The headed meronomy and its potential role in language

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Abstract

It is known that concepts can be organized hierarchically either in the form of a *taxonomy* (a kind hierarchy), or a *meronomy* (a part-whole hierarchy). A meronomy can be seen as describing how certain wholes decompose into particular constituents, or alternatively, how wholes of a particular constitution are constructed. On the latter view, the meronomy is seen to be a way of assembling meanings by hierarchical construction. This begs the question of how meronomies are related to language; this may also be described as a system for assembling meaning by hierarchical (i.e., grammatical) construction. This article investigates the relationship, and argues it is potentially of relevance to the study of language.

Keywords: meronomy, taxonomy, semantics, knowledge representation, conceptual structure

1 Introduction

It has long been known that concepts can be organized hierarchically in two ways. In what is called a *taxonomy*, every child node is a special case of its parent: the concept represented by the child specializes (i.e., is extensionally subsumed by) the concept represented by the parent. In what is known as a *meronomy*, every child node represents a part of its parent. As Tversky comments, these 'two modes of decomposition reflect two general forms of organization of knowledge, taxonomic, that is, subdivision into kinds, and partonomic, that is, subdivision into parts' (Tversky, 1989, p. 983). Another way to make the distinction is to say that, in a taxonomy, nodes are connected by *is-a* links, whereas in a meronomy, they are connected by *has-a* links.

Taxonomic organization is often illustrated by the system of classification devised by Linnaeus (1753). Every node in the Linnaean system names a phenomenon of the natural world, with the root division being between plants, animals and minerals. Each of these major classes is then further subdivided into orders, families, and other classes. The nodes in the Linnean system label natural classes, rather than concepts. But this makes no difference to the semantics. The identification of a class can always be considered to identify the

concept whose extension is the class in question. The class of mammals, for example, can be considered the extension of MAMMAL.

Two illustrations of taxonomic organization are shown in Figure 1. These follow the usual convention of drawing the hierarchy with its root at the top. The taxonomy of panel (A) deals with animal concepts. EAGLE, BUZZARD and FALCON are shown to be special cases of BIRD, whish is shown to be a special case of ANIMAL. TROUT and SHARK are shown to be special cases of FISH, which is also shown to be a special case of ANIMAL. The hierarchical relationships can also be described in a top-down way. We can say that ANIMAL generalizes or subsumes BIRD and FISH, for example. The taxonomy of Panel (B) deals with shape concepts in a similar way.

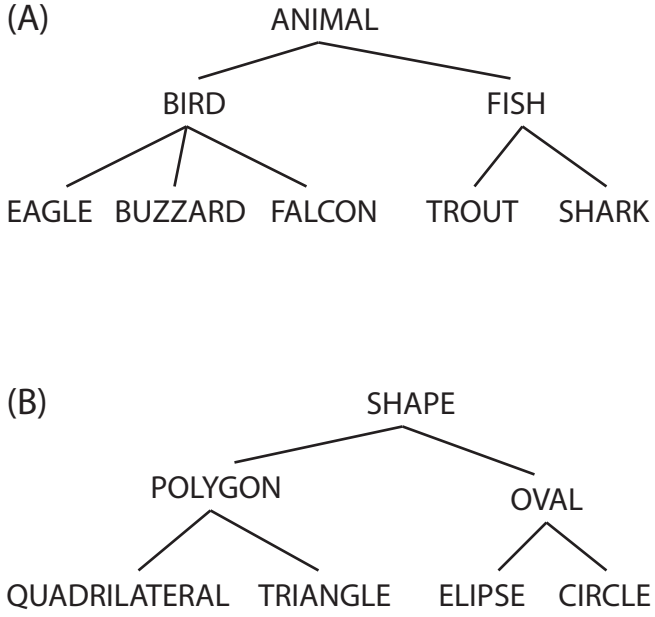

Figure 1: Two simple taxonomies.

The second standard form of hierarchical organization is the meronomy. (The term 'partonomy' is sometimes used instead of 'meronomy'. But the present paper will stick to the latter in general.) In a meronomy, we again have a hierarchy of concepts. But in this case the child-parent relationships express parthood rather than subsumption. The concept represented by a child node represents a part of the entity (or, more generally, *phenomenon*) represented by the parent. Two meronomies are shown in figure below. These hierarchies are also drawn with the root at the top; but to emphasize that it is parthood rather than subsumption that is represented, links from child nodes to parents remain separate—they are not brought together at a point. The meronomy of panel

(A) shows a decomposition of CAR. This is shown to admit (as parts) ENGINE, WHEEL, and HEADLIGHT, where the former admits CRANKCASE and CARBURETOR, and the latter admits BULB and REFLECTOR. The meronomy of panel (B) shows a decomposition of THERMOS. This is shown to admit as parts BOTTLE, HANDLE and SPOUT, where the former admits FLASK and MANTLE, and the latter admits STOPPER, HEAD and GASKET.

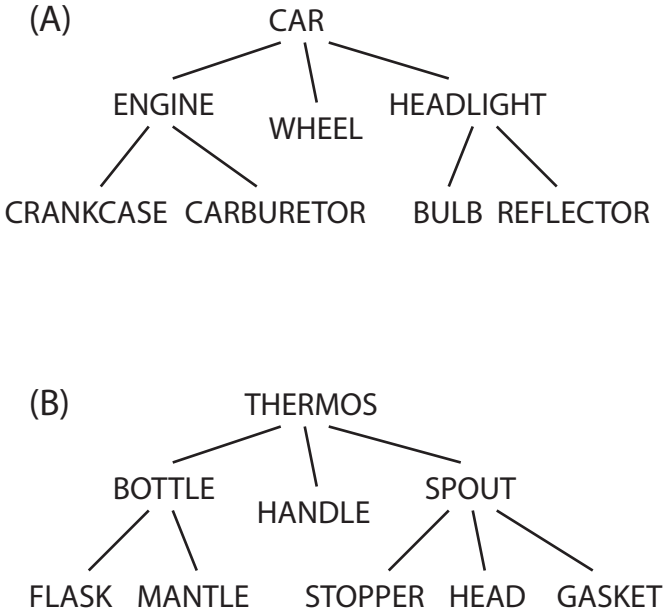

Figure 2: Sample meronomies.

In principle, meronomies of a simplified form can also be constructed. If each parent represents no more than the sum of the stated parts, the hierarchy expresses pure part-whole relationships. The wholes are not characterised in any way other than as the sum of the specified parts. To illustrate, imagine a situation in which LEGS and SURFACE are the parts of interest. These might be viewed as the parts of a table or a stool. But we can construct a meronomy which cites them as the parts of a whole, without specifying the whole independently. One way to draw a meronomy of this type leaves the parent nodes unlabeled, as in panel (A) of Figure 3. An alternative approach inserts COMBINATION (or some other way of conceptualizing 'sum of the parts') as the head of each unit. This approach is illustrated in (B).

