Reference Determination and Conceptual Change

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Abstract

The paper discusses reference determination from the point of view of conceptual change in science. The first part of the discussion uses the homology concept, a natural kind term from biology, as an example. It is argued that the causal theory of reference gives an incomplete account of reference determination even in the case of natural kind terms. Moreover, even if descriptions of the referent are taken into account, this does not yield a satisfactory account of reference in the case of the homology concept. I suggest that in addition to the factors that standard theories of reference invoke the scientific use of concepts and the epistemic interests pursued with concepts are important factors in determining the reference of scientific concepts. In the second part, I argue for a moderate holism about reference determination according to which the set of conditions that determine the reference of a concept is relatively open and different conditions may be reference fixing depending on the context in which this concept is used. It is also suggested that which features are reference determining in a particular case may depend on the philosophical interests that underlie reference ascription and the study of conceptual change.

The topic of the present discussion is the reference of scientific concepts in particular from the point of view of conceptual change. In the first part of my paper, I discuss reference determination by using an important natural kind term from biology — the homology concept — as a case study. Nowadays there are actually two distinct homology concepts used, which differ in reference. Thus, a theory of reference determination has at least to account for the difference between these two natural kind concepts. First, I address (purely) causal theories of reference. Whereas a causal theory of reference is often considered as giving a satisfactory account in the case of natural kind term reference, I shall argue that this is not the case. Second, apart from causal factors, descriptions of the referent have traditionally been viewed as being relevant for reference determination. (This applies to contemporary causal theories as well, as it is nowadays acknowledged that apart from causal factors descriptions also have an impact on how the reference of natural kind concepts is determined.) However, in the case of the two homology concepts to be discussed, descriptions of the referent of each concept are insufficient to account for the difference in extension of these two concepts. My proposal is that even in the case of natural kind terms, reference is determined based on other factors in addition to the factors that standard theories of reference invoke. What theories of reference have to take into account as determinants of reference are *pragmatic* features of how concepts are scientifically used and for what *epistemic and explanatory purposes* they are used.

In last part of the paper, I argue for a *moderate holism* about reference determination, i.e., the idea that there is no clear-cut and unique boundary between those features that determine reference and those that do not have a bearing on reference fixing and that instead the set of conditions that determine the reference of a concept is relatively open. This is due to the fact that the conditions that are reference fixing may

vary from context to context in which a particular concept is used. It is also suggested that which features are reference determining in a particular case may depend on the philosophical interests that underlie reference ascription and the study of conceptual change. Since philosophers may approach the same concept with different explanatory purposes in mind (in different studies of this concept), it may happen that for one and the same concept used by a particular scientists different features are viewed as reference fixing and a different referent may be assigned depending on the particular philosophical interests used in a particular study.

Phylogenetic and Developmental Homology

Homology is actually a concept of central importance for biology, though it has not yet been popular in philosophical discussions. For the purposes of this paper, only a brief discussion of the two contemporary homology concepts can be offered. I have given a detailed argument as to why they are actually two distinct concepts elsewhere.[1] My discussion in this section will explain why we have two natural kind concepts that differ in reference. As it turns out, this account does not primarily invoke the core features of standard theories of reference (descriptions of the referent and samples of the kind and their stereotypical properties). The subsequent section will argue that standard causal and descriptive factors of reference determination alone cannot adequately account for the difference in extension of the two homology concept. Instead, the difference is to be explained in terms of the scientific use of these two concepts and the epistemic and explanatory goals for which they are used. I start with the phylogenetic homology concept, which is the original homology concept that emerged in the 19th century and is still used in current comparative and evolutionary biology.

[1]Reference omitted for the purpose of anonymous review.

The phylogenetic homology concept is a relation used for the comparison of organisms and their structures. Two structures in different species are *homologous* to each other in case they are inherited from one and the same structure in the common ancestor. For example, the wing of bats is homologous to the arm of humans because they are both derived from the forelimb of the mammalian ancestor. In fact, even the individual bones of the human arm perfectly correspond to and are thus homologous to the bones of the bat wing. Figure 1 illustrates homologous bones in the case of several mammals. Homologous structures are the 'same' or the 'corresponding' structures in different species. Homology is an equivalence relation and thus the structures that are homologous to a particular structure form an equivalence class. The members of such a class of mutually homologous structures are called *homologues*. Homologues are often given the same name (see Fig. 1), even if they consist of structures from very different species. For instance, biologists just talk about 'the' epithalamus (a part of the brain), referring to a structure that exists across the large and diverse group of vertebrates.

