Chapter 5
Reductive Explanation

Reduction reconciles diversity and directionality with strong unity. Unity is cashed out in terms of identity. Diversity is descriptive, or conceptual. Directionality is the directionality of explanatory dependence. A sentence of the form '*F-ness* reduces to *G-ness*' expresses a truth if and only if (i) for every *x*, if *x* is *F* then (*x* is *F* *because* *x* is *G*), and (ii) *F-ness* = *G-ness*; the explanation in condition (i) is non-conceptual. The direction of the dependence relation depends upon features of the descriptions under which an object is presented by the expressions flanking the reduction predicate. It goes from *water* to H_2O, but not from H_2O to *water*. This is so because of a difference in semantic facts about 'water' and 'H_2O', facts other than those regarding reference or designation. Recall: Expressions do not matter in this respect. Similarly, ontology does not matter (water just is H_2O).

Is this all there is to say about reduction? It is not. In this chapter, I will give a more thorough idea of how descriptive or conceptual diversity is tied to the directionality of reduction.

I will suggest that the explanatory directionality of reduction is tied to differences in how different descriptive or conceptual contents, or Fregean senses present us with entities *as having different properties*. The idea is this: Re-describing an object, we may get better access to its nature. Directionality of reduction just is directionality that stems from a difference in the degree to which conceptual or descriptive contents give access to an objects nature, or its constitutive structure. This is reductive dependence. Intuitively, water reduces to H_2O because 'H_2O' presents us with water under properties that differ relevantly from those under which 'water' presents us with water. The present section proposes an account of this difference in the sense that it offers a semantic model that enables us to tie reductive dependence to specific semantic features of expressions that pick out a reduced or a reducing object. The difference just is the difference tracked by the directionality of explanatory dependence. Thus, I will not come up with a "reductive" account of reductive explanation; explanatory notions will occur in the characterizations of the central notions of the theory proposed here.

In a first step, I will propose an intuitive outline of the model (Sect. 5.1). I will then introduce the details (Sects. 5.2, 5.3 and 5.4) and argue that a mereological

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interpretation of reductive dependence is bound to fail (Sect. 5.5). I will then introduce a more thorough version of *Explication I*, show that the explication meets the job description, and characterize derivative notions (Sect. 5.6). Finally, it will be shown how the proposal offered here provides a structure for explications that exploit other resources (Sect. 5.7).

5.1 The Model: An Intuitive Outline

Things have, on the view proposed here, properties *according to* a description. The properties an entity has according to a description are captured by the technical notion of a *property structure*. Some expressions give access to *constitutive property structures*, a special case of property structures, of the entities they designate. A constitutive property structure gives, to some extent, access to the object's nature. Different constitutive property structures differ in the degree to which they give access to an object's nature. Consider, again, 'water' and 'H_2O' (here treated as an *empirical formula*, lacking information about structural arrangement, to avoid complexity). The designatum of 'H_2O' is, when presented under the concept of H_2O, presented as *the entity instances of which exemplify the property of having exactly three atomic constituents, two of which exemplify the property of being hydrogen, and one of which exemplifies the property of being oxygen.* In this, the meaning of 'H_2O' relevantly differs from the meaning of 'water'. If 'water' has descriptive content, describable, say, in terms of quenching thirst and being tasteless, then the meaning of 'water' presents us with instances of water as quenching thirst and being tasteless. If 'water' lacks descriptive content, then instances of water are presented as being water by 'water' – that's it. Thus, the concepts of H_2O and water present us with water under different property structures. A property structure is an abstract object an expression *E* gives access to, which contains exactly those properties the entity designated or signified by *E* has *according* to *E*'s conceptual content, or meaning. The directionality of reductive explanation tracks relevant differences in property structures that present one and the same object.

In order to cash out this idea, we need a precise idea of the following notions: that of (i) a property structure, (ii) a constitutive property structure, and (iii) of having properties according to a description.

Here is the short, intuitive version: a property structure is a tuple of properties and functions defined over properties. A constitutive property structure is a property structure that contains constitutive properties of the entity so described or presented; the notion of *being a constitutive property of* is here understood as an explanatory notion. And an object *x has specific properties according to the meaning or conceptual content of an expression E* iff according to the proposition that *E* adequately describes an object, *y*, *y* has these properties, and $x = y$. Before giving a more thorough interpretation of these and related notions, let me address two questions that may seem to suggest themselves: (i) what is the supposed relation between property-structures and meanings or conceptual contents? And (ii) shouldn't we try to get rid of expressions such as 'in virtue of' and 'because' in a characterization of reduction?

5.1.1 Property Structures and Semantics

It is important to note that talk about property structures is supposed to model *one aspect* of (non-Fregean) meaning, (Fregean) sense, or conceptual content instead of fully capturing this idea. There might be more to the meaning, sense, or conceptual content of the *explanans* and the *explanandum* of reductive explanation, or to the meaning of instances of '*a*' and '*b*' in a sentence of the form '*a* reduces to *b*' than what is explicit in property structure talk. There are two ways of interpreting this distinction. On the one hand, we might adopt *semantic pluralism*, according to which different semantic values of an expression may play a role in different contexts. The relevant semantic values may shift from context to context.[1] This idea obviously goes back to Frege, who himself introduced different sorts of semantic values, or semantic relations. Thus, one might want to be liberal and hold that property structures are one semantic value of expressions, one amongst others – the one that kicks in, for example, when we want to understand reductive statements.

Alternatively, we could just say that whatever the semantic value of an expression actually is, it *determines* a property structure; in this sense, we are able to model an expression's semantic value in terms of a property-structure, and it is this aspect which helps illuminating the semantic condition on instances of reductive relations. I will adopt this latter, less committal interpretation. This interpretation suits the purpose of arriving at an explication: An explication should be sparse in the sense that it should not invoke assumptions that are not required to explicate the target concept. Later, I will suggest that the explication could be given a two-dimensionalist interpretation (see Sect. 5.7).[2] Whatever meanings are, the reductionist is committed to the idea that meanings determine or correspond to something like property structures, and play a role similar to the role these structures play within the explication offered below.

It is sometimes assumed that constituents of meanings are concepts rather than properties or individuals. Schiffer characterizes the relation between Fregean propositions (as meanings of sentences) and Russellian conceptions of propositions,

[1]David Chalmers (2004) suggests that epistemologically explicated notions of meaning may play a role in some contexts, whereas metaphysically explicated notions may play a role in others, and none of these is more fundamental than the other. See Sect. 5.7 for a discussion. Similarly, Albert Newen introduces meanings as vector spaces (1996), which comprise several semantic values for expressions.

[2]Apparently, it could also be phrased in hyper-intensional semantics such as those proposed by Tichy (1988) and Cresswell (1985), and also Church (1973, 1974, 1993).

writing that "[j]ust as the Russellian may take $<<x_1, \ldots, x_n>R^n>$ to represent the form of any proposition, so the Fregean may take it to be represented by $<<c_1, \ldots, c_n>C^n>$" (Schiffer 2003, 22), where the building blocks of propositions are *concepts* of properties or objects, rather than properties or objects themselves.[3] The interpretation given here does not contradict the assumption that there might be meanings the building blocks of which are *not* properties (or individuals), but rather concepts of these (or, in Fregean terms: *senses*). But even on the Fregean interpretation, we should assume that meanings or conceptual contents give access to property structures. From a sentence of the form 'F*a*' we can infer that *a* exemplifies the property of being *F*. According to Strawson (1974, 33) and Quine (1980, 164) these are synonymous.[4] Predicates are used to attribute properties, at least sometimes, and, under a semantically realist interpretation of science, at least in science. Thus, it is quite natural to accept that simple predicates and kind terms give access to properties, and that semantically complex expressions give access to things as having properties. But what is the difference? Maybe there is none. This is a topic that is largely irrelevant for the present purpose. The important point is this: Properties are the things in virtue of which entities that exemplify these properties behave the way they do. Properties are not representational in nature. If concepts are representational in nature, then there is an important difference. But, one might want to ask, what are properties?

Let me respond with this dialectical remark instead of a straightforward answer. In Sect. 2.4 I mentioned several possibilities to conceive of properties. The account proposed here is compatible with all of these interpretations. So, I rely on an intuitive notion of a property, a notion that is partly characterized as follows: Properties do not belong to the representational furniture of our world, and they form the class of things some of which are such that in virtue of them, space-time objects behave the way they do. We might go a step further and claim, with Bealer (1993, 20), that we should take properties at *face value*, that is: the category of properties should be treated as a category which is not to be rephrased in, say, set-theoretical terminology. From a dialectical point of view, we could adopt this assumption: Within the account proposed here, the notion of a property is interpreted as basic. But what about explanatory concepts?

[3] If we assume that property-structures are semantic values, we might want to hold that the account given here is a version of Russellian semantics. At first sight, one might hope that, building on an understanding of a sense as a mode of presentation, one could describe Fregean senses in terms of property-structures. For a critical examination of the notion of a mode of presentation, see (Künne 2001).

[4] Schnieder (2006) argues that this thesis is false, because there is a difference in understanding conditions between sentences explicitly attributing properties and those that rely on the 'predication-mode'. For present purposes, this difference does not matter; all that is required is the assumption that the inference is correct.

5.1.2 *Treating 'Because' as Basic*

The notion of a constitutive property structure will be cashed out in explanatory terminology. Obviously, one might feel tempted to try to eliminate expressions such as 'in virtue of', 'because', and 'by' from the model of reduction. However, as the long-lasting discussion on related topics, such as supervenience and ontological dependence shows (for an overview, see Correia 2008), these attempts are not very promising. Modal notions do not help to perform the relevant trick of defining a relevantly directional relation (unless we *stipulate* directionality). I will not try to get rid of such expressions. Following a recent trend in related domains, I suggest that we take directionality at *face value*. However, saying that explanatory notions cannot be analyzed away is *not* to say that there isn't anything interesting to say about them; in our case, it is not to say that there isn't anything interesting to say about the connection between descriptive plurality and explanatory directionality. In this sense, I will introduce a model that enables us to give a precise idea of the semantic conditions the *explanans* and the *explanandum* of a reductive explanation have to meet in order to enter a true instance of this type of explanation.[5]

Ideally, to obtain an expression that gives us the relevant property structure for another expression, we have to rely on a meaning revealing definition of the latter. From the definiens of such a definition, we can obtain a (usually complex) expression that contains constituents that designate the relevant building blocks of property-structures. Intuitively, this feature makes them transparent with respect to the property-structure's organization. In the sections to follow, we can then apply an operator to the resulting expression, which designates the property-structure itself, rather than the designatum or significatum of the expression we started with. This can be conceived of as a procedure consisting of two individual steps to obtain a term that is transparent with respect to the building blocks of the property structure it designates – a procedure to obtain a property structure term. Having introduced this procedure, we can give an idea of what it is for a thing to be a certain way according to a description. We will reflect upon the metaphysics of property structures and define a number of notions relevant to account for reduction. Building on these definitions, we can then suggest a more thorough explication of a core notion of

[5]This is not the common way to treat issues of explanation, at least in the philosophy of science. Often, kinds of explanations are described with respect to how they relate to pragmatic issues (van Fraassen 1980), to epistemological issues (according to the interpretation of Covering-Law models of explanation as being tied to the form of arguments), and to epistemic procedures of discovery (Craver 2007; Bechtel 2007) and intervention (Woodward 2003; Craver 2005). Types of explanations can be individuated in terms of characterizability within a specified framework (we then arrive at characterizations such as 'explanations that fit the DN-model') or in terms of how they relate to causation or other ontological relations (we then arrive at characterizations such as 'causal explanation'). However, it should be clear that this is a way to account for explanation; learning something about the conditions on the semantics of explanans and explanandum (conditions fixing when these are appropriate), we learn a lot about this sort of explanation.

reduction, defend this explication's adequacy, define derivative notions and point to alternative conceptions of those objects that play the role property structures play in the present account.

5.2 Meaning-Revealing Definitions and Property-Structures

Basically, a property structure (henceforth, 'PS') consists of properties and, sometimes, functions that map properties or states of affairs onto properties or states of affairs. PSs will be conceived of as being fully determined by the PSs an expression's semantically simple constituents give access to and these constituents' arrangement (this mimics compositionality). This will base a procedure to *obtain* expressions that refer to PSs in an interesting way – in a way that makes the arrangement of properties and functions in a PS transparent. Thus, let us, in a first step, reflect upon which expressions come in an appropriate format to enable us to grasp the property structures they give access to. In the case of complex expressions that consist of semantically simple expressions *only* (and for semantically simple expressions themselves) we can easily arrive at the basic constituents of the PS this expression gives access to. Moreover, the syntax of such an expression will give access to the arrangement of the properties within this structure. For semantically complex expressions that are syntactically simple, we have to rely on characterizations that illuminate these expressions' meanings. Assuming that ultimately, these characterizations will contain semantically simple expressions only, we can, again, easily identify the property-structure's constituents and their arrangement. Obviously, relying on expressions that contain semantically simple expressions *only* is an idealization. However, it will help to make the idea precise.