As meronomies of this type provide no separate information about the head of each hierarchical unit, they can be termed *unheaded*. In practice, meronomies are rarely of this type. More commonly, each parent represents a named concept, and its identity is supplied accordingly (Tversky and Hemenway, 1984). The

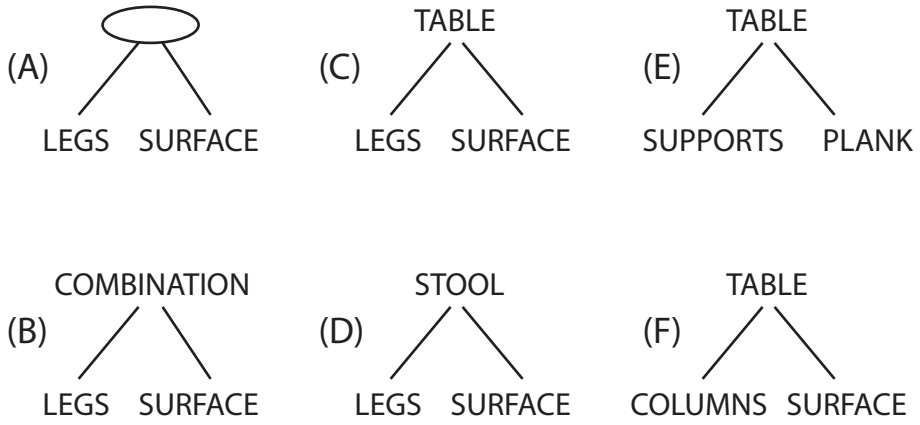

Figure 3: Comparison of headed and unheaded meronomies.

whole that is realized at the unit in question is then *more* than the sum of the cited parts, with the head concept providing the specification.[1] Meronomies which do provide head concepts in this way are naturally termed *headed*.

Meronomies of both types are shown in Figure 3. Panel (C) shows a headed meronomy in which LEGS and SURFACE are given as parts of TABLE. Panel (D) shows the case where they are given as parts of STOOL. In one case, the whole that is represented is a kind of table; in the other, it is a kind of stool. This reveals the non-deterministic aspect of the headed meronomy. Where head concepts are provided, there can be different ways of making a whole out of the same parts. Another consequence is that there can be different ways of giving parts to the same whole. This is illustrated in panels (E) and (F). In (E), the parts of TABLE are given, not as LEGS and SURFACE, but as SUPPORTS and PLANK. In (F), they are given as COLUMNS and SURFACE. The whole that is represented is a kind of table in both cases. What differs is the portrayed constitution.

Headed meronomies have the attraction of being more expressive. But they also pose theoretical difficulties for ontology. One problem is that, as noted, they are generally non-unique. As Tversky (2005) observes, it is normally found that there are multiple ways of decomposing particular wholes into constituents. Multiple meronomies can generally be constructed from the same concepts. This is not the case with a taxonomy: a taxonomy can be incomplete, or plain wrong, but it cannot be non-unique. Another difficulty is that taxonomies are not

[1] This is the type of part-whole relationship that Aristotle draws attention to in saying that 'The whole is something over and above its parts, and not just the sum of them all' (Metaphysics, Book H, 1045: 8-10: Ross, 1924). In similar vein, John Stuart Mill writes 'it appears to me the Complex Idea, formed by the blending together of several simpler ones, should ... be said to *result from*, or be *generated by*, the simple ideas, not to consist of them' (Mill, 1843/1965, p. 29).

transitive in the way taxonomies are (Cruse, 1979; Winston and Herrmann, 1987; Gerstl and Pribbenow, 1995). The *is-a* link which forms the basis of a taxonomy is a transitive relation. If X is subsumed within Y, and Y is subsumed within Z, then X is also subsumed within Z. Any predicate true of X must also be true of Y and Z. Taxonomies facilitate inference accordingly.

In a headed meronomy, on the other hand, transitivity is typically lost. Depending on the concepts used to characterise wholes, the possession of a part at one level of the hierarchy may not imply its possession at a higher level. Commenting on this, Artale et al. (1996) observe that various authors

> have noticed that transitivity does not always hold [in a meronomy] ... As an example, consider the following case: an arm is part of a musician, the musician is part of an orchestra, but it would sound a bit strange to state that the arm is part of the orchestra (Artale et al., 1996, p. 350).

Another illustration is offered by Varzi (1996). The scenario in this case involves doors, door-handles and houses. Varzi notes that 'the handle is part of the door, the door is part of the house, but the handle is not part of the house' (Varzi, 1996, p. 261). Again, it is seen that parthood at one level of the hierarchy does not extend to a supervening unit. While there is a *has-a* relation between door-handles and doors, this does not imply the same relation between door-handles and houses.

The head concepts in a headed meronomy form barriers to transitivity, then. As their semantic properties are unconstrained, they cannot be relied on to transitively extend parthood relationships. The simpler, unheaded meronomy is another matter. Here, the implicit head concept for each unit signifies summation of the parts: it might be COMBINATION, for example. Assuming that combining two sets of parts produces their union, parts of a whole at one level of the hierarchy are then also parts of any supervening wholes. On this basis, the unheaded meronomy guarantees transitivity, just as the taxonomy does.

Difficulties arising from the instability of part-whole relations have been widely discussed (Artale et al., 1996; Bittner and Donnelly, 2005; Gerstl and Pribbenow, 1995; Odell, 1998; Shanks et al., 2004; Varzi, 2004; 2006; Vieu and Aurnague, 2005; Winston and Herrmann, 1987; Johansson, 2006; Fiorini and Gärdenfors, 2014). They pose a major obstacle for any project which seeks to build a formal calculus around the parthood relation (Varzi, 1996). The 'merology' of the early 20th Century mathematician Lesniewski is a case in point. Intended to be a formal theory of the parthood relation, merology was originally conceived as an alternative to classical set theory (Simons, 1987; Lewis, 1991). Unfortunately, the difficulty of stabilizing the semantics of the parthood relation obstructs projects of this kind (Habel et al., 1995).

In the view of Fiorini and Gärdenfors, 'the tendency to ascribe transitivity to simple part relations possibly comes from its association with the notion of spatial inclusion, which is transitive in nature' (Fiorini and Gärdenfors, 2014, p. 138). But, as Tversky points out, objects 'can be decomposed in many different

ways, for example, into sides, such as top, bottom, front, and back, or into material components, such as plastic, metal, or stone' (Tversky, 2005, p. 9).[2] It is also found that parts can 'be optional; in the sense, they might or might not appear in the whole to which they relate to' (Fiorini and Gärdenfors, 2014, p. 138). Viewing the parthood relation as necessarily transitive can be ruled out on both counts.

Attempts have been made to systematize the forms that the parthood relation can take (e.g. Simons, 1987; Chaffin et al., 1988; Gerstl and Pribbenow, 1995). But it has not been possible to reproduce transitivity in a generally satisfactory way. In Fiorini and Gärdenfors' view, understanding the part-whole relation will require a different, and specifically cognitive approach. As they observe, 'the difficulties in representing part-whole relations using ontology representation languages ... serve as good arguments for approaching the problem using a cognitive semantics framework' (Fiorini and Gärdenfors, 2014, p. 140).