A class of homologues is a *natural kind*. As a class of homologues is an equivalence class of the 'is homologous to' relation, the homology concept actually defines a whole set of natural kinds. Thus homology is in fact a natural kind concept. Homologues form a natural kind for the following reasons. Homologues, e.g., the forelimb of different land-living vertebrates, are inherited from a particular structure in the common ancestor. The common ancestry ensures that many of the properties that hold for some homologues hold for all homologues. Morphological, histological, and developmental features can be (inductively) inferred from one homologue to the homologous structure in other species. Thus homologues are a natural kind in that we can project their properties.[2] This is very important for comparative and evolutionary biology, and the

[2]Projectability of properties is one of the hallmarks of natural kinds. In general, a notion of natural kind that is adequate for biology is the one that has been made prominent by Richard Boyd (1991,

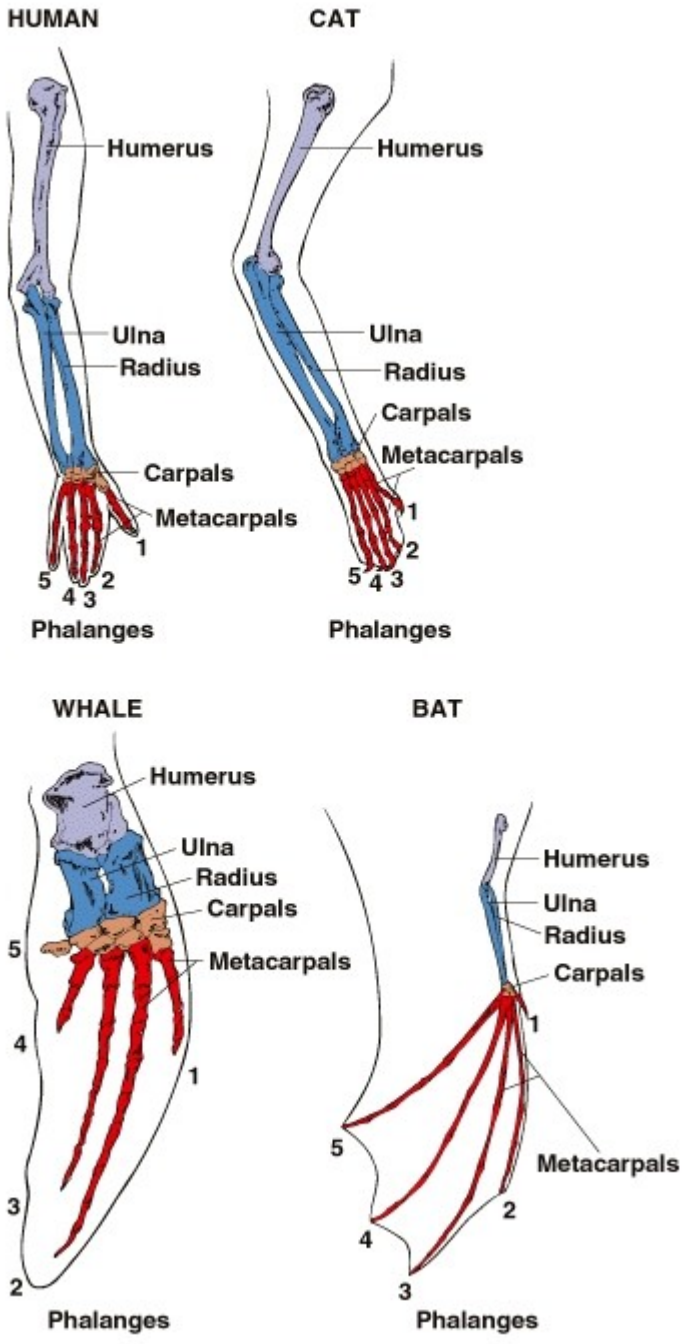

Figure 1: Homologies of the mammalian forelimb

reason why *homology individuates characters*. Individuating characters and structures by means of homology (rather than other principles) allows for unified and general descriptions of the properties of organisms that apply to large groups of organisms. For instance, many of the morphological, developmental, and physiological properties of the epithalamus of one vertebrate apply to all vertebrates in general. Moreover, by determining what the different homologues of an organism are, homology breaks an organism down into its natural parts. Homology literally carves nature at its joints. As it turns out, whether something is really a part of an organism depends on whether we can identify the same part in other organisms and species. The fact that homology is a natural kind concept is also shown by the fact that biologists were originally unclear about the 'essence' of homology that makes two structures homologous. The homology concept was introduced in pre-Darwinian comparative biology, and metaphysical notions such as Platonic ideas were sometimes invoked to explain what makes two structures homologous. With the advent of Darwinism it became clear that common ancestry is the defining feature of homology — two structures are homologous if they are inherited from the same structure in the common ancestor.