Consider again 'H_2O' and assume that each of its meaningful constituents is semantically simple. Intuitively, it gives access to a PS that contains, among other properties, the property of being a proper part of (recall that relations are here treated as n-ary properties, with $n > 1$), the property of being hydrogen and the property of being oxygen. This PS can easily be obtained from the predicate '_is H_2O', or one of its ordinary language reformulations. The basic constituents of the PS H_2O gives access to are the properties signified by predicates or designated by terms which, together, form the complex term 'H_2O' (or one of its ordinary language reformulations), and rules associated with the formation of this term.

What about syntactically simple, semantically complex expressions? Assume that 'water' means 'being tasteless and being liquid'. In this case, the constituents of the property structure 'water' gives access to are not obtainable from constituents of 'water'; rather, they are obtainable from an *appropriate analysis or characterization of the concept of water*.[6] Thus, sometimes, to account for the PS an expression gives

[6]For the proposed account to work, we do not have to rely on a too demanding sense of 'analysis' or 'meaning-revealing definition', i.e. on a sense that suggests that an appropriate definiens and its

access to, we have to rely on characterizations of the meaning of that expression; this will be the case iff the expression does not fully reveal the relevant semantic structure.

Let me comment upon several sorts of meaning-characterizations, conceived of as definitions, pertinent in the context of reduction to make this idea more precise. We will then be able to build upon the definiens of such a definition (or the counterpart in a meaning-characterization of a non-predicate, like a term or a sentence) of an expression *E* to specify the PS under which *E* presents its designatum (if it is a term) or significatum (if it is a predicate or a sentence). There are at least three ways we can treat the complex meaning of an expressions, which might be relevant in the case of reduction: the meaning of functional terms, of directly referential terms, and of alleged cases of non-functional terms. The next Sect. (5.2.1) comments on these cases, before we turn to the idea that meaning revealing definitions can differ in the degree of explicitness (Sect. 5.2.2). Building on the notion of a maximally explicit definition, we are in a position to give an idea of how we get access to property-structures.

5.2.1 Arriving at the Meaning of Expressions

If functional terms gain their meaning by the theory they are used in, the property structure they reveal will (at least partly) be given via a definition building on the Ramsey sentence of the theory the term occurs in (if you are not familiar with the notion, please read the first few paragraphs in Sect. 6.7). Thus, to appropriately model the property structures of the terms in 'pain reduces to C-fiber stimulation', we should not model the property structure revealed by 'pain' as *being pain*. Assume that pain is exhaustively described by being the internal state that maps tissue

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definiendum must be strictly synonymous, although this is the way the account is presented here. To bypass problems concerning the analytic-synthetic distinction (Quine 1951) or the paradox of analysis (Black 1944), we could rely on a notion weaker than that of synonymy or analyticity; just substitute it by the concept of a functionally appropriate explication. Building on some such idea, we could rely on a notion of *meaning similarity*, or *similarity in use*. But don't we have to give a precise idea of how this is supposed to work? We do not. The job-description of the technical term reduction does, I suggest, commit us to the idea that meanings present us with an object in a specific way. An appropriate model of reduction is bound to give an idea of how meanings manage to do this. Thereby, any appropriate model of reduction is committed to the assumption that different meanings present us with objects in different ways. One way of cashing out a difference in meaning is this: Two expressions have different meanings (in the relevant sense) iff they have different illuminating definitions. An appropriate definiendum gives access to the relevant property structure under which the definiens presents us with an object. But what is an appropriate definiendum? One way of cashing out this idea is in terms of analyticity or synonymy. An alternative explication might build upon the idea that the appropriateness of a definiendum, even for non-technical expressions, is to be cashed out in terms of explication, or something similar, rather than analyticity or synonymy. The overall-strategy, however, will remain the same.

damage onto yelling (thus, assume a very simplified version of folk-psychology). Assume, moreover, that the concepts of *tissue damage* and *yelling* are not further analyzable. Then, the functional concept of pain is fully given by *being such that any instance of it is caused by tissue damage and causes a yelling*. From this, we can obtain the relevant property structure. Thus, for functional terms, there is a well-established procedure to obtain the relevant definitions. But what if functional definitions are not always available?

Directly referential expressions lack descriptive content, as Kripke famously argued (Kripke 1980). A number of expressions that play a prominent role in reductions may turn out to be directly referential, such as ‘water’, ‘iron’, and numerous other expressions we use in extra-scientific discourse to talk about our environment. That is: these expressions may have a referent or signify something, but, at the same time, lack meaning (in the sense the term ‘meaning’ is employed here). I propose the following treatment of these cases: If, say, ‘water’ lacks meaning but designates the property of being water, then it presents us with water *as being water*. Note that this treatment is insensitive to a possible difference between semantically simple expressions that designate properties under a simple concept and directly referential expressions. This will not matter much for the discussion to follow.

Assume that some ordinary-language expressions, like qualia-terms or, maybe, expressions like ‘knowledge’, have a meaning that is not functional in nature and can be revealed only via conceptual analysis that does not explicitly rely on a Ramsey-sentence, or, in Chalmer’s terms, by reflection on meaning, or ideal rational reflection only (Chalmers 2002, 2004, 2006). Maybe, for some notions, this is the way to go. Note, however, that possibly problematic cases of conceptual analysis will, under some widely shared assumptions, hardly play any crucial role at all in reduction: If natural kind terms lack meaning or if their meaning can be given by functional characterizations, and if it is either natural kind terms or scientific terms (including functional terms) which flank ‘_reduces to_’ in true reduction statements, then the account proposed here will, at least for the relevant kinds of reduction, just not be concerned with issues of *conceptual analysis* of non-functionally analyzable ordinary language expressions; it will merely be concerned with natural kind terms, functional terms and scientific terms.

5.2.2 An Ideal Demand: Maximal Explicitness of a Definition

Now, meaning revealing definitions are often hard to arrive at. So, we should regard the condition that we have to build upon definitions that fully reveal the meaning of the expression we are interested in as an ideal demand rather than a strict requirement needed to make sense of the idea of a PS. Explicit descriptions of PSs can vary in degree of specificity. Let us return to the pain-example to illustrate this point. Assume that the meaning of ‘yelling’ is not further analyzable, but that the meaning of ‘tissue damage’ is, say, in terms of *rearrangement of tissue-structures such that due to this rearrangement, these structures cannot fulfill their primary* *biological function anymore*. Then, we could give a more precise analysis saying that pain is the property that is such that its instances are caused by events that consist of a rearrangement of tissue-structures such that due to this rearrangement, these structures cannot fulfill their primary biological function anymore, and they cause yelling. Thus, definitions come in *degrees* of illumination – they possibly contain expressions the meanings of which could be further analyzed. We can then *compare any two definitions* D^1 *and* D^2 *of a predicate 'F_' with respect to which of the predicates occurring in the definiens are further analyzable and which are not.* Similarly, if the PS 'knowledge' gives access to is tied to a characterization of the meaning of 'knowledge' in terms of *being such that any instance is a belief, is true, and is justified*, then it contains properties presented under concepts that are not semantically basic, although the expressions are syntactically basic. The meaning of 'belief' would, according to a functional interpretation of mental terms, be given by a definition obtained from the relevant Ramsey sentence. Any definition of knowledge, which contains a meaning revealing definition of 'belief' in its definiens, instead of 'belief' itself, would be finer grained than the original definition in terms of belief, truth, and justification; more precisely, it would be finer grained with respect to the meaning of 'belief' (or 'is a belief', or 'being a belief'). So, what one might call the problem of granularity is to be solved by allowing for differences in how the definitions reveal the meanings of the terms defined. For the present purpose, we should assume that in ideal cases, we are able to give a full-blown definition, which does not contain predicates or terms that are further analyzable. This can be captured as follows: *An appropriate characterization of the meaning of a term E is maximally explicit iff it does not contain a constituent that is further analyzable.* However, in practice, we do not always have to go all the way down (if there is such a way) to a full-blown definition, which does not leave open one single conceptual issue. In the present context, it suffices to show that for some description in an *explanans* of a reductive explanation, there is a definition that reveals *one* constitutive property structure it gives access to, such that this constitutive property structure can be judged to be more fundamental than the PS given in the *explanandum*. The role of property structures in a characterization of reduction could thus be fulfilled even if an expression gives access to more than one property structure.

To sum up: a PS presents us with entities (if any) as exemplifying (or being related to objects exemplifying) specific properties. Assume that 'water' cannot be further analyzed. Then, it is associated with a property structure that presents us with water as being water. 'H_2O', however, is associated with a property structure that presents us with water as being constituted by exactly three atoms, two of which instantiate the property of being hydrogen, whereas one instantiates the property of being oxygen. The basis for obtaining property structures is, ideally, a definition that fully reveals the meaning of the relevant expression. In the ideal case, we would rely on analyses or characterizations of meanings that are maximally explicit. The notion of analyzability should here be understood in a wide sense, such that any sort of illuminating definition is captured. A characterization can either be a definition of a predicate or a characterization of the meaning of a term or a sentence, which signifies a state of affairs.

Building on this notion, we can give a characterization of a property structure an expression gives access to. *A property structure an expression E gives access to consists of exactly those properties the syntactically simple predicates and terms of a maximally explicit characterization of the meaning of E signify or designate, and of functions working on these properties that fix the property structure's structure in a way determined by the structure of the maximally explicit characterization of E.*

Note that according to this interpretation, we should allow for some expressions to be the appropriate characterizations of their own meaning. This is the case iff these expressions do not contain constituents that are further analyzable. Now, one might object that there are no maximally explicit definitions. Meaning just does not behave that way. If this were correct, we could easily weaken the notion of a property structure an expression gives access to as follows: Which property structure an expression gives access to might be *contextualized* to *different meaning revealing definitions*. Thus, expressions do not give access to property structures *simpliciter*, but rather with respect to meaning revealing characterizations. For the sake of simplicity, I will stick to the assumption that for every expression, there is one maximally explicit meaning-characterization. But how do we arrive at the relevant properties that constitute a PS, based on a given definiens?

5.3 Property Structure Terms

Here is a simple procedure for obtaining expressions that designate property structures from predicates or general terms. This procedure constitutes the first step to obtain property-structure terms, i.e. terms that are transparent with respect to the property-structure a corresponding expression gives access to. To begin with, consider unary predicates that are syntactically simple in the sense that they do not contain other predicates as constituents. For example, from '_is water' we obtain the term 'the property of being water' that designates the property the predicate signifies. Similarly for kinds of events (which are here treated as properties): from '_ is social cognition', we obtain 'the property of being/the event type of social cognition'. For n-ary properties with $n > 1$ (that is: relations), we have to follow a slightly different procedure. For example, what the two-place predicate '_recognizes_' signifies can be designated by 'the relation of recognition'. Similarly, for three-place predicates: the relation signified by '_ lies in between _ and _' can be designated by 'the relation of lying in between _ and _'. Sometimes, it is worth mentioning the number of relata; consider the two predicates '_ lies in the intersection of _ and _' and '_lies in the intersection of _ and _ and _'. We would get 'the relation of lying in the intersection of two entities' and 'the relation of lying in the intersection of three entities'. (Note that these expressions are ambiguous. Take the first as an example: According to one sense, it designates the property signified by 'there are two entities, _ lies in the intersection of'; this is a *unary property* rather than a relation.) Now, entities do not possess or exemplify relations; rather, they *stand in* relations to other objects.

Using these and similar operations, we are, at least in principle, able to transform any expression that employs the predication-mode to attribute properties into expressions that explicitly attribute properties only. In order to do so appropriately, these operations should be applied to simple constituents of expressions; it would miss the point to treat the predicate '_has instances which have exactly three constituents, two of which are hydrogen and one of which is oxygen' as a simple predicate, expressing a unary property, although it does. Rather, we should apply the operations to constituents that *lack* (semantically relevant) syntactical parts. Thus, they should be applied to simple syntactic constituents – constituents which themselves do not contain predicates or terms designating properties.