The present paper starts from the same assessment. It also adopts a specifically cognitive approach to the parthood relation. But this is not done with a view to restoring transitivity (or some other inferential property) to the meronomy. Rather, it is done in order to explore the relationship with language. While the meronomy is generally seen as depicting the way an entity can be decomposed, it can also be seen as a way of assembling complex meanings. The meronomy which makes LEGS and SURFACE parts of TABLE, can be seen as constructing the concept of a table with these particular parts. From the ontological point of view, switching from a decompositional to a compositional perspective may seem of no value. But from the linguistic perspective, it reveals something of interest—that the headed meronomy can be viewed, not just as a medium of decomposition, but also as a way of constructing meaning. A structure that is seen to be inherently problematic from the ontological perspective then takes on a more positive appearance. It comes to be recognized as something whose constructive function is potentially relevant to the study of semantics, and language more generally.

The remainder of the paper develops the argument in more detail. The section immediately to follow (Section 2) explores the semantic function of the meronomy in depth. The focus here is on the way headed meronomies can express different forms of meaning. Section 3 then examines the relationship with language. Finally, Section 4 presents a summary and concluding comments. The terminological approach will continue to adopt the conventions used above. Concept names will be written in upper case (e.g., TABLE). Meronomic hierarchies will be drawn with the root uppermost, and with links adjoining head nodes at separate points. Taxonomic hierarchies will be drawn with the root uppermost, and with links adjoining head notes at a single point.

[2]Tversky notes that functional significance tends to dominate what is perceived to be a plausible part: 'Good parts are also those that have functional significance, the legs of chairs and tables and people support them, and the arms of people are used for reaching and carrying and writing and slicing and any number of important activities ' (Tversky, 2005, p. 9).

2 The meronomy as a constructive medium

It is useful to begin by setting out some assumptions that will apply. Particularly important to what follows is the understanding that the concepts in a meronomy are potentially abstract. They are not required to be concrete. The concepts SAILING and FISHING are potentially considered parts within PASTIME, even though they represent nothing concrete; see Figure 4 panel (A). Similarly, RECEPTION and SERVICE can be considered parts within WEDDING, as in panel (B). In view of this, the term 'constituents' will be generally be preferred to 'parts', as this avoids the implication of concreteness. On this basis, the first meronomy would be seen to describe how sailing and fishing can be the constituents of a pastime.

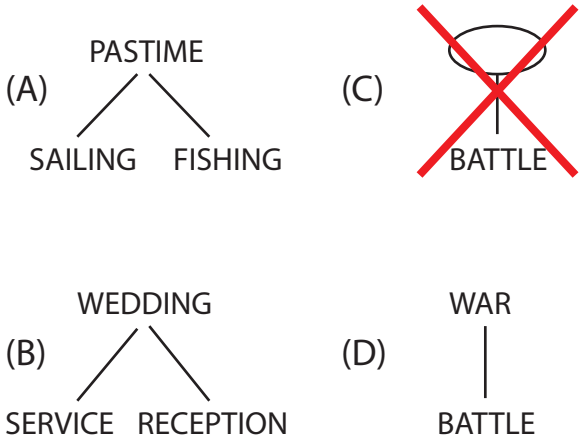

Figure 4: Headed meronomies with abstract concepts.

Any English noun written in upper case is considered to name the signified concept, where this can include abstract nouns (e.g., PASTIME), count nouns (e.g., LEG/LEGS) and mass nouns (e.g., WATER). English conventions governing the use of indefinite articles will be followed where relevant. If X, Y and Z are all singular count nouns, a meronomy in which Z is made the head with respect to X and Y will be said to state that *an* X and *a* Y can be constituents within *a* Z, for example.

Also acknowledged is that there are no constraints on the hierarchical forms a headed meronomy can take. With head concepts fulfilling the function of characterizing wholes, the only constraint affecting constituents is that each must be a legitimate constituent of the whole in question. There is no requirement for there to be more than one constituent. By the same token, a meronomic unit need not cite *all* the constituents of a whole, even if they can be established.[3] A

[3]This acknowledges Fiorini and Gärdenfors' point that parts can 'be optional; in the sense,

meronomic unit is valid just in case the head concept can semantically accommodate the cited constituents. To illustrate, a meronomic unit which makes Z the head concept with respect to X and Y is valid just in case X and Y can be constituents of (or within) Z.

The legitimacy of singleton constituent sets is particularly of interest. Part-whole units of this kind may seem counterintuitive but in a headed meronomy, they are perfectly legitimate. As each whole is characterized by a dedicated head concept, there is no requirement for more than one constituent to be supplied. Consider the relationship between WAR and BATTLE, for example. A battle can be a constituent within a war. Hence WAR can be the head of a meronomic unit that has BATTLE as its sole constituent. The meronomy of Figure 4 panel (D) is meaningful and well-constructed.

In the case of the *unheaded* meronomy, the reverse applies. Here, the whole is defined purely as the sum of the parts. A singleton constituent set is then logically ruled out. Such a structure would imply identity between the single constituent and the whole: the hierarchical organization would be meaningless. An invalid meronomy of this kind (featuring BATTLE as its constituent) appears (crossed-out) in Figure 4, panel (C).

Having stated the assumptions that will be in force, it is possible to begin exploring the creative function of the headed meronomy in more detail. It has already been noted that such structures are always implicitly constructive. Consider the meronomy of Figure 4, panel (A). This records that SAILING and FISHING can be the constituents of a PASTIME. The structure depicts the way one concept can be decomposed into two others. We can also see it as a way of constructing a particular idea: the idea of a pastime involving sailing and fishing. The idea is constructed by hierarchically accommodating within PASTIME the constituents SAILING and FISHING. The effect is to construct an idea in which sailing and fishing are made the constituents of a pastime.

The meronomy of Figure 4, panel (B) can be viewed in a similar way. We can either see this as recording that WEDDING can be decomposed into the constituents SERVICE and RECEPTION. Or we can see it as showing how the idea of a wedding involving a service and reception is put together by hierarchical accommodation. On the one hand, the interpretation is decompositional. On the other, it is compositional. What is revealed in the latter case is how a particular idea can be obtained by accommodation of particular constituents within a particular whole.

2.1 Expression of classical definitions

One implication of the above is that headed meronomies can be the means of expressing classical concept definitions. According to a long-standing account, now termed the classical theory, concepts are constructed in the mind by stipulation of necessary and sufficient features (Laurence and Margolis, 1999).

they might or might not appear in the whole to which they relate to' (Fiorini and Gärdenfors, 2014, p. 138).

In the familiar example, the concept BACHELOR is considered to be constructed/defined by conjoining the features MASCULINE and UNMARRIED, the assumption being that all bachelors have these attributes in common. Since features are themselves concepts (Smith and Medin, 1981), the effect is to construct a conjunction with particular concepts as its constituents. Hence, the classical definition of BACHELOR can be expressed as a meronomy which has CONJUNCTION as its head concept, and the features MASCULINE and UNMARRIED as constituents. This is illustrated in Figure 5.

