Why Rigid Designation Cannot Stand on Scientific Ground

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ABSTRACT

I do not think the notion of rigidity in designation can be correct, at least not in any way that can serve to ground a semantics that purports both to be fundamental in a semiotical sense and to respect the best science of the day. A careful examination of both the content and the character of our best scientific knowledge not only cannot support anything like what the notion of rigidity requires, but actually shows the notion to be, at bottom, incoherent. In particular, the scientific meaning of natural kind terms can be determined only within the context of a fixed scientific framework and not *sub specie æternitatis*. Along the way, I provide grounds for the rejection of essentialist views of the ontology of natural kinds.

Contents

> Rationalists, wearing square hats,
> Think, in square rooms,
> Looking at the floor,
> looking at the ceiling.
> They confine themselves
> To right-angled triangles.
> If they tried rhomboids,
> Cones, waving lines, ellipses—
> As, for example, the ellipse of the half-moon—
> Rationalists would wear sombreros.
>
> Wallace Stevens
> "Six Significant Landscapes"

1 Introduction

One important school of thought in the philosophical study of meaning over the last 40 or so years, propounded originally by Putnam and Kripke, revolves around the idea of the so-called rigidity of reference, itself grounded in part on a funny sort of Aristotelian essentialism about individuals and species. For the sake of convenience and brevity, I will, for lack of a better term, nominate that cluster of ideas and positions 'the rigid view'. I do not know whether this school constitutes the dominant or primary school of thought in philosophy today. I do know that it has exerted and continues to exert a profound influence on much of the most influential work in the area over the last 40 years. So called possible-world semantics, *à la* David Lewis and his followers, for example, a program of considerable current, active research, assumes a form of rigidity of reference in its notion of trans-world identity, at least so far as properties of systems are concerned. Even those points of view in the mainstream opposed to one or more fundamental tenets of the rigid view often share with it, at the most fundamental level, the picture of what a theory of meaning ought to or must look like, to wit, as founded on the idea of reference as a more or less primitive and ineliminable component of the idea of meaning. The rigid view, in my opinion, most clearly articulates this vision while at the same time, in the guises I treat in this paper, paying at least lip-service to the conceit that our scientific knowledge of the physical world ought to constrain and inform our attempts to comprehend meaning, in so far as it is a relation between language and the world.

I do not think the rigid view or anything that depends on something like its notion of rigidity can be correct, at least not as an account of semantics that purports both to be fundamental in a semiotical sense and to respect the best science of the day. A careful examination of both the content and the character of our best scientific knowledge of the world shows not only that they cannot support anything like what the notion of rigidity requires, but shows the notion to be, at bottom, incoherent. In particular, the meaning of natural kind terms can be fixed only within the context of a particular scientific framework, which must itself include at the least something like a fixed theory and family of experimental practices. It will follow more or less immediately from this fact that the idea of rigidity cannot stand. My arguments, for the same reasons, speak against essentialist views of the ontology of natural kinds.

During the course of the discussion, I contrarily advert to and even quote from and controvert in some detail the works of only two philosophers, Putnam and Kripke, whom I consider archetypical of the picture behind the rigid view and many of its contemporary alternatives.[1] Even though I do not explicitly address other philosophers and accounts, I ask the reader to bear in mind my target is not this philosopher or that work but rather the entire picture that motivates and seems to justify those sorts of positions in the first place.

My arguments do not pertain to the idea of reference and designation in an account of the semantics of ordinary language, at least in so far as such a semantics does not purport to ground itself in any deep way on scientific knowledge, as, for example, those of Keith Donnellan or Gareth Evans.[2] My arguments pertain only to reference as part of an account of semantics that explicitly purports to stand on the ground of scientific knowledge. Indeed, part of the implicit thrust of the arguments is that, *pace* Quine, there is a very sharp distinction indeed between the sort of meaning that scientific language has and the sort the language of the workaday world has. I see no *prima facie* problem with having reference as a semantically fundamental component of an account of the meaning of ordinary language, although I myself do not think it is in the end viable even there.[3]

2 Rigidity

I shall use the following standard definition (Putnam 1975, p. 231) for the idea of rigid designation:

> a designator [is *rigid*] (in a given sentence) if (in that sentence) it refers to the same individual [or kind] in every possible world in which the designator designates

The idea that a designator can be thought of as designating "the same individual [or kind] in every possible world" presupposes the idea that we can identify the same individual or kind across possible worlds. Let us grant that conceit for the sake of argument.

Now, Kripke (1980, lecture 1, p. 43) says something remarkable about this:[4]

[1] I want to emphasize, indeed, that I endorse many of the conclusions that Putnam (1975) arrives at. I balk only at the methods and arguments. In particular, much of the argument of §4 can be construed as what I hope to be an improved version of Putnam's argument that intension does not determine extension—that meaning ain't in the head.

[2] Peter Machamer has remarked to me that Donnellan, at least, intended his semantics to be applicable to scientific language even if not explicitly grounded in scientific knowledge. A trivial emendation of my arguments here speak against such a conception.

[3] Perhaps even rigidity of reference can be used to ground a semantics of non-scientific language—*non-scientific* in the very strong sense that no advance in or refinement of scientific knowledge can affect the meaning of its terms—but I myself doubt it; in any event, to emphasize the point again, my arguments do not bear on that sort of case.

[4] The argumentative context for this proposition is a little tricky. Kripke proposes it in his argument that descriptions cannot serve to fix the identity of individuals across possible worlds, but he does so in particular as a suggestion

> The question of essential properties so-called is supposed to be equivalent (and it is equivalent) to the question of 'identity across possible worlds'.

I suspect he holds this because he sees only two other ways to do things. If the fixation of reference "across possible worlds" is not to degenerate into a mere iteration of stipulated associations, such as

1. stuff ϕ_A in possible world A (the referent in A of 'ϕ_A') is the same as stuff ϕ in the actual world
2. stuff ϕ_B in possible world B (the referent in B of 'ϕ_B') is the same as stuff ϕ in the actual world
3. ...

and if it is not going to devolve upon a descriptive account ("ϕ_B in possible world B is that unique stuff most closely satisfying the (bundle of) description(s) Δ"), as Kripke, Putnam, *et al.*, reject, then one must have recourse to something like essences, or, in less inflammatory language, hidden structures. Because I also know of no other way of going about these things, I shall assume for the sake of the paper's arguments that rigidity is grounded upon an essential hidden structure of individuals and kinds.

