Nouns in WordNet: A Lexical Inheritance System

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Definitions of common nouns typically give a superordinate term plus distinguishing features; that information provides the basis for organizing noun files in WordNet. The superordinate relation (hyponymy) generates a hierarchical semantic organization that is duplicated in the noun files by the use of labeled pointers between sets of synonyms (synsets). The hierarchy is limited in depth, seldom exceeding more than a dozen levels. Distinguishing features are entered in such a way as to create a lexical inheritance system, a system in which each word inherits the distinguishing features of all its superordinates. Three types of distinguishing features are discussed: attributes (modification), parts (meronymy), and functions (predication), but only meronymy is presently implemented in the noun files. Antonymy is also found between nouns, but it is not a fundamental organizing principle for nouns.

Coverage is partitioned into twenty-five topical files, each of which deals with a different primitive semantic component.

As this is written, WordNet contains approximately 57,000 noun word forms organized into approximately 48,800 word meanings (synsets). The numbers are approximate because WordNet continues to grow—one advantage of an on-line database. Many of these nouns are compounds, of course; a few are artificial collocations invented for the convenience of categorization. No attempt has been made to include proper nouns; on the other hand, since many common nouns once were names, no serious attempt has been made to exclude them. In terms of coverage, WordNet's goals differ little from those of a good standard handheld collegiate-level dictionary. It is in the organization of that information that WordNet aspires to innovation.

If someone asks how to use a conventional dictionary, it is customary to explain the different kinds of information packed into lexical entries: spelling, pronunciation, inflected and derivative forms, etymology, part of speech, definitions and illustrative uses of alternative senses, synonyms and antonyms, special usage notes, occasional line drawings or plates—a good dictionary is a remarkable store of information. But if someone asks how to improve a dictionary, it becomes necessary to consider what is not included. And when, as in the case of WordNet, improvements are intended to reflect psycholinguistic principles, the focal concern becomes what is not included in the definitions.

Examples offer the simplest way to characterize the omissions. Take one meaning of the noun *tree*, the sense having to do with trees as plants. Conventional dictionaries define this sense of *tree* by some such gloss as: *a plant that is large, woody, perennial, and has a distinct trunk*. Of course, the actual wording is usually more felicitous—*a large, woody, perennial plant with a distinct trunk*, for example—but the underlying logic is the same: superordinate plus distinguishers. The point is that the prototypical definition of a noun consists of its immediate superordinate (*plant*, in this example), followed by a relative clause that describes how this instance differs from all other instances.

What is missing from this definition? Anyone educated to expect this kind of thing in a dictionary will not feel that anything is missing. But the definition is woefully incomplete. It does not say, for example, that trees have roots, or that they consist of cells having cellulose walls, or even that they are living organisms. Of course, if you look up the superordinate term, *plant*, you may find that kind of information—unless, of course, you make a mistake and choose the definition of *plant* that says it is a place where some product is manufactured. There is, after all, nothing in the definition of *tree* that specifies which sense of *plant* is the appropriate superordinate. That specification is omitted on the assumption that the reader is not an idiot, a Martian, or a computer. But it is instructive to note that, even though intelligent readers can supply it for themselves, important information about the superordinate term is missing from the definition.

Second, this definition of *tree* contains no information about coordinate terms. The existence of other kinds of plants is a plausible conjecture, but no help is given in finding them. A reader curious about coordinate terms has little alternative but to scan the dictionary from A to Z, noting along the way each occurrence of a definition with the superordinate term *plant*. Even this heroic strategy might not succeed if the lexicographers, not expecting such use of their work, did not maintain strict uniformity in their choice of superordinate terms. *Tree* is probably an unfair example in this respect, since the distinction between trees and bushes is so unclear—the same plant that grows into a tall tree in one location may be little more than a bush in a less favorable climate. Botanists have little use for the lay term *tree*—many trees are gymnosperms, many others angiosperms. Even for well-behaved definitions, however, a conventional dictionary leaves the discovery of coordinate terms as a challenging exercise for the reader.

