to classify chemical substances, and instead macroscopic thermodynamic features, such as Gibbs' rule provide more helpful standards for classifying substances (see Needham 'What is water?', *Analysis* **60** (2000), 13–21; and Needham 'The discovery that water is H_2O', *International Studies in the Philosophy of Science* **16** (2002), 205–226). On Needham's account, deuterium oxide would indeed qualify as a separate chemical substance (for a criticism of thermodynamic considerations as a criterion for classifying chemical substances, see R. Hendry 'Entropy and chemical substance', *Philosophy of Science* **77** (2010), 921–932). Although Needham's suggestion is a helpful one, in what follows I stick with scientific orthodoxy in taking the microscopic atomic-number dependent properties as the basis for chemical elements' classifications (as per periodic table), and in taking the macroscopic thermodynamic properties as supervenient on them. In particular, I endorse Robin Hendry's ('Microstructuralism: problems and prospects', in K. Ruthenberg and J. van Brakel (eds.) *Stuff: the nature of chemical substances* (Würzburg: Königshausen und von Neumann, 2008), 118) characterization of microstructuralism as 'committed to two dependence theses: (i) the physical exhaustion of the chemical (take away the microphysical properties and there is nothing chemical left), and (ii) supervenience of chemical kind membership on microphysical properties (there can be no change, or difference, in chemical kind membership without some change, or difference, in microphysical properties' intended as a non-reductionist

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What lessons should we draw from the intricate (historical and scientific) details of the 'Deuterium Earth story continued'? The first obvious lesson is the sheer historical contingency of dubbing and re-dubbing, echoing Hacking's.[28] That Urey's 'deuterium' was ultimately chosen over Rutherford's 'diplogen' or Lewis's 'dygen' is a sheer historical contingency, based on the tacit principle that the discoverer gets priority in naming. We might well have chosen 'dwater' to designate D_2O. But one thing is certain. From these series of historical contingencies of dubbing and re-dubbing, it does *not* follow that we *did not* discover that D_2O is a *kind of water*. Nor does it follow – as LaPorte recommends – that D_2O content is neither necessary nor sufficient to fix the reference of both 'dwater' and 'heavy water'. I take it that for a paradigm sample of D_2O *not* to be baptised as a kind of water, but as some new liquid, a main condition would need be satisfied:

(I) the paradigm sample of D_2O would have to bear ***no*** *same microstructural-kind relation* to any ordinary sample of water in our planet.

But in fact, any paradigm sample of D_2O would fail to meet condition (I.) on two distinct grounds:

i. isotopes, although not chemically identical, share nonetheless many physical properties, given the same atomic number – which is the reason why they do not occupy separate places in the periodic table (Bohr lost the battle of dubbing, but won the war on the periodic table).[29] Hence, given the same atomic number, and given our system of periodic classification,

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thesis. My goal here is to assess LaPorte's criticism of Putnam's view that it is the relation *same microstructural kind* to paradigm sample of 'water' in our actual world that establishes whether deuterium oxide is a kind of water. Whether or not microstructuralism is in turn correct as a view of chemical classification is a separate issue, which falls outside the aim and scope of this paper.

[28] I. Hacking, 'The contingencies of ambiguity', *Analysis* **67** (2007), 269–77.

[29] Robin Hendry ('Elements, compounds and other chemical kinds', *Philosophy of Science* **73** (2006), 864–875; and 'The elements and conceptual change', in H. Beebee and Sabbarton-Leary (eds) *The Semantics and Metaphysics of Natural Kinds* (New York: Routledge, 2010), 148) has poignantly stressed this point against LaPorte by noting how atomic mass bears no close relationship to chemical behaviour because isotopes of two different elements may share the same atomic weight.

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scientists are justified in counting isotopic varieties of water (such as D_2O) as *kinds* of 'water'.[30] The physical properties of D_2O and H_2O on a *molar basis* are sufficiently similar, and differences emerge at the macroscopic level of their thermodynamic properties (such as temperature of maximum density). On the basis of physical similarity at the molar basis, there is again no overwhelming reason for counting deuterium oxide as a distinct substance from ordinary water, which recall is not pure protium oxide but a mixture of several isotopic varieties (although LaPorte is correct in noting that at the macroscopic level of properties, including its melting and freezing points, it looks like a distinct substance). Then, D_2O differs from ordinary H_2O at the level of chemical *macroscopic* properties, but not at the level of the physical *microscopic* properties. But to count as a distinct substance not bearing same microstructural-kind relation, D_2O would need to differ from ordinary H_2O in terms of physical *and* chemical properties, which is not the case.