Traditionally, morphological structures such as bones, organs, blood vessels, and nerves have been viewed as homologous. But nowadays also tissue types, cell types, genes, and proteins in different species are recognized as being homologous. In sum, homology applies to all types of characters and this concept is being viewed as the basis of comparative and evolutionary biology (Abouheif et al. 1997; Donoghue 1992; Hall 1994; Laubichler 2000). This is due to the fact that homology individuates characters and supports inductive inferences from the properties of one species to other species.[3]

1999) and Paul Griffiths (1999). Homologues are clearly a natural kind in this sense.

[3] "Homology is the central concept for *all* of biology. Whenever we say that a mammalian hormone is the 'same' as a fish hormone, that a human gene sequence is the 'same' as a sequence in a chimp or

The discussion so far was about the phylogenetic homology concept as still used in comparative and evolutionary biology. In the last few decades, however, a new homology concept emerged among biologists with a developmental perspective on evolution. This homology concept is used in particular in evolutionary developmental biology (evo-devo), a relatively new field that tries to synthesize knowledge from the historically separate disciplines of evolutionary and developmental biology. Proponents of this new field maintain that knowledge about developmental mechanisms is crucial in answering certain questions about morphological evolution, and that traditional Neo-Darwinian evolutionary theory ignored certain important questions about evolution or made use of an incomplete conceptual framework (Hall 1998; Arthur 2000; Wagner et al. 2000). I call this new homology concept used in evo-devo the *developmental homology concept*. It is a distinct concept because evolutionary developmental biology uses its homology concept for different purposes than traditional evolutionary and comparative biology. Once the more traditional phylogenetic homology concept became integrated into the new research agenda of evo-devo, it underwent change by being used to pursue new epistemic and explanatory goals. The traditional phylogenetic homology concept is used to make *inferences* and obtain unified descriptions of different species. Evolutionary developmental biology, however, is not primarily interested in the comparison and classification of organisms. Instead, the focus is on the explanation of how structures originate in development. The goal is to have a *causal-mechanistic explanation* of why the same (homologous) structures develop in different organisms such as in parent and offspring. The theoretical purpose of the developmental homology concept is to account for morphological unity, i.e., the fact the same structure reliably re-appears

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a mouse, that a HOX gene is the 'same' in a mouse, a fruit fly, a frog, and a human — even when we argue that discoveries about a roundworm, a fruit fly, a frog, a mouse, or a chimp have relevance to the human condition — we have made a bold and direct statement about homology." (Wake 1994, p. 265)

over many generations (despite potential evolutionary modification of this structure), so that homologues can be stable building blocks of organisms and units of evolution change. The phylogenetic homology concept makes reference to common ancestry, but notions such as common ancestry or the inheritance of 'genetic information' do not yield any causal understanding of how and why structures reliably emerge in subsequent generations — and the latter is what is important for a developmental approach (Wagner 1989, 1994; Roth 1991, 1994). The phylogenetic homology concept can be used to make inferences, but it does not underwrite causal-mechanistic explanations. The developmental homology concepts supports such explanations by embodying knowledge about developmental mechanisms.

A consequence of this conceptual difference is that the two homology concepts have a different extension. Developmental homology has a larger extension in that it includes so-called *serial homologues*. Sometimes an organism has a structure that occurs repeatedly, for instance hair in mammals, leafs in plants, the vertebrae in vertebrates, or the segments in segmented animals. This multiple occurrence of the same structure is called serial homology. For instance, two vertebrae in an individual are serial homologues. Thus structures within one and the same individual (rather than structures of different species) are serially homologous. Biologists using a developmental homology concept acknowledge the existence of serial homologues (Riedl 1978; van Valen 1982; Roth 1988; Wagner 1989; Minelli and Peruffo 1991; Haszprunar 1992; Gilbert et al. 1996; Minelli 2003). The existence of a repeated pattern is an important starting point for developmental research. The question is whether this pattern is due to some underlying developmental commonality, e.g., something like a duplication of genes or a duplication of a developmental program (at work in different parts of an organisms). The developmental homology concept is intended to give a causal-mechanistic account

of why the same structures develop and re-appear *within* and *between* organisms. Serial homologues are one instance where the 'same' structure reoccurs and call for a developmental explanation. The traditional phylogenetic homology concept, in contrast, does not include serial homologues. The reason is that phylogenetic homology is used for the comparison of *different species*, and comparative biologists sometimes reject the very idea of serial homology on this ground (Ax 1989; Bock 1989; Schmitt 1989).