3 Water and H_2O

3.1 What Is Water?

Water is the canonical example of a natural kind used in discussion of these matters. To get a grip on the sort of stuff we must take water to be for the sake of those arguments, consider Putnam's (1975, p. 223) characterization of XYZ, the stuff on Twin Earth that is supposed to be practically the same as water in our world:

> One of the peculiarities of Twin Earth is that the liquid called 'water' is not H_2O but a different liquid whose chemical formula is very long and complicated. I shall abbreviate this chemical formula simply as XYZ. I shall suppose that XYZ is indistinguishable from water at normal temperatures and pressures. In particular, it tastes like water and it quenches thirst like water. Also, I shall suppose that the oceans and lakes and seas of Twin Earth contain XYZ and not water, that it rains XYZ on Twin Earth and not water, *etc.*

In other words, XYZ—or water$_2$, as opposed to the water$_1$ we have in our world (which I will continue to designate by 'water' unless there is a chance of ambiguity)—must be indistinguishable from

for the motivation that may drive descriptivists to construct and propose the sorts of account they do. Still, it is clear from the course of the argument that he himself endorses the proposition and uses it to ground, in part, his notion of rigidity. He seems to think, therefore, that the descriptivists have sound motivations but mis-use them to guide the contruction of accounts that are on his view not viable.

water over an extraordinarily broad spectrum of environmental conditions and states (temperatures, pressures, *etc.*, all those Putnam qualifies as "normal"), such as super-heated and under great pressure in thermal vents at the bottom of the ocean (since the oceans on Twin Earth are filled with it), very cold and rarefied as vapor at 80,000 feet (since the atmosphere of Twin Earth contains it), in the enzymatically complex and strongly buffered conditions in which organic metabolism takes place in any of tens of millions of different species of organisms (since the creatures on Twin Earth imbibe it), and so on.

It is clear from the argumentative context that Putnam takes water$_2$ to be indistinguishable from water in all its operational properties, to use his term, *viz.*, those essential qualitative properties that a normal speaker without any scientific training would be familiar with, such as the fact that it functions as a more or less universal solvent, that it expands on freezing, *etc.* (even though most speakers might not express those facts in the language I use). Several such properties, in fact, play an integral role in the characterization of water as a particular kind of stuff as modeled by the classical theory of fluid dynamics, Navier-Stokes theory, in a sense the natural theory to use when scientifically investigating water when it is treated simply as a gross fluid possessing those properties familiar to normal speakers.[5] Most normal speakers, from having swum or having stirred soup, have a sense of how stiffly water resists the motion of bodies through it; that is a measure of the shear viscosity of water, one of the quantities Navier-Stokes theory attributes to the fluids it models. They also have a sense of how quickly heat disperses through water (from, say, having sat in a bathtub of cool water when the hot tap was suddenly turned on) and of how much heat it takes to raise water's temperature (from having watched the teapot waiting for it to boil) and of how long it takes for hot water to cool (from having waited for their tea to become drinkable); those measure its thermoconductivity and its heat capacity, respectively, also quantities Navier-Stokes theory attributes to fluids it treats.

Normal speakers of course do not in general know accurate numerical values for water's shear viscosity or any of those other quantities, but we have a feel for them. The important point for later in the argument is that, so far as Navier-Stokes theory goes, to specify enough of those sorts of quantities of a fluid—its *kinematical* quantities—suffices to fix it as a species of Navier-Stokes fluid: any fluid that shares the same numerical values for all those quantities will behave identically to water in all circumstances in which Navier-Stokes theory can adequately model it, *is* in fact water in the only way one can even formulate the idea within the context of the theory. In other words, a specification of values for all a fluid's kinematic quantities defines it as something like a natural kind in the context of Navier-Stokes theory.

[5]Strictly speaking, Navier-Stokes theory by itself does not suffice to treat all the operational properties of water I discuss, even when one fortifies it with the appropriate equation of state idiosyncratic to water. One also needs to call on the resources of other theoretical and phenomenological frameworks, such as theories of sound, surfaces, thermal convection, diffusion, shock waves, *et al.* For the sake of brevity, I shall continue to speak as though Navier-Stokes theory by itself suffices for the treatment of all the properties I mention. None of the trans-theoretical problems of the sort I discuss in §4.2 arise in this case. (See, *e.g.*, Lamb (1932) and Landau and Lifschitz (1975) for accounts that treat all these theoretical structures in a more or less unified framework.)

Several of those properties and many more important ones like them derive theoretically from the fact that H_2O is a small, simple, thermodynamically stable, non-organic molecule composed of light non-metallic atoms whose intramolecular forces are mediated by Hydrogen rather than covalent bonds.[6]

3.2 What Is H_2O?

It is not enough to say that H_2O is a molecular structure composed of two H atoms and one O atom, for the same is true of a collection consisting of a single H atom and the negatively charged ion OH^-. H_2O is two H atoms and one O atom jointly arranged in a particular, stereometrically stable configuration: the water molecule. In point of fact, however, no portion of water, no matter how pure or small and no matter in what state or environment, consists of water molecules. Pure liquid water under normal conditions, for example, consists of a mixed bath of several ionic species, including not only H_2O but also H^+, OH^- and H_3O^+ among several others, to mention only the most commonly occurring, all held together by a hyper-dense, stereometrically complex network of Hydrogen bonds with extraordinarily rich characteristic symmetry patterns. In this bath, moreover, the true H_2O molecules share among themselves no canonical shape and no canonical form of the Hamiltonian governing its dynamical evolution; the geometry of each constituent molecule and its energetic properties rather depend sensitively on the composition of its immediate ionic neighborhood and the concomitant character of the node it finds itself inhabiting in the ambient web of Hydrogen bonds. (For the sake of brevity, nonetheless, I will often in this paper abbreviate talk about the molecular structure of water by using 'H_2O'.)