ii. Most importantly, naturally occurring water is a mixture of several isotopic species of both hydrogen and oxygen, whose very small percentages are not sufficient to alter the overall chemical and thermodynamic properties of ordinary water at the macroscopic level. This is the reason why isotopic varieties are normally included in the extension of 'water', and not classified as separate substances.[31] In particular, the very low D/H ratio in naturally occurring water means we will

[30] A clarification is in order here. The above observation is not meant to be a sweeping claim to the effect that it would be unconceivable to take isotopic varieties (say, protium and tritium, where the latter is radioactive) as two different substances. Instead, the observation above is meant to be a simple remark that given our current periodic table, and given Bohr's victory over the role of atomic number in the classification of elements, it just happens that in any Putnamian-like baptism of D_2O *in our actual world* isotopic varieties of water are not normally classified as different substances. Appealing to the intuition that one is radioactive and the other is not, does not begin to show that they should or could be counted as two separate substances.

[31] I do not want to suggest that low concentration of substances in nature is a ground for not counting them as distinct kinds. If this were the case, then many substances (e.g. rare earths) would not qualify as distinct kinds, which is obviously false. Instead, I am making the more modest claim that given the low percentage of isotopic varieties (such as deuterium oxide) in naturally occurring water, there is no paradigm sample for LaPorte's imagined baptism of D_2O as not a kind of water *in our planet*.

> never encounter a Deuterium Earth's ocean, or any significant amount of naturally occurring deuterium oxide that could serve as a paradigm sample for the Earthlings' imagined baptism (because of chemical *macroscopic* differences with our ordinary H_2O), *pace* LaPorte's fictional scenario. The only significant amount of D_2O that we *could* encounter and that could function as a paradigm sample for the Earthlings' imagined baptism would be industrially produced via causal mechanisms involving either distillation or chemical exchange from ordinary water. But this would undercut the seemingly probative force of LaPorte's thought-experiment as presumably the quantities so produced would not count as naturally occurring *in our actual world* (which is a key aspect of any Putnamian-like baptism – see more on this point in Section 4.1).

Thus, either the Deuterium Earth's ocean sample does not meet condition (I.) (because of i.); or it does meet condition (I.) at the cost of not being a *paradigm* sample of deuterium oxide (because of ii.). Ordinary D_2O does bear *same microstructural-kind relation* to ordinary H_2O to deserve *The Times*'s appellative of 'a new kind of water'.

LaPorte suggests that the Earthlings' conclusion that D_2O is not a kind of water is justified by the absence of *same microstructural kind* relation to what we ordinarily call 'water',[32] given that the liquid does not support aquatic forms of life, has a different melting and freezing point, etc. But as it happens, at the bare microstructural level and physical properties at the molar basis, there are no overwhelming differences between the physical properties of ordinary H_2O and those of ordinary D_2O. The differences arise at the *macrostructural* level, where thermodynamic properties enter, due to the complex dynamics of liquid water. Thus, to claim that D_2O may not be counted as a *kind of water* on the basis of these macroscopic thermodynamic properties would not *per se* undermine the Putnamian claim that D_2O does bear the *same microstructural kind* relation to the majority of what we have been calling 'water' all along.

But there is more. Most of what we have been calling 'water' consists of an isotopic mixture at the microstructural level, with tap waters from various countries easily differing by as much as 15 percent in the D/H ratio.[33] And in the absence of a single sample

32 Op. cit. note 1, 107.

33 H. Craig 'Standard for reporting concentrations of deuterium and oxygen-18 in natural waters', *Science* vol. **133**, No. 3467 (1961), 1833.

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of average ocean water easily available to circulate widely, a new 'standard mean ocean water' (SMOW) was defined in relation to the National Bureau of Standards isotopic reference sample No. 1 (NBS-1), such that

$$D/H\ (SMOW) \equiv 1.050\ D/H\ (NBS\text{-}1)$$

'thus tying the standard to a sample readily available for world-wide distribution'.[34] With the new SMOW in place, it has been possible to measure the deuterium enrichments per millage in various samples of ocean water, ranging from the −0.7 of the Atlantic, to the +0.9 of the Pacific, and +0.1 of the Indian ocean, leading to an average D/H ratio of 1/6328.[35]

The standards used to measure the deuterium enrichments of ocean waters might be regarded as conventional stipulations. But they do not make the inclusion of deuterium enrichments into the kind 'water' itself a stipulation, nor do they make the Pacific ocean more 'dwatery' than the Atlantic! On the contrary, our resilient use of the term 'water' to designate average ocean water and the scientific quest for a consistent measurement standard for its isotopic varieties speaks against the seemingly probative force of LaPorte's thought-experiment. If we take the term 'water' to designate the life-supporting liquid we are accustomed to from lakes, oceans, and rain, then given the very small (average) D/H ratio in naturally occurring water, we are justified in taking isotopic varieties as one kind of chemical substance that we have been calling 'water' all along.

