2.3 Functional Kinds

As a final talking point, this section briefly discusses the role of functions in determining membership to a kind. This brings forward an interesting aspect of chemical kindhood, namely, its connection to biology and biological classification.

Case IV. Macromolecules

Certain chemical compounds are identified as kinds not in terms of their microstructure, but in terms of a function they serve. That function may be chemical or biological. When chemical, a function is typically conferred to organic compounds by so-called functional groups, that is, 'an atom, or a group of atoms that has similar chemical properties whenever it occurs in different compounds' (IUPAC 2014: 605). Examples of functionally defined compound-kinds include alcohols, carboxylic acids, amines and ketones. When biological, a function is typically conferred to macromolecules (though not exclusively) that figure in physiological processes and is said to serve evolutionary or etiological considerations (Tahko 2020: 800).[29] Examples include proteins, genes and vitamins, and are often called biochemical kinds. Such groupings are invoked to describe biological behaviour and figure in inductive generalisations and explanations of biological phenomena.

[29] Macromolecules are molecules 'of high relative molecular mass, the structure of which essentially comprises the multiple repetition of units derived, actually or conceptually, from molecules of low relative molecular mass' (IUPAC 2014: 870).

The problem with functionally defined compound-kinds is that (at least part of) their unifying property is their function, undermining microstructural essentialism.[30] Tahko spells out this problem in terms of 'multiple realisation' and 'multiple determination'. Multiple realisation occurs when '(t)here may be a difference between (entities) A and B which explains why, even though each is capable of performing a certain function, they each do so in a different way' (2020: 814). For example, 'haemoglobin' refers to a group of macromolecules with different microstructures whose members are unified by their shared 'ability to bind and release oxygen' in an organism (Tahko 2020: 808). Such examples of multiple realisation putatively show that microstructure is not necessary for compounds to belong to a kind (thus undermining both interpretations of 'essential'; see Section 2.1).

Multiple determinability occurs when a microstructure realises multiple (biological or chemical) functions. An example is moonlighting proteins which have one primary structure (i.e. they are formed of the same sequence of amino acids) but fold up in different ways, thus resulting in different three-dimensional structures, each identified as a distinct kind (Tahko 2020: 804; Tobin 2010b). This is considered problematic for microstructural essentialism because (primary) microstructure is not the unifying property of protein-kinds. In fact, Tobin argues that moonlighting proteins are additionally problematic because they are 'intrinsically unstructured' or disordered, thus undermining the essential role of structure in conferring them as members of a protein-kind (2010b: 41).

There are also organic molecules that exhibit multiple determinability: an organic molecule can have a specific structure yet be considered a member of multiple chemical kinds depending on the chemical function it serves. For example, some compounds are classified as both alcohols and carboxylic acids (or, as both amines or amides). So, a compound's membership to a kind can be conferred by different chemical functions and not by its microstructure, thus undermining microstructural essentialism for chemical compounds (Goodwin 2011).

Several responses have been offered to these challenges. First, one could argue that this is evidence of some form of pluralism about natural kinds, such as Dupré's promiscuous realism (see Case III) or Slater's macromolecular pluralism. Slater (2009) claims that there is no principled way to invoke structure to distinguish between proteins; instead, there is a plurality of equally legitimate biochemical classifications. Bartol (2016) defends a 'dual theory about kinds' (see also Longy 2018). This theory purports that there are two distinct kinds of kinds: the chemical kind and the biological kind (and no biochemical kind).

[30] Specifying the function of a kind may be viewed as necessary or sufficient to picking members of a kind.

In this context, multiple determination putatively shows that a member of a chemical kind can contain multiple members of biological kinds. Multiple realisation shows that a member of a biological kind can contain multiple members of chemical kinds (Bartol 2016: 549). In contrast to this theory, Bellazzi (2022) argues that we should think of such groupings as genuinely biochemical kinds; that is, kinds whose membership is conferred by their microstructure and by their function.

Lastly, there are ways to defend microstructural essentialism too. Goodwin (2011) for example argues for the 'fundamental role' of structure. Based on an analysis of organic chemistry, he claims that molecular structure is fundamental because it explains why a functional group classification is appropriate at a particular instance, and because a compound's modal capacity to function a certain way is in virtue of its structure (Goodwin 2011: 538–40). (This is similar to favouring a sort of dispositionalist view about kinds.) Alternatively, one could adopt the 'powers-based subset strategy', which takes the causal powers of a (biological or chemical) function to be the proper subset of the powers of the microstructure of the compound that has that function (Tahko 2020: 806). This way, microstructural essentialism is not undermined by multiple realisability or multiple determinability because microstructure is (in the sense specified by Tahko) ontologically prior to the relevant function (Tahko 2020: 822).

Overall, whether chemical kinds are natural can only be answered on a case-by-case basis. It is likely that different chemical case studies warrant different answers as to whether they correspond to natural groupings in the world, with some representing natural kinds and others not. Moreover, as the example of chemical compounds showed, even the most paradigmatic chemical case studies for natural kinds are not definitively settled. Furthermore, this analysis may also prompt a revisionist attitude towards the very notion of natural kinds and its distinction from artificial kinds. Which route to select is left for the reader to choose!