From the molecular properties of the mixed ionic bath, using the quantum theory of chemistry, we can deduce accurate numerical values for water's kinematic quantities, including its specific heats, its specific gravity, its viscosity, its solvency for various solutes, its thermoconductivity, its electrical resistance and magnetic permeability, its transparency to light of different frequencies, its refractive index, and so on. Indeed, it is this immediate linkage of its molecular structure to its gross physical properties, the possibility of such direct linkage, that allows us to say that its chemical composition is relevant, in some way or other, to our classification of it as a distinguished kind of stuff—a natural kind—in the sense relevant to the goals of the rigid program, for it is exactly these kinematic quantities that define the qualitative operational properties that typify the normal samples of water that are themselves to ground the aboriginal reference of the term 'water'. That we can do this itself depends in turn on the fact that, for a number of different sorts of investigations, in a variety of circumstances, we have well entrenched, well understood methods for defining, for a given

[6] See Eisenberg and Kauzmann (1969, *passim*, but esp. ch. 8, §4, pp. 246–253), and Marechal (2007, *passim*) for a more up-to-date account. For the sake of brevity, I will not cite them again in the paper, but the interested reader should consult them (and others like them) for detailed accounts of the claims I make about the physical properties of water and H_2O. I cite the Eisenberg and Kauzmann as well as the Marechal not only because it is a beautiful classic but also because of its publication date: 1969. All the scientifically substantiated facts about water I rely on in my arguments were well known in the scientific community at the time that Putnam, Kripke, *et al.*, worked the foundations of the rigid program out. They should have known better.

portion of water, the theoretical structures representing the distribution of the molecular states of its constitutive ionic bath and the details of the molecular behavior in the bath. We have a belief—an abiding faith—that for all those different sorts of investigations, in all the physical circumstances in which we may conduct them, the relevant theoretical, representational structures, different as they may be, will bear structural relations among themselves of a sort profound enough for us to declare that each models the same "kind" of system as all the rest, *viz.*, water. That, however, is not immediately obvious from what I have said—it is itself a matter for scientific investigation and philosophical argumentation.

4 Water Is Not $\mathtt{H_2O}$; $\mathtt{H_2O}$ Is Not $\mathtt{H_2O}$

> [T]he dimensions of our earth and its time of rotation, though, relatively to our present means of comparison, very permanent, are not so by any physical necessity. The earth might contract by cooling, or it might be enlarged by a layer of meteorites falling on it, or its rate of revolution might slowly slacken, and yet it would continue to be as much a planet as before.
>
> But a molecule, say of hydrogen, if either its mass or its time of vibration were to be altered in the least, would no longer be a molecule of hydrogen.
>
> James Clerk Maxwell
> "Address to the Mathematical and Physical Sections of the British Association (1870)"

The argument against rigidity comes in three parts. In the first two, I show that the proposition "water is $\mathtt{H_2O}$" cannot characterize water in any sense that would allow it to serve as the target of a rigid designator. In particular, in the first (§4.1), I conclude that anything like rigidity in a full blown semantics of possible worlds cannot work by showing the incoherence of *Gedankenexperimente* such as Putnam's Twin Earth. In the second (§4.2), I show that a weak form of rigidity, so to speak, one that applies only in the actual world and for counterfactuals weakly construed (*i.e.*, not grounded in a full blown possible-worlds semantics), also cannot be coherently defined. Finally, in §4.3, I consider arguments opposed to those of the first two sections and show them wanting.

4.1 Twin Earth Is Not Possible

In asking whether "water is $\mathtt{H_2O}$" is correct in a way relevant to the foundation of rigid designation, in the context of a semantics based on possible worlds such as that Kripke (1980), *e.g.*, seems to champion, it will be useful to use Putnam's (1975, p. 225) relation $\mathtt{same_L}$: that in which a sample of liquid in one possible world must stand to one in another in order for them to be samples of the same natural kind of liquid. Indeed, $\mathtt{same_L}$ exactly encodes the rigidity of the designator 'water' in this formulation of the semantics. In his infamous *Gedankenexperiment*, the stuff 'water' designates on Twin Earth, having the molecular composition $\mathtt{XYZ}$, does not stand in the relation $\mathtt{same_L}$ to the stuff 'water' designates on Earth, which is H_2O. Putnam explicitly says $\texttt{same}_L$ is a *theoretical* relation, to be determined, in principle, by scientific investigation, as it must be for his account to use the purported fact that water has the molecular structure H_2O to ground the rigidity of the reference of 'water'.[7]

To begin, then, note that much of the force of Twin Earth as an example comes from the fact that, as explicitly stated in the passage from Putnam (1975, p. 223) I quoted at some length above on page 4, water_2 (XYZ) has all the operational properties of water. Thus, he implicitly assumes that, for any kind of stuff we have operational knowledge of, and for any amount of operational knowledge we have about that stuff, it is possible that some other stuff exists that conforms to (in the obvious sense) the operational knowledge about the former but is, at some physical level, not the same as the former. He further demands, explicitly this time, that the idea of the "same" in this case must be based on a *scientifically* defined cross-world relation such as $\texttt{same}_L$. Because $\texttt{same}_L$ is a scientifically defined relation, it can, *ipso facto*, be defined only in possible worlds that are of such a sort as to be appropriately represented by something like the same fundamental scientific theories as we use in ours. If that were not the case—if the best scientific theories in two different possible worlds were so fundamentally different that one could not meaningfully translate between them—then one or the other will treat any particular relation such as $\texttt{same}_L$ as meaningless, destroying the idea of rigidity, as I proceed now to show.

To be more explicit, part of Putnam's argument has the following form:

1. we have a pre-scientific usage of a term, based on pre-scientific, but still physically rich and broad, operational knowledge of canonical samples of the stuff
2. the advance of science shows that (most of) the (normal) samples of the stuff (in the actual world) we referred to using the pre-scientific term in fact share a hidden structure
3. that hidden structure allows us to articulate a (more precise) meaning for the term, which still refers to the same stuff
4. it could have happened otherwise: science could have discovered no physically relevant hidden structure shared among the samples of stuff, while the fundamental theories of physics remain otherwise not intolerably different
5. thus, it makes sense to use a scientifically defined relation like $\texttt{same}_L$ to compare the referents of the same term as used in two separate possible world, since the science is not intolerably different between the two worlds

This, however, is not always true. (In fact, I find it likely that it is almost never, if ever at all, true.) In particular, the example of XYZ on Twin Earth violates it in several ways.

[7] As an aside I remark that, on its face, it does not seem that $\texttt{same}_L$ can be a scientifically grounded relation *at all*, in so far as it is not one that can ever, by definition, be investigated experimentally—we have no experimental access to stuff in worlds other than the actual one on which to actually perform comparative experiments. Where there is no experimental access *in principle*, however, then there is no science. I waive this problem for the sake of argument.