Moreover, if we consider that pure D_2O does not occur naturally, then the term 'water' used to designate Earth's ocean liquid, and the term 'dwater' used to designate Deuterium Earth's ocean liquid, would presumably both refer to isotopic mixtures, distinguished only by different ratios of D/H content (low on planet Earth, and high on Deuterium Earth). But then the difference between the Earth's ocean liquid and the Deuterium Earth's one would be just a matter of degree. And if the Earth's ocean liquid deserves the name of 'water' despite being an isotopic mixture, one may wonder why the Deuterium Earth's ocean liquid should be denied such an appellative.

To sum up so far, if at the microstructural level ordinary D_2O and ordinary H_2O do not differ that much and if the macroscopic differences (arising at the level of thermodynamic properties) are presumably supervenient on the physical properties at the microstructural

[34] Op. cit note 33, 1833.
[35] Op. cit, 1833.

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level,[36] the case can be made for why facts about the D_2O content of Deuterium Earth's ocean liquid underwrite the conclusion that it is, after all, an isotopic *kind of water*. Since LaPorte's story relies heavily on those facts, the Deuterium Earth story does not license the conclusion that we could have gone either way in taking D_2O as a *kind of water* or not.

But it is not just the scientific credibility of the vernacular kind term 'dwater' (i.e. meaning 'not-a-kind-of-water') that is at stake here. As I am going to argue in the next Section, also from a *semantic* point of view, 'dwater' is not on a par with 'heavy water'. Recall that in LaPorte's story both Earthlings and Earth scientists have apparently access to the same scientific information about the microstructural nature of deuterium oxide; they just happen to use two different vernacular kind terms to refer to D_2O. LaPorte's story does not tell us whether the Earthlings prior to 1935 know or use the scientific kind term 'deuterium oxide'. All we know is that they call 'dwater' what the Earth scientists call 'heavy water'. Let us grant that they both refer to the same microstructure, namely D_2O, but they diverge about vernacular kind terms.

I contend that the two vernacular kind terms are not semantically on a par, because vernacular kind terms are opaque, so to speak, under coextensive predicate substitution.[37] Despite both 'dwater' and 'heavy water' being coextensive with the predicate 'being D_2O', it is not the case that we can substitute 'dwater' for 'heavy water' in any sentence in which the latter appears (e.g. in inductive inferences) and preserve the projectibility of the term. The reason is that despite having the same extension (D_2O), 'dwater' and 'heavy water' have different intensions. 'Dwater' is the vernacular kind term given to D_2O in a fictional baptism where all the available evidence about *macroscopic* properties (melting and freezing points, poisonous nature for living creatures, and so forth) suggests that the substance in question is *not* a kind of water. Vice versa, 'heavy water' is the vernacular kind term given to D_2O in the real baptism

[36] See footnote 27.

[37] I echo here Fred Dretske's ('Laws of nature', *Philosophy of science* **44** (1977), 248–68) similar argument for laws of nature intended as necessitation relations between universal properties. In that context, the opacity under co-extensive predicate substitution serves as an argument for the view that laws cannot be understood as true universal generalizations. In my case, the opacity under co-extensive predicate substitution serves as an argument for the view that we cannot interchange co-extensive vernacular kind terms in inductive inferences, *salva projectibility*.

by *The Times* in December 1933, where the available evidence about the very low percentage of this isotopic variety in naturally occurring water suggested that the substance in question was *a kind of water*. Thus, co-extensivity notwithstanding, the different intensions translate into the two terms being opaque under co-extensive predicate substitution. Opacity has consequences for the projectibility of the terms. In particular, it gives rise to a dilemma. *Either* the two terms are not interchangeable because, as I am going to show in the next Section, while 'heavy water' is projectible, 'dwater' is not. *Or,* for them to be interchangeable in inductive inferences *salva projectibility*, 'dwater' would have to be construed as synonymous with 'heavy water', i.e. as a *kind of water*, undermining in this way LaPorte's story that 'dwater' denotes D_2O as *not-a-kind-of-water*.