5.3.1 Building Constituents of Property Structure Terms

Since natural language is quite flexible, we have to idealize. In order to avoid complexity, I will ignore quantified phrases, definite descriptions and expressions which contain n-ary relations with $n > 2$. Here are the relevant operations on constituents of an expression *E* which contains expressions from a small fragment of English, namely, simple predicates of an arity $n < 3$, singular terms, and connectives like 'and', 'not' and the like:

1. For general terms *F* or *R* and for simple predicates '_is *F*' or '_*R*_' which do not take arguments in an expression *E* and occur in *E*, introduce 'being an *F*' or 'the *R*-relation'.
2. For any simple one-place predicate which takes an argument in *E*, '*a* is *F*', occurring in *E* introduce '*a* exemplifies the property of being *F*'.
3. For any simple two-place predicate that takes one argument in *E* as follows '*a* *R*_', introduce '*a* stands in relation *R* to _'.
4. For any simple two-place predicate that takes two arguments in *E*, introduce '*a* stands in relation *R* to *b*'.
5. For any simple two place predicate which takes one argument as follows: '_*Rb*' introduce '_stands in relation *R* to *b*'.

This procedure will give us the collection of properties the property structure *E* gives access to consists of: it consists of properties referred to by constituents of the resulting expression. The syntactic structure of *E* will have changed slightly; however, the positions of connectives like 'and', and quantifiers and so forth will not have been altered. Let me comment upon the contribution of such expressions to the property structure a complex expression containing some of these elements gives access to. This will be an intuitive outline, rather than an appropriate definition. In the Appendix, a more precise interpretation of the contribution of 'and' and similar expressions will be offered. For the present purpose, however, an intuitive understanding is sufficient.

5.3.2 The Role of Connectives and Quantifiers

The *syntactic* operation of generating a term that is disjunctive but nevertheless takes the form of a singular term ('the property which is such that it is either realized by *F* or is realized by *G* or is realized by ...') is beyond suspicion. However, following syntactic rules is not to follow ontological ones. But sometimes, complex constructions do refer to or signify something: Intuitively, '*Fx* and *Gx*' may signify the *property of being F and G*. For example, 'the property of having exactly one hydrogen atom and two oxygen atoms' *refers*, although it is a complex term. But what does 'and' contribute to the property structure of expressions of the form 'The property of being *F* and *G*' (or more complex expressions)? Clearly, 'being red and being green' differs from 'being red or being green'. Following a tradition in the philosophy of language, I suggest treating the contribution of 'and', 'or' and similar expressions, like quantifiers, in this context as expressing functions that map properties or states of affairs onto properties, or states of affairs. For example, in 'being red and being green', 'and' expresses a function that maps the property of being red and the property of being green onto the property of being red and green (if there is such a property). Similarly, for quantifiers: The loving relation is not to be confused with the property of there being someone one loves. The former is signified by '_loves_', the latter by 'there is someone _ loves'. Here, the existential quantifier is treated as expressing a function that maps the binary property (the loving relation) onto the unary property of there being someone one loves. Similarly, applying 'there is an *x* such that' to '*z* loves *x* more than *y*', we get a new predicate, namely: 'there is an *x* such that *z* loves *x* more than *y*'. Here, the quantifier maps a three-place relation onto a binary one. I suggest following this idea of treating the relevant expressions as determining such functions, with two qualifications to accommodate doubts which are pretty frequent in the less Platonistic areas of the reduction debate: The functions will be regarded as *partial* functions, and we do not take natural language expressions like 'and', 'there is at least one' and so forth to *express* such functions, but merely to determine these functions. Let me explain.

Properties and states of affairs and tuples of these form the domain of these functions. If the result of the application of a quantifier is a sentence, then we should regard it as signifying *the state of affairs we can signify (or a fact we can allegedly state, if it holds) using that sentence*. If the result of the application to an n-place predicate signifying an n-ary property (with $n > 2$) or relation is an $n - 1$ place predicate, it yields the $n - 1$-ary property or relation that is signified by the resulting predicate (if this predicate signifies any property at all). If 'and' is applied to sentences '*p*' and '*q*' then it takes the pair of states of affairs *that p* and *that q* as an argument and yields the state of affairs *that p and q*. If it is applied to a predicate '_is *F*' and a sentence '*q*', it takes the pair *<the property of being an F, that q>* as an argument and yields the property signified by the open sentence so generated (if this open sentence signifies a property at all). So it does when applied to two predicates: It takes the pair of properties signified by these predicates as arguments and yields the property signified by the complex predicate so generated (if this predicate signifies a property at all). So does ‘not’ with states or properties, and other connectives that are mimicked by sentential connectives in predicate logic.[7]

Thus, these functions sometimes yield a new entity, and sometimes they do not. This depends upon which properties actually exist, and which facts actually obtain. Thus, we interpret them as partial functions and specify that if they assign a value to an argument (we do not know when this is the case) how they do this. This captures the idea that some disjunctive property-expressions may signify or refer to properties, whereas others do not (see Sect. 6.5.2). But how do these functions relate to the natural language expressions ‘and’, ‘or’ and natural language quantifiers? If we were to give a formal treatment of these expressions, we could assign these functions as these expressions’ semantic values. However, we can easily be a little more cautious here without making the idea useless.

To illustrate the strategy, let us focus on ‘and’; similar expressions can be treated in a similar fashion. Let the natural language meaning of ‘and’ in instances of an expression of the form ‘being *F* and *G*’ be *[and]**. Let the function associated with ‘and’ described above be f^{and}. According to the strong interpretation, which is the basis for formal language treatments of such natural language issues, $[\text{and}]^* = f^{\text{and}}$, that is: ‘and’ expresses a partial function which maps tuples of properties or states of affairs onto properties or states of affairs, or is undefined. This is the basis for a formal language treatment in the sense that here, some formal language item *B* corresponding to natural language item *B** is assigned a semantic value which is assumed to *be* the semantic values of *B**. According to the weak reading, [and]* merely *determines* such a function as follows:

> *Necessarily, there is a function* f^{and} *such that*, for any expression of the form ‘being F and G’, $f^{and}{}_{<F,\,G>}$ = *the property of being F and G, or* $f^{and}{}_{(<F,\,G>)}$ *is undefined.*

A property structure an expression *E* gives access to may contain some of the functions just described. Note that in addition to expressions determining functions and property designators, property structure terms may involve individual constants. For example, ‘_exemplifies the property of being loved by Peter’ contains ‘Peter’. They may also involve singular term forming operators. I shall ignore these expressions here, because they would make things unnecessarily complex – the account proposed here is limited to cases of property- and states of affairs-reduction. An interpretation of how individuals relate to properties they uniquely instantiate in terms of satisfaction allows for an expansion of the account (see Sect. 5.4.3).

We are now in a position to move from a given definiens, in the appropriate format containing expressions that explicitly designate properties, to terms that designate these property structures.

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[7]If we were to introduce an exemplification-relation, then we could model this as follows: The exemplification relation behaves in a similar way: it takes properties and individuals or bound variables as arguments and maps them onto new properties or onto states of affairs (in case the number of individuals or bound variables is identical to the arity of the property).

5.3.3 An Operator for Designating Property Structures

Applying the following operator: 'The property structure of '_'' to expressions that are gained by the procedure just outlined from a maximally explicit characterization of the meaning of an expression *E*, we arrive at an expression, which transparently gives access to the property structure *E* give access to. Application of this operator forms the second step in our procedure to obtain property structure terms. So, this is how the operator functions:

It is a meta-linguistic operator. Its content can intuitively be captured by 'The way the (alleged)[8] designatum/significatum of '_' *is* according to '_'' (in both argument-positions, we have to substitute the same expression). PSs can thus be characterized as ways things are according to an expression or a description or a conceptual content. The operator builds upon the idea that to be a certain way according to a description is to instantiate certain properties according to a description, or to stand in a specific relation to other objects that exemplify specific properties according to the description.

This operator thus bears striking similarities to so called *story operators*,[9] although these operators are normally cashed out in terms of truths according to a story; they are sentential operators. In contrast, nothing is true according to the descriptive content of a singular term, or according to a rigid designator, or a predicate, just because these descriptive contents are not descriptive contents of sentences. However, we can introduce a similar idea in the present case. The idea of *being a certain way according to a description* might be further explicated as follows, given that an object is a certain way only according to a sentence or a proposition, rather than according to a predicate or a term: *an object x is F according to a description D iff according to the proposition that there is a y, which is adequately described by D, y is F, & y = x*. Thus, we now have a *sentence* ('there is an object which is adequately described by *D*') that expresses a proposition according to which an object is a certain way. If this object exists, then there is an object that *is* a certain way according to a description. Thus, the operator could be cashed out in terms of a sentential operator. What an object is according to a description can be known on a priori grounds, or on reflection on meaning alone; the content of the description gives the way an object is according to that description, and to be in a position to know that is to grasp what the description *means*.

Accordingly, water is, according to the description 'H_2O', an entity that stands in the instantiation relation to entities that stand in the part whole relation to three atoms, two of which exemplify the property of being hydrogen and one of which exemplifies the property of being oxygen. (Thus, sometimes an entity is presented by a description that is given in terms of *standing in a relation to*

[8]We need to be cautious; there might be cases where no object is designated at all.

[9]These play a role in models of make-believe (Walton 1990) and, without reference to the psychological aspect of make-believe, in Künne (1983, 1990).

objects (here: instantiation), which, in turn, stand *in a relation to objects* (here: part-whole relation), which, in turn, *are a specific way* (here: being hydrogen and being oxygen)). Thus, we have characterized the idea of a property structure term ('PST'). *It is the result of applying, first, the procedure described above to a maximally explicit meaning characterization of a term E, and then applying the operator 'The property structure of '_'' to the result of the previous step.* We thus obtain an expression that designates the property structure of the expression we started with in an interesting, namely, a *transparent* way. This is a *Property Structure Term* (henceforth: PST). We have, thus far, primarily commented upon expressions designating PSs. Let us now briefly comment upon the metaphysics of PSs.

5.4 The Metaphysics and the Functioning of Property Structures

I suggest treating PSs as *tuples* of properties, functions, and tuples thereof. This enables us to intuitively model the semantic impact of the syntactic structure of PSTs in a convenient way.

The property structure 'the property of being red and green' gives access to is the tuple <and, <being red, being green>>,[10] where 'and' is treated as designating the partial function it determines in its ordinary use as described above. Similarly, 'Peter loves Mary' can be interpreted as <the loving relation, <Peter, Mary>>. Similarly, the property structure '_is a tiger or is red and green' gives access to is this structure: <or, <<being a tiger>, <and, <<being red>, <being green>>>>. Thereby, we arrive at structured entities that clearly deserve the name of a property structure: Their constituents are properties or tuples of properties, facts (intuitively: an n-ary property whose positions are occupied by n objects), and functions. A more detailed account of how these property structures can be conceived of is proposed in the appendix. This requires a semi-formal treatment of PSTs; for example, to handle the scope of quantifiers that bind variables, we have to deviate from the grammatical surface structure of ordinary language PSTs. However, given this intuitive outline, we are in a position to account for several relations that are of crucial importance to explicate the notion of a constitutive structure. To repeat: *The property structure an expression E gives access to is a tuple of properties and, sometimes, functions on properties and states; it is a way an object is according to E.* As a limiting case, we might allow for property structures which just are one property: If 'water' lacks

[10]This already points to one problem: Tuples are finer individuated than one would normally assume the semantic value of expressions like 'being red and being green' to be. There is a difference between <and, <being red, being green>> and <and, <being green, being red>>. But is there a semantic difference between 'being red and being green' and 'being green and being red'?

descriptive content, then the PS it gives access to is just *being water*, rather than <being water>. Building on this characterization, we can introduce the relevant notion of a constitutive structure and related notions.

5.4.1 Basic and Complex Constituents

It will be convenient to introduce the notion of a basic constituent of a property structure:

(Def. Basic constituents): *A basic constituent y of a property structure PS is a property referred to by some simple property designator (obtained from a simple predicate) or a kind term in a PST.*

Thus, all and only those constituents of a property structure that are referred to by a relevantly semantically basic constituent of a PST are basic. Now, we can also define the notion of a *complex constituent*. Complex constituents are, intuitively, tuples that may function as property structures themselves and that are not basic; they are a way an object is according to a semantically complex description of that object. For example, in the description 'being red and being green or being a lion', 'being red and green' designates a complex constituent of the property structure.

(Def. Complex Constituent): *A complex constituent CPS of a property structure PS is a non-basic constituent of PS.*

5.4.2 Determination of Objects

Property structures and their complex and basic constituents *determine* properties or states of affairs (recall that our property-structure talk does not allow for determination of, say, individuals) in a specific way:

(Def. Determination) *An entity x is determined by a property structure PS of an expression E iff x is the only object which is the way the referent or significatum of E is according to E.*

What is determined by a PS of an expression *E* will be identical to what *E* designates or signifies (if anything) iff the property structure an expression gives access to is similar to its meaning in the sense that it *determines its designatum* (as the Fregean would have it for Fregean sense). Note that sometimes, no object is that way – one may deny that there is the property of being a square triangle, although there might be a property structure that appears to determine a property. However, the proposition that *according to the proposition* that there is a property adequately described by the descriptive content of 'being a square triangle', there is a property of being a square triangle whose instances are squares and triangles does not entail that there is such a property. Thus, the existence of a property structure that seems to determine a unique entity does not ensure that the entity exists.