Liquid H_2O in the aggregate (*i.e.*, in gross portions of water) has several properties unique among all known physical stuffs, among them: it ionizes both acids and bases (*i.e.*, it is a truly universal solvent); its density decreases on freezing; and there are several ranges of temperature and pressure in which an increase in pressure at constant temperature causes its viscosity to decrease rather than increase. It also has several highly unusual though not unique properties, such as its extraordinarily high heat capacity. These properties are all essential to the role water plays both as the greatest component (by mass) in the constitution of all life-forms we know (excluding viruses, though most viruses cannot long survive without water in their immediate environment) and as the most important regulator of the behavior of Earth's environment (in virtue of the fact that it is the most abundant kind of stuff found on the planet's surface, even more abundant by mass than air). All these properties in turn are directly grounded on the fact that liquid water consists of a mixed bath of several ionic species held together by a hyper-dense network of Hydrogen bonds. Not only is the hyper-dense network of Hydrogen bonds characteristic of liquid H_2O itself unique as a physical structure among all physical stuffs we know of, but it more or less follows from our best current theories that no other molecular mixture of any sort besides the mixed ionic bath of liquid water could support such a network of bonds. In other words, according to our best theories, not only are the seemingly unique properties of water in fact unique, but they must be in the following strong sense: if we found other stuff that shared all those properties, then the quantum theory of chemistry, and *a fortiori* quantum mechanics itself, would be wrong. At a certain point—and this is the crucial matter—, after one fixes enough operationally definable properties of the right sort of the stuff at hand, in this case those of water discussed in §3.1, "having the same operationally definable properties" more or less *entails* "having the same microstructure" at a deeper level of theory, on pain of falsifying whatever deeper theory one works with, at least according to the strictures of our best present theories.[8]

So, we know that quantum mechanics cannot cannot hold in that possible world. We have, therefore, no clue whatsoever what forms of forces and physical relations govern the nature and evolution of physical systems in that world. We know only that they do not resemble those of our most fundamental theories in the slightest. Thus the rigid view has no right to assume that "hidden structure" can be compared unproblematically across worlds, because it may happen that the very theories in the terms of which we articulate "hidden structure" not only may not hold in those other worlds, but that what scientific laws do hold in that world do not have the resources for the articulation of anything like the hidden structure our best theories posit. The rigid view must assume this, however, in order to say that the stuff's hidden structure determines what it is to be a member of a natural kind in all possible worlds in which the relevant operational properties can be

[8] Indeed, as I show in §5 below, Twin Earth as specifically described by Putnam transgresses another fundamental physical theory: no molecule represented by a "very long and complicated" chemical formula, such as XYZ, could possibly have the stability and long-livedness of water under the amazingly varied environmental and intrinsic conditions we find water in without massive violations of the Second Law of Thermodynamics. Such large molecules would quickly denature into more primitive ones without buffering uniformly strongly across a wide range of envinromental conditions.

characterized in a pre-scientific way.

Say, for the sake of more concrete discussion, that we want to define a scientifically based relation such as $\texttt{same}_{\mathrm{L}}$ between the actual world A, in which we think the fundamental laws are quantum in character, and another possible world B in which the best fundamental laws are classical in character and have the form of Newtonian mechanics and classical electrodynamics (Maxwell theory, say, with a fixed frame of absolute rest, perhaps a luminiferous ether). Even if we try to define $\texttt{same}_{\mathrm{L}}$ using non-quantum chemistry, the relation will be meaningless according to the science of B and will be trivially unsatisfiable according to us. To see this, it suffices to note that the world of B can have nothing remotely like atoms (and *a fortiori* nothing remotely like molecules) as represented in our non-quantum chemistry, because as is well known classical Maxwell theory has no solutions representing stable atomic configurations—the orbiting electron must very quickly radiate its kinetic energy away and spiral down into the oppositely charged nucleus. Thus, if we define $\texttt{same}_{\mathrm{L}}$ as something like "having in B the same molecular structure as in A", then trivially no pair of liquids, one in A and the other in B, will satisfy the relation, for there are no liquids in B having any "molecular structure" period, much more the molecular structure of a liquid in A.

The problem is more severe than this, however. If $\texttt{same}_{\mathrm{L}}$ is to be a scientifically grounded relation, and if it is to respect the dictum in possible-worlds semantics that there is nothing metaphysically privileged about the actual world (at least so far as that part captured by its semantics is concerned), then there ought to be a canonical definition of it meaningful to scientists in every possible world; but there isn't. One can't simply say that the relation $\texttt{same}_{\mathrm{L}}$ is trivially vacuous in B with its classical laws; rather, the scientists in that possible world cannot even begin to investigate whether any stuff in their world can satisfy it, because they do not have the conceptual resources to investigate a claim such as "this liquid has such-and-such molecular structure". To see the severity of the situation, try to imagine how a contemporary scientist in the actual world would attempt to investigate whether water was an Empedoclean element. Because we have no way to formulate the idea of an Empedoclean element in the semantics of our best current physical theories in any way that we can be sure preserves the semantic content of that notion from an Empedoclean theory, it follows that we have no way to know whether or not a putative relation $\texttt{same}_{\mathrm{E}}$, that purportedly holding between two samples of the same Empedoclean element in different possible worlds, has any pairs satisfying it such that one of the pairs is in the actual world. It is not that we think the relation is empty, so far as stuff in the actual world goes: we cannot even formulate the terms required to characterize the relation and so begin to investigate whether or not it is empty. How could one verify one had captured the proper semantic content?

I can perhaps grant that we know what it means to say, in the actual world, that a glass of water does not contain an Empedoclean element *simpliciter*. When faced with a "possible world" governed by Empedoclean physics, however, the best we can do is shrug when asked whether $\texttt{same}_{\mathrm{E}}$ is true of any stuffs in our world. We do not know whether we can translate those laws into our terms, and operational properties will not suffice, by the rigid crowd's own lights. When given a proposition formulated in a set of concepts utterly foreign to the best science of the day with no other context and no other guidance, investigation into the meaning, much more the truth, of the proposition cannot get off the ground.

It is curious that the fact that science demands, in a strong sense, that water be H_2O itself has as a consequence that the designation of 'water' is not rigid: XYZ is possible only in a world in which quantum mechanics is not a good theory, and so in which all bets are off about what constitutes hidden structure and how to compare it to what it is in this world.