3 Realism and Reduction

Atoms, Phlogiston, Molecular Structure and Chemical Bonds

Looking for chemical kinds is one way chemistry can be used to understand the world and its structure. One can also raise a more general question about chemistry. Namely, what is real? Do the entities, properties, processes and so on posited by chemistry exist, and are they objective and independent of chemists?[31] To what extent should we accept that what chemistry tells us about the world is true? These questions are part of the scientific realism debate.

[31] Unless otherwise stated, 'entities' refers to objects, properties, processes and anything else that can exist.

Scientific realism is the idea that the entities posited by our best current science exist mind-independently in the world, and that the theories and hypotheses science formulates in terms of those entities are (at least approximately) true when taken literally (e.g. Boyd 1983; Fine 1986; Laudan 1981). According to Psillos, there are three distinct theses contained within the idea of scientific realism: semantic, metaphysical and epistemic (2005: xix). This section investigates the metaphysical thesis from the perspective of chemistry; namely, does the world have an objective structure that is (partially) captured by the entities posited by our best current chemistry?[32] That is, do chemical entities inhabit the world? In this context, scientific realism denies that unobservable entities are instruments or fictions posited to manipulate the world in useful ways. Instead, the world is made of and structured by the entities and relations posited by our best current science. The goal of this section is to investigate whether these realist claims can be convincingly supported for chemical entities (and which ones specifically).

The issue of natural kinds is closely related to the issue of scientific realism. This is because when accepting scientific groupings as natural kinds, it is common to accept those kinds as real.[33] To say, for example, that the element gold is a natural kind involves the (often implicit) claim that the kind-gold exists in a mind-independent manner. There are different ways one can spell out this claim about kinds. First, one could argue that the categories we take as referring to natural kinds are real, distinct objects (distinct even from their own instances). As such, kinds are taken to exist as some sort of abstract entity or universal.[34] This position is called strong realism about kinds (Bird and Tobin 2022). On another interpretation, natural kinds are real in the sense that they reflect divisions or structures in the world. In this context, kinds are not distinct things; they are real in the sense that they reveal some part of the structure of the world. This position is called weak realism (Bird and Tobin 2022).

Some philosophers claim that to accept natural kinds is to be a scientific realist (e.g. Psillos 2005). This is sensible when one interprets the issue of natural kinds from a weak realist perspective. In this context, scientific realism can be formulated as the idea that the 'world has a definite and mind-independent natural-kind structure' (Psillos 2005: xvii). On the other hand, for a strong realist about kinds the issue of natural kinds is not settled by

[32] Semantic issues around truth and how it is assigned to theoretical assertions, as well as issues regarding reference, are largely overlooked.

[33] This is not always the case. Nominalists about kinds may believe that scientific groupings are just artificial or may accept that the instances of a kind are real but not the kind itself.

[34] There are different ways one can take kinds to be an abstract entity or universal. For example, Hawley and Bird (2011) view them as complex universals and Lowe (1998) as substantial universals.

adopting scientific realism. This is because there is an additional question to answer; namely, do natural kinds exist as distinct objects in the world?[35]

Perhaps adherence to scientific realism does not require the acceptance of natural kinds either from a strong or a weak realist perspective. For example, I could believe that the air I now breathe contains oxygen or that my necklace in the drawer is made of gold, and that these things exist independently of me conceiving them but make no commitment to any groupings into which they may fall. Such a view is, for instance, proposed for certain biological kinds, as it is difficult to identify common properties shared by all their instances (e.g. Hull 1978). Another option is to be a realist about things in the world yet believe that such things are only members of artificial groupings (e.g. Chakravartty 2007). On the other hand, one might argue that it is not possible to deny the existence of natural kinds and be a scientific realist at the same time. On this view, if I believe that a chemical reaction occurs when I am breathing oxygen that leads to the production of carbon dioxide, it is because I adhere to the generalisations posited by science about those entities as categories, aka kinds.

So, there are different ways to be a realist about different things, and the realist question is far from settled even if we take as decisive the arguments presented in Section 2 in favour and against chemical kinds. In fact, Section 2 showed that there are different ways to understand natural kinds and different things one can regard as such. Inevitably, this affects the extent to which a commitment to realism in chemistry implies a commitment to chemical kindhood (and vice versa) that deserves further investigation. In any case, the only restriction imposed on any position about realism and kinds is that it is logically consistent and consistent with the results of our best current chemistry.

The relations between realism and kinds are not further investigated. Henceforth, the question of realism in chemistry is investigated separately. This is not uncommon practice. Whether chemical entities are natural kinds is usually discussed separately from the debate about their reality.

Section 3.1 presents the realist and anti-realist arguments that have been formulated with respect to chemical entities and particularly about atoms, molecules and phlogiston. Section 3.2 discusses chemistry's relation to quantum physics: it presents a central antireductionist argument and two metaphysical accounts that have been produced by its acceptance (strong emergence and ontological pluralism). The case of molecular structure is examined. Section 3.3 presents an account of unity which offers an alternative way of understanding chemistry's relation to quantum physics that maintains the reality of chemical stuff. The case study is the chemical bond.

35 I do not investigate this.