Toward a Broader Account of Reference Determination

Given the fact that nowadays there are two different homology concepts that differ in reference, one may wonder whether standard theories of reference determination are in a position to account for this difference in extension. First, I want to address (purely) causal theories of reference. Theories of reference often invoke causal factors in quite general ways. For instance, the reference of a term may be inherited from other members of a linguistic community. In this paper, I am not concerned with and will not challenge these general causal-historical determinants of reference. The focus of my critique is on causal theories of reference for *natural kind concepts*. The original picture of how reference to a natural kind is established is given by Putnam (1975). The idea is that we pick out a sample of the kind by ostension or stereotypical description and the referent is that natural kind to which the sample belongs. This original account had to be modified and refined. Natural kinds in science may not be observable, even though their effects are. Thus, the referent of an introduced term is that kind that is causally responsible for the observed effects (Newton-Smith 1981; Sterelny 1983). P. Kyle Stanford and Philip Kitcher (2000), however, point out that if we say that the referent is any object that has the same microstructural properties as those of the sample that cause the observed properties, then these causing microstructural properties cannot be the

total cause of the properties (otherwise the kind would necessarily have the observed properties, which contradicts the idea that the descriptions used to introduce the term need not apply to all members of the kind). They solve this problem of picking out the relevant subset of the total cause by offering a very sophisticated causal theory of natural kind concepts. On their account, reference is determined based on a set of samples of the kind and a set of foils, and a set of stereotypical properties that is shared by all members of the kind, but not by all foils.[4]

My brief discussion of the phylogenetic and developmental homology concept explained their difference — including the difference in reference — based on how these concepts are embedded in the conceptual practices of these fields and for what scientific purposes they are used. The phylogenetic homology concept supports inferences and is used to obtain unified comparative knowledge of different species. The developmental homology concept underwrites causal-mechanistic explanations and is used to explain why structures reappear in subsequent generations and sometimes several times within an individual. My claim is that these pragmatic and epistemic aspects of concepts are a crucial factor contributing to reference determination, and that standard causal theories of natural kind concepts do not address these factors adequately. To be sure, causal theories can acknowledge that these factors have some influence on reference determination. Epistemic and pragmatic aspects can be claimed to influence

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[4]The precise account is as follows: A natural kind concept T is associated with (i) a set of samples and a set of foils, (ii) and a set of stereotypical properties P_j that is shared by all samples, but each foil does not share all stereotypical properties. Then the reference of T is determined as follows:

$$\text{extension of } T = \{\, x \mid x \text{ has the same inner constitution that is a common constituent in the total cause of each of the properties } P_j \text{ in each of the samples, and that is absent from all of the foils} \,\}$$

In other words (leaving the foils aside), if $C_{i,j}$ is the total cause of sample j having property i, consider the features that are the intersection of the $C_{i,j}$. The natural kind term refers exactly to all objects that have these features. (Note that on this account, a member of the natural kind need not have any of the stereotypical properties.)

which samples and stereotypical properties are used, while the latter are the real determinants of reference. However, my point is that samples and stereotypical properties *alone* do not determine the reference of natural kind concepts, and that instead the epistemic and pragmatic aspects of concepts have a *direct* influence on reference that goes beyond picking out certain samples and properties.

Sophisticated causal theories such as Stanford and Kitcher (2000) view samples, foils, and some of their properties as the core determinants of the reference of natural kind concepts. While samples surely played a role when the phylogenetic homology concept emerged, samples, foils, and properties alone cannot account for reference. In fact, these factors are not even sufficient to account for the *difference of reference* between the phylogenetic and the developmental homology concept. Proponents of the causal theory might try to argue that the reference of developmental homology is fixed by means of samples (and properties) that actually include serial homologues, while phylogenetic homology is defined using (besides standard homologues as samples) alleged serial homologues as foils. However, this does not fit biological practice. Labeling alleged serial homologues as foils was of no importance for early evolutionary and comparative biologists, but their comparative research agenda determines the extension of 'homology.' The current debate with developmental biologists about the existence of serial homologues is not the *origin* but the *consequence* of the existence of two different homology concepts. When nowadays an evolutionary biologist insists that there are no such things as serial homologues, then this is not a statement that fixes the reference of her homology concept, but it is just the expression of the previously established fact that her homology concept does not refer to serial homologues.

