Varieties of Properties: An Alternative Distinction among Qualities.

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Abstract

The traditional distinction between primary (observation independent) and secondary (observation dependent) qualities is not based on a difference that can be sustained in the full light of contemporary scientific understanding. An alternative division of physical and chemical properties is proposed. Like the traditional division of qualities, the alternative system has two main categories. Properties of compound particulars that result from simple combination (e.g., addition) of the properties of their component parts constitute the first class: properties that depend on details of interactions between component parts (e.g. cooperative effects) make up the second type. Application of the alternative dichotomy is considered for the cases of mass (traditionally a primary property) and color (a secondary quality, in the usual division). Both these types of properties can fall in either of the two classes of the alternate division of qualities, depending on the nature of the interaction that occurs between components. Both mass and color show that intermediate cases occur. Application of the alternative categorical scheme is straightforward, but not always simple. The proposed system shows that in chemical combination (and, perforce, in the many more complex systems common in human culture) interactions profoundly influence properties of entities that enter the interaction. This is not adequately treated by philosophical theories of wholes and parts (mereology), which should be extended to apply to such important cases.

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mixis, cooperative interactions, autocatalysis, dissipative structures, mixed valence, IVCT.

Philosophers often use the term 'property' in a very wide sense — to designate whatever can truthfully be said of something. For instance, Mary Kate McGowen holds that

> ….. properties are just what members of an extension share. [1]

In a classic 1969 paper [2], Hilary Putnam pointed out that such indiscriminate understanding of the concept of property conflates two notions that historically were carefully distinguished. He uses the term 'predicate' for one of these two ideas, and (while soliciting suggestions for a more apposite name) employs the designation 'physical property' for the other (by analogy with the well established usage of 'physical magnitude').

In the first (predicate) way of using the word, a property is whatever may be said (predicated) of something, in the other (physical property) mode of discourse, a property is an intrinsic characteristic of an entity. The term 'quality' seems close in meaning to Putnam's physical property. Examples of both types of usage can be found in this volume. When Paul Needham [3] discusses 'substance properties,' he clearly means the condition of being a substance — a predicate rather than a physical property or quality. In contrast, when S. H. Vollmer considers [4] the distinction between 'primary and secondary qualities,' and G. Krishnan Vemulapalli [5] discusses the origin of molecular properties, they are dealing with what Putnam calls physical properties, rather than with mere predicates.

Charles Sanders Peirce (1839-1914) (who worked as a consulting chemical engineer after his retirement from government service) — held that a property is best understood as how a thing behaves, or would behave, in some operation.

> Consider what effects, that might conceivably have practical bearings, we conceive the object of our conceptions to have. Then, our conception of these effects is the whole of our conception of the object….let us ask what we mean by calling a thing *hard*. Evidently, that it will not be scratched by many other substances. The whole conception of this quality, as of every other, lies in its conceived effects. [6]

This characterization clearly does not apply to properties considered as applicable predicates, but does describe every sort of physical property (in Putnam's sense). It is important to note that (for Peirce) every property involves some definite operation – a procedure more or less clearly specified, or at least capable of being specified. The remainder of this paper concerns physical properties or qualities, rather than the larger class of true predicates.

Putnam also accepts [2] a further distinction — that between $physical_2$ properties (those dealt with by physics proper) and $physical_1$ (all other) properties. Properties that necessarily involve mention of two or more chemical species in their specification (e.g., hydrogen gas has the property of flammability, that is to say, dihydrogen burns in dioxygen to produce water) are what chemists call 'chemical properties' – a subdivision of what Putnam calls '$physical_1$ properties.'

Things Are Recognized by Properties

A maxim (apparently of unknown origin) that is now current in American politics makes a deep philosophical point:

> If it walks like a duck, swims like a duck, and quacks like duck — *it's a duck*.

As Alfred North Whitehead (1861-1947) observed, 'For physics, the thing itself is what it does.' [7]. It seems that this also applies in general, so far as physical properties (in Putnam's sense) are concerned. This point seems related to ‘The Principle of the Identity of Indiscernibles’ of Gottfried Leibniz (1646-1716):

> No two substances are completely similar, or differ solely in number….This implies: if x = y, then from G(x) we may infer G(y) for any G, and conversely. [8]

This idea was clearly not original with Leibniz. Consider 'The Principle of Difference' of Rāmānuja (India, *c.* 1070 A.D.)