5.4.3 Satisfying Property Structures

Now, we are in a position to define a notion of satisfaction. Consider predicates and the PSs they give access to first. Take, for example, the predicate '_is the author of *The Life and Opinions of Tristram Shandy, Gentleman*'. The property so determined is the property of being the author of *The Life and Opinions of Tristram Shandy, Gentleman*. Now, this property *applies to* or is *satisfied by* the *x* which instantiates the property determined by this structure, namely the property of being the author of *The Life and Opinions of Tristram Shandy, Gentleman*. Thus, it is Laurence Sterne. This is so because the property of being the author of *The Life and Opinions of Tristram Shandy, Gentleman* is instantiated by Laurence Sterne only. Similarly, the property structure *being a horse* is satisfied by the set of horses, because the property determined by this structure is instantiated by the elements of this set. The property structure *the property of being the author of* is satisfied by pairs of objects which instantiate this property. Property structures which determine an n-ary relation (with $n > 1$) are satisfied by n-tuples of objects, namely, those tuples whose elements instantiate that relation. In the case of PSs which determine a unary property, the set of entities which instantiate the so determined property satisfies that property structure (or, if it is just one object, this object satisfies that structure). For property structures that determine a state of affairs, the object satisfying the property structure is the state determined by this property structure. We can characterize this in terms of an extension, where 'extension' is understood as follows: If a property structure PS determines a unary property *P*, its extension is the set of individuals that are P (or, if the property is satisfied by a one-set, we may allow as a convention to say that the extension = the only element of that set). If PS determines an n-ary property *P* (with $n > 1$), the extension is a set of n-tuples which instantiate P. If a property structure PS determines a state of affairs *F* then the extension just is this state of affairs.

(Def. Satisfaction) *An entity x satisfies a property structure PS iff x belongs to (or is) the extension of PS.*

On this basis, we can define the notion of a constitutive structure.[11]

[11]Based on these notions, we could describe the functioning of definite description forming operators, such as the jota-operator, when applied to a predicate that signifies a unary property with only one instance, as a function which takes what is determined by a PS to what satisfies the PS.

5.4.4 Constitutive Structures

The notion of a constitutive structure will enable us to account for what mimics the explanatory directionality at the conceptual level, or the level of property structures. Intuitively, the idea is that we can account for the directionality of reductive explanation as follows: the truth of a reductive explanation that *x* is *F because x* is *G depends* on facts about differences in how the property signified by '*F*' and '*G*' *is according to the respective descriptive contents* of '*F*' and '*G*'. This is parallel to the idea that a true causal explanation that *x* is *F because y* is *G* depends on, say, the laws governing, and metaphysical features of *x*'s being *F* and *y*'s being *G*; or, alternatively, that it depends on regularities among *F*s and *G*s. We thereby give information on what the causal explanation depends on. In the present case, I propose that reductive explanations depend on differences in property structures under which the reduced or reducing object is presented. And just like the accounts of mechanistic dependence discussed in Chap. 4 do not aim at a "reductive" account of mechanistic dependence in counterfactual or probabilistic terms, the present proposal does not aim at coming up with a "reductive" account of reduction. The difference in conceptual representation just is the difference in virtue of which the directionality of reductive explanation goes from water to H_2O, rather than the other way around.

We already defined a notion of reduction. This definition is, I submit, perfectly fine. However, we now enrich this definition by giving additional information on what sort of features reductive explanatory dependencies track. They do *not* track relational features of, or differences between reduced and reducing object. Rather, they track differences in modes of presentation, or differences in property structures, differences in the transparency with respect to the object's nature. We start with an indirect characterization. Reductive explanations track differences in property structures as follows: A property structure PS_1 is a constitutive structure of *x* with respect to a property structure PS_2 iff PS_1 and PS_2 determine the same entity, and whatever satisfies PS_2 does so because it satisfies PS_1. The property structure 'H_2O' gives access to is a constitutive structure of water with respect to the property structure 'water' gives access to because whatever is water, it is the way the concept of water has it (satisfies the property structure of 'water') because it is the way the concept of H_2O has it (satisfies the property structure of 'H2O'). We thus mirror (*Explication I*). Assume that 'water' is a directly referential term. Whatever satisfies the property of being water, it does so because it has the properties that correspond to the property structure 'H_2O' gives access to. Based on this indirect characterization of a constitutive structure, we can account for the candidate features of different property structures that back up the dependence relation, such as mereological relations: If reduction relations track mereological relations, then any property structure which presents us with an object in terms of its parts is at a "lower level" than any property structure which presents us with the same object as a whole, or at a "higher level" of composition. Recall the minimal condition on property-talk proposed above: properties are non-representational entities, entities in virtue of which causal objects behave the way they do. Being presented as having properties, that is: being presented by a property structure, can thus, intuitively, give access to the "causal architecture" of an entity. If a property structure gives access to the properties in virtue of which the object does what it does, or is what it is, it is a constitutive property structure. If an expression, such as 'H_2O' gives access to the causal organization of an object, then it is at a lower level than any directly referential expression which presents us with the same entity in a basic way, or than any expression that presents us with an object under a phenomenal property structure. If so, the property structure 'H_2O' gives access to is a constitutive structure with respect to the property structure 'water' gives access to. We can thus define a relational notion of a constitutive property structure.

(Def. Constitutive PS) *x is a constitutive property structure of an entity y with respect to a property structure x* iff*
x and x are PS-s that both determine y, and are such that for every z, if z satisfies x* it satisfies x* because it satisfies x.*[12]

Again, the explanation is not the explanation of conceptual constitution. In this sense, the constitutive structure is *explanatorily prior* to the property structure with respect to which it is a constitutive structure. A non-constitutive property structure is a property structure that is not a constitutive structure with respect to any other property structure. A constitutive property structure is a property structure that is a constitutive structure with respect to some other property structure. How does this relate to reduction? 'Water reduces to H_2O' is true because (i) water = H_2O and, given that directly referential expressions never give access to an entity's nature, (ii) the PS of 'water' is not a constitutive structure of water and the PS of 'H_2O' is a constitutive structure of water. This is the paradigm case of reduction of folk-theories to scientific theories. However, this structure is not preserved in inter-theory reductions. Sometimes, both, the *explanans* and *explanandum* in a reductive explanation as well as '*a*' and '*b*' in '*a* reduces to *b*' present the target under constitutive structures. A quantum mechanical description of water will, if physicalism is correct, be at a lower level than the description of water in terms of H_2O. Thus, we need to distinguish levels of constitutive structures. Fundamental constitutive structures are property structures which are constitutive, and which are such that there is no property structure which is constitutive with respect to it. But why stick to explanatory notions in the explication of a constitutive structure? Why not try to spell it out in terms of promising mereological relations? For one, a notion of reduction should be independent of such strong metaphysical commitments.

[12]Note that in case the property structure determines an individual (given an appropriate operator) or a fact, the object satisfying the structure is the object determined by the structure. I assume that the definition could easily be given in terms of determination, rather than in terms of satisfaction. One may want to discuss what is prior: explanatory relations among instances or explanatory relations among properties. Here, I chose to describe the notion in terms of a relation among instances, without being committed to any such priority claim.

As pointed out before, reduction is neutral with respect to what actually is the fundamental level. But this is not the only problem mereological interpretations of reduction face.

5.5 Constitutive Property Structures and Mereology

Let me first illustrate the hope to define the notion of a constitutive structure in a way that yields a "reductive" account of reduction, that is: explicate it independently of explanatory notions, assuming that reduction tracks mereological relations. It will turn out that even the naturalist should not describe reduction in mereological terminology, unlike, for example, Schaffner (1993) and Horst (2007) suggest.

The lower the level of a constitutive structure, the deeper the access we get to an object's nature. The set of hydrogen atoms satisfies the property structure *being hydrogen* (or an appropriate complex structure which is based on the meaning of 'hydrogen'). Similarly, the set of oxygen atoms satisfies the property structure *being oxygen*. In this sense, the property structure given by H_2O gives us water in terms of its (instances') parts. Put differently: The way water is according to 'H_2O' is a way its (instances') parts are. In this case, being a constitutive structure relates to mereological relations. This seems to support the assumption that reduction is tied to mereological relations, an assumption seemingly shared by Schaffner (1993) (see Sect. 7.4), Kim (2008) and others (Chalmers 1996, 43; Fodor 1974, 107). Consider the following case: Take, H_2O and a quantum mechanical description of water, here abbreviated '$water_{quantum}$'. Both give access to a constitutive structure of water, but nevertheless, we should assume that H_2O reduces to $water_{quantum}$, or that something is H_2O because it is $water_{quantum}$, and that, thus, we have to account for a relevant difference between the distinct constitutive property structures these terms give access to. What does this difference consist in? Again, one might feel tempted to tie the difference to mereology.

For cases where reduction tracks mereological relations, we can give a criterion for the directionality of reduction that is independent of explanatory notions. One constituent of water has the property of being an oxygen atom *because* it has certain physical features that are revealed in a quantum-mechanical description. Similarly, an appropriate answer to what an oxygen atom basically *is*, we may expect an answer in quantum-mechanical terms. And, similarly, an oxygen atom connects to two hydrogen atoms under specific conditions because of its physical features. Thus, the explanatory dependence can now be accounted for in terms of objects determined by (basic or complex) constituents of the property structure that depicts the object at a higher level of mereological composition. Accordingly, we can introduce a relativized criterion for level-comparison, that is based on how property structure mirror mereological constitution. Let me illustrate this point: The property structure a description of water that is a mix of deictic-expressions (that give us the property of having two constituents that are hydrogen-atoms) and a quantum-mechanical description of the oxygen atom gives access to is at a lower level than the PS 'H_2O' gives access to with respect to the property of being an oxygen-atom. A quantum mechanical description will contain properties of "parts" of O-molecules, that is: of objects that satisfy a constituent of the property structure 'H_2O' gives access to. These properties and parts are not reflected in the property structure 'H_2O' gives access to.[13] We thus get: *A constitutive structure CS is at a lower mereological level than a property structure PS with respect to some constituent P of PS iff CS and PS determine the same entity, and CS contains some complex structure C that determines the same entity P determines, and C, unlike P, consists of properties that are satisfied by parts of objects that satisfy P.* But does reduction track mereological dependence?

If pain reduces to C-fiber stimulation, then pain events are not given in terms of "parts" of pain. Ignore the issue of "parts" of events (an issue mechanistic accounts may shed light on); let pains be possible activation of *one* C-fiber; then, there is no proper part of the object of C-fiber activation (namely, the C-fiber) which plays a role in the reduction. Similarly, one might want to say that *being an iron constituent* reduces to *being a Fe-atom*. If so, we have reduction without mereological decomposition – Fe-atoms are not parts of the iron-constituents we aimed at; they just *are* these iron-constituents. Thus, part-whole relations are not always crucial for our understanding of reductions, even if naturalism is true.

In addition, let me repeat the more general reason to describe reductive dependence independent of mereological dependence, already discussed in Chap. 2. Assume that an idealist and a naturalist discuss issues of reduction. They agree upon everything except for the directionality of reduction. Assume that the idealist is not conceptually incoherent when claiming that, say, C-fiber firing reduces to a mental entity, and *that this mental entity does not have parts*. If so, we should not define our notion of reduction in mereological terms. Mereology does not come for free for the reductionist. It is a substantial point to claim that at least some things reduce to their parts. Thus, we should not explicate reduction in terms of mereological relations. Using the apparatus of property structures, we can now come up with a more thorough explication of reduction.

5.6 An Explication of Reduction

Possession of the notion of levels of constitutive structures enables us to give truth conditions for reduction statements of the form '*a* reduces to *b*', where the terms substituted for '*a*' and '*b*' do not designate theories.

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[13]This also matches inter-level integration, as, for example, suggested and discussed in (Darden and Maull 1977; Schaffner 2006; Craver 2007). We may replace some descriptions by others, but do not fully reduce one level. Neuroscience makes use of behavioral notions in order to capture the behavior the neuronal patterns influence or are influenced by.