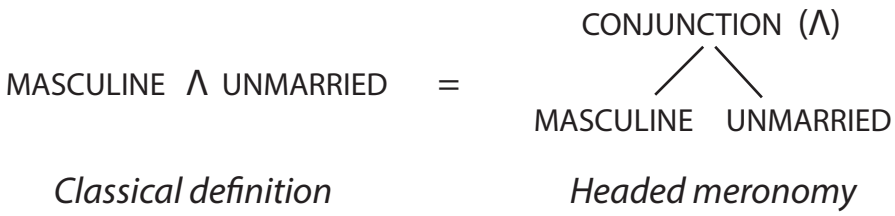

Figure 5: A classical definition expressed as a headed meronomy.

In the modern era, the classical theory has been largely abandoned, as it has become apparent that concepts may have no features in common (Wittgenstein, 1953, aphorism 66), and that valid definitions are few and far between (Laurence and Margolis, 1999).[4] Nevertheless, the classical definition remains a valid form of concept construction, and its capacity to be expressed as a headed meronomy highlights the constructive capacity of the medium. A classical definition is semantically equivalent to a one-level headed meronomy with CONJUNCTION as head. Arguably, this special case can be reduced to that of the unheaded meronomy. If we take CONJUNCTION to signify 'sum of the parts', it follows that a classical definition is equivalent to a one-level unheaded meronomy.

2.2 Expression of relational schemas

Further ways in which headed meronomies can mediate concept-construction become apparent when we consider use of relational concepts. Consider the concept BLOCKAGE for example. This concept has a specifically relational meaning. It refers to a situation in which there is a certain relationship between a blocking entity and a blocked entity.[5] Since we can conceive of a blockage involving a rock and a pipe, it follows that the concept can be the head of

[4]Recognition that concepts can represent prototypes/stereotypes has also played a significant role. As Murphy notes, 'The groundbreaking work of Eleanor Rosch in the 1970s essentially killed the classical view, so that it is not now the theory of any actual researcher in this area' (Murphy, 2002, p. 16). Fodor is equally emphatic: 'these days almost nobody thinks that concepts are definitions' (Fodor, 1998, p. 44).

[5]Strictly speaking, it refers to a situation where there is a blocking relationship between any number of blocking entities, and a blocked entity.

a meronomic unit in which ROCK and PIPE are constituents. The structure obtained is shown in Figure 6, panel (A).

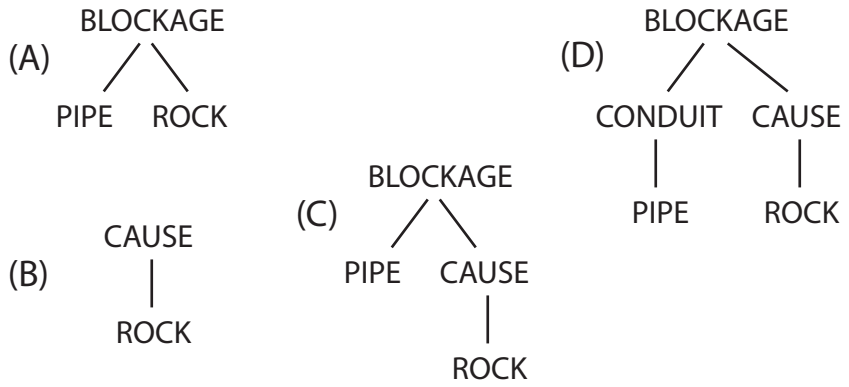

Figure 6: Meronomic construction of a relational schema.

This particular construction is interesting for resembling a relational schema, where the term is understood as in (Halford et al., 1998; Halford, 2005; Gentner, 2005; Gentner and Kurtz, 2005; Hummel and Holyoak, 2005; Doumas et al., 2008). It is integral to what BLOCKAGE means, that constituents of a blockage must have a certain relationship—the relationship of blocking. When constituents are supplied, as in the structure above, they are implicitly placed into this relationship. This does not fix the directionality of the relationship, however. That aspect of meaning remains undetermined. Which entity is blocking, and which is blocked remains open. The meaning of the construction in panel (A) covers both the situation in which it is the pipe blocking the rock, and where it is the rock blocking the pipe.

The semantic ambiguity can be resolved by adding more structure to the hierarchy. One way to proceed makes use of CAUSE. Given we can conceive of a cause involving a rock, the construction of panel (B) is valid. This construction, which makes ROCK the sole constituent of CAUSE, can then be substituted for ROCK in the original meronomy. This yields the structure of panel (C). What is then obtained is the concept of a blockage in which the constituents are (1) a pipe and (2) a cause constituted of a rock.

This description can also be expressed in a more intuitive way. With a single constituent, the head concept in a construction can be viewed as an additional classification of the constituent. It is legitimate, then, to use either 'classified as' or 'is a constituent of' to convey the relationship. In the case above, the meronomy can be said to construct the concept of a blockage involving a pipe and a rock, where the rock is classified as a cause. The meaning is identical, but the wording is more natural.

Going one step further, we could make PIPE the constituent in a unit headed

by CONDUIT. This yields the meronomy of panel (D). What is now constructed is the concept of a blockage involving a pipe and a rock, where the rock is classified as cause, and the pipe as conduit. By adding meronomic units in this way, it is possible to individuate roles. We can establish the roles that particular constituents play within the relationship signified by the head concept—the relationship into which the constituents are implicitly placed. The CAUSE-headed unit serves to assign ROCK the role of CAUSE. The CONDUIT-headed unit serves to assign PIPE the role of CONDUIT. What is then obtained is a relational schema in all but name.

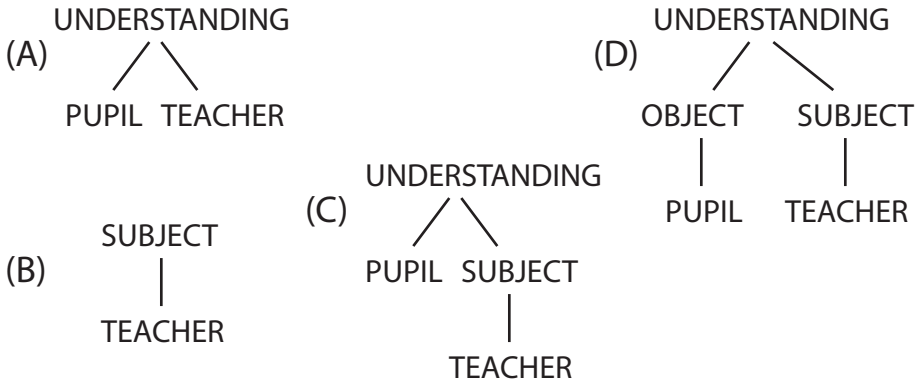

Figure 7: Meronomic construction of a relational schema.

Another illustration can be devised using UNDERSTANDING. An understanding can exist between a teacher and a pupil. Hence, a teacher and a pupil can be the constituents in an understanding, and a meronomic unit with TEACHER and PUPIL as constituents, and UNDERSTANDING as head is valid. Again, this leaves the roles ambiguous. It is not established whether it is the teacher who understands the pupil, the pupil who understands the teacher, or both. Using the concepts SUBJECT and OBJECT, where these have their standard linguistic meaning, we can build single-constituent constructions which have the effect of classifying the teacher as subject, and the pupil as object. Incorporating these into the original meronomy then produces the structure of Figure 7, panel (D). This builds the idea of an understanding involving a teacher and pupil, where it is the teacher who understands the pupil specifically. This example further reveals the ability of the headed meronomy to express relational schemas.