4. Why 'dwater' does not have the same semantic status of 'heavy water'. A Goodmanian twist to the Deuterium Earth story.

Should the Earthlings then agree with the Earth scientists that the Deuterium Earth's ocean liquid is, after all, a kind of water? In the light of the discussion in the previous Section, and in the absence of two alternative systems of chemical classification for D_2O in current chemistry,[38] it would prove hard to resist this conclusion. Let us grant then that the Earthlings eventually agree with the Earth scientists, upon hearing their report in 1935, that D_2O is after all, a new kind of water. But they insist on preferring their own vernacular kind term 'dwater', as opposed to 'heavy water', to mark the significant differences between the two liquids at the macro-structural level. The imagined dialogue may go as follows:

> *Earth scientists*: 'So, you can see that the Deuterium Earth's ocean liquid is after all *a kind of* water in the light of its physical properties on a molar scale, and very low ratio in naturally occurring isotopic mixtures'.

[38] LaPorte's analogous case for biological kind terms (op. cit. note 1, ch. 3) is more successful than his case for chemical kind terms, in my view, precisely because in biology there are competing biological schools (cladistics and evolutionary taxonomy), for classifying biological species and higher taxa. The present article should then be read not as an attempt to criticise LaPorte's view *tout court*, but instead as raising a difficulty for extending his account to chemical kind terms (at least, in the specific case of deuterium oxide).

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Earthlings: 'Fine. But we really feel that your vernacular kind term "heavy water" under-represents the very peculiar chemical features of the new liquid, and creates the potentially misleading association with what we ordinarily call "water". After all, "water" is associated with a life-supporting liquid, whereas this liquid here is poisonous to all higher forms of life. We'd rather stick to our original term "dwater" to demarcate the chemical difference between the two. The two vernacular kind terms "dwater" and "heavy water" are on a par from a semantic point of view. They both refer to the same stuff, namely D_2O. Yet they mark an important difference. "Dwater" refers to D_2O not as a kind of water, i.e. it refers to D_2O with respect to those aspects in which it differs from what we ordinarily call "water".'

Earth scientists: 'Do you mean with respect to the relevant thermodynamic differences at the macroscopic level, such as temperature of maximum density, and hence boiling and freezing points, and its implications for glucose oxidation and ATP synthesis?'

Earthlings: 'Yes, precisely. We feel that those relevant differences deserve a brand new name, at a sufficient distance from "water" and associates (i.e. "heavy water"). Had we been at the Royal Society meeting in 1933 when the issue of the name was highly debated, we would have pushed for this alternative option. After all, it is only a semantic stipulation whether we include D_2O into the existing kind term "water" (and just add an adjective to it) or we coin a new name for it. Semantically, "dwater" is on equal footing with "heavy water" and could be used interchangeably with it: it could feature into the same inductive inferences'.

Earth scientists: 'Unfortunately, you are late in the dispute about naming. The choice has already been made.'

Earthlings: 'But things could have gone otherwise. Had our expedition come back two years earlier, we would have lobbied for the alternative name "dwater" and won the battle at the Royal Society meeting, where, from what we have heard, some scientists like Aston shared our feelings.'

What should we make of the Earthlings' thesis of semantic stipulation? To be defensible, one must prove that the two vernacular kind terms 'dwater' (as the Earthlings dub the Deuterium Earth's liquid) and 'heavy water' (as the Earth scientists call it) are semantically on a par. But, in fact, if we take LaPorte seriously – i.e. that there is no Putnamian fact of the matter as to whether deuterium oxide is or is not a kind of water (i.e. that D_2O content is neither necessary nor sufficient to fix the reference of the term, and that it is only a matter of refining our vague use of kind terms) – then an unwelcome Goodmanian scenario may arise.

Projectibility[39] is a distinctive feature of natural kind terms under a variety of alternative accounts (from Boyd's and Kornblith's realism about kinds, to Hacking's nominalism, and Kuhn's constructivism).[40] Kind terms must be projectible for them to be the basis of successful inductive inferences in science.[41] Thus, for 'dwater' to

[39] At the end of *Fact, Fiction, and Forecast*, Goodman suggested that his analysis of projectibility could be used to distinguish between genuine and artificial kinds, or more genuine from less genuine ones: 'For surely the entrenchment of classes is some measure of their genuineness as kinds; roughly speaking, two things are the most akin according as there is a more specific and better entrenched predicate that applies to both', N. Goodman *Fact, Fiction, and Forecast,* 3rd ed. (Indianapolis: Bobbs-Merrill, 1973), 123.