> Should anyone ……assert [that] the theory of a substance free from all difference is immediately established by one’s own consciousness, we reply that he is ….refuted by the fact …….that all consciousness implies difference. [9]

In various ways, each of the four statements quoted above indicates that we recognize things (and get to 'know' them, in so far as we do) by their properties.

Are Things *Made of* Properties?

The point made in the previous section is sometimes interpreted in what seems to be a very odd way. Some contemporary philosophers consider that things are *nothing but* aggregations of properties. For instance, one of the central doctrines of a work in which Robert Neville aims to set out a philosophy of nature that would also ground hermeneutics is:

> …determinate things are harmonies of essential and conditional features. [10]

Also, David Weisman recently set out to frame 'a metaphysics' – consistent with what he takes to be current physical science – which will also apply to concerns of the social sciences. One of his basic statements is similar to Neville's presupposition quoted above, but even more clearly (though perhaps less cautiously) phrased:

> Everything is constituted, exclusively, of its properties. [11]

Notions of this sort have a long history. George Berkeley (1685-1783) held that all objects are 'collections of ideas.'[12]. Bertrand Russell (1872 – 1970) held that things are bundles of universals. D.M. Armstrong concludes that the 'bundle of universals' doctrine is not likely to be sound, since no one has yet devised a plausible account of:

> ….a bundling principle that holds together the properties 'of' a particular. [13]

Whatever else may be the case, the idea that things are composed of properties is not a feature of contemporary physical science. An example of the cool reception that this notion receives in scientific circles is that a main justification for postulating the Higgs Field in high-energy physics is to avoid having free-floating properties. [14] No matter what sort notion of property one employs, it seems clear that (both in general speech and in scientific discourse) properties are generally *ascribable to entities*. In both popular and scientific usage, every property has reference to at least one thing. In that sense, properties are abstractions from existing (or imagined) things. On that basis it is difficult to understand *how* a property or a feature could be *prior* (either temporally or ontologically) to *that of which* it is a feature. If properties require some entity in which to inhere, it might seem that Weisman, and possibly Neville as well, have fallen into *the fallacy of misplaced concreteness:*

> … the error of mistaking the abstract for the concrete. [15]

Traditional Distinction between Primary and Secondary Qualities

There is an ancient tradition of dividing properties into a small number of classes. Aristotle (384-382, B.C.E.) states:

> Quality then seems to have practically two meanings, and one of these is more proper. The primary quality is the differentia of substance… Secondly, there are the modifications of things in motion *qua* in motion…. [16]

Galileo Galilei (1564–1642) distinguished two sorts of properties: primary qualities (e.g., spatial extension) [b] were held to be intrinsic characteristics of the entity – secondary properties (color, taste, etc.) depended on interaction with some perceiving subject.

> Now I say that whenever I conceive some material or corporeal substance, I immediately feel the need to think of it as bounded, as having this or that shape, or being large or small in relation to other things, and in some specific place at any given time; as being in motion or at rest; as touching or not touching some other body, as being one in number or few or many. From these conditions, I cannot separate such a substance by any stretch of my imagination. But that it must be white or red, bitter or sweet, noisy or silent, of sweet or foul odor, my mind does not feel compelled to bring in as necessary accompaniments….Hence I think that tastes, odors, colors, and so on are no more than mere names so far as the object in which we place them is concerned, and that they reside only in the consciousness. Hence if the living creature were removed all these qualities would be wiped away and annihilated. [17]

A somewhat similar division was employed by John Locke (1632–1704):

> *The* ideas *that make up our complex ones of corporeal substances* are of three sorts. *First*, the *ideas* of the primary qualities of things, which are discovered by our senses, and are in them even when we perceive them not; such are the bulk, figure, number, situation, and motion of the parts of bodies which are really in them, whether we take notice of them or no. *Secondly*, the sensible secondary qualities which, depending on these, are nothing but the powers these substances have to produce several *ideas* in us by our senses; which *ideas* are not in the things themselves otherwise than as anything is in its cause. *Thirdly*, the aptness we consider in any substance to give or receive such alteration of primary qualities, as that the substance, so altered should produce in us different ideas from what it did before: ….[18]

The traditional primary–secondary distinction clearly refers to what Putnam calls physical properties, rather than to predicates.