Third, a similar challenge faces a reader who is interested in knowing the different kinds of trees. In addition to looking through the dictionary for such familiar trees as pine or maple or oak, a reader might wish to know which trees are deciduous, which are hardwoods, or how many different kinds of conifers there are. Dictionaries contain much of this information, but only the most determined reader would try to dig it out. The prototypical definition points upward, to a superordinate term, not sideways to coordinate terms or downward to hyponyms.

Fourth, everyone knows a great deal about trees that lexicographers would not include in a definition of *tree*. For example, trees have bark and twigs, they grow from seeds, adult trees are much taller than human beings, they manufacture their own food by photosynthesis, they provide shade and protection from the wind, they grow wild in forests, their wood is used in construction and for fuel, and so on. Someone who was totally innocent about trees would not be able to construct an accurate concept of them if nothing more were available than the information required to define *tree*. A dictionary definition draws some important distinctions and serves to remind the reader of something that is presumed to be familiar already; it is not intended as a catalogue of general knowledge. There is a place for encyclopedias as well as dictionaries.

Note that much of the missing information is structural, rather than factual. That is to say, lexicographers make an effort to cover all of the factual information about the meanings of each word, but the organization of the conventional dictionary into discrete, alphabetized entries and the economic pressure to minimize redundancy make the reassembly of this scattered information a formidable chore.

Lexical Inheritance Systems

It has often been observed that lexicographers are caught in a web of words. Sometimes it is posed as a conundrum: since words are used to define words, how can lexicography escape circularity? Every dictionary probably contains a few vacuous circles, instances where word W_a is used to define word W_b and W_b is also used to define W_a; in such cases, presumably, the lexicographer inadvertently overlooked the need to define one or the other of these synonyms in terms of something else. Circularity is the exception, not the rule.

The fundamental design that lexicographers try to impose on the semantic memory for nouns is not a circle, but a tree (in the sense of *tree* as a graphical representation). It is a defining property of tree graphs that they branch from a single stem without forming circular loops. The lexical tree can be reconstructed by following trails of superordinate terms: *oak* @→ *tree* @→ *plant* @→ *organism*, for example, where '@→' is the transitive, asymmetric, semantic relation that can be read 'is a' or 'is a kind of.' (By convention, '@→' is said to point upward.) This design creates a sequence of levels, a hierarchy, going from many specific terms at the lower levels to a few generic terms at the top. Hierarchies provide conceptual skeletons for nouns; information about individual nouns is hung on this structure like ornaments on a Christmas tree.

The semantic relation that is represented above by '@→' has been called the ISA relation, or the hypernymic or superordinate relation (since it points to a hypernym or superordinate term); it goes from specific to generic and so is a generalization. Whenever it is the case that a noun W_h @→ a noun W_s, there is always an inverse relation, W_s ~→ W_h. That is to say, if W_s is the superordinate of W_h, then W_h is the subordinate or hyponym of W_s. The inverse semantic relation '~→' goes from generic to specific (from superordinate to hyponym) and so is a specialization.

Since a noun usually has a single superordinate, dictionaries include the superordinate in the definition; since a noun can have many hyponyms, English dictionaries do not list them (the French dictionary *Le Grand Robert* is an exception). Even though the specialization relation is not made explicit in standard dictionaries of English, it is a logical derivative of the generalization relation. In WordNet, lexicographers code the generalization relation '@→' explicitly with a labeled pointer between lexical concepts or senses. When the lexicographers' files are converted automatically into the lexical database, one step in this process is to insert inverse pointers for the specialization relation '~→'. Thus, the lexical database is a hierarchy that can be searched upward or downward with equal speed.

Hierarchies of this sort are widely used by computer programmers to organize large databases (Touretzky, 1986). They have the advantage that information common to many items in the database need not be stored with every item. In other words, database experts and lexicographers both resort to hierarchical structures for the same reason: to save space. Computer scientists call such hierarchies ‘‘inheritance systems,’’ because they think of specific items inheriting information from their generic superordinates. That is to say, all of the properties of the superordinate are assumed to be properties of the subordinate as well; instead of listing those properties redundantly with both items, they are listed only with the superordinate and a pointer from the subordinate to the superordinate is understood to mean ‘‘for additional properties, look here.’’