[40] R. Boyd 'Realism, anti-foundationalism, and the enthusiasm for natural kinds', *Philosophical Studies* **61** (1991), 127–48. H. Kornblith *Inductive inference and its natural ground. An essay in naturalistic epistemology* (Cambridge, Mass.: MIT Press, 1993). I. Hacking 'Working in a New World: the Taxonomic Solution', on P. Horwich (ed.) *World Changes. Thomas Kuhn and the Nature of Science* (Cambridge, Mass.: MIT Press, 1993), 275–310. T. Kuhn 'Afterwards', in P. Horwich (ed.) *World Changes. Thomas Kuhn and the Nature of Science* (Cambridge, Mass.: MIT Press, 1993), 311–39. While Goodman's notion of projectibility is tied to his notion of entrenchment (i.e. how often a predicate or a natural kind term has been successfully projected in the past), some philosophers after Goodman have married projectibility to truth as in Boyd's case, where kind terms are said to be projectible because they latch onto the causal structure of the world (Boyd, op. cit., 139). Other philosophers have retained projectibility without giving an account of it in terms of truth or entrenchment (as in Hacking's case). Others, like Kuhn (1993, op. cit., 315–9), have defended projectibility within the context of a *prima facie* constructivist position. In what follows, I am going to be noncommittal about the nature of projectibility and I take it simply as a measure of natural kind terms' amenability to supporting successful inductive inferences.

[41] One may be suspicious about projectibility on the ground of Popperian doubts about the success of our inductive inferences in general. But this would be a *non-sequitur*. One of the key motivations for natural kinds is that they are meant to support our inductive inferences and explanations, quite independently of whether one is realist, nominalist or constructivist about kinds (as clarified in the footnote above). Even a Popperian, with reservations about our ability to project into the future,

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be semantically on a par with 'heavy water', one must show that it is projectible, i.e. that it supports successful inductive inferences. But 'dwater' is in fact vulnerable to the new riddle of induction, as the following Goodmanian twist to LaPorte's story shows. In Section 4.2, I consider some possible responses to it, and conclude that none of them successfully evades the Goodmanian scenario.

4.1. A Goodmanian twist to the Deuterium Earth story

Let us go back to the beginning of our story. It is the year of the expedition (1905) and the Earthlings have just landed on Deuterium Earth with a jar containing ocean-water. The liquid inside the jar looks *prima facie* identical to the liquid that fills the ocean on Deuterium Earth. But they soon realise that there are some important differences between the two. They decide to dub the non-better-identified microstructure of the Deuterium Earth's liquid as PQR. Eventually, through sophisticated testing, the Earthlings find out that the ocean-liquid consists of an oxygen atom and two hydrogen atoms that happen to have a bigger mass than the hydrogen atoms known to them, because of an additional neutron in the nucleus. They aptly dub the chemical element 'deuterium' in homage to Deuterium Earth, re-dub accordingly the microstructure of the ocean-liquid as D_2O, and the ocean-liquid itself as 'dwater' to mark the difference from 'water' of planet Earth. So far, this bit of the story follows exactly LaPorte's. Here is now the Goodmanian twist. By dubbing the ocean-liquid 'dwater', upon inspecting several samples, the Earthlings draw the following inductive generalization:

(A) The liquid that fills the ocean on Deuterium Earth is dwater.

Many years elapse. It is the year 1935: the Earthlings return at last to planet Earth, with a jar containing the ocean-liquid from Deuterium Earth. The Earth scientists compare the liquid with samples of a new

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would owe us an account of why inductive inferences about green emeralds have been successful up to date. And normally such an account would involve reference to natural kinds, quite independently of which view of natural kinds one favours (i.e. again realist, nominalist, or constructivist), and independently also of what view one endorses about the relation between natural kinds and dispositional properties, for example (e.g., whether kind membership can be identified with a set of necessary and sufficient dispositional properties).

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chemical element they have just identified as deuterium, and whose combination with oxygen gives deuterium oxide or 'heavy water', as they call the new isotopic kind of water. By comparing several samples, the Earth scientists conclude

(B) The liquid that fills the ocean on Deuterium Earth is heavy water.