Locke's primary/secondary distinction was criticized roundly by Bishop George Berkeley [19], who maintained (as does S. H. Vollmer, in this volume) that even the so-called primary properties depend in some way on perception, so that the primary–secondary distinction collapses for want of a fundamental basis in fact.

A Proposal for an Alternative Distinction among Qualities

Just prior to the passage quoted above, Locke makes clear how (and to what extent) he understood *substance*:

> So that if anyone will examine himself concerning his *notion of pure substance in general*, he will find that he has no other idea of it at all but only a supposition of he knows not what support of such qualities as are capable of producing simple *ideas* in us; such qualities are commonly called accidents.[20]

Many aspects of the material universe are now much more clearly understood than they were when Locke wrote about that 'supposition of he knows not what'. In particular, there no longer seems to be any great mystery about the formation and properties of simple chemical compounds — substances, in the chemical sense. Papers in this volume [21] and elsewhere [22] demonstrate that chemists have good understanding of the sorts of closure of networks of relationships between components that generate and sustain chemical substances.

In a contemporary discussion of the meaning of the concept of substance, Ruth Garrett Millikan holds:

> Substances…. are whatever one can learn from given only one or a few encounters, various skills or information that will apply to other encounters. …. Further, this possibility must be grounded in some kind of natural necessity. ….The function of a substance concept is to make possible this sort of learning and use of knowledge for a specific substance. [23]

Chemists understand that, rather than being made up of properties, features, or qualities, chemical entities are composed of components — constituent entities that interact in specific ways which go to produce (through 'natural necessity') integrations that persist through time and sustain repeated interactions — chemical structures [24]. If we adopt this[c] outlook, what becomes of the primary/secondary property distinction?

If we are persuaded by Berkeley (and by Vollmer) that assessing any and all properties depends on the means used for the assessment, so that the traditional dichotomy is no longer tenable, is there a satisfactory alternate basis on which we could we make a distinction among main classes of properties? I suggest that there is firm basis in contemporary science for an alternative distinction between types of qualities (physical properties). This newer dichotomy is similar in some respects to the traditional division between primary and secondary qualities — but has a quite different fundamental basis. The alternative distinction that I favor is between those properties of an individual particular that are the simple resultant (a sum, say) of aggregation of corresponding properties of the component parts of the entity in question, and properties that are not such resultants. On the basis of the current state of scientific understanding, this division of qualities — between those that result from simple combination of properties of components (let's call this 'the first class') and those that depend on the components in more complex ways ('the second class') — is as clear as the traditional dichotomy, and may well be more useful.

The question might arise as to what meaning such words as aggregation, combination, or summation might have in this context. [d] One general answer to this question involves a 'thought experiment' in which a particular is constructed from the same components as comprise an entity of interest, in such a way that the combination gives rise to no change or modification in any of the components so combined. (This is what logicians call a 'mereological sum.') For many qualities (weight, for example) the properties of the hypothetical mereological sum often can be computed directly from the properties of the components. To the extent that the value of the property of the mereological sum, however reckoned, is the same as the corresponding property value of the actual particular of interest, that property should be considered a property of the first class in the new division. If the quality of the actual particular of interest differs from that computed for the mereological sum, then that property should be regarded as a property of the second class. [e] In the case of some qualities (such as viscosity) it may not be possible (in view of the best scientific understanding available at the time) to compute (or possibly even to conceive) how qualities of individual components might be aggregated to yield the property of the composite particular. In such cases, the property in question should be assigned (provisionally) to the second class.

Applying the Proposed Alternative Distinction

Some properties of the compound individuals that chemists deal with do, in fact, result from mere summation of the properties of the components of those complex particulars. Other properties depend on specific *interactions* between components – whether those components are like or unlike — rather than simply on the properties of the components (as individual particulars). Cooperative action of chemical individuals occurs quite commonly, and often with great effect. An adequate survey of cooperative activity of chemical species is not possible here, but a few examples may be mentioned.