Apart from causal factors of reference fixing, descriptions have traditionally been

viewed as determinants of reference.[5] So the difference between phylogenetic and developmental homology could be explained by using theoretical statements about the referents of these two concepts. Maybe this is the case. Some descriptions of homologues surely have an impact on the reference of 'homology.' But if by descriptive elements one has some necessary or sufficient properties in mind that the user associates with the concept or that are analytically linked to the concept, then it is not clear whether this can really yield a satisfactory account. The above discussion tried to make clear that there are actually two distinct concepts of homology in use, but it did this neither by relying on samples and foils, nor by invoking any special descriptions of homologues. The point is that on standard descriptive approaches, what determines reference are descriptions of the *referent* (such as gold is a yellow metal in the case of the concept 'gold'). While my account did make some use of descriptions of *homologues* — the referent of the homology concept — the crucial features of my account were those that specified the practical use of the *homology concept* and the theoretical goals for which this *concept* is used. For instance, a description used by an evolutionary developmental biologists such as 'homologues are the building blocks of organisms' — if properly understood — is not simply a description of homologues. For a comparative or a traditional evolutionary biologists would assent to this claim (taken in isolation), despite the fact that such a description is supposed to determine the difference between the developmental and the phylogenetic homology concept. The statement 'homologues

[5]This applies to modern causal theories as well, as current causal theories are not purely causal theories and instead include descriptive factors as well (Devitt and Sterelny 1999; Stanford and Kitcher 2000). In addition to theories that combine causal and descriptive factors, there is a well-known contemporary version of a descriptive theory of reference usually called 'causal descriptivism.' The idea is that reference is fixed by descriptions, which may include statements making reference to causal features and relations, such as the causal powers of kinds. Prominent proponents of causal descriptivism are Lewis (1984), Kroon (1987), Jackson (1998a, 1998b), and Chalmers (2002a, 2002b). My subsequent remarks on descriptive reference determination apply to causal descriptivism as well.

are the building blocks of organisms' — as used by developmental approaches — is in fact a short-hand, referring to a larger explanatory agenda that attempts to explain the evolutionary and developmental origin, stability and modification of these building blocks. It is this latter fact about the use of the developmental homology concept that marks the difference from the phylogenetic concept. Our best evidence for there being two concepts that differ in reference is the fact that these two concepts are used for different epistemic and theoretical goals. And my claim is that the reference of these concepts is determined by the way these concepts are embedded in different conceptual practices.

It is surely possible to use a very broad notion of 'description' that includes any type of implicit knowledge connected to a concept. On such an account, the features to which I appeal are in fact reference-determining descriptions. While in this case one would have a descriptive theory of reference (that could include causal elements as well), my important point is that it has to be recognized that these descriptions are not descriptions as traditionally understood, they are neither traditional analyticities nor primarily theoretical statements about the referent. The same point applies to intentions, which have also been viewed as determinants of referents. The factors to which my account of reference appeals — the explanatory purposes for which a concept is used — could be viewed as intentions.[6] Still, it is important to bear in mind that standard theories of reference usually appeal to intentions in a different and more restricted sense. A typical way to make use of intentions is illustrated by the theory of Philip Kitcher (1982, 1993). Kitcher combines descriptive and causal determinants of reference, and on his account, the speaker's intentions determine which causal factors and which descriptions are actually reference determining (see Devitt and Sterelny

[6]Though how a research approach or a scientific community uses a particular concept may not simply be an intention of an individual.

1999 for a similar usage of intentions). Given that I do not view causal factors and descriptions of the referent alone as reference determining, intentions that pick out one of these factors cannot be sufficient either. While my account could be viewed as making recourse to the intentions of concept users in some sense, these intentions have to understood broader than standard theories of reference do.

My critical discussion of standard theories of the reference was based on one natural kind term — 'homology' as used with a different meaning and reference in different biological fields. But I think that the same point applies to other natural kind concepts as well. Another likely candidate is the species concept, which has figured prominently in philosophical discussion as an example of a natural kind term. My assumption is that a close look at how reference is actually determined by scientists and their practice in the case of species and other examples reveals that real cases cannot be adequately accounted for by current theories of reference, in particular not causal theories of reference. My proposal is that even in the case of natural kind concepts we need a broader account of reference fixing. Apart from samples, their stereotypical properties, and theoretical statements about the referent, there are other factors that have a crucial influence on reference. These are aspects of how concepts are scientifically used and for what epistemic purposes they are used.