The Earth scientists go on to explain to the Earthlings all the recent events concerning the discovery of the new isotope, as per Section 3 above. The Earthlings, faced with the new pieces of evidence eventually *agree* with the Earth scientists that from a scientific point of view, it is after all a new *kind of water*. But they insist on using their old terminology 'dwater' to mark *semantically* the difference from ordinary water, which they perceive as blurred by the term 'heavy water'. They also claim, as we saw in Section 4, that 'dwater' is semantically on equal footing with 'heavy water': they can both be used interchangeably in inductive inferences. It is after all just a matter of semantic stipulation (as opposed to discovery) – they argue, along LaPorte's lines – that the new liquid ended up being classified as a *kind of water*.

Now, if this were the case, the Earthlings would be vulnerable to the new riddle of induction. The term 'dwater' would be like Goodman's grue: something is dwater if and only if it is first examined prior to time *t* (say, 1935) and found to be *not-a-kind-of-water*; or, it is examined after time *t* and found to be *a-kind-of-water*. *If* there is no fact of the matter as to whether D_2O is or is not a kind of water and if D_2O content is neither necessary nor sufficient to fix the reference of the term, and we could have gone either way – *then* the Earthlings (who in 1935 are likely to *accept* the Earth scientists' conclusion as per Section 3) would be vulnerable to drawing 'gruified' (or better 'dwateried') inductive inferences like (A), whereby at time *t* (namely, in 1935) the same evidence that supports the Earth scientists' statement (B), namely that the liquid that fills the ocean on Deuterium Earth is a kind of water (called 'heavy water'), supports also the Earthlings' parallel statement (A) that the liquid that fills the ocean on Deuterium Earth is not a kind of water (called 'dwater').

Let me clarify this point. If one endorses the Putnamian view that the meaning of a natural kind term is not fixed by what Putnam calls the stereotype,[42] i.e. the various beliefs speakers may associate with

[42] Putnam ('The meaning of "meaning"', in H. Putnam *Mind, Language, and Reality: Philosophical Papers* vol. 2, (Cambridge: Cambridge University Press, 1975), 269) famously defined the meaning of a word (say 'water') as a four-component vector, including: 1. Semantic

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the term (for example, in the case of 'dwater', beliefs concerning its poisonous nature, its ability to be used in a weapon and so on), but it is instead fixed by the extension of the term (e.g. D_2O),[43] then in every possible world (including Deuterium Earth), in which a substance bears *same microstructural-kind relation* to what we ordinarily call 'water' on planet Earth (intended in the way specified in Section 3 above, i.e. in the Earth scientists' sense of 'water' as including all its isotopic varieties), *that substance* would count as a kind of 'water'. Under the Putnamian account, D_2O content is necessary and sufficient to fix the reference of the natural kind term. Moreover, the Kripkean rigidity of natural kind terms is understood as following from the fact that when *we* (in the *actual world*) give the ostensive definition '*this* liquid (say, deuterium oxide) is a kind of water', we intend that for every possible world *W* and every possible liquid *x* in *W*, *x* is a kind of water if and only if *x* bears the same microstructural-kind relation to the entity referred to as 'this' *in the actual world* (i.e., in the Earth scientists' world).[44] For Putnam, natural kind terms are rigid designators to the extent that the Putnamian meaning of 'meaning' is fixed by ostensive definition of paradigm samples *in our actual world*.

By rejecting Putnam's meaning of 'meaning', and by re-coupling Kripkean rigidity to some form of semantic stipulation, LaPorte suggests that natural kind terms can still be rigid designators *de jure* (not *de facto*), but whether or not *this* liquid (e.g. deuterium oxide) counts as a kind of water is ultimately a matter of speakers' decision: *we decided* to count it as such, but we *might as well have decided otherwise* (had we had the first encounter with this liquid that the Earthlings, for example, had on Deuterium Earth). However, the reasons why the Earthlings – in this hypothetical first encounter scenario – did not count *this* liquid as a kind of water seem to have nothing to do with any *fact of the matter* about the isotopic nature of deuterium oxide per se, and all to do with the Earthlings' beliefs

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marker (e.g. natural kind; liquid); 2. Syntactic marker (e.g. mass noun, concrete); 3. Stereotype (e.g. colorless; transparent;...); and 4. Extension (e.g. H_2O). Putnam identified the meaning of 'meaning' with the extension of the word.

43 Recall that for Putnam, op. cit. note 42, 270, 'although we have to use a *description* of the extension to *give* the extension, we think of the component in question as being the *extension* (the *set*), not the description of the extension'.