4.2 An Embarrassment of Theories

That completes the first part of this section's argument, which shows that 'water' cannot designate rigidly in any sense required by an account of possible-world semantics that is not simply iterative or descriptive.[9] I now approach the same target from a different direction, one that will show that the entire idea of rigid reference is incoherent. Let us restrict attention to the actual world, and ask whether our best science can ground the sort of referential relations that the rigid view requires even within this restricted scope to make sense of the proposition "water is H_2O".

In this context the proposition "water is H_2O" must stand as an implicit answer by proxy to the question (or: a question such as) "what does 'water' refer to?" Again, this must be settled by scientific investigation, according to the lights of the rigid view, in part by the definition and application of a relation like $\mathtt{same}_L$, though in this case with the scope of its domain restricted to (ordered pairs of) portions of stuff in the actual world (or at least stuff in possible worlds governed by something quite close to our laws). Now one must ask, however: investigation in the context of what theory or theories, with what allowed or possible range of experimental technique and practice? And once one does this, one recognizes that $\mathtt{same}_L$ is also an empirical and pragmatic relation as well, if, indeed, sense is to be made of it at all.

One way to get a grip on the question of the theory to use in addressing the issue is by asking the level of theory, as it were, one will use. As intimated in §3.2, the proposition "water is H_2O" naturally finds its home in a theory of classical or quantum chemistry. We will consider now what a higher-level theory such as Navier-Stokes theory has to say about the question "what does 'water' refer to?", as well as what a lower-level theory such as the Standard Model of fundamental, high-energy particle physics has to say.

Now, as I sketched in §3.1, water is a type of Navier-Stokes fluid having a set of characteristic values for its kinematic quantities that define it within the context of the theory as a particular natural kind. In fact, in a natural sense Navier-Stokes theory is the most fundamental theory that provides a sound theoretical representation common to all liquid and gaseous bodies of water *qua* liquid and gas (both of which the theory treats well)—*i.e.*, *qua* stuff that fits all the quantitative operational properties of water that Putnam relies on in asserting that there is such a thing as a quasi-canonical collection of normal, local samples of the stuff that grounds the attribution of a shared, hidden structure (ignoring ice, which Navier-Stokes theory cannot treat). Why should this not be the definitive account of water to be used in rigidly fixing the designation of 'water'? If it

[9] I think this sort of argument can be re-marshalled and extended to controvert Lewisian forms of possible-world semantics, *viz.*, one grounded on counterpart theory. That is a project for a future time, however.

were to be so, rather than "water is H_2O", we should have as the definition "water is that Navier-Stokes fluid characterized, at room temperature and atmospheric pressure, by the value μ for its mass density, θ for its thermoconductivity, C_V for its specific heat at constant volume, C_P for its specific heat at constant pressure, α for its shear-viscosity, β for its bulk-viscosity, v_s for its speed of sound, ν_R for its Rayleigh number, ...". That certainly does not trip off the tongue so lightly as the traditional definition, but that makes no nevermind for our purposes. It does define a shared, hidden structure in Putnam's sense. Why ought it not be considered, and not H_2O, the nature of water that grounds the rigidity of its role as referent?[10]

According to Navier-Stokes theory, in fact, water liquid and water vapor are two different natural kinds of stuff because the respective values of their kinematic quantities differ, albeit they are different natural kinds that can transform into each other by way of phase changes (by heating or cooling past the respective critical points, say), but that is no problem because the same happens with the natural kind H_2O in the context of chemistry, which can transform into the natural kinds Hydrogen and Oxygen under electrolysis. Someone wedded to the definition of water as H_2O could perhaps point to the fact that the relevant kinematic quantities even in the context of Navier-Stokes theory perhaps do not suffice to define water as a kind (and if they do not, then nothing in the theory will), in so far as they are not true constants but in fact vary under varying states of the stuff and environmental conditions. In the event, however, those variations are not even observable unless one goes down to a fine enough level of theoretical representation and concomitant level of experimental precision—but this is exactly the case with water as represented in chemistry as well, for, as we have seen, the relative amounts and types of its ionic constituents will change with changing states and environments as will even the stereometric configuration and form of the individual atoms, molecules, ions and Hydrogen bonds constituting the portion of stuff. Nothing, then, it seems, stops us from using Navier-Stokes theory rather than chemistry to give a definitive account of water.

A situation of a radically different sort confronts us if we attempt to treat water at a deep level of theory, say by use of the Standard Model, our theory of fundamental quantum particles and processes, which posits quarks (the constituents of baryons such as protons and π-mesons), leptons (particles such as electrons and neutrinos) and photons as the fundamental types or families under which any given particle will be classified. It is one of our two most fundamental physical theories, along with general relativity, treating all known fields and matter at the smallest spatial and temporal scales and the highest energies. Can we say, then, that water is a particular fixed, stable configuration of quarks, leptons and photons? In fact, it seems on the face of it impossible to say so in any sense unambiguous or even meaningful in the context of the theory.

Think of water vapor high in the atmosphere, subject to strong cosmic radiation, and still water deep in a cavern under the surface of the Earth sheltered from the spray of exotic, highly energetic fundamental particles composing cosmic rays. What theoretical, representational structures should

[10] Note that, if one takes this point of view, one may, if one wants, take the case of Twin Earth, in so far as sense can be made of it all, rather to show that the extension of 'water' was wrongly characterized from the start: it should in fact rather have comprised all samples both of H_2O and of XYZ, since they are of the same kind according to Navier-Stokes theory, and we do have reason to think that Navier-Stokes theory holds on Twin Earth.

we use in the Standard Model to treat each? In the event, one does not have the semantics in the Standard Model (terms, predicates, relations, rules of inference, methods of investigation and verification, *et al.*) to translate into its own terms any account of water given by a theory such as quantum chemistry. The fundamental, stable structures the Standard Model's theoretical resources provide come in the form of irreducible representations of particular symmetry groups—mathematical objects of a very high level of abstractness, with no conceivable application to the even indirect representation of physical stuffs at the operational level nor to molecular configurations such as H_2O. How can one possibly define "gross fluid viscosity", for example, in the Standard Model in its present form, using only the terms it makes available? I do not see how one could even begin to model a water molecule in the Standard Model. One cannot define that sort of (relatively) gross spatial configuration of atoms in it because, among other reasons, irreducible representations of symmetry groups do not provide the terms for the representation of any gross spatial configuration. Think as well of the characteristic energies, very great, almost incomprehensibly so compared to those in the workaday, operational world, at which the Standard Model becomes viable as a theory and at which the phenomena it treats become theoretically tractable and experimentally accessible—far too high for water molecules to exist much more to be modeled by the terms of the theory, even if the terms were themselves amenable to it.