Hardness and fragility of salt crystals depend in complex ways on relationships between the positive and negative ions that are components of the crystal – and often on concerted action of myriads of ions (*martinsitic* transitions). [26] The pattern of scattered radiation that emerges from a crystal irradiated with X-rays depends on the microscopic structure of the crystal – the relative arrangement of the component atoms. [27] The details of the NMR spectra of organic molecules depends on interactions of all the components atoms of the molecules. [28] Femtosecond spectroscopy is made possible by cooperative interactions of molecules. [29] The density variations that result in ice floating in water cannot be understood without attention to highly cooperative interactions of water molecules both in liquid water and in ice. [30] Origin of complex spatial and temporal order in far from equilibrium open chemical systems [31] depends on complex networks of cooperative action between various components of those mixtures. Colors (spectra) of dissolved species often depend in subtle ways on cooperative interactions of myriads of solvent molecules. [32] All of these qualities are not simply computable from the properties of the individual particulars (components) involved. To the extent that this is the case, all these are examples of properties of the second class in the proposed new division.

As an indication of how the proposed division of properties might work, let us consider mass (a standard example of a traditional primary quality) and color (a frequently discussed secondary property). Every student of chemistry learns to compute the molecular weight of organic compounds, and the formula weight of ionic materials. Knowing the weight of all the components of a chemical species, one can easily compute the total (molecular or formula) weight. Within an accuracy that is quite sufficient for the many manipulations carried out in university chemistry laboratories, the mass property is simply additive. On this basis, mass is property of the first class, at least so far as simple chemistry goes. The alert reader has probably already thought of the objection that helium atoms (such as those formed in the Sun by the Bethe-Weizsacker mechanism [33]) are substantially lighter than the total mass of the four hydrogen atoms that may be regarded as the components of those helium atoms — the units from which the helium atoms arise in the Sun, say. This weight difference is due to the high energies that are characteristic inter-nuclear bonding — when the helium atom is synthesized from four protons, mass is converted into intra-nuclear binding energy. Even though mass is not conserved in nuclear reactions, conservation of mass generally applies to a very high degree of precision in chemical contexts. Energies involved in chemical bonds are many orders of magnitude smaller than the energies involved in intra-nuclear interactions, so that (within the precision of all but the most refined measurements) the total mass of a chemical molecule may be taken as the sum of the masses of the component atoms. Mass is not a quality of the first class (simply additive) in some absolute sense, but may quite properly be regarded as a quality of the first class for ordinary purposes of chemistry.

Color is perhaps a more interesting case. Is the color of a compound simply the sum of the colors of the components? There are some cases in which color is an additive property, and some in which color is not additive. Aqueous solutions of salts of transition metals (copper, chromium, iron, etc.) are customarily used for discussing colors with beginning students. Is the color of an aqueous solution of copper sulfate simply the sum of the colors of the components of that solution? Such solutions follow Beer's law — the absorbance of light (at a fixed wavelength near the red end of the visible spectrum) by a solution of cupric ion is strictly proportional to the concentration of cupric ion in solution. In this case, color is just as additive as is the mass of the components of organic molecules. But then what becomes of the distinction — what might correspond to a quality of the second type?

Colors of many intensely colored materials relate to the colors of their components in ways that are quite different from the simple additivity characteristic of cupric ion solutions. Chemicals that contain two or more metals ions in different states of oxidation (mixed-valence species) can undergo what is known as Intervalence Charge Transfer (IVCT). This is a process in which the molecule changes from a state with one particular distribution of electronic charge to a state with a quite different charge distribution. (In some cases it is appropriate to consider that this shift corresponds to the movement of a single electron from one metal center to another.) For reasons that are quite well understood [34], but outside the scope of this paper, the IVCT transition can correspond to very high absorption of light — some (but not all) mixed valence species are exceedingly highly colored. Although the intensity of the blue color of dilute aqueous solutions of cupric sulfate depends linearly on the concentration of copper ions – indicating simple additivity, the colors of the dark coloring matter of inks (e.g., Prussian Blue, Turnbull's Blue) depend not on single ions but on *interactions* between two different ions. In such cases doubling the concentration of the metal ions may increase the color by factors of about four times rather than causing simple doubling.