Inheritance is most easily understood for names. If you hear that your friend has acquired a collie named Rex, you do not need to ask whether Rex is an animal, whether Rex has hair, four legs, and a tail, or whether Rex shares any other properties known to characterize collies. Such questions would be distinctly odd. Since you have been told that Rex is a collie, you are expected to understand that Rex inherits all the properties that define *collie*. And, implicitly, that *collie* inherits the properties of *dog*, which inherits the properties of of *canine*, and so on.

Clearly, an inheritance system is implicit in the prototypical lexicographic definition of a noun. A lexicographer does not store the information that is common to *tree* and *plant* with both entries; the lexicographer stores the redundant information only with *plant*, then writes the definition of *tree* in such a way that a reader will know where to find it. With a printed dictionary, however, a user must look up repeated entries in order to find information that can be instantly retrieved and displayed by a computer.

WordNet is a lexical inheritance system; a systematic effort has been made to connect hyponyms with their superordinates (and vice versa). In the WordNet database, an entry for *tree* contains a reference, or pointer ‘@→,’ to an entry for *plant*; the pointer is labeled ‘‘superordinate’’ by the arbitrary symbol ‘@.’ Thus, the synset for tree would look something like:

{ *tree, plant,@ conifer,~ alder,~* . . . }

where the ‘. . .’ is filled with many more pointers to hyponyms. In the database, the pointer ‘@’ to the superordinate *plant* will be reflected by an inverse pointer ‘~’ to *tree* in the synset for *plant*; that pointer is labeled ‘‘hyponym’’ by the arbitrary symbol ‘~’:

{ *plant, flora, organism,@ tree,~* . . . }

{*tree*} is not the only hyponym of {*plant, flora*}, of course; others have been omitted here in order not to obscure the reciprocity of ‘@’ and ‘~’. The computer is programmed to use these labeled pointers to construct whatever information a user requests; the arbitrary symbols ‘@’ and ‘~’ are suppressed when the requested information is displayed. (There is no need for special tags on *tree* or *plant*, to distinguish which senses are intended because nouns denoting living plants are all in one file, whereas nouns denoting graphical trees or manufacturing plants are elsewhere, as will be explained below.)

It should be noted, at least parenthetically, that WordNet assumes that a distinction can always be drawn between synonymy and hyponymy. In practice, of course, this distinction is not always clear, but in a conventional dictionary that causes no problems. For example, a conventional dictionary can include in its entry for *board* the information that this term can be used to refer to surf boards or to skate boards. That is to say, in addition to the generic meaning of *board*, there are specific meanings of *board* that are hyponyms of the generic meaning. If the information were entered this way in WordNet, however, then a request for information about the superordinates of *board* would elicit the same path twice, the only difference being that one path would be prefaced by {*surf board, board*} @→ *board*. In WordNet, therefore, an effort has been made to avoid entries in which a term is its own hyponym. Thus, for example, *cat* is entered in WordNet as the superordinate of *big cat* and *house cat*, even though to most people the primary sense of *cat*—the meaning that comes first to mind—is {*house cat, tabby, pussy, pussy cat, domesticated cat*}. WordNet does not make explicit the fact that *cat* is frequently used to refer to pet cats, but relies on general linguistic knowledge that a superordinate term can replace a more specific term whenever the context insures that no confusion will result.

What benefits follow from treating lexical knowledge as an inheritance system? In the introduction to this paper, four examples of information missing from conventional definitions were described. Of those four, the first three can be repaired by the judicious use of labeled pointers; with a computer it is as easy to move from superordinate to hyponyms as it is to move from hyponym to superordinate. The fourth omission—of all the associated general knowledge about a referent that is not given in a term's definition—stands uncorrected in WordNet; somewhere a line must be drawn between lexical concepts and general knowledge, and WordNet is designed on the assumption that the standard lexicographic line is probably as distinct as any could be.

Psycholinguistic Assumptions

Since WordNet is supposed to be organized according to principles governing human lexical memory, the decision to organize the nouns as an inheritance system reflects a psycholinguistic judgment about the mental lexicon. What kinds of evidence provide a basis for such decisions?