2.3 Expression of structured meanings

As meronomies can have arbitrarily many levels, the concepts they construct can have arbitrarily complex, structured meanings. The capacity for hierarchical

accommodation endows concepts with the ability to act as a 'construction set' in this sense. This can be illustrated by combining some of the meronomies set out above. We might take the meronomy that constructs the idea of a pastime of sailing and fishing, and combine this with the meronomy based on UNDERSTANDING. One way of doing this is illustrated in Figure 8, panel (A). Here, the object of the understanding becomes a pastime of sailing and fishing, and the constituent classified as subject is a bachelor. The meaning obtained is that of a bachelor understanding a pastime of sailing and fishing.

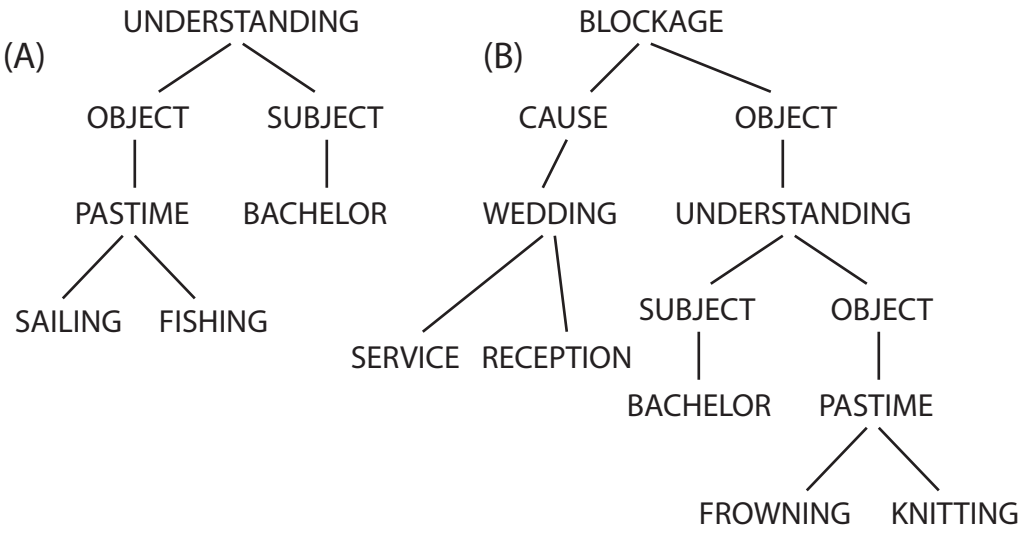

Figure 8: Expression of structured meanings.

Incorporating the BLOCKAGE concept, and adding the concepts FROWNING and KNITTING, we can extend the meronomy of panel (A) to form the meronomy of panel (B). Here, it is the understanding by a bachelor (of a particular pastime) which is blocked, while the constituent classified as cause is a certain kind of wedding. The meaning obtained, accordingly, is that of a blockage in an understanding (by a bachelor, of a pastime of frowning and knitting), caused by a wedding constituted of a service and reception. Quite possibly this bizarre idea has never before been expressed. It is not unreasonable to assume no situation with this description would ever arise. Nevertheless, the meronomy is well-formed and semantically precise. It is a legitimate product of the concepts deployed. Every hierarchical unit respects the semantic range of the head concept deployed. Where a particular constituent is cited, the concept is an acceptable constituent of the concept that heads the unit.

3 Connecting the meronomy to language

The meronomy is traditionally seen as a way of representing part-whole relations. Taken in full generality, however, the formalism well goes beyond this, as seen above. Allowing that concepts can be abstract and relational, and that hierarchical units can be singly constituted, the headed meronomy enables complex meanings to be assembled by hierarchical construction. This points to a possible connection with language. Language can also be described as a system for assembling meaning by hierarchical (grammatical) construction. How is construction of meaning by language related to construction of meaning by meronomy? If we compare the hierarchical linguistic construction of a particular meaning with its corresponding meronomic construction, should we expect to see a correspondence? Or, are the two structures likely to be completely unrelated?

A logical first step is to compare a meronomically constructed meaning against a linguistic equivalent. There is the problem that, in original form, the latter is a sequence of symbols rather than a hierarchy. The hierarchy is inferred by grammatical analysis. This can be overcome by recognizing that a meronomy can, like a grammar, function as a generative model. Given an ordering for the elements in a meronomic unit, the unit generates a sequence; namely, the elements put into the specified order. Given all units in a headed meronomy are specified in this way, the structure itself generates a sequence. This is obtained by putting the elements of the root unit in the specified order, with the procedure applied recursively to any structured constituent.

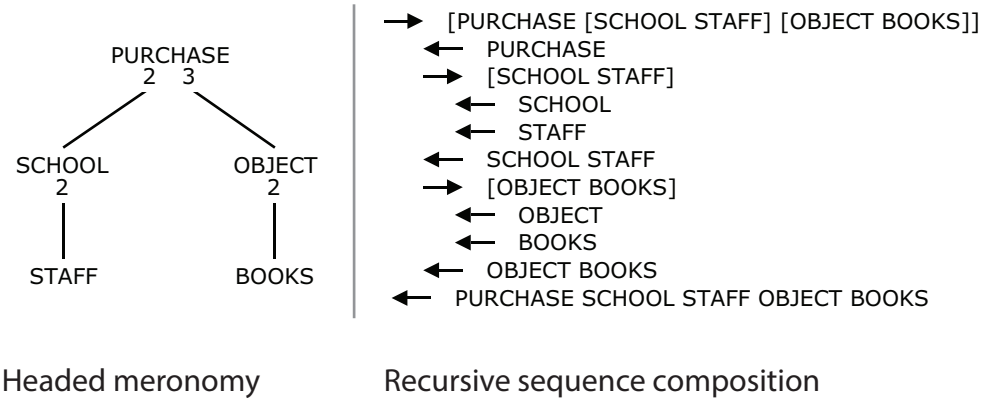

Figure 9: A headed meronomy viewed as a generative model for a sequence.

This way of using a headed meronomy is illustrated in Figure 9. In the left panel is a headed meronomy which makes BOOKS (classified as constitutive of an OBJECT) and STAFF (classified as constitutive of a SCHOOL) the constituents of a PURCHASE. The meaning obtained is that of a purchase of

books by staff of a school. Notice all units in the meronomy are given an ordering, indicated by the integer labels. The desired position of each constituent is specified at the top of its connecting line, with the head element being placed in the position that remains unfilled (labels counting up from 1). The specified ordering for the root unit thus places PURCHASE in position 1, SCHOOL in position 2, and OBJECT in position 3.

Given the specified orderings, the meronomy generates a sequence by recursive descent. The process is illustrated in the right panel of Figure 9, using bracketing and leftmost placement of heads to denote hierarchical structure. Lines starting with a right-arrow represent application of the procedure to the unit specified. Lines starting with a left-arrow represent the sequence obtained in a particular case. Indentation is used to represent recursive embedding, with the indentation increasing at each level of recursion. The sequence finally obtained (see the bottom line) is PURCHASE SCHOOL STAFF OBJECT BOOKS.