5.6.1 The Core Notion

The definition is given in a schematic way: For ‘*a*’ and ‘*b*’ substitute kind terms (or event-terms, or property designators . . .) or terms referring to states of affairs – we thus arrive an a general explication:

(Explication – Schematic) *A sentence of the form ‘a reduces to b’ expresses a truth iff*

(i) *$a = b$, and*
(ii) *‘a’ gives access to property structure PS^A, and ‘b’ gives access to PS^B*
(iii) *PS^B is a constitutive structure of b with respect to PS^A.*

There are two ways for PS^B to be at a lower level than PS^A: either the latter is not a constitutive structure, or it is a constitutive structure which is at a higher level. The second and the third requirement model the relevant meaning aspect. This definition makes transparent that reduction is not asymmetric. This does not mean that it is symmetric – recall the discussion in Chap. 3. We can also give a non-schematic definition, building on the idea that sensitivity to semantic facts other than reference or designation is captured by formulations such as ‘_is presented under/as being _’:

(Explication – non-Schematic) *x, when presented under PS1, reduces to x, when presented under PS2 iff*
PS2 is a constitutive structure of x with respect to PS1.

This is supposed to capture a generalized version of the idea underlying (*Explication I*): that *F-ness* reduces to *G-ness* if and only if (i) for every *x*, if *x* is *F* then (*x* is *F because x* is *G*), and (ii) *F-ness* = *G-ness*. It captures this idea, but it is not limited to this notion of reduction. To illustrate this point, consider, for example, a case of what one might describe as fact-reduction: The fact that this amount of water freezes reduces to the fact that this sum of H_2O molecules forms lattice structures. Here, what is presented under the property structure of a sentence is a *fact* (a worldly entity, such as a Russellian proposition).[14] We arrive at the following derivative characterization, which is a special case of reduction as covered in the definition just proposed:

(Explication III – Facts) The fact that *p* reduces to the fact that *q iff*

(i) *p* because *q*, and
(ii) the fact that *p* = the fact that *q*.

[14]This idea is inspired by the suggestion of an anonymous referee; according to this suggestion, we could describe theory reduction in terms of fact reduction – the fact that the reduced theory is true reduces to the fact that the reducing theory is true. This idea is picked up again in Chap. 8, footnote 4.

Further derivative explications will be proposed below. It is now time to turn to a first evaluation of the proposed explication.

An expression presents an object either under a concept or does not present it under a concept (if it is a directly referential expression). An object, if presented under a concept, is presented as having certain properties. Different concepts present objects as having different properties. Sometimes, an object instantiates some properties because it instantiates other properties. If materialism is correct then water has the property of being tasteless partly because it has the property of being constituted by H_2O-molecules. This connection is made transparent in reduction-statements that connect terms that express a conceptual content. For reduction statements in which the term on the reducing side lacks conceptual content, things are different: Here, the concept expressed by the term on the reducing side is transparent to at least some properties of the object in virtue of which it behaves the way it does, or is what it is. Dependencies between an object's satisfying different property-structures captures this very idea. But how to argue for the idea that this model is promising? First, we can draw an intermediate conclusion: To the extent that this definition is *sound* and *captures the relevant intuitions concerning the notion of reduction*, it shows that skepticism about notions of ontological reduction is misguided. We can give an appropriate explication. Hence, we should not be afraid of this kind of reduction.

Recall the job-description given above:

(Job-Description): We need a definition that

(i) accounts for the directionality, such that it gives a definition according to which if *a* reduces to *b*, then necessarily, *b* does not reduce to *a*, and
(ii) accounts for the idea of unity (ideally in the sense of strong unity) without elimination.

In addition, it will be desirable that our definition enables us to

(iii) illuminate the paradigmatic cases;
(iv) explain the intuitive characterizations of the notion of reduction;
(v) account for related topics, such as reduction and physicalism, reduction and scientific unification, and similar issues; i.e. the explication should yield a fruitful notion by fulfilling the explanatory task associated with 'reduction'.

We have shown that the explication meets criteria (i) and (ii). Let us briefly apply the explication to paradigmatic cases and informal characterizations of reduction in the literature, showing that it also meets criteria (iii) and (iv). The model perfectly matches the guiding intuitions. In the next chapters, I will argue that it is, in addition, fruitful, and, hence, meets criterion (v): It can be applied to the reduction debates in the philosophy of mind and the philosophy of science as well as to a number of related, unsolved problems tied to reduction, such as the epistemology of reductions, reductive explanations and interventions, and reduction and unification.

The explication captures the paradigmatic cases. We have already commented upon the water-H_2O case. Let me now comment upon the two cases Nagel mentions: mean kinetic energy and temperature, and headaches and what gives rise to them, to illustrate the idea. The meaning of ‘mean kinetic energy’ gives access to a property structure which is at a lower level than the property structure the meaning of ‘temperature’ gives access to – it gives the resources to explain temperature in terms of events some object’s entities engage in, which give rise to, and, in this sense, *reductively explain* the occurrence of temperature. Having a specific temperature is, by assumption, having a specific mean kinetic energy. Moreover, parts of objects that have a certain temperature must behave in a specific way for the occurrence of a specific temperature. Finally, this behavior of parts is captured by the property structure under which ‘mean kinetic energy’ presents us with temperature. Thus, the case is covered by the idea of a constitutive structure. Note again that this is not very surprising: The notion of a constitutive structure is an explanatory notion. It just reveals the explanatorily relevant aspects of the concept under which ‘mean kinetic energy’ presents us with temperature.

Similarly for headaches: The conditions for the occurrence of headaches are here interpreted as being fixed by a constitutive structure the basic properties of which belong to a lower level. Some constitutive structure could fix “the detailed physical, chemical, and physiological conditions for the occurrence of headaches” (or one of these), such that once the relevant constitutive structure is “ascertained [. . .] an explanation will have been found for the occurrence of headaches.” (Nagel 1961, 366) Thereby, we give an interpretation of what Nagel seemed to have had in mind introducing these examples to illuminate the notion of reduction.

The same holds for (the internal process of) social cognition and the mirror neuron mechanism, pain and C-fiber stimulation, and water and H_2O. Each of these examples comprises a re-description in terms of constitutive structures, either in terms of parts or merely in terms of properties that are explanatorily relevant for the occurrence of properties under which the object is presented by the higher-level description. Thus, one condition on an appropriate explication of the notion of reduction is met: It should cover the relevant examples. It does not only cover these examples, it also *explains* why they are cases of reductions (given that the relevant identity links actually hold true): They form correct reductive statements because the target of the *explanandum* is given by a property structure in the *explanandum* which is *not constitutive*, and in the *explanans* it is given in terms of a constitutive property structure. If it were constitutive in the *explanandum*, it had to be constitutive *at a lower level* in the *explanans*. Thus, the explication of the notion of reduction not only covers, but also illuminates the paradigmatic cases of alleged reductions.

The intuitive characterizations we find in the literature are also covered. The explication of reduction can be used to illuminate the somewhat metaphorical or at least underdetermined sketches of what reduction consists in, sketches that build upon an intuitive understanding of being *over and above*, of *levels*, of *assimilation of distinctive traits,* and of *macroscopic phenomena*. Let me list these statements again:

(Kim) If Xs are reduced, or reducible, to Ys, there are no Xs over and above Ys. (cf. Kim 2006, 275f., (given in a similar fashion by Smart 1959))

(Wimsatt) Inter-level reductions are compositional. They localize, identify, and articulate mechanisms that explain upper level phenomena, relationships and entities. (Wimsatt 2006, 449)

(Chalmers) [W]hen [in the context of a reductive explanation, *RvR*] we give an appropriate account of lower-level processes, an explanation of the higher-level phenomenon falls out. (Chalmers 1996, 42)

(Nagel-1) [In reductions, A] set of distinctive traits of some subject matter is assimilated to what is patently a set of quite dissimilar traits. (Nagel 1961, 339f.)

(Nagel-2) [The reduced] science deals with macroscopic phenomena, while the [reducing] science postulates a microscopic constitution for those macroscopic processes. (Nagel 1961, 340)

(Sarkar) The reduced theory is explained by a reducing theory which is presumed to be more fundamental. (Sarkar 1992, 167)

For the Kim/Smart-intuition, we get a straightforward re-interpretation: Reduction guarantees that the reduced entity does not exist over and above the reducing entity because it requires *identity* of the two. Wimsatt's assumption and Nagel's second characterization are covered and explicated in a similarly straightforward way: The notion of a *constitutive property structure* gives a precise idea of the notion of a "microscopic constitution" (Nagel), and it matches the idea that in reductions, we "identify, localize and articulate" (Wimsatt) the composition of mechanisms or, more broadly, entities when presented as being constituted in a certain way; although reduction does not essentially track mereological dependence, it tracks mereological dependence where mereological dependence matches reductive dependence. The explanatory aspect pertinent in Wimsatt, Chalmers, and Sarkar is built into the model of reduction proposed here. Now, consider Nagel's first remark: That a "set of distinctive traits" is "assimilated to what is patently a set of quite dissimilar traits". This is achieved by identifying an entity presented under one specific property structure with an entity presented under one *dissimilar* property structure. Conceive of distinct sets of traits in terms of distinct property structures. These are clearly dissimilar. Despite the fact that they are dissimilar, like the property structure of 'water' and that of 'H_2O', they might nevertheless determine the same entity. Now, Nagel seems to think of more general relations, not only covering *two* property structures which determine one and the same entity, but rather covering pairs of sets of traits which are the unique sets of traits associated with two theories or sciences. Assume that folk-chemistry gives us chemical kinds under rigid designators, or under phenomenal properties. Chemistry gives us chemical kinds in different ways. Then, once we are able to show how everything folk-chemistry gives access to can be reduced to chemistry, we have really shown what Nagel seems to have had in mind: The set of properties under which chemical entities are presented by property structures the language of folk-chemistry gives access to is thus assimilated to the set of properties under which chemical language gives access to the same entities.

Similarly for psychology and neuroscience: We may try to reduce psychological traits (the properties under which mental kinds are presented in folk-psychology) to neuroscientific traits (the properties under which mental kinds are presented in neuroscience). Once we succeeded, these dissimilar traits are *assimilated*. Thereby, it is shown how these traits connect (in Chap. 9 this topic and its connection to unification and scientific levels will be addressed in more detail).[15]

Thus, the constraints imposed on an appropriate explication of the notion of reduction by the intuitive descriptions are met. If these intuitive sketches of reduction are representative, it has been shown that the concept of reduction as explicated here does not violate the constraints imposed on it by its use in philosophical discourse. Moreover, we can introduce fruitful explications of derivative notions, building on the framework just proposed.

5.6.2 Derivative Notions of Reduction: Partial Reduction, Plural Reduction, and Generic Reduction-Statements

Building on the core notion, we will later be able to define notions of token-reduction, type reduction and theory reduction. Three notions of reduction that might be of particular importance, and which are not so easily obtainable from the above definition, are those of *partial reduction*, where the reduction base is not fully represented in the explanans of a reductive explanation, of *plural reduction*, where in a reduction statement, the explanans refers to a conjunction of constituents of the target of the explanandum (an idea pertinent in the debate on mechanistic explanation (see Chap. 4)), and what one may want to call a 'generic' notion of reduction (or better: 'generic reduction statements'), which is best re-defined in terms of a meta-semantic notion. Intuitively, it is this notion that enables us to express general theses about how particular reduction statements are to be shaped. Partial reduction is parasitic on a notion of plural reduction. So, let us first address this latter conception.

5.6.2.1 Plural Reduction

How to account for cases such as 'the heart pumps blood by the organized contraction of muscle fibers' within a reductive framework? Is there no option for the reductionist to accommodate such cases, without buying into a theory of non-derivative plural identity? There is. Recall the brief discussion of reduction and

[15]The idea of assimilation thus makes it hard to conceive of reductions to come in a case by case manner. We do not reduce particular traits and then conclude that we can reduce the entirety of, say, chemical traits. So, it is important to note again that here, I am not concerned with explaining how reductions are carried out.

mereological dependence (see Sect. 5.5). Assume that mereological dependence is one form of reductive dependence. Then any sum reduces to its (proper) parts. Take, as an example, 'this statue reduces to this particular atom, and to this particular atom, and ...' (and let us grant that statues are nothing but the material they are made of). Does it follow that this statue = this particular atom, and this particular atom, and ... ? Here is a suggestion how to bypass the topic of plural identity in the context of reduction. There is an easy operation on the expression on the right hand side of the identity sign, which generates a singular term; namely, applying 'the mereological sum of_' to this expression. We thus arrive at a truth, and an interesting one: The sentence 'the statue reduces to the mereological sum of this atom, and this atom, and ...' can be treated in the ordinary way. If the reduction statement is true, then this particular statue is this particular statue *because* it is the mereological sum of this atom, and this atom etc., and this particular statue is identical to the mereological sum of these atoms. How can we exploit this idea for other cases, which do not involve mereological dependence?