The isolation of nouns into a separate lexical subsystem receives some support from clinical observations of patients with anomic aphasia. After a left-hemisphere stroke that affects the ability to communicate linguistically, most patients are left with a deficit in naming ability (Caramazza and Berndt, 1978). In anomic aphasia, there is a specific inability to name objects. When confronted with an apple, say, patients may be unable to utter ‘‘apple,’’ even though they will reject such suggestions as *shoe* or *banana*, and will recognize that *apple* is correct when it is provided. They have similar difficulties in naming pictured objects, or in providing a name when given its definition, or in using nouns in spontaneous speech. Nouns that occur frequently in everyday usage tend to be more accessible than are rarely used nouns, but a patient with severe anomia looks for all the world like someone whose semantic memory for nouns has become disconnected from the rest of the lexicon. However, clinical symptoms are characterized by great variability from one patient to the next, so no great weight should be assigned to such observations.

Psycholinguistic evidence that knowledge of nouns is organized hierarchically comes from the ease with which people handle anaphoric nouns and comparative constructions. (1) Superordinate nouns can serve as anaphors referring back to their hyponyms. For example, in such constructions as *He owned a rifle, but the gun had not been fired*, it is immediately understood that *the gun* is an anaphoric noun with *a rifle* as its antecedent. Moreover, (2) superordinates and their hyponyms cannot be compared (Bever and Rosenbaum, 1970). For example, both *A rifle is safer than a gun* and *A gun is safer than a rifle* are immediately recognized as semantically anomalous. Such judgments demand an explanation in terms of hierarchical semantic relations.

More to the point, however, is the question: is there psycholinguistic evidence that people's lexical memory for nouns forms an inheritance system? The first person to make this claim explicit seems to have been Quillian (1967, 1968). Experimental tests of Quillian's proposal were reported in a seminal paper by Collins and Quillian (1969), who assumed that reaction times can be used to indicate the number of hierarchical levels separating two meanings. They observed, for example, that it takes less time to respond True to ‘‘A canary can sing’’ than to ‘‘A canary can fly,’’ and still more time is required to respond True to ‘‘A canary has skin.’’ In this example, it is assumed that *can sing* is stored as a feature of *canary*, *can fly* as a feature of *bird*, and *has skin* as a feature of *animal*. If all three features had been stored directly as features of *canary*, they could all have been retrieved with equal speed. The reaction times are not equal because additional time is required to retrieve *can fly* and *has skin* from the superordinate concepts. Collins and Quillian concluded from such observations that generic information is not stored redundantly, but is retrieved when needed. (In WordNet, the hierarchy is: *canary @→ finch @→ passerine @→ bird @→ vertebrate @→ animal*, but these intervening levels do not affect the general argument that Collins and Quillian were making.)

Most psycholinguists agree that English common nouns are organized hierarchically in semantic memory, but whether generic information is inherited or is stored redundantly is still moot (Smith, 1978). The publication of Collins and Quillian's (1969) experiments stimulated considerable research, in the course of which a number of problems were raised. For example, according to Quillian's theory, *robin* and *ostrich* share the same kind of semantic link to the superordinate *bird*, yet ‘‘A robin is a bird’’ is confirmed more rapidly than is ‘‘An ostrich is a bird’’ (Wilkins, 1971). Or, again, *can move* and *has ears* are both properties that people associate with *animal*, yet ‘‘An animal can move’’ is confirmed more rapidly than is ‘‘An animal has ears’’ (Conrad, 1972). From these and similar results, many psycholinguists concluded that Quillian was wrong, that semantic memory for nouns is not organized as an inheritance system.

An alternative conclusion—the conclusion on which WordNet is based—is that the inheritance assumption is correct, but that reaction times do not measure what Collins and Quillian, and other experimentalists assumed they did. Perhaps reaction times indicate a pragmatic rather than a semantic distance—a difference in word use, rather than a difference in word meaning (Miller and Charles, 1991).