Robin and Day [35] famously distinguished three types of mixed valence materials — substances that contain two or more metallic ions in various states of oxidation. For Class I complexes the UV-visible spectrum (color) of the complex is the sum of the corresponding spectra (colors) of the components. (In this case color is a quality of the first type in the new division.) In compounds of Robin and Day's Class II, the spectra of the components are present, but a new set of spectral features (color) is observed that is characteristic of the intervalence charge transfer (IVCT) of the specific combination of metal ions present. In Class III compounds, the new IVCT bands are intense enough to make the colors of the components unobservable [35]. The colors of Robin and Day Class III mixed-valence species are quite different in origin from the colors of corresponding Class I substances. In the case of Class I substances, the color of the compound is directly predictable from the colors of the components — color is a property of the first class. Conversely, there is no direct relationship between the spectra of Class III complexes and the colors (spectra) of their components — in these cases color is a property of the second class on the alternative division.

Notice that it is not possible to say that property F is (simply) a first-type property, while property G is (simply) a property of the second type. However in any concrete case is should be a straightforward task to decide whether a particular property of a certain compound particular corresponds to the appropriate sum of the corresponding properties of all of the components of that individual, or does not so correspond. On this basis, it should be possible to determine in every case, for chemical species x, y, and z, that F(x) is of the first type, F(y) is of the second type — perhaps F(z) might be intermediate between the two classes (e.g., the colors of Robin and Day class II mixed-valence compounds.) To the extent that this is correct, the proposed alternative distinction is clear and practically applicable.

Cui Bono?

So, what's the point? A major question remains: who would benefit by the introduction of this alternative distinction? Scientists make distinctions of this general sort quite routinely and unselfconsciously. There seems to be little for scientists to learn through this distinction. But it seems fair to say that most philosophers have yet to recognize that, when components enter into chemical combination, those components do not, in general, maintain the same identity that they would have had, absent that combination. In spite of the recognition of this problem by Aristotle and the scholastics [37], by Hegel [38], and by John Stuart Mill [39], contemporary philosophers often tend tacitly to assume that all properties are properties of the first (additive) class [40]. When interaction between components is strong (as it often is in chemical combination — such as in Robin and Day class III species) properties of the second type predominate. Interactions of parts within wholes also take place in astronomical, biological, psychological, economic, sociological, linguistic, and conceptual systems. These part-whole relationships are all at least as complex as chemical combination. It would be useful to develop a mereology adequate to deal with chemical systems, in order to facilitate future progress in dealing with other and more complex problems. Integration of such insights with the philosophical study of wholes and parts (mereology) is only in its initial stages. [41, 42] It seems that one major advantage of use the proposed distinction would be to facilitate development of the theory and practice of this aspect of philosophical logic in this direction — to specify how this could be achieved is clearly outside the scope of this paper.

Notes

a) 6540 North 27th St., Arlington, VA 22213. 703 532 5238.

b) I am indebted to Prof. Daniel Rothbart for pointing out that Galileo, in contrast to Newton and later authors, did not consider mass as a primary property.

c) Contrary to what was generally thought some years ago (and is still maintained by Weisman) there is no theoretical or experimental evidence in contemporary science for considering that there is some fundamental level of description – some set of simple particles (or fields) from which all higher level entities are built. There are reasons that are at least as good for holding that every concrete entity has parts, and that each and all of those parts also are composed of components.

d) I am grateful to Prof. Daniel Rothbart for raising this point.

e) I thank Prof. Rom Harré for pointing out that the proposed division is similar to the distinction – used in biology and philosophy of biology – between properties ascribable to individual organisms and characteristics that result from interactions between organisms in groups, and that the proposed division is also – if less directly– related to some psychological distinctions used by Polanyi, e.g., that between 'focal' and 'subsidiary' awareness. [25]

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42. Needham, P. *In this volume.* This paper makes a start on adapting received versions of mereology to chemistry, but much remains to be done.