If plural reduction statements of the form '*a* reduces to *b1, b2* ...' are true, then there is a relation *R*, such that there is a unique *x* which is such that *x* stands in *R* to *b1, b2* ... Sums of objects are the unique entities which stand in the *being the mereological sum of*-relation to their parts. For other cases, such as complex events, the reductionist should assume that there is a similar relation. Otherwise, we do not get the reduction: in a straightforward sense, the whole or composite would be more than its parts. Thus, here is a suggestion for plural reduction:

(Explication IV – Plural -Reduction) *x, when presented under PS1,* ***plural-reduces*** *to* $y_1, \ldots y_n$ *iff*

(i) *there is an object z, a relation R such that z R* $y_1 \ldots y_n$*, and there is a property structure PS2, and*
(ii) *PS2 describes z as standing in R to* $y_1, \ldots y_n$, and
(iii) *x, when presented under PS1, reduces to z, when presented under PS2.*

Thus, cases of plural reduction can be accounted for within this framework without commitment to plural identities. Based on this notion, we can easily explicate a notion of partial reduction.

5.6.2.2 Partial Reduction

A partial reduction just gives an incomplete reduction base, but it does so in the right terminology. The notion of a partial reduction is a technical notion that is supposed to mirror mistakes or blind spots in alleged reductions. For example, even if mirror neurons play an important role in the cognition of others as social beings, this does not mean that they do the relevant job alone, and it seems rather far fetched to claim that the cognition of others as social is nothing but the activation of certain patterns of mirror neurons. Being the activation of the relevant pattern of mirror neurons may thus be an essential part of the process of social cognition, but the property structure this description gives access to does not determine social cognition. The suggestion I wish to make is based on the notion of plural reduction just defined. Intuitively, a partial reduction is a plural reduction where the list of objects that together form the reduced entity is not complete – this is probably standard in mechanistic explanations, so that mechanistic explanations can be conceived of as partial reductions, if monism is true.[16] Interesting partial reductions will be partial reductions with an eye on especially interesting aspects of the reduction base. Social cognition in humans may involve processing of visual information. This is an interesting topic, but it is relatively well understood. Thus, focusing on the mirror neuron mechanism, a particularly relevant part of the reduction base is described. So, here is the explication.

(Explication V – Partial Reduction) *x, when presented under PS1,* ***partially reduces*** *to y1, yn … iff*
there are some objects y2, … ym, (with $\{y1, \ldots yn\} \cap \{y2, \ldots ym\} = \varnothing$*) such that x plural reduces to y1 … yn, y2 … ym.*

Correspondingly, we may label the core notion of reduction defined above 'full reduction'. Let us now turn to constructions in which 'reduction' is frequently used, which express general theses about reduction relations.

5.6.2.3 A Generic Notion of Reduction

Consider the sentence: 'This table is *nothing but* (the sum of) this tabletop, these legs and these screws'. Although the 'nothing but'-locution is symmetrical, it may be used to articulate one's reductionist inclinations; one may wish to continue: '… this table *reduces to* (the sum of) this tabletop, these legs and these screws'. Such sentences may motivate the generic claim that *wholes are nothing but, and, hence, reduce to (sums of) their parts*. In quantified sentences, we can use the reduction predicate. In these contexts, it does not perfectly fit the description proposed above. Although one may wish to claim that *being a whole* (fully) reduces to *being a sum of parts* in the sense of the explication proposed here, one may want to state that wholes (fully) reduce to (sums of) their parts in order to articulate the generic statement that whatever is a whole, it reduces to its parts. The latter claim is not adequately captured by the former. To see this, consider the claim that tables (fully) reduce to (sums of) their parts. This is not to be conflated with the claim that *being*

[16]The use of 'partial reduction' thus deviates from the use employed by Schaffner (2006, 2012), who takes partial reductions to be less than fully fledged Nagelian theory reductions, or, alternatively, something close to local (though possibly full) mechanistic explanations. A number of the reductions covered by the proposal offered here as *full reductions* would, under Schaffner's notion of a partial reduction, probably turn out to be partial reductions. See Sect. 7.6 for a discussion.

a table (fully) reduces to *being a sum of parts*. Another prominent example is the generic claim that mental properties (fully) reduce to physical properties. So, how to give an explication of this phenomenon? (Although this may not be the appropriate way to handle generic statements, I talk as if there were a generic *notion* of reduction, so that the concept expressed by the predicate in these contexts would turn out to be responsible for the phenomenon, rather than the entire sentence.) I suggest explicating generic statements as meta-linguistic claims about conditions on appropriate modes of presentations in true reduction statements. On this view, mental properties reduce to physical properties if and only if for every *x*, if *x* is a mental property, then there is a mode of presentation *m1*, there is a mode of presentation *m2*, such *x*, when presented under *m1* reduces to *x* when presented under *m2*, and *m1* presents us with *x* as mental, and *m2* presents us with *x* as physical. This explication hinges on the assumption that modes of presentations, and, hence, property structures can present us with objects as mental, or as physical, or as wholes, or as sums of parts. This idea will be made explicit in Sect. 9.1. Until then, we will have to rely on an intuitive understanding of property structures that present us with objects as being of a certain kind. Let us, for cases like 'wholes reduce to their parts' and 'mental properties reduce to physical properties', express this idea saying that a property structure presents us with what it determines as a mental object *if and only if* it is a mental property structure.

(Explication VI – Generic -Reduction) *F-s reduce to G-s iff*
for every x that is an F, there is a PS1, a PS2, such that

(i) *x, when, presented under PS1 reduces to x, when presented under PS2, and*
(ii) *PS1 is an F-property structure, and*
(iii) *PS2 is a G-property structure.*

For the claim that *tables* reduce to their parts, we have, ignoring the more complex quantification involved, to make a little detour: if tables reduce to their parts then they do so in virtue of the fact that there is a type of property structures to which the property structure 'table' gives access to belongs. This type, say, being a material whole,[17] is such that its instances, when presented under property structures that present us with them as wholes or artifacts, reduce to themselves when presented under property structures of a different type: namely, under property structures which present us with them as being constituted by parts (and their properties) of such wholes. This aspect is already pertinent in the above explications of plural

[17]Note that it is not clear at all to which type a given property structure belongs; most of them will belong to more than just one such type. Which type is actually at stake (or which, in an appropriate reconstruction of such statements with the goal of a fruitful explication) will probably be determined by context: In a debate about material objects, where participants agree that all material wholes have the same metaphysical status, but do not agree as to what this status *is*, we should not count reference to tables as giving an example of a property structure of the type artifact-property structure. In a debate about the status of artifacts, however, this may be appropriate.

and partial reduction: on the right-hand side of the reduction predicate, no specific property structure is required, under which the plurality of objects is to be presented. The discussion of generic reduction suggests that this is so because mentioning of the objects is sufficient to point to the fact that it is in virtue of being constituted by these objects, and in virtue of these objects' properties, that the reduced item behaves the way it does, or is what it is.

The account presented here thus covers the core uses of 'reduces to'. However, it builds upon a specific interpretation of the relevant relational features of the expressions that pick out the reduced entity in true reduction statements. Other accounts may build on other candidate features. Two such possible proposals, a semantic and a pragmatic one, will briefly be discussed in the next section.

5.7 Rival Explications

As laid out in Chap. 2, the proposed characterization has the status of an explication. An explication derives its merits and deficiencies from various aspects. Partly, its quality hinges on the vocabulary it employs. As suggested in Chap. 2, two explications may yield strikingly similar results despite the fact that they exploit vastly different conceptual resources, as long as they exhibit similar structural features. This section is supposed to contrast the present proposal with two rival interpretations one may come up with in order to account for reduction; they are both compatible with (Explication I), but suggest different interpretations of the source of the directionality. These rival interpretations are structurally similar to the one proposed here, but they do not carve reduction in terms of *property-structures*. The first uses a two-dimensional framework, the second is more pragmatist in spirit. I will leave it at intuitive sketches, so as to make clear how the apparatus presented above would have to be adjusted in order to fit these rival accounts, and to indicate why I think that carving the explication in terms of property structures is advantageous.

5.7.1 Reduction Within a 2-D Framework

David Chalmers' attempt to model core features of Fregean senses within a two-dimensional framework provides the resources to mimic at least some of the features presented above, so that a similar explication in terms of the 2-D framework can be given. On this view, what has here been called a 'conceptual' difference, turns out to be an epistemological difference – a difference in epistemically defined primary intensions of expressions. Let me, first, introduce the core ideas of Chalmers' theory, then apply it to the case of reduction and finally hint to two problems that seem to occur within the framework. The summary to follow draws heavily on my (van Riel 2011).[18] According to two-dimensionalism, an expression can be associated with two semantic values – a primary intension and a secondary intension, which, together, generate a third value: a two-dimensional intension. Chalmers interprets primary intensions as functions from scenarios to extensions at scenarios and secondary intensions as functions from possible worlds to extensions at possible worlds. Chalmers intends to use this framework in order to model a number of relevant aspects of meaning, and to give an idea of how a priority, necessity, and conceptual analysis interconnect. Primary intensions are used to model something like Fregean sense. In order to understand the notion of a primary intension, we have to explain the notion of a *scenario* in the first place, and we have to explain how this notion is used in order to better grasp how meaning, or Fregean sense, relates to cognitive significance. There are two ways to conceive of scenarios: *scenarios as centered worlds* and *scenarios as epistemic possibilities.*

According to the centered world interpretation, scenarios are triples of ordinary possible worlds, individuals, and times. Individuals and times are introduced to handle indexical claims; they fix a certain point of view on or in the world. A primary intension of a sentence *S* obeys the following principle: *S*'s primary intension delivers the value TRUE for a scenario *W* if and only if the conditional 'If *W* is actual, then *S*' is a priori. Here, we consider a world as actual. Scenarios are associated with canonical descriptions. These canonical descriptions are supposed to guarantee that the material conditional of the form 'if *W* is actual, then *S*' comes in an appropriate form. There might be many different ways to refer to *W* we can use to generate instances of 'if *W* is actual, then *S*', that do not suit the purpose of evaluating *S* at *W* using a material conditional of this form.[19] So, in a sense, it is the appropriate descriptions of worlds that do the job of fixing the criteria for a primary intension, not the worlds themselves. To be more precise, the relevant conditional should be described as follows: 'If *W* (under description *D*), is actual, then *S*'. On different occasions, Chalmers proposes different ways one might conceive of primary intensions, ways that do not involve the notion of apriority. They all have in common that they use epistemic notions to evaluate the relation between a scenario under a description and a given expression; these differences do not matter for what follows.

According to the second alternative, scenarios are described in epistemological vocabulary. According to this interpretation, we should conceive of a scenario as a complete description of a way the world might be, which meets two requirements: It is epistemologically possible, and it is complete, such that there is no question which cannot be settled with respect to this description on a priori grounds (Chalmers 2004). More precisely: In this case, a scenario is an *equivalence class* of sentences of (non-natural) language *L*, which is such that (i) any member, *D*, of the class is epistemologically possible, and which (ii) is complete in the sense that no

[18]For a detailed introduction, see (Chalmers 2004).

[19]For a detailed discussion of the notion of a canonical description and different ways to interpret or replace apriority, see (Chalmers 2004, 2006).

sentence of *L* is indeterminate given *D*. *Epistemic possibility* is cashed out in terms of apriority or similar notions: A proposition that *p* is epistemologically possible if and only of it is not a priori that not *p*, and that *p* is epistemologically necessary iff that *p* is a priori. Intuitively, primary intensions, on this interpretation, behave similar to how they behave in the scenarios-as-centered-worlds case: Consider a description *D* of the equivalence class. Then, for a sentence *S*, its primary intension yields TRUE for a scenario under *D* if and only if 'If *D*, then *S*' is a priori.

Up to now, we have focused on sentences. Primary intensions for sub-sentential expressions pose special problems, so I will merely comment on primary intensions of singular terms that do not involve indexicals, and I will presuppose that we take scenarios to be centered worlds. In this relatively simple case, a singular term's ('*S*') primary intension is a function from scenarios (*W*) under descriptions (*D*) to extensions (*E*), such that the relevant instance of the schema "If *W* (under *D*) is actual, then $E = S$" is a priori. For example, if a world in which the brightest star in the morning is Riegel Delta were actual then Hesperus would be Riegel Delta. This inference is a priori/based on purely rational grounds (this gives an idea of what it is to consider a world *as actual* to account for an expression's intension).