Reference and the study of conceptual change in science

The last part of my paper deals with the reference of scientific terms in general, which need not be natural kind terms. The discussion so far argued that there are factors that influence reference, on which theories of reference have not focused — namely, the epistemic purposes for which scientific concepts are used. One the one hand, these factors are quite salient and visible features of scientific practice, that clearly distin-

guish the phylogenetic and the developmental homology concept, for instance. On the other hand, these factors do not boil down to a few isolated descriptions or causal factors; instead, they are quite general and broad aspects of concept use. The following discussion deals with a quite different sense in which it is not the case that reference is determined by a clearly delimited set of causal and descriptive factors. The point is that even though causal features and descriptions determine reference, there is no unique and clear-cut distinction between those feature that determine reference and those that do not influence reference. David Papineau (1996), focusing on descriptive reference determination of theoretical term, acknowledges that there is no clear distinction between those and other parts of a theory that defines a term. Papineau's point is that this usually raises no problem as the extension of the term is unaffected by this vagueness of reference determining conditions (though there may be cases where the vagueness leads to referential indeterminacy, so that disambiguation ought to occur). My discussion has a different focus. I will point to cases where one concept actually differs in reference from context to context. Such cases show that the set of reference determining conditions is not only vague, but that this set is large and relatively open and unbounded.

Philip Kitcher (1978, 1993) argued convincingly that the reference of scientific terms is context-sensitive. In particular, when studying reference the unit of analysis is not the term-type, but the term token, i.e., a term as uttered on a particular occasion. The reason is that the reference of a scientific term may change from token to token. One of Kitcher's examples is the term 'phlogiston' as used by a phlogiston chemist such as Priestley. As is well know, on many occasion this term was non-referential. Since reference was fixed by associated descriptions such as 'phlogiston is what is emitted in combustion,' and nothing satisfies this description, the term 'phlogiston' did not

refer. However, Kitcher argues that there are other occasions, on which the term did refer. For instance, when Priestley prepared a gas that he took to be 'air from which phlogiston was removed,' breathed this gas and described the effects on him, Priestley was actually referring to the gas he breathed — namely, oxygen. The reason is that the best account of this particular case is that a causal (rather than descriptive) mode of reference obtained and Priestley successfully referred to the substance with which he was in direct contact. Even though Kitcher does not put it this way, the philosophical upshot I want to highlight is that a theory of concepts that assumes that a concept is defined by a clearly delimited set of reference fixing conditions cannot account for this reference change from token to token. If a concept were associated with a precisely delineated set of reference-fixing conditions, then this set would pick out in each case a unique referent (or no referent or several referent to which the term partially refers).[7] My explanation of the situation described by Kitcher is that a term is connected with a large and relatively open set of beliefs and other features that can influence reference, and that in a particular context greater weight is given to a certain set of beliefs so that reference is determined in this particular way. For instance, some of Priestley's beliefs are theoretical descriptions that are supposed to pick out 'phlogiston' (even though actually no object satisfies this description). Other beliefs are about him preparing, handling, or breathing 'air from which phlogiston was removed.' Depending on the particular context, some of these beliefs are more salient than others, determining whether Priestleys utterances do not refer or refer to oxygen.

Cases where the reference of a term changes from token to token are not confined

[7]There are well-known cases where the reference of a term is context-sensitive. This may happen in the case of indexicals. Another case is when a term is ambiguous, and thus actually expressing different concepts with distinct extensions on different occasions. While indexicals and ambiguous terms do not require the assumption that there is no clear-cut set of reference fixing conditions for a concept, the cases of reference change which I discuss are not of these standard kinds.

to examples from the history of science. Henry Jackman (unpubl.) makes the same point based on traditional thought experiments. In the case of the reference of the term 'arthritis' as used by Bert (see Burge 1979), some have argued that it refers to arthritis, while others have taken him to refer to tharthritis (a condition which includes both arthritis and rheumatoid ailments of the limbs, particularly the thigh). Jackman's point is that either referent may obtain depending on the particular case. In some cases, Bert is best viewed as talking about arthritis (e.g., when he appeals to doctor's knowledge about 'arthritis'), in other cases, his belief that he has 'arthritis' in his thigh is more important for reference determination, so that he refers to tharthritis. Similarly, in the case of a person being unbeknownst to him moved to Twin-Earth, some of his 'water' utterances refer to H_2O (e.g., when talking about his past experience), while others refer to XYZ (e.g., when directed at objects on Twin-Earth). The point is that virtually *any* belief or other condition may be reference determining in *some* special context.