A connection to language can then be made by arranging for sequence-construction to use concept symbols rather than concept names. One way of doing this is shown in Figure 10. Here, a single-character symbol is specified for each concept. This appears to the right of the concept name, immediately after the colon. The symbol for PURCHASE is defined to be 'z', for example. Notice also that the root ordering in this case places the symbol for PURCHASE in third position, rather than first. Recursive sequence construction then proceeds as shown on the right. The final output obtained is *w x y v z*.

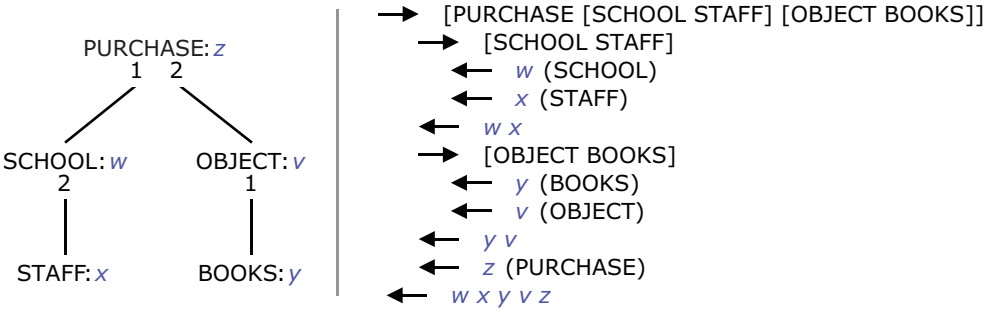

Figure 10: Recursive sequence composition using concept symbols.

This scheme can be viewed as a kind of language—albeit very simple—in the following sense. Given knowledge of the way concepts are symbolized, the ordering specifications, and the accommodative capacities of the concepts involved, there is only one interpretation of *w x y v a*. This is the headed meronomy from which the sequence was derived. The symbol sequence encodes, and thus conveys, the meaning the meronomy constructs. To make the same point in the other direction, consider the shorter sequence *y v z x*. It can be deduced that this can only encode the meronomy [PURCHASE STAFF [OBJECT BOOKS]]. In this case, STAFF and BOOKS (classified as OBJECT) are made constituents

of a PURCHASE. The meaning of the sequence is a purchase of books by staff, as opposed to a purchase of books by school staff.

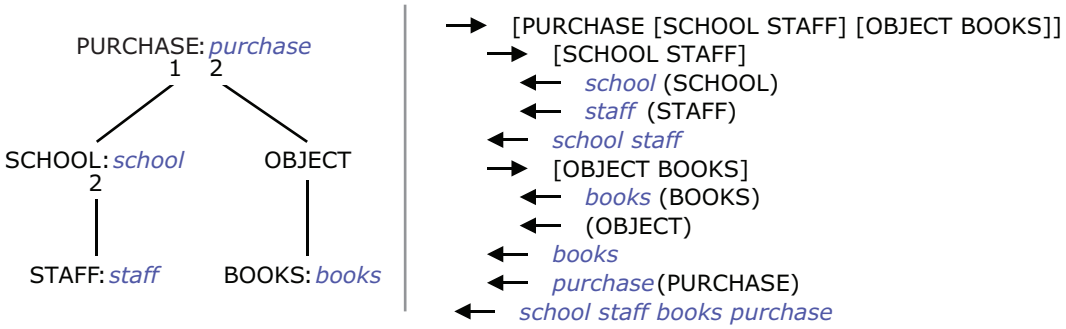

Figure 11: Recursive sequence composition using English symbols.

To further develop the example, we can specify meaningful English words as symbols. One way of doing this is shown in Figure 11. In this case, no symbol is given for OBJECT. Since its unit has a single constituent, this ensures the output generated for the unit is just the output generated for the constituent. The final sequence obtained is *school staff books purchase*. Again, this has an unambiguous meaning in the form of the meronomy from which it was generated. As an expression of English, it is obviously ungrammatical however. To obtain a grammatically correct, English expression of the underlying idea, we must modify the root ordering to ensure *purchase* is placed in second rather than third position, as in Figure 12. The sequence obtained is then the grammatically correct *school staff purchase books*. This expresses, in meaningful and grammatical English, the idea constructed by the meronomy: the purchase of books by school staff.

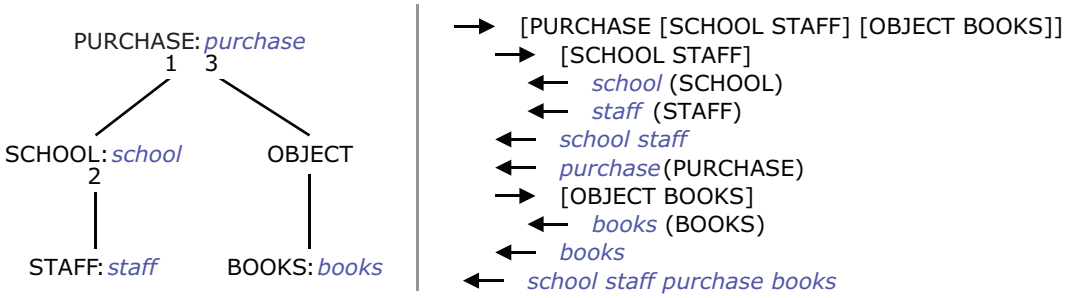

Figure 12: Composition of grammatical English.

What light does this shed on the relationship between language and the

meronomy? How does hierarchical meronomic construction relate to hierarchical grammatical construction? A natural syntactic analysis of *school staff purchase books* views *purchase* as a transitive verb (of SVO form), with *school staff* as subject, *books* as object, and *school* taken to be an adjective. This analysis is represented schematically in the left panel of Figure 12. This structure cannot be directly compared against the meronomic hierarchy, as it has ordered branches. The grammatical structure is more than a merely hierarchical specification. The two structures can be compared from the functional point of view, however.

With *purchase* taken to be a transitive verb, *school staff* is seen to be the subject within the action denoted by *purchase*, while *books* is the object. Subject and object are both made constituents within the action denoted by *purchase*. A meronomic structure that makes them constituents within the concept symbolized by *purchase* is then alike. But the root of the grammatical structure and the root of the meronomic structure can be equated in a stricter sense. Equipping the meronomic root with the specified ordering has the effect of establishing the ordering of constituents specified by the grammatical root. The two units are thus fully equivalent in their generative function. The subunit in the structure can then be related in the same way, as indicated in the top right of the figure.