Whereas the first approach to scenarios is based on the notion of metaphysically possible worlds we are familiar with, the second approach describes scenarios in epistemological terms from the beginning. In order to construct primary intensions, epistemological notions are required in both cases. The basic idea is that primary intensions are functions that obey epistemological constraints. I will use the term 'scenario' in both cases, just like Chalmers does. Given that primary intensions can be conceived of as *structured entities* (see Chalmers 2011), and that primary intensions are supposed to capture Fregean senses, or modes of presentation, we could define the core notion of reduction in a way strikingly similar to the way the notion was explicated above; a (possibly structured) primary intension we arrive at after we analyzed the conceptual content of an expression may be more or less transparent with respect to the nature of the object it designates or signifies. If so, we may arrive at a hierarchy of primary intensions for objects, a hierarchy that mirrors a reductive hierarchy in a way strikingly similar to the way property structures mirror such a hierarchy. Then, intuitively, '*a* reduces to *b*' expresses a truth iff *a*, when presented under the primary intension of '*a*', reduces to *a*, when presented under the primary intension of '*b*'. This will be the case iff $a = b$ and the primary intension of '*b*' is transparent with respect to the nature of *b*, and the primary intension of '*a*' is not transparent with respect to the nature of *a*, or it is less transparent with respect to the nature of *b* than the primary intension of '*b*'. For primary intensions that determine properties, we can easily illustrate how we arrive at corresponding notions of determination and satisfaction: An object or a set of objects satisfies a primary intension iff it is the unique object or set of objects that instantiates the property determined by this intension. Given that properties are secondary intensions (let us assume that for the sake of simplicity), then the property determined by the primary intension of a property-designator '*a*' just is the secondary intension of '*a*'.

Note firstly that there is an interesting connection between this characterization of reduction and the characterization proposed above: Assume that every primary intension (at least every primary intension that occurs in a simple or complex descriptive content of an intension that actually picks out an object) determines, in the ordinary sense, the property of being the way the primary intension would have it (maybe the secondary intension). The (non-structured) primary intension of '_is tasteless' determines *the property of being tasteless*. If this generalizes, and if we treat primary intensions of logical vocabulary as specifying functions on primary intensions and corresponding functions on properties, and if the explication within the 2-D framework is correct, then the explication proposed above is correct. For any structure of primary intensions, we will get a property structure of corresponding properties.

So, can we decide between the two? The proposal offered above is less committal in the sense that it does not commit one to a particular notion of Fregean senses, like Chalmer's 2-D framework does. If sparse commitment translates into quality, the framework proposed above is advantageous, especially since everyone who endorses 2-D semantics is free to endorse it, or a 2-D version of it, as well. (I guess that similar arguments work for algorithm-based, or procedural semantic theories of Fregean senses.)

But there is more to be said: primary intensions are described in purely epistemic vocabulary. This feature is, in the context of explicating a notion of reduction, highly problematic, because it blocks a way to explain the cognitive or epistemic differences between reduced and reducing item. Since pragmatic and alternative "cognitive" accounts suffer from a structurally similar problem, I will turn to these first and then close with a critical note on this point.

5.7.2 Reduction Within Pragmatic and Cognitive Frameworks

Another obvious candidate to illuminate the relevant aspect that is responsible for the directionality is this: The difference is *cognitive and pragmatic* in nature. This idea has been put forward, for example, by Robert Van Gulick in a series of papers (1992, 2001):

> [T]he problem is to find a way, if possible, for us to use the contextually embedded resources of the reducing theory to do the equally contextual representational work done by the items in the theory we are trying to reduce. Nor should we ignore the [. . .] pragmatic parameter [. . .]. Success in real-world representation is in large part a practical matter of whether and how fully our attempted representation provides us with practical causal and epistemic access to our intended representational target. A good theory or model succeeds as a representation if it affords us reliable avenues for predicting, manipulating, and causally interacting with the items it aims to represent. (Van Gulick 2001, 14)

From this characterization, that is offered with an eye on the *pragmatic and epistemic success* of reductions, we can easily derive a characterization of how we could reconcile diversity and directionality with unity: '*a* reduces to *b*' expresses a truth only if $a = b$ and there is a difference in pragmatic and representational features of '*a*' and '*b*' (where representational or conceptual features are described as cognitive features).

A similar idea, cast in purely epistemic terminology, seems to underlie a proposal offered by Berent Enç (1976). On Van Gulick's view, conceptual differences are ultimately to be explained in cognitive and pragmatic terms. In contrast, Enç, employs the term 'epistemological framework', an expression he does not explicate in detail. His description of the situation comes close to the puzzle discussed in Chap. 3: According to Enç, there is a generative relation that reconciles explanatory directionality with identity. This generative relation is dependent on differences in "epistemic frameworks". Unfortunately, this notion invokes an unexplained notion of causation, and it does not give the resources to see how the puzzle vanishes; rather, the suggestion mainly consists in accepting that there is a tension in the assumption that identity in reduction may go together with what Enç describes as explanatory or causal asymmetry. He writes:

> The assumption [that an explanatory asymmetry is sufficient to exclude identity] is false. Explanation is an epistemological endeavor. Identity is a metaphysical fact. It is entirely possible for two property descriptions 'φ' and 'ψ' to refer to the same property in all possible worlds, and yet, since we may know that an object answers the description 'φ' antecedently, a new theory that shows the object to answer the description 'ψ' may succeed in telling us why the object answers the first description, or it may succeed in deepening our understanding of the fact that the object answers the first description. (Enç 1976, 290)

The 'epistemological' features of explanations Enç refers to are left unexplained. Again, on this view, '*a* reduces to *b*' expresses a truth only if $a = b$ and '*a*' and '*b*' differ with respect to relational *epistemic* properties. Thus, unlike the proposals briefly discussed in this section, the proposal offered above suggests that the difference between reduced and reducing item stems from non-cognitive, non-epistemic, and non-pragmatic semantic differences between the reduced and the reducing item. The 2-D characterization hinted at in the previous section grounds the reductive relation in epistemological properties of the reduced and the reducing item as well; here, conceptual or semantic aspects are *described in epistemological terminology*. The next section discusses one problem these views face.

5.7.3 Reductive Dependence as Grounding Epistemic and Pragmatic Differences

How a theory of Fregean sense should look like is a question that has to be settled on independent grounds. Thus, what ultimately is the correct version of the definition of reduction will, hopefully, fall out of our correct semantic theory. Just like the question of what theories basically are will decide, to some extent, which version of a characterization of theory-reduction is more appropriate – a syntactic or a semantic one – a theory of what Fregean senses basically are will ultimately decide how to account for the features mimicked by the notion of a property structure. Thus, as long as they preserve the structure of the characterization given above, different accounts may look equally appropriate, as long as we ignore our semantic prejudices and biases operating in the background of our philosophical judgments. Let me articulate one of my fundamental semantic convictions, and then argue that this conviction nicely matches an implicit commitment in the reduction debate and, thus, is perfectly suited to shape an appropriate explication of reduction, which is supposed to reveal such implicit commitments.

The concept of H_2O gives a better epistemic access to water (at least in some respects) than the concept of water (if there is such a concept). Grasping the concept of H_2O, and knowing that a given sample of water is H_2O may come with a practical advantage – we improve our chances to successfully manipulate water (see Sect. 9.4). But does this give reason to assume that the conceptual difference is basically epistemological, cognitive or pragmatic *in nature*? Conceptual differences are not to be conflated with epistemic or pragmatic differences. The difference between water and H_2O is conceptual in nature. Conceptual differences *explain* the relevant epistemic and pragmatic differences. On this view, there is an epistemic and a pragmatic difference *because* there is a conceptual difference. This is what I take to be part of the Fregean view that difference in sense *explains*, and is not to be conflated with difference in cognitive role (Frege 1892, for a discussion, see (van Riel 2011)); it is opposed to semantic theories that tie notions such as Fregean sense or conceptual content to epistemic notions (such as Chalmers 2002, 2004, 2006). Accordingly, once we have fixed the relevant conceptual difference, we should be in a position to illuminate the resulting epistemic difference. This is why this conviction is particularly well suited to give a characterization of reduction, in the sense that it captures an assumption at least implicit in the reduction debate.

It has been widely assumed that part of the benefits of reductions is that they go together with scientific *progress*. This progress may very well be epistemic or pragmatic in nature. Moving from folk chemistry to chemistry that employs a formal apparatus is good because, as Van Gulick suggests, the representational framwork is cognitively more appropriate and has the capacity to lead to pragmatic success. But is this a brute fact? What is responsible for this difference in epistemic, cognitive and pragmatic success? On pragmatic and epistemic accounts, the notion of reduction won't tell us. It will just tell us *that* there is an epistemic or pragmatic difference. It will not tell us what this difference depends on. So, if the commitment to the idea that in principle, reduction goes together with epistemic and pragmatic progress, and if such progress is not a brute fact but rather depends on properties of the reduced and the reducing item, then reference to semantic features, which are not, in turn, explicated in pragmatic or epistemic terms, forms a good starting point. To this extent, the proposal offered above is more powerful than its rivals. Epistemic, cognitive and pragmatic differences between knowledge that a given sample of water is water, and knowledge that a given sample of water is H_2O result from, and are not to be conflated with, semantic differences between 'water' and 'H_2O'. The different cognitive, pragmatic, or a priori roles of these expressions are grounded in, and are not to be conflated with, their respective conceptual contents. This assumption may very well turn out to be false; but this has to be decided on independent grounds, and the explication proposed here could easily be adjusted.

5.8 Conclusion

We have defined an appropriate core notion of reduction, which captures the characterizations offered before, and three important derivative notions. The core notion matches the job description, and it is motivated by the solution to the puzzle offered in Chap. 3 as well as by the alleged similarity between mechanistic and reductive explanation.

Q1: How can we reconcile *diversity* and *directionality* with strong *unity*?

...

Th. 4: A core notion and derivative notions of reduction can be explicated; the explication fits paradigmatic cases, is coherent (solves the puzzle) and satisfies an intuitive job-description.

...

The explication proposed here uses a model of property structures. Alternative ways of capturing a similar idea are easily conceivable. However, it has been argued that the version proposed here is (i) modest, in that property structures are said to be determined by whatever plays the role of Fregean senses, and (ii) it offers the resources to explain epistemic, cognitive and pragmatic differences between different conceptual contents – a feature I take to be an advantage within the context of the reduction debate.

We can now move on to further motivate the proposal, applying it to the reduction debates in the philosophy of mind and the philosophy of science, as well as related issues in Part II.[20] The following Appendix contains a semi-formal treatment of property structure terms (it will not be referred to in the remainder of the book).

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[20]Note that the distinction between two reduction-debates (one in the philosophy of science, another in the philosophy of mind) is based on an idealization. The discussion in the philosophy of mind was strongly influenced by early models of reduction developed in the philosophy of science. However, we can distinguish between two different *foci* or *tendencies* in the two fields: In the post-Nagelian debate on reduction in the philosophy of science, the discussion was often though not invariably driven by *extension first* approaches. This is suggested not only by the examples which are given and which are intensively discussed, but also by the explicitly mentioned goal to describe *actual* theory-succession (Kemeny and Oppenheim 1956; Wimsatt 1974; Sneed 1971). This is why in the post-Nagelian debate on reduction in the philosophy of science, *replacement* played such a crucial role, and identity-based reduction did not receive special attention. Contrary to that, in the philosophy of mind the notion of reduction attracted attention partly because it seemed to give a *metaphysical* picture of the relation between the mind and underlying processes – a relation completely independent of actual scientific developments. This is, again, pertinent in some branches of the Philosophy of Science – namely, when issues regarding unity are discussed (Carnap 1934; Oppenheim and Putnam 1958; Causey 1977; Cartwright 1999). This motivates the idea of drawing the distinction between one reduction-debate in the philosophy of science and another in the philosophy of mind.

Appendix: A Semi-formal Treatment of Property Structure Terms

This appendix introduces a semi-formal treatment of property structure terms (‘*PST*s’). Only a limited number of cases of PSTs will be covered by this semi-formal treatment. However, the overall strategy should become apparent. The semi-formal treatment of these terms will be introduced as follows: In a first step, a *schema structure* (S_{ps}) for property structure terms will be introduced. A schema structure contains a list of schematic expressions and syntactic rules to form complex schematic expressions, and, here, it contains additional operators that enable us to treat natural language expressions in a relatively uniform way. In this, it is similar to the characterization of the syntax of a formal language. However, the expressions obtainable from a schema-structure will not be given an interpretation; rather, their instances *come* with a meaning – instances of schemata obtainable from this schema-structure are natural language expressions or expressions generated by the application of operators to natural language expressions. The semantic values of the results of the application of these operators crucially depend upon the meanings of the natural language expressions these operators are applied to, and they will be given in a meta-linguistic fashion, referring to the meaning of the expression they are applied to.

A Set of Rules for Obtaining Schemata for Property Structure Terms

The schema structure will be called ‘S_{ps}’. It contains schema letters and additional operators.