Indeed, the problem is even more severe than I have so far sketched. According to the Standard Model, the phenomena it treats can always be described in any of a competing number of ways, as there is a many-to-one relation between groups of particular particles and their fundamental interactions on the one hand and irreducible representations of symmetry groups on the other. Heisenberg (1989, *passim*) makes this point trenchantly, in his discussion of the fact that at the fundamental level 'divide' and 'consist of' lose in particle physics anything like their ordinary meanings, precisely because the same fundamental, theoretical structures can be embodied by different configurations of different sorts of particles entering into superficially different forms of interactions. The best we can do is provide a very long list of the sorts of composite systems and interactions they enter into we should expect to obtain in any spacetime locus in which particular phenomena occur, with some rough estimates of the relative frequencies of their occurrences. There seems no principled, more or less natural way to define a fixed, stable, hidden structure in this long list, at least in no way analogous to that in the naive picture of H_2O. In consequence, according to the Standard Model neither water nor H_2O can be natural kinds at all.

So, in sum, if we choose Navier-Stokes theory to model water, then water vapor and liquid water are different natural kinds, but we cannot discuss ice or H_2O; if we use chemistry, then it seems difficult to discuss water itself at all, and H_2O definitely does not come out as a natural kind; and in the Standard Model, almost nothing comes out as a natural kind, and in any event certainly not water or H_2O. The idea of rigid designation cannot even begin to get off the ground in this diremptive state of affairs.

There is no such thing as "*the* nature of water" (Putnam 1975, p. 233—italics his). One has various means of attempting to characterize water in various scientific frameworks, along with the belief and the hope[11] that these are all, in some sense, “the same”. As we have seen, however, the attempt by itself will fail in most of our best scientific frameworks. Likewise, there is no such thing as “*the* physically important properties of water” (Putnam 1975, pp. 232, 239). One does not need to be an anti-realist to recognize and admit that these are—indeed, must be—idiosyncratic to a particular framework, in a very strong sense: an important property in one framework may not even be definable in another. This is not necessarily a point bearing or turning on issues of reduction, supervenience or emergence. It is a pragmatic point grounded in the character of the scientific knowledge and practice deriving from the form of science we *actually have achieved*, in the senses both of firmly established result and of ongoing, productive enterprise, no matter what forms of science we hope or desire may come in the future. The pragmatic character of the point shows itself in the fact that it need be no stronger than the assertion that there are certain problems involving water that one framework can pose and solve that others cannot (the flow around a cylinder, the evaporation rate under given conditions, the calculation of specific heats, *etc.*). Depending on what the issues at hand are, one will employ one framework or another. It is in this sense that the relevant differences in type and definability of properties is a pragmatic affair—a part of pragmatics in the sense of the linguist, not of, *e.g.*, Peirce or James.[12]

In sum, even when we restrict attention to the actual world, the character of our scientific knowledge about water and H_2O requires that the bare question of whether or not they respectively constitute something like natural kinds has no unambiguous answer: in order to fix an answer, one must have first fixed an at least inchoate theoretical and experimental framework within the context of which the question can be made precise enough so as to have a definite answer. Once one has fixed such a framework, then there is often (though not always) a definite, unambiguous answer, but the rigid view cannot accomodate this fact, for it requires the answer to have been settled once and for all, *sub specie æternitatis*, irrespective of the content and form of our current scientific knowledge—otherwise, the terms ‘water’ and ‘H_2O’ would not refer rigidly but only contingently, thereby robbing the referring relation of one of its strongest putative claims to fundamentality according (albeit often implicitly) to much contemporary thought.

[11] I am tempted to say: philosophy is a belief and a hope, sophism a belief and a desire.

[12] Kripke (1980, lecture III, pp. 117–118) seems to recognize the possibility of this sort of analysis in giving an account of a scientific concept:

> . . . I found in a more phenomenological account of metals the statement that it’s very difficult to say what a metal is. (It talks about malleability, ductility, and the like, but none of these exactly work.) On the other hand, something about the periodic table gave a description of elements as metals in terms of the valency properties. This may make some people think right away that there are really two concepts of metal operating here, a phenomenological one and a scientific one which then replaces it. This I reject. . .

To the best of my exegetical abilities, however, I can find no argument he gives for the rejection, only the bare assertion of rigidity.

4.3 Earth Is Silicates, Calcites, Carbonates and Nitrates

Still, the intuition is strong that there must be a way to parlay our knowledge of the chemical structure of water, such as it is, into an account of a hidden structure that we can use to ground something like rigidity. Because quantum chemistry gives us the deepest theory in which we can characterize something like a hidden structure that allows us to derive water's operational properties, the most promising route appears to be to use it to define the best hidden structure we can, which in this case must consist of a set of lists of the varieties and relative concentrations of the ionic solutions, the geometries of the ions and molecules in the mixed bath, and the stereometries of the network of Hydrogen bonds characteristic of H_2O under all possible environmental conditions in all possible states.

I first remark against such a proposal that it seems at best contingent, even once one has accepted the need for a scientific framework, or, to be more precise, the claim that quantum chemistry is the deepest framework for the description seems contingent, for it is always possible that in the future a deeper theory will come along and allow us to do the job at that even deeper level. We just do not know, so the "rigidity" quantum chemistry can afford even in the highly attenuated form of brutely descriptive lists seems limp at best.

In the event, I have stronger reasons to reject such ideas. Recall that, for the rigid crowd, it is the putative fact that water has a fixed, canonical microstructure ("water is H_2O") that justifies the claim that the term 'water' designates rigidly, at least for "normal samples" (Putnam 1975, p. 233) of the stuff. We know this, the story goes, as and only as a result of scientific investigation. Now, compare the structure of our scientific knowledge of water and H_2O (as most briefly sketched in §3) with that of our knowledge of earth (as in the first element, before air, fire and water).