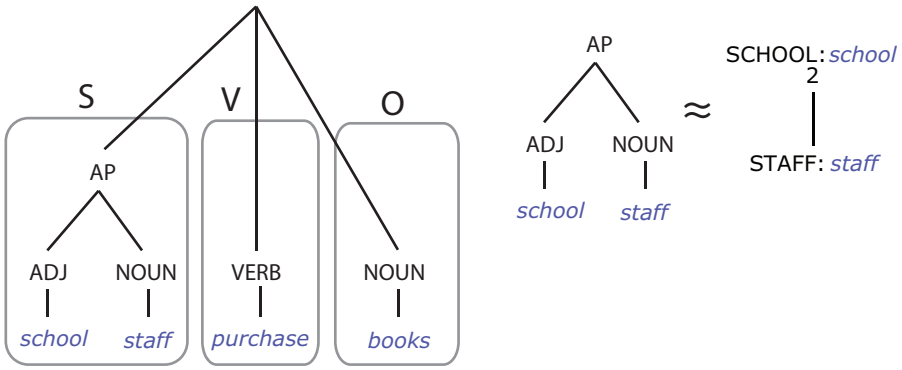

Figure 13: Grammatical structure.

The example hints at a close relationship between syntactic and meronomic structure. Given appropriate specification of orderings, the two are found to be essentially equivalent. Their generative behavior is identical. Grammatical rules, such as AP $\rightarrow$ ADJ NOUN, can be seen as a conjoined specification of sequence and structure, in which the structure is specified using syntactic labels. The meronomy, on the other hand, specifies structure and sequence separately. At the same time, it makes the structure a purely semantic formulation. On the grammatical view, a separate system is required to draw out the semantics. On

the meronomic view, semantics is nested within syntax. The meronomic view unifies syntax and semantics in this sense.

Questions of generality are clearly raised, however. Does this correspondence apply across the board, or just in this particular case? To find out, it is necessary to consider a broad range of cases, and a small study is set out in Appendix A. But the development of examples is not completely straightforward. In the case of written language, syntactic analysis organizes words and morphemes into a tree structure. As every word/morpheme has a meaning, the effect is to give meanings a hierarchical organization. It is also often possible to identity the grammatical head of any syntactic unit. For example, the ADJ would generally be seen to be the head of an ADJ NOUN structure. The grammatical head then typically corresponds to the conceptual head. The indications are, then, that we should be able to extract from any syntactic analysis an underlying headed meronomy. Once the implicit sequencing of the former is made explicit in the latter, the result should be an analysis that illustrates the envisaged correspondence.

The problem is that the meanings in question may be difficult to express in the form of concept names. This can obstruct the extraction of meronomic structure. Consider the word *the* for example. This has a meaning, and it is reasonable to suppose the meaning must have a mental concept. But what name should this concept be given? The simplest approach is to name the concept THE. The meaning constructed by *the men* can then be meronomically expressed as [THE MEN]. Unfortunately, this entails taking MEN to be classified as a constituent within a THE. A better approach is to introduce a new name, which captures the general meaning of the word. One might take the position that the concept induced by *the* is DEFINITE.ENTITY, for example. The meronomic form would then become [DEFINITE.ENTITY MEN], which makes MEN a constituent within a DEFINITE.ENTITY, which is less clumsy.

The naming problem arises more often than not. (The example set out above, involving a purchase of books by school staff, is a carefully contrived exception.) Verbs may induce concepts whose names deviate significantly from their textual form. Consider use of the verb *to like*, in the sentence *John likes Mary*. The verb in this context takes the third person, present form. The concept induced is that of some individual liking something in the present. But what name should it be given? The simple option of naming the concept LIKES leads to awkward descriptions as before. Again, a better approach is to introduce a new name which properly captures the concept in question. The concept might be named X.LIKES.Y, for example. This allows us to say that [X.LIKES.Y JOHN MARY] refers to a case of X.LIKES.Y in which the constituents are JOHN and MARY.

The problem is no less an obstacle in the case of morphological constructions. In the sentence *John liked Mary*, the verb *to like* is inflected for past tense by attachment of the suffix *+ed*. There are then two parts to the syntactic structure—the stem and the suffix—and the meronomic counterpart has two parts accordingly. One of these is the concept induced by *+ed*. But what name should be used? Can we name the concept PAST.BEHAVIOR perhaps? If so

then *liked* can be rendered meronomically as [PAST.BEHAVIOR X.LIKES.Y]. This refers to a PAST.BEHAVIOR in which X.LIKES.Y—the liking of X by Y—is a constituent.

In practice, demonstrating the connection between syntactic and meronomic structure faces some obstacles, then. Names must be given to the concepts induced by words and morphemes. There is no agreed way of doing this, and the tentative ideas set out above may be viewed as contentious. It would be premature to draw any final conclusions, then. The example developed above, together with the examples of Appendix A, may be seen as suggestive of an underlying relationship between syntax and meronomy. It may be that semantic structure is nested within syntactic structure as envisaged. It may be that semantic structure is essentially meronomic, and that syntactic structure is what emerges when sequences are obtained generatively from semantic structure enriched with sequential preferences. More work, both empirical and theoretical, is needed to determine the true situation, however.

4 Summary and concluding comments

Theorists agree that concepts can be organized hierarchically in just two ways: the taxonomy and the meronomy. In general, meronomies can incorporate abstract/relational concepts, head concepts and singly constituted units. As such, they are not just a way of representing part-whole relations—they are also a way of building complex meanings by hierarchical construction. Understood this way, the headed meronomy is seen to be a semantic formalism in effect.

The potential connection to language then becomes of interest. Languages are seen to construct complex meanings by placing individual bearers of meaning (e.g., words and morphemes) into tree structures. As trees are hierarchical, there is the question of how this compares to meronomic construction of meaning. How does hierarchical construction of meaning by meronomy relate to linguistic construction of meaning?

The present article sets out some evidence suggestive of an intimate relationship. Cases can be identified where grammatical syntax stems from conjoining structural and sequential aspects of a headed meronomy. One example was set out above, and more are presented in Appendix A. With the relationship understood this way, semantics is seen to be nested within syntax. To put it the other way around, the sequence-specific headed meronomy is found to separate syntactic structure into two parts: one specifically sequential and one specifically semantic. With this done, semantic analysis becomes an integral part of syntactic analysis, and vice versa.

Whether this relationship exists more generally requires further examination of concrete cases. Any such investigation entails giving names to the mental concepts induced by the (meanings of) words and morphemes. There is no standard way of doing this, and theorists may disagree as to whether it can be done at all. At present, then, the conclusion can only be that the headed meronomy is *potentially* connected to language in the envisaged way.

Appendix A: Worked examples

The examples presented below are based on analyses taken from the current incarnation of the World Atlas of Syntactic Structures (Dryer and Haspelmath, 2011), identified by the aconym 'WALS' below. Each example demonstrates meronomic composition of a grammatical sentence in a different language.

1. Japanese illustration

Consider the sentence 'John read the letter.' This expresses the idea of John reading a specific letter some time in the past. More specifically, it expresses the idea of a past reading action in which the constituents were John and a letter, classified as a definite entity. Accordingly, the meaning can be constructed meronomically as in the left panel of Figure 14. Notice that here, the head concept of the root unit is itself meronomically constructed, as shown in the inserted panel.