Schema-letters of S_{ps} and operators:

– Variables ‘x’, ‘y’, with or without index (with the substitution class {‘x^1’, ‘x^2’, . . . ‘x^n’, ‘y^1’, ‘y^2’ . . . ‘y^n’}.
– Predicate letters ‘P^n’, ‘Q^n’ (with $n \geq 1$, with or without index) for natural language predicates that are simple in the sense that they do not contain predicates or singular terms as constituents.
– Letters for kind terms ‘A’, with or without index, which do not contain predicates or other terms as constituents.

Additional Operators

– ‘< . . . , . . . >’ (which represents the identically looking sign for n-tuples),
– ‘[. . .]’ (stands for ‘[. . .]’ – an operator that works on predicates the argument positions of which are taken by free variables; it is similar to operators ‘the property signified by ‘ . . . ’’ and similar operators),

– '&' (designating the function on properties and states 'and' determines)[21]
– EXISTS (designating the function on properties and states which is determined by the existential quantifier)
– The set of operators that are expressed by expressions of the form '… $^{\xi 1}$' (Putting a variable in this place after an expression, we express a function from properties to properties or states of affairs, a function that does not have a natural language counterpart; in natural language, this function is captured by arrangement: the property signified by '… loves Peter' is distinct from the property signified by 'Peter loves …'. In our schema, we need to distinguish between these properties. Instead of relying on arrangement, we introduce this set of operators. They mimic the syntactic function of arrangement of expressions occupying argument-positions within complex predicates.)

Note that this fragment does not contain place-holders for modal operators, or something that corresponds to an operator like 'the fact that …' (which would make things unnecessary complex) and a considerable number of other operators which might be relevant for scientific discourse. Thus, we should regard the account presented here as a partial account of property structures. We can now recursively define the set of property-structure *term*-schemata. I shall talk about 'terms' from now on *simpliciter*. It should be noted, however, that these terms are *schemata* for terms.

Terms (term-schemata) in S_{ps}:

– If Φ^n is an n-place predicate (with $n \geq 1$) and $\xi_1 \ldots \xi_n$ are variables, then '$[\Phi\xi_1 \ldots \xi_n]$' is a *term*.

The goal of this rule is to build an operator that takes a predicate as an argument. The result is a term referring to the property signified by the predicate.

– If α is a kind term, then α is a *term*.

Kind terms just contribute the kind they designate to property structures. The following two rules give a procedure to model conjunction and the existential quantifier.

– If α_1 and α_2 are *terms*, then $<\&, <\alpha_1, \alpha_2>>$ is a *term*.
– If α is a *term* and ξ_1 is a variable which is free in α, then $<EXIST\ \xi_1, \alpha>$ is a *term*.

Here, the variable ξ is bound by a quantifier EXIST in an instance of a schema of the form $<EXIST\ \xi, <\alpha>>$ iff it occurs within the scope of the quantifier, namely, within '$<\alpha>$'.

– If α is a *term* with free variables ξ_1-ξ_n, and $\beta_1 \ldots \beta_m$ are *terms* and $n \geq m$, then $<\alpha, <\beta_1\xi^1, \ldots \beta_m\xi^m>>$ is a *term*.

[21] Other connectives are ignored here to keep things simple. However, other connectives can be introduced in a similar fashion.

This is supposed to capture the idea that we can generate complex expressions, where ‘a’ is obtained from an n-ary predicate with free argument positions $\xi_1 - \xi_n$, some or all of which are taken by ‘$\beta_1\xi^1$’, … ‘$\beta_m\xi^m$’. The resulting property structure term will model the property structure of a predicate whose *arity* is $n - m$ or, in case that $n - m = 0$, of a sentence. The final clause states that all and only those terms obtainable from this procedure are property structure terms.

– All and only those *terms* obtainable in a finite number of steps from the previous rules are *terms* in S_{ps}.

Now, for example, the expression ‘<&, <[x is a ball], [x is red]>>’ is an instance of a schema obtainable from this schema structure, namely: <&, <[Px], [Qx]>>. Similarly ‘<EXIST x, <[x is an instance of y], <[z is wise]$^{y>}$>>’ is an instance of: <EXIST x, <[Px,y], <α^y>>>.

What about the semantics of instances of schemata obtainable from the schema structure just given?

Semantic characterizations of Instances of S_{ps} Schemata

For simple predicates and simple singular terms, it is not complicated to give the semantic values – they come with the meaning they have, and if they designate or signify something, then their contribution to the ontological structure can intuitively be made precise as follows: The operator ‘[. . .]’ takes predicates and refers to the property the predicate signifies, if any. Kind terms contribute the kind they designate. Thus, the property structure we get access to by an instance of (an instance of) ‘[Φ $\xi_1 \ldots \xi_n$]’ is the property signified by the predicate that is substituted for the instance of Φ. But what about quantifiers or what is treated in predicate logic as sentential operators? The basic idea is to treat them as designating partial functions that map properties (or other objects) onto properties (and other objects). The general idea for this procedure has been spelled out above (Chap. 5). What has been taken as being merely *determined* by the relevant natural language expression will here be treated as the semantic value of the expressions generated by the application of the additional operators.

We now characterize an interpretation function I_{ps}. This function specifies the semantics for simple expressions that conform to the schema structure given above. Let D^p be the set of properties, D^F the set of states of affairs, D^I the set of individuals, and $D^{PF} = D^P \cup D^F$ and $D = D^P \cup D^F \cup D^I$, and D^{Pred} be the set of simple predicates. We then get the following characterization of our interpretation function (let ‘α’ stand for kind terms).

(Characterization Interpretation Function I_{ps})

- $I_{ps}(\alpha)$ = *the entity designated by* α *(if any).*
- $I_{ps}([\ldots]) = f\colon D^{Pred} \rightarrow D^{P}$, *such that* $f(x) = y \in D$ *or f(x)is undefined. (f(x) = y, such that x signifies y, if anything).*[22]
- $I_{ps}(\&) = f\colon D^{PF} \times D^{PF} \rightarrow D^{PF}$, *such that* $f(x) = y \in D^{PF}$ *or f(x)is undefined. (f(x) = the significatum of the appropriate instance of ‘*y_1 *and* y_2*’, with* $x = <z_1, z_2>$ *and the instance of* y_1 *signifies or designates* z_1 *and the instance of* y_2 *designates or signifies* z_2*, if anything).*
- $I_{ps}(EXIST) = f\colon D^{P} \rightarrow D^{PF}$, *such that* $f(x) = y \in D^{PF}$ *or f(x) is undefined. (f(x) = the significatum of the appropriate instance of ‘There is at least some y such that Fy’ with F signifying x, if anything).*
- $I_{ps}(\xi^{1} \ldots \xi^{n}) = f\colon D^{P} \rightarrow D^{PF}$, *such that* $f(x) = y \in D^{PF}$ *or f(x) is undefined. (f(x) = the significatum of any appropriate instance of ‘Fa,* $y_n, \ldots y_m$*’* $(n/m \geq 0)$*, with x = the property signified by ‘Fa’, if anything)*

The tuple-operator, ‘< … >’, works as usual.

We can now define the notion of a property structure:

(Def. property structure of an expression): *A property structure an expression E gives access to is the referent of an instance of a schema generated in* S_{ps} *obtained from E.*

Note again that S_{ps} is limited; thus, it should be extended whenever necessary. Again, property structures and their complex and simple constituents sometimes determine properties or states in a specific way; namely, they determine what is signified, referred to or stated by the expression they are obtained from (if this expression signifies, refers to or states anything), given that this is fully determined by the property structure in the following way (to mark the difference to the characterization above, an asterisk is added):

(Def. Determination):* *A property structure PS determines an entity x as follows:*

- *Iff PS takes the form a and ‘a’ is a kind term, then a = x.*
- *Iff PS takes the form [Φ …], then [Φ …] = x.*
- *Iff PS takes the form* $<f<a_1, \ldots a_n>>$ *and* a_1 *determines* $x_1 \ldots$ *and* a_n *determines* x_n *then* $f(<x_1 \ldots x_n>) = x$*.*

[22] Thus, we assume that any property that could enter a property structure is expressible.

- *Iff PS takes the form* $<a, < \beta_1\xi^1, \ldots \beta_n\xi^n>$ *such that a determines the m-ary property y and* β_1 *determines* $x_1 \ldots$ *and* β_n *determines* x_n *then*
  - *if* $m - n > 0$, *then* $x =$ *the* $(m - n)$*-ary property of standing in y to* $x_1, \ldots, x_n$*,, or*
  - *if* $m - n = 0$, *then* $x =$ *the fact that* $x_1 \ldots x_n$ *instantiate y.*

Note that we lack an operator similar to the iota-operator. Intuitively, introduction of such an expression would enable us to generate property structures that determine individuals. The notion of satisfaction can be introduced in a way similar to the way it was given above: the extension, or the extension's members satisfy the property structure. Now, let us turn to an example in order to make these ideas more precise, and to illustrate how these tuples relate to reductive explanation.

An Example

Consider, again, the following two expressions.

'Water'; 'H_2O'.

Needless to say: It will be taken for granted that H_2O = water. Let 'water' be a kind term which does not have a meaning, but only a referent. Then we get the following property structure the expression gives access to in its ordinary use:

[x is water].

Now, assume that 'water' has a meaning, given by the predicate '_is tasteless and liquid'. We would get:

< [&], <[x is tasteless], [x is liquid]>>

'H_2O', in contrast, gives access to a property structure that reveals its chemical constitution. Intuitively, it is the property which is instantiated by entities that have the property of having a proper part that is an oxygen atom and two proper parts that are hydrogen atoms.[23] We can then compare these distinct PSs (of 'water' and 'H_2O') with respect to their basic properties:

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[23]To model the property structure 'H_2O' gives access to, we should add the connective '→' (if, then) and the general quantifier 'EVERY' to be characterized in a way similar to 'and' and 'EXIST'. Let '_ is a PP of _' be '_is a proper part of_'.

<EVERY y, <→, <[x is instantiated by y], <EXIST z_1,z_2, z_3, <&, <&, <[z_1 is a PP of y], <&, <[z_2 is a PP of y], [z_3 is a PP of y]>>>>, <&, <[z_1 is hydrogen], <&, <[z_2 is hydrogen], [z_3 is oxygen]>>>>>>>>

This version still neglects some details, because the language still lacks expressive power. We should add:

<¬, <EXIST a z* <[z* is a PP of y], ¬ [z* is identical to z_1], ¬[z* is identical to z_2], ¬[z* is identical to z_3]>.

On the one hand we have *being water* or *being tasteless* and *being liquid*. The PS of 'H_2O' will contain:

[x is hydrogen], [x is oxygen], [x is a proper part of y].

These are clearly properties of constituents of water-molecules. Moreover, these are properties that are explanatorily relevant for why water behaves the way it does, and, according to some interpretations, that explain to a certain extent what water basically is. This parallels the idea underlying mechanistic explanation: We explain a whole in terms of the causally relevant organization of its parts. Thus, we can explain why some *explanans* is appropriate for an *explanandum* referring to the property structure under which it gives access to the target of the *explanandum*: In virtue of giving us a constitutive structure, the *explanans* is appropriate.

Thus, we have outlined a semi-formal treatment of property-structure terms that gives a more precise idea of the metaphysics of property structures. Let me finish these remarks mentioning that the notion of a tuple is nevertheless problematic in this context: There can be many property structure terms that are instances of a schema obtainable from S_{ps} for one non-ambiguous natural language expression. For example, a conjunction with only two conjuncts can be modeled in two different ways: a natural language predicate of the form '_is F &_ is G' can be modeled as '<&<[Fy], [Gx]>>' and as '<&<[Gy], [Fx]>>'. Now, intuitively, property structures are less fine grained than tuples. Thus, these tuples should function as a mere model for property structures only.

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This ensures that within the limits of our schema structure, we fix that water-instances do not have more than three constituents. Moreover, we should add <&, <<¬, [$z_1$is identical to z_2]>,<¬, [$z_2$is identical to z_3]>>> to ensure that H_2O has three constituents. Alternatively, we could introduce a further operator, namely, 'there are exactly three'. Note that being water is the property that is determined by this structure: The leftmost operator ('EVERY y') contributes a function that maps the property signified by 'if _is instantiated by _ then there is a z_1, z_2, z_3 such that z_1 is a proper part of _ and z_2 is a proper part of _ and z_3 is a proper part of _and z_1 is hydrogen and z_2 is hydrogen and z_3 is oxygen' onto the property signified by 'for any y, if y instantiates _, then there is a z_1, z_2, z_3 such that z_1 is a proper part of y and z_2 is a proper part y of and z_3 is a proper part of y and z_1 is hydrogen and z_2 is hydrogen and z_3 is oxygen'. This predicate, however, signifies a property which is instantiated by the property of being water *only*. It is satisfied by what is water – the extension of the property.

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