Pace Empedocles, we do not think that all samples of earth share a hidden microstructure. Nonetheless, if we take small enough samples of the stuff, we can always associate a microstate to it, perhaps a complicated one that defies easy analysis or statement, but one still. Assume then, along these lines, that earth is, in the globally aggregated average, composed of 60% silicates, 15% calcites, 15% carbonates, 9% nitrates, and 1% compounds formed of more rarely occurring elements (such as Molybdenum). (I do not know whether this is accurate, but I do know it is not absurdly wrong; in any event, its wrongness in detail does not affect my argument.) On Twin Earth, however, earth_2 is DEF, a term representing some complex mixture of different sorts of compounds, utterly unlike silicates, calcites, carbonates and nitrates at the molecular level but sharing all the ordinary, workaday traits of earth on Earth, in all its variety: in the rural Twin American South, it is thick, red clay, suitable for growing cotton and casting bricks; in the vineyards of Twin Chablis, in the north of Twin Bourgogne, it is a gravelly, loose, yellow dirt replete with fossils, yielding chardonnay grapes from which a rich, dry wine with characteristic flavors of calcareous minerals is vinted; in the jungles of northern Twin Borneo, it is a rich, black, spermy loam supporting an opulent growth of flora, ranging from hardwoods such as teak to softwood trees bearing gelatinous, sweet fruit such as lychee to species of orchids and ferns numbering in the thousands; and so on.

Now, is earth_1, earth as it appears on our world, a natural kind? It seems not, for some stuff's being "in the globally aggregated average, composed of 60% silicates, 15% calcites, 15% carbonates, 9% nitrates, and 1% compounds formed of more rarely occurring elements" would seem to cut no scientific ice. Can we not say, however, that the fixed microstructure of earth is the disjoint union of all the various microstructures we find in "normal samples" of the stuff from all over the world, and so that earth has a nature after all? We can of course say it, but it will still be the case that, in Putnam's phrase, we have only "operational knowledge" of earth, not a scientific analysis yielding substantive physical knowledge of the stuff along the lines of our knowledge of H_2O. We know, for example, what grows well in various types of earth, those types differentiated by gross properties such as its capacity for holding moisture, its density, its cohesiveness, its color, *etc.*, none requiring the sort of exactitude science would render by, say, a chemical or spectroscopic analysis of its molecular composition. We can know these properties rather based on the kind of experiential, pragmatic knowledge a local farmer accrues over the years in her daily husbandry.[13]

This is not to say there is nothing that could count as a scientific analysis of earth, of the particular Terran distribution of silicates, calcites, carbonates, nitrates, and rare elements, and, so we assume, one of `DEF` as well, in the same vein as an analysis of H_2O. Neither is it to say that one cannot use a scientific analysis of a particular patch of dirt to sharpen one's knowledge of what will grow there, perhaps by a spectroscopic analysis of its nitric and calcitic content. It is only to say that there is no way for us to infer from any of our scientific knowledge what sorts of ordinary properties a particular kind of earth will have from a knowledge of the composition of its constituent molecules. Knowing that a particular bit of it is 60% silicate compounds, 15% calcites, 15% carbonates, 9% nitrates and 1% rare elements, or that it is `DEF`, cannot, by itself, allow us to infer what its specific heats will be, or what its specific gravity will be, or what sorts of solubility it will have in various solvents, much more what will grow well in it. We could not infer any of these even were we to have a detailed and exact catalogue of the percentages of every single distinct type of molecule in it, a complete breakdown of all the silicates, all the calcites, all the carbonates, all the nitrates, and all the rare elements. Because it is a gross mixture rather than a molecular compound, we would need something like, at the least, a detailed knowledge of the stereometry and relative spatial configurations of the individual molecules in order to calculate those sorts of things. Indeed, it is not even clear whether this knowledge, detailed as it could be, would get us anywhere—we know so little, scientifically, about the way the molecular composition of complex mixtures (as opposed to chemical compounds) yield their gross properties, so little about what aspects of that composition are most relevant for the definition and manifestation of such properties, that any account of the sorts of studies required to move in a deductive way from properties at the molecular level to those at the gross level must remain speculative into the far foreseeable future.

Compare this with our knowledge of water and H_2O as discussed in §§3.1–3.2. First, consider

[13] To paraphrase Aristotle (*Metaphysics*, Book A, §1, 981a20–30): the one with experience can act without telling you why; the one with understanding can tell you why but may not be able to act. This is one way to sum up Putnam's (1975) Hypothesis of the Universality of the Division of Linguistic Labor, which I think must be a fundamental component of any adequate account of meaning—it is one of the very few philosophical principles I feel confident in saying is correct without serious qualification, in this or any other branch of the discipline.

water. The operational knowledge we have of water does not differ greatly in kind from that we have of earth: earth is opaque and water transparent; earth dissolves in water and water solubilizes earth; earth covers the parts of the Earth not covered by water; flora grow in earth, when water is available; and so on. (Indeed, I suspect that the parallels in both form and content in our operational knowledge of water and earth respectively is what in part led the ancients to make them two of their primary four elements.) Nor do the characters of our respective states of knowledge of the molecular structure of earth and that of H_2O differ in any qualitative way. They differ only in the degree of depth to and comprehension with which we are able to enter into investigation of them. If we had finer instruments, more powerful computers and better mathematical models for those sorts of systems, we could employ the quantum theory of chemistry to investigate the properties of (various bits of) earth as readily as we do those of different samples of water (or even different portions of the same sample of water, given the great variation in local structure possible in the mixed ionic bath marbled with its dense web of Hydrogen bonds) under all the conditions and in all the states in which we do. It seems that, given any sample of earth, we could, depending on the sort of investigation at hand and the physical circumstances of that sample, construct an adequate theoretical representation of it. Given this one and another theoretical model representing a different sample of earth, there may be no set of structural relations between the two of the sort that we believe underwrites our identification of two separate physical systems as being both water, no matter the differences between the sorts of investigation we make of each and their different physical circumstances. Then again, there may be. We just do not know, for the answer to that question depends on what we mean by "same", which in turn depends on the fineness of the precision of our measurements, the sophistication and detail of the theoretical resources we have at hand, and the purposes we have when we enter into the investigation. We do not even know, in any scientifically precise or even meaningful way, what sorts of relations between actual theoretical structures we require to make the identifications we in fact do, even in the case of water.