In sum, these cases support a *moderate holism* about reference determination. Michael Devitt (1993) argued against holism and for a localism in the context of an inferential role semantics. His suggestion is to view those inferences as meaning constitutive that are reference determining. However, this proposal yields a localism only insofar as there is a unique and clear-cut distinction between reference-determining and other inferences. As my discussion shows, in general there is no such distinction, so that we do not get a real localism about reference determination. In a later discussion, Devitt (1996) appears to argue for 'localism' in the sense that for each term *token*, there is a specific set of reference determining conditions (p. 88). This position is consistent with my account, however, the exclusive focus on term tokens obscures that fact that in the case of term types the situation may be quite different, as there can be an open set

of reference fixing conditions. Kitcher's insight that term tokens are the unit of analysis means nothing but that reference may change from token to token. It does not amount to the idea that concepts are to be identified with term tokens (unlike term types, as traditionally done in the case of non-ambiguous terms). As philosophical analysis has to address the reference and reference determination of concepts (i.e., term types) and my discussion is about this standard issue, the label 'moderate holism' is the best way to capture the fact that the set of conditions that fix reference for a concept is open and that the conditions relevant for a particular case (a term token) may vary from context to context.[8]

Finally, I suggest that what a term refers to may depend on the philosophical interests underlying reference ascription and the study of conceptual change. Even though Kitcher points out that the referent of a term — and thus the conditions that determine reference — can change from token to token, he assumes that in each particular case, the speaker's intentions fully specify which conditions are reference-determining, so that the referent is unambiguously picked out. For instance, the speaker's intention determine whether a certain description is reference fixing or whether the causal contact with a substance is the decisive feature. However, a scientists may be ignorant about the referent and its properties, and even have false beliefs about it. Priestley, for instance, was unaware of the fact that the substance he prepared was oxygen, and that the description 'substance emitted in combustion' does not refer to phlogiston. While Kitcher assumes that in each case Priestley had a "dominant intention" that specified whether a causal or descriptive way of reference determination obtained (Kitcher 1982, p. 344; 1993, p. 77), in many cases Priestley may have had several intentions that he

[8]My account is a moderate holism because it is obviously not the case that all descriptions and other conditions determine reference (which would be a radical holism). Moderate holism, unlike radical holism, is what typical holists endorse (Bilgrami 1992; Khalidi 1995; Jackman unpubl.)

took to be reference determining, but that were actually in conflict. In such a situation, a standard move is to appeal to partial reference (sensu Field 1973) and to say that the term (token) partially referred to different referents. My suggestion is that even though there are not always dominant intentions and the like that pick out a unique referent, we can do better than having to accept that reference is indeterminate because of partial reference.

Even if the speaker's beliefs and intentions, her physical environment (causal relations) and social environment (other speakers) do not determine a unique referent, in addition we can appeal to the explanatory interests that underlie the study of conceptual change. A particular philosophical interests may favor one assignment of reference over another, so that the vagueness as to which conditions are reference determining and the indeterminacy of reference is cleared up. If we assign one referent (e.g., assuming that Priestley referred to oxygen in certain situations), then we make the speaker rational in certain respects (Priestleys utterances were not non-referential, he was right about the effects in him of the gas he breathed, some of the arguments for the phlogiston theory still had some force for his opponents). In other respects, however, the speaker is clearly wrong (Priestley misconstrued the chemical nature of the gas he breathed). There are cases where there is no unique reference assignment that would best fit the speaker's intentions and her physical and social context or maximize the speaker's rationality.[9] Instead, one possible assignment of reference makes a speaker reliable and rational about some issues, but not others, while another possible reference assignment makes her reliable and rational about other features. My point is that the interests underlying a particular study of conceptual change (or reference ascription

[9]In the first place, there may be no unique measure of overall rationality (or degree of fit with reference determining conditions) to be maximized. Measures of rationality may depend on the explanatory interests of the philosopher studying the history of science, i.e., the interests determine in the first place what the person is to be rational about.

more generally) may fit with one particular assignment of reference much better than with others. Thus, these explanatory interests may determine a certain referent, even if reference would be indeterminate if we did not take the relevance of such interests into account.[10]

So far, for purposes of exposition my discussion focused on cases where different *referents* could be assigned to a particular term (uttered on a certain occasion). If different referents can be assigned depending on our philosophical interests, then necessarily different conditions are reference determining relative to our interests. In fact, my point applies more generally to *reference fixing conditions*. What conditions (what descriptions, causal features, etc.) are viewed as reference determining may generally be dependent on our philosophical interests. If it is the case — as I assume — that different interests may actually determine different reference fixing condition for one and the same term (token), then this does not necessarily imply different referents, as the same referent can be picked out by different reference determining conditions. Thus, even if a standard case obtains where there is no referential indeterminacy and a unique referent is to be assigned no matter what our philosophical interests are, this does not mean that in such a case the reference conditions are uniquely determined independently of our explanatory interests. While cases of potential indeterminacy of reference actually support the idea that philosophical interests of reference ascription may be relevant, reference determination may be generally dependent on such interests even if this interest-relativity does not show up as change in the referent. In sum, my