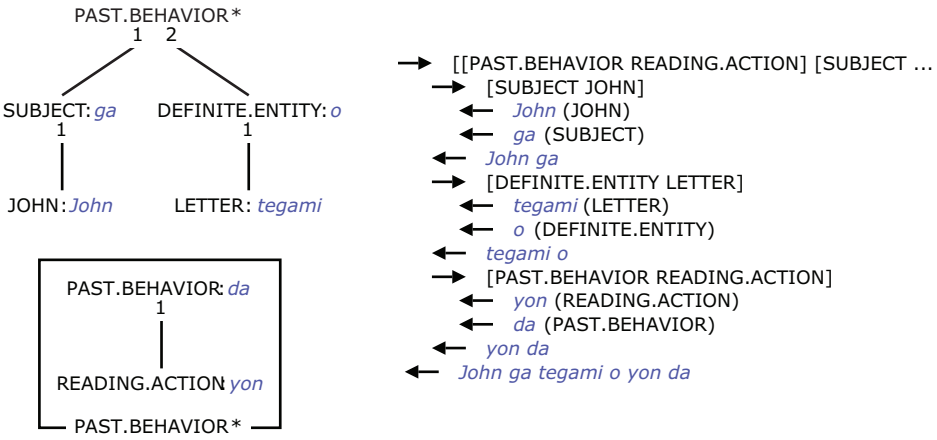

Figure 14: Meronomic derivation of a Japanese sentence.

Translated into Japanese, the sentence becomes *Johnga tegamio yonda*, which may be analysed as follows (WALS, Ch. 82, Ex. 2.).

John-ga	*tegami-o*	*yon-da*
John-SUBJ	letter-OBJ	read-PST

'John read the letter'

With word-breaks imposed, the generative output derived from the meronomy using the specified symbols and orderings is the relevant Japanese sentence. The generative process is represented schematically in the right panel of Fig-

ure 14. Here and below, lines in a sequence composition may be truncated for length.

2. Arawak illustration

Consider the sentence 'yesterday a man gave cassava bread to me'. This expresses the idea of an event occurring yesterday constituted of a giving action, for which the constituents were an indefinite man, cassava bread and 'me'. The meaning can thus be constructed meronomically, as in Figure 15.

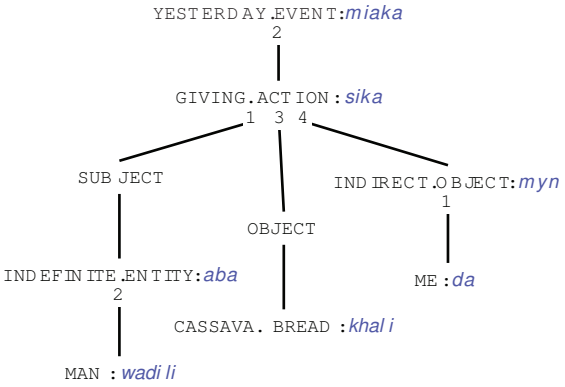

Figure 15: Meronomic construction of the meaning of 'yesterday a man gave cassava bread to me'.

Translated into the Suriname language of Arawak, the sentence becomes *Miaka aba wadili sika khali damyn*, which may be analysed as follows (WALS, Ch. 84, Ex. 4.).

Miaka	*aba*	*wadili*	*sika*	*khali*	*da-myn*
yesterday	INDEF	man	give	cassava.bread	1SG-to

'Yesterday a man gave cassava.bread to me'

Given the specified orderings and symbols, construction of the sentence by recursive sequence composition then proceeds as shown in Figure 16. With word-breaks imposed, the output obtained is the relevant Arawak sentence.

3. Panjyma illustration

Consider the sentence 'that lizard will eat the meat'. This states that a distally located lizard will eat some specific meat, some time in the future. The meaning is that of a future eating action in which the constituents are a lizard (classified

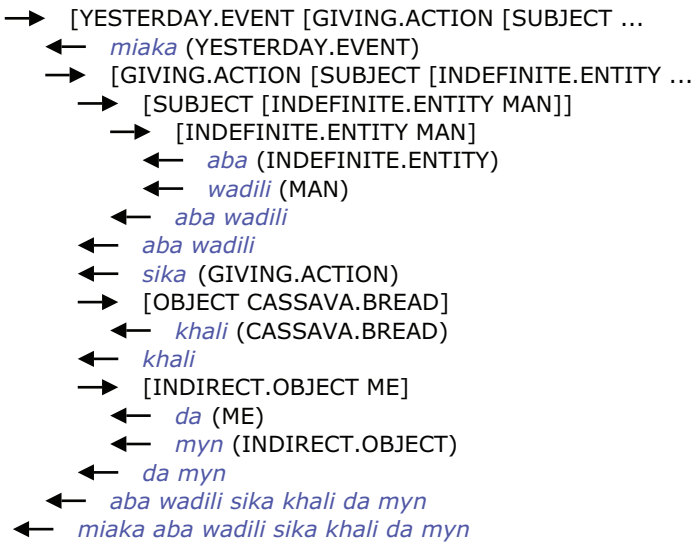

Figure 16: Meronomic derivation of an Arawak sentence.

as distal) and meat (classified as a definite entity). Letting the concept induced by the verb *to eat* be named X.EATS.Y, the meaning can be constructed meronomically as in the left panels of Figure 17. Again, the root concept is meronomically constructed, as shown in the bottom-left panel.

Translated into the language of Panjyma, the sentence becomes *Ngunha parnka ngarna-rta mantu-yu*, which may be analyzed as follows (Dench, 1991, p. 193; see also WALS-13 Ch. 105, Ex. 2).

Ngunha	*parnka*	*ngarna-rta*	*mantu-yu*
DEM	lizard	eat-FUT	meat-ACC

'That lizard will eat the meat'

Given the specified symbols and orderings, the generative output obtained from the meronomy is as shown in the right panel of Figure 17. With word-breaks imposed, this is the relevant Panjyma sentence.

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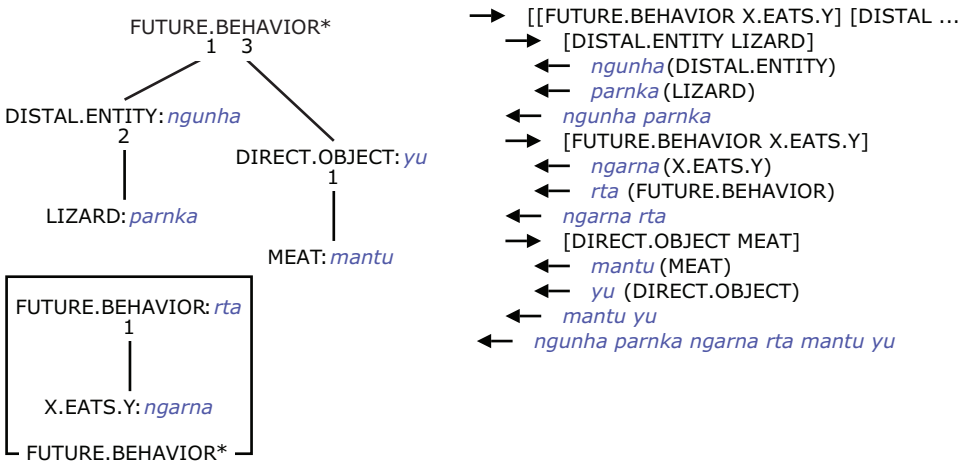

Figure 17: Meronomic derivation of a Panjyma sentence.

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