This is just to say that our relative ignorance of earth would not stop us from constructing a largely descriptive theory of it, in the same sense as meteorology is a largely descriptive theory of weather and geology of gross surface structures on the surface and interior of a planet. One such theory, for example, that might give us "the essence of earth" in the sense from physical chemistry gestured at by Putnam, might consist of something like the following: a map of ordered sets (dates and geological locations, including depth from the surface, *etc.*) to sets of propositions (descriptions of the proportions of silicates, calcites, *etc.*, more or less exact descriptions of the fine structure of the molecular content and stereometric configuration, descriptions of gross properties such as heat capacity, *etc.*); and a set of rules for inferring from this map, given any possibly earthlike substance, whether it is in fact earth. This is not a pretty or elegant or even clever theoretical account of earth's microstructure, but it is a theoretical account of it.

But now what is to stop us from constructing "theoretical" accounts of piles of dried leaves and bits of string? Old, boiled chicken bones? Or any congeries of stuff one can have the perversity to throw together and claim as a scientifically characterized natural kind? If one allows an iterative, brutely descriptive set of lists of the sort solid-state physics in conjunction with physical chemistry can provide for earth as a fixation of hidden structure—and if one allows quantum chemistry to do it for water, there seems no reason not to allow those theories to do it for earth—then the distinction between, on the one hand, natural kinds and, on the other, otherwise unrelated aggregations of stuff just breaks down. One has made, in effect, *every* congeries of stuff one can throw together into a "natural kind" of the sort that can serve as a target for a rigid desiginator.

5 The Scientific Tahāfut al-Falāsifa; Or, The Perfidy of Examples

> The power of daring anything their fancy suggests has always been conceded to the painter and the poet.
>
> Horace

Horace is not wrong. But that power should not be conceded to the philosopher.

Recall that Putnam stipulates that XYZ represent a "very long and complicated" chemical formula; in other words, the molecules of water$_2$ are large, complex things composed of many different sorts of atoms. This posit, however, in conjunction with the claim that XYZ manifests all the properties of H_2O over as wide a spectrum of environmental conditions and circumstances as it must, contravenes one of the most fundamental principles in all of physics, the Second Law of Thermodynamics, which says, roughly speaking, that entropy does not decrease over time. According to thermodynamics, any stuff with a large, complex molecular structure composed of several different types of atoms has, *ipso facto*, a very low entropy. It is physically impossible that a quantity of the stuff of the same order of magnitude as that of H_2O on Earth should have a chemical stability remotely comparable to that of H_2O: a molecule of XYZ, in the absence of enormous buffering, buffering, moreover, that would have to differ to accomodate differing environmental conditions, would naturally denature into constituent sub-molecules at a rapid rate under many, many conditions that ordinary water finds itself in, such as super-heated and under great pressure in thermal vents at the bottom of the ocean, and in the enzymatically complex conditions of organic metabolism in all the organisms on Earth. Otherwise the Second Law would be null and void. One might wonder whether the example could be salvaged by making XYZ the (short, simple) formula for a small, thermodynamically stable molecule rather than a long and complicated formula for a large molecule? In fact, even if XYZ were short and simple, it would turn out that the example would still violate quantum mechanics, as the argument in §4.1 showed.

I already adverted in footnote 6 to the fact that all the scientific knowledge one needed to see that "water is H_2O" could not work to fix the designation of 'water' in any way that would support rigidity was already extant at the time the example was formulated and deployed. Philosophers have a tendency to deploy simple examples putatively based on science without bothering to verify whether or not our best science actually supports the use to which they want to put the examples.

Casual deployment of thought experiments is a dangerous game. It takes a lot of knowledge to construct a conceit as grandiose as Twin Earth that is not a pure fairy tale.

The analogy to fairy tales is instructive. A fairy tale may help us understand what picture a people has of the world, of their relations to it, and of their relations to and with one another, with a particular eye to the distraction and education of the young; it can teach us nothing about the nature of the world itself or about the sorts of knowledge we may or may not be able to secure about the world, divorced from our own psychological, cultural and social predilections.

Examples, in my opinion, and especially those of the *Gedankenexperiment* type, serve only two purposes well: to motivate, and then only when followed by a more general analysis abstracted from the particulars of the example; and to confute (counter-examples). They can serve neither purpose when their construction derives only or largely from intuition and a sense that the details are not important, rather than from hard knowledge.

Kripke (1980, p. 44, italics his) sums up the intuition that underlies the libertine deployment of such thought experiments in philosophy: "'Possible worlds' are *stipulated*, not *discovered* by powerful telescopes." *Argumentum ex italico.* (See also *loc. cit.*, p. 49: "Generally things aren't 'found out' about a counterfactual situation, [*sic*] they are stipulated.") But that's wrong. We *do* discover them, using the telescopes our theories and other empirical knowledge provide us. The free ride is over. *Fictional* worlds are stipulated, not possible ones. Philosophers have to justify their so-called possible worlds.

References

Eisenberg, D. and W. Kauzmann (1969). *The Structure and Properties of Water.* New York: Oxford University Press.

Heisenberg, W. (1989). What is an elementary particle? In *Encounters with Einstein, and Other Essays on People, Places and Particles*, pp. 71–88. Princeton, NJ: Princeton University Press. A Translation of *Tradition in der Wissenschaft.* Originally published in English as *Tradition in Science*, by Seabury Press (San Francisco, CA, 1983).

Kripke, S. (1980). *Naming and Necessity.* Cambridge, MA: Harvard University Press.

Lamb, H. (1932). *Hydrodynamics* (sixth ed.). New York: Dover Publications. The 1945 Dover reprint of the 1932 edition published by the Cambridge University Press.

Landau, L. and E. Lifschitz (1975). *Fluid Mechanics* (Second ed.). Oxford: Pergamon Press. An expanded, revised edition of the original 1959 edition. Translated from the Russian by J. Sykes and W. Reid.

Marechal, Y. (2007). *The Hydrogen Bond and the Water Molecule: The Physics and Chemistry of Water, Aqueous and Bio-Media.* Amsterdam: Elsevier Science.

Maxwell, J. C. (1870). Address to the mathematical and physical sections of the British Association. In *The Scientific Papers of J. C. Maxwell*, Volume II, pp. 215–229. New York: Dover

Publications, Inc. Originally delivered to the Mathematical and Physical Sections of the British Association, Liverpool, September 15, 1870, and subsequently published in the *British Association Report*, XL, 1–9.

Putnam, H. (1975). The meaning of 'meaning'. In *Mind, Language and Reality: Philosophical Papers*, Volume 2, Chapter 12, pp. 215–271. Cambridge: Cambridge University Press.