44 See Putnam, op. cit., 231, on this point.

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about the poisonous nature of the liquid, its ability to be used in a weapon, and so on (what Putnam would call the stereotype of a natural kind term). Had the Earthlings' had alternative beliefs about *this* liquid, the liquid might have counted as a kind of water, after all.

Moral: once we dispense with the Putnamian view that there is a fact of the matter as to whether *this* liquid (deuterium oxide) here in *our actual world* is a kind of water (also called 'heavy water'), and once we open the door to the alternative view that whether D_2O is or is not a kind of water is ultimately a matter of semantic stipulation, nothing seems to prevent the Earthlings from coining a new term such as 'dwater' (following LaPorte's own suggestion) and drawing *dwateried* inductive inferences from it. Goodman's grue could become an unwelcome real possibility, given the thesis of semantic stipulation.

4.2. Four possible responses to the Goodmanian twist

(1) First response: serendipity

Given the way LaPorte designs the Deuterium Earth story, one may reply that the Goodmanian scenario is at worst innocuous, and at best a blessing. After time *t* (1935) the inductive generalizations that the Earthlings draw for 'dwater' coincide with the inductive generalizations that the Earth scientists are drawing for 'heavy water' as an isotopic variety of water. While gruified inferences diverge after time *t*, dwateried inferences serendipitously converge after time *t*.

But the serendipitous convergence cannot be backtracked[45] prior to time *t*. Prior to time *t*, the same evidence (a jar of ocean-liquid) would support divergent inductive inferences for the Earthlings, who would conclude that it is not a kind of water, and the Earth scientists, who would identify it as an isotopic kind of water. Nor can one reply that prior to time *t* (i.e. 1935) the problem did not arise because the Earth scientists did not know about deuterium oxide, nor could draw inductive inferences about it. The Earth scientists knew about

[45] Goodman's paradox does not just apply to predictions about future cases, but more in general to inductive inferences involving projections from examined cases to (past, present, and future) unexamined cases. See on this point E. Sober, 'No model, no inference: a Bayesian primer on the grue problem', in D. Stalker (ed.) *Grue, the New Riddle of Induction* (La Salle, Illinois: Open Court Publishing Company, 1994), 193–223; and R. Israel 'Two interpretations of grue – or how to misunderstand the new riddle of induction', *Analysis* **64** (2004), 335–9.

deuterium as early as 1931 when Urey identified it as an isotope of hydrogen by evaporating liquid hydrogen at low temperatures.

(2) Second response: non-projectibility

Another strategy could be to bite the bullet and concede that 'dwater' is non-projectible (any more than 'grue' is). In particular, while the vernacular kind term 'heavy water' is entrenched in the Earth scientists' vocabulary, 'dwater' is not. The former has been successfully projected in the past, while the latter has not. Moreover, the former enter in the Earth scientists' vocabulary together with a series of laws of nature; the latter does not. One could then grant that 'dwater' is non-projectible. But the biting-the-bullet strategy would not help here. If 'dwater' has to bear the semantic weight that LaPorte's story attaches to it with the thesis of semantic stipulation, it ought to be projectible for it to be an alternative live option on equal footing with 'heavy water'.

(3) Third response: referential coincidence

Here is a more promising reply one might consider. 'Dwater' is in fact projectible (or, at least, as projectible as 'heavy water') since they are just two different vernacular kind terms referring to D_2O. It is tempting to think that the Goodmanian scenario does not arise, because, after all, both prior to and after time t (i.e. 1935), 'dwater' picks out D_2O: the Earthlings and the Earth scientists are simply using two different terms ('dwater' and 'heavy water') to refer exactly to the same liquid with the same microstructure.