[10]Stephen Schiffer (1981) made similar remarks in the context of assigning truth-conditions to sentences. On his account, a theory of truth needs to maximize how reliable the interpreted person is, but what it makes her reliable about depends on our explanatory interest. Schiffer concludes that there is not a unique assignment of truth values and no determine truth-conditions. My concern is obviously not to argue for referential indeterminacy, but for the interest-dependence of reference ascription (which may remove indeterminacy).

suggestion is that the philosophical interests underlying reference ascription and the study of conceptual change influence reference determination, and as the same concept or term (token) may studied with different interests in view, different studies may assign different reference fixing condition, which may but need not lead to different assignments of referents. In this sense, reference may be determined based not only on the speaker's beliefs and intentions and her physical and social environment, but these explanatory interests are reference determining as well.

In this paper, I cannot give a illustration of how the interests underlying the study of conceptual case may influence which conditions are reference determining. But a concrete case where this could be carried out is the reference of the term 'gene' as used by different geneticists at the same time and in particular in different decades. In the 1960s, the assumption was that genes are clearly delimited stretches of DNA characterized by a particular structure. However, as it turned out the biological facts are much more complicated. Even though genes may be considered a natural kind, genes are clearly a very heterogeneous kind. It is often not clear what has to count as the entity that accounts for the production of gene products. Nowadays, one and the same collection of DNA stretches may be viewed as a single gene by some molecular biologists, while others would view this collection as consisting of two or more genes.[11] Given this situation, it is often not clear to which entity a contemporary biologists actually refers when talking about 'genes' in a certain context. Arguably, different referents could be assigned and a fortiori different conditions (descriptions, intentions, physical facts) can be viewed as reference determining. The situation is even more problematic if we attempt to interpret the referent of the term 'gene' as used by different

[11]These findings of molecular biology in the last two decades and in particular recent research in genomics led to a certain fragmentation of the gene concept or even the view that there is simply no unique gene concept. See Griffiths (2002), Moss (2003), and in particular the contribution in Beurton et al. (2000).

biologists in the historical period of Mendelian genetics. Even if the assumption were that Mendelian geneticists referred to the natural kind of genes as understood nowadays, this would not settle the issue due to the mentioned fact that the category of genes is not clearly delineated and that it is biologically undetermined what genes precisely are. In addition, many Mendelian geneticists used the gene concept in a way that they probably referred to entities that are nowadays not viewed as molecular genes. Overall, is quite unclear what the precise referent and the reference fixing conditions of the term 'gene' were as used by different Mendelian geneticists. My approach has the advantage that we do not have to settle with indeterminacy of the referent or the conditions determining the referent. If we take the explanatory interests that underlie a particular study of conceptual change into account, then we are in a much better position to pick out more precisely delineated reference fixing conditions and probably a unique referent for this particular study.

Conclusion

The first part of my discussion criticized traditional theories of reference insofar as they rely on causal factors and descriptions of the referent as the main factors of reference determination. Even though the reference of natural kind terms is often taken to be relatively straightforward, my discussion showed that even in such a case further conditions are important determinants of reference. My claim was that pragmatic features of concept use and the epistemic and explanatory interests which are pursued by the use of scientific concepts are further features that fix the reference of scientific terms. In the second part of the paper, I argued for a moderate holism about reference determination, i.e., the idea that there is no clear-cut and unique boundary between those features that determine reference and those that do not have a bearing

on reference fixing. Rather, the reference of a concept is determined based on a large and relatively open set of reference fixing conditions. These two claims made in the paper are distinct, but taken together they reinforce the idea that the reference of a term is not fixed by a few theoretical beliefs, intentions, or causal relations. Instead, the reference of a concept is constituted based on many beliefs of a speaker that can be reference-determining on some occasions and the general way in which a concept is used in scientific practice. Finally, I suggested that that the philosophical interests that underlie reference ascription and the study of conceptual change may bear on which features are reference determining in a particular case. Thus, reference need not always be fully and unambiguously fixed by the speaker and her physical and social environment, but the explanatory interests of the person ascribing reference may clear up the intrinsic vagueness between reference determining and other conditions and remove referential indeterminacy. Since philosophers may approach the same concept with different explanatory purposes in mind (in different studies of this concept), it may happen that for one and the same scientific term different features are viewed as reference fixing and a different referent may be assigned depending in the particular interests used in a particular study.

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