Tempting as it is, there is however a major problem with this response. This line of argument is simply precluded to LaPorte, who against Putnam *denies* that D_2O content is *necessary and sufficient* to fix the reference of the term. So, *unless* LaPorte embraces Putnam's view that D_2O content is necessary and sufficient to fix the reference of both 'heavy water' and 'dwater', it is difficult to see how he could avail himself of this response. Although 'dwater' refers to D_2O all along in LaPorte's story, precisely because LaPorte does not accept Putnam's causal theory of reference, and defends instead the view that the two terms 'heavy water' and 'dwater' pick out different descriptions about D_2O (as an isotopic *kind-of-water* versus *not-a-kind-of-water*, respectively), the Goodmanian scenario cannot be easily averted. Same microstructure notwithstanding, the two terms have different *intensions*. 'Dwater' is introduced in the Earthlings' baptism to connote D_2O in those aspects in which it differs significantly from ordinary water (e.g., macroscopic, chemical properties associated with its being poisonous, having different freezing and melting points). 'Heavy water' is introduced in the Earth scientists' baptism to connote D_2O in those aspects in which it bears sufficient similarity with ordinary water (e.g. microscopic, physical properties associated with its isotopic nature). 'Dwater' connotes D_2O as *not-a-kind-of-water*. 'Heavy water' connotes D_2O as *a-kind-of-water*. By connoting different properties of D_2O (or, if you like, by associating different descriptions, or different intensions to D_2O), the two terms are opaque under co-extensive predicate substitution, with the result that they cannot be interchanged in inductive inferences *salva projectibility*: while 'heavy water' is projectible, 'dwater' is not.

In particular, in 1935, upon their return to planet Earth and upon hearing the above report from the Earth scientists (as per Section 3), the Earthlings are likely to accept that from a *scientific* point of view the paradigm sample of Deuterium Earth's ocean liquid bears the *same (or sufficiently similar) microstructural kind* relation to what we ordinarily call 'water', making 'dwater' no more projectible than 'grue'.

(4) Fourth response: stipulation versus discovery

One might rejoin that LaPorte's view escapes the problem because we *did not discover* that D_2O is a kind of water any more than we *discovered* that H_2O is water. If it is just a matter of semantic stipulation whether D_2O counts as a kind of water, it is not after all paradoxical that something that does not count as a variety of water prior to time *t*, may count as such after *t*.

But the problem remains. For the case to be made that the Earthlings' option of not counting D_2O as a kind of water is semantically on a par with the Earth scientists' alternative option (hence, for the two terms 'dwater' and 'heavy water' to be interchangeable in inductive inferences), 'dwater' would have to be construed as *synonymous with* 'heavy water', i.e. it would have to be *surreptitiously* construed as connoting D_2O as a *kind-of-water*. It is not surprising that 'coincidentally'[46] (and in blissful ignorance of) the Earthlings arrive at the same conclusions of the Earth scientists about the atomic microstructure of deuterium oxide (without in fact even knowing anything about isotopes, or knowing the difference between microscopic atomic-number-dependent and macroscopic atomic-weight-dependent properties), and even about its chemical reactions in a H-bomb, twenty or so years before one was in fact

[46] LaPorte, op. cit. note 1, 107.

built and tested on planet Earth (in the early 1950s with the consequent destruction of the Bikini Atoll in Micronesia). Without mentioning that the 'sophisticated techniques' through which the Earthlings eventually learn about the unusual hydrogen composition of the ocean-liquid are presumably one and the same distillation techniques used by Harold Urey in 1931 to identify the hydrogen isotope.

In sum, to escape the Goodmanian scenario and argue for the projectibility of 'dwater' as a semantically live option on a par with 'heavy water', one must pack into the term 'dwater' as many scientific assumptions as possible about the D_2O content as an isotopic *kind-of-water*, including its far-away-in-the-future performance in an H-bomb (with a Deuterium Earth-equivalent of the Bikini Atoll). In this way, the projectibility of 'dwater' becomes parasitic on the projectibility of 'heavy water' as an isotopic kind of water.

But if the projectibility of 'dwater' is ultimately parasitic upon the projectibility of 'heavy water' (because scientific facts about the D_2O content determine the reference of 'dwater' as much as they determine the reference of 'heavy water'), then the two are no longer *alternative* options. The Deuterium Earth story would no longer support the thesis of semantic stipulation, according to which we could have gone either way in taking D_2O as a kind of water or not.

5. Conclusion

This is after all only a story. We do not have competing chemical schools, classifying D_2O, respectively, as a kind of water or not (by contrast with biology, where there are competing biological schools for the classification of higher taxa). Perhaps an account of what makes both 'heavy water' and 'dwater' projectible (without falling back onto Putnamian assumptions about the D_2O content being necessary and sufficient to fix the reference of the terms) is available within the resources of LaPorte's view. Perhaps rigidity *de jure* of kind terms can be of some help here. But LaPorte gives no indication of how an account of projectibility would look like within the resources of his view of natural kind terms. And without such an account, the received chemical orthodoxy that D_2O is an isotopic kind of water, and that Deuterium Earth's ocean is *watery* after all, seems to stand unscathed.

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