Semantic Components

One way to construe the hierarchical principle is to assume that all nouns are contained in a single hierarchy. If so, the topmost, or most generic level would be semantically empty. In principle, it is possible to put some vague abstraction designated, say, {*entity*}, at the top; to make {*object, thing*} and {*idea*} its immediate hyponyms, and so to continue down to more specific meanings, thus pulling all nouns together into a single hierarchical memory structure. In practice, however, these abstract generic concepts carry little semantic information; it is doubtful that people could even agree on appropriate words to express them.

The alternative is to partition the nouns with a set of semantic primes—to select a (relatively small) number of generic concepts and to treat each one as the unique beginner of a separate hierarchy. These multiple hierarchies correspond to relatively distinct semantic fields, each with its own vocabulary. That is to say, since the features that characterize a unique beginner are inherited by all of its hyponyms, a unique beginner can be regarded as a primitive semantic component of all words in its hierarchically structured semantic field. Partitioning the nouns also has practical advantages: it reduces the size of the files that the lexicographers must work with, and makes it possible to assign the writing and editing of different files to different lexicographers.

Table 1
List of 25 unique beginners for WordNet nouns

{*act, action, activity*}	{*natural object*}
{*animal, fauna*}	{*natural phenomenon*}
{*artifact*}	{*person, human being*}
{*attribute, property*}	{*plant, flora*}
{*body, corpus*}	{*possession*}
{*cognition, knowledge*}	{*process*}
{*communication*}	{*quantity, amount*}
{*event, happening*}	{*relation*}
{*feeling, emotion*}	{*shape*}
{*food*}	{*state, condition*}
{*group, collection*}	{*substance*}
{*location, place*}	{*time*}
{*motive*}	

The problem, of course, is to decide what these primitive semantic components should be. Different workers make different choices; one important criterion is that, collectively, they should provide a place for every English noun. WordNet has adopted the set of twenty-five unique beginners that are listed in Table 1. These hierarchies vary widely in size and are not mutually exclusive—some cross-referencing is required—but on the whole they cover distinct conceptual and lexical domains. They were selected after considering the possible adjective-noun combinations that could be expected to occur (that analysis was carried out by Philip N. Johnson-Laird). The rationale will be discussed below.

Once the primitive semantic components had been chosen, however, some natural groupings among them were observed. Seven of the components, for example, were concerned with living or non-living things; they could be arranged hierarchically as diagrammed in Figure 1. Accordingly, a small ‘Tops’ file was created in order to include these semantic relations in the system. However, the great bulk of WordNet’s nouns are contained in the twenty-five component files.

Figure 1. Diagrammatic representation of hyponymic relations among seven unique beginners denoting different kinds of tangible things.

		{*plant, flora*}
	{*living thing, organism*}	{*animal, fauna*}
		{*person, human being*}
{*thing, entity*}		
		{*natural object*}
		{*artifact*}
	{*non-living thing, object*}	{*substance*}
		{*food*}

It is of some interest that these files are relatively shallow. In principle, of course, there is no limit to the number of levels an inheritance system can have. Lexical inheritance systems, however, seldom go more than ten levels deep, and the deepest examples usually contain technical levels that are not part of the everyday vocabulary. For example, a Shetland pony is a pony, a horse, an equid, an odd-toed ungulate, a herbivore, a mammal, a vertebrate, and an animal; pursuing it into the Tops file adds organism and entity: eleven levels, most of them technical. Some hierarchies are deeper than others: man-made artifacts sometimes go six or seven levels deep (*roadster @→ car @→ motor vehicle @→ wheeled vehicle @→ vehicle @→ conveyance @→ artifact*), whereas the hierarchy of persons runs about three or four (one of the deepest is *televangelist @→ evangelist @→ preacher @→ clergyman @→ spiritual leader @→ person*). Advocates of redundant storage of the information associated with these concepts point out that the more generic information would be repeated over and over in a redundant system, so each additional level would put an increasingly severe burden on lexical memory—a possible reason that the number of levels is limited.

Distinguishing Features

These hierarchies of nominal concepts are said to have a level, somewhere in the middle, where most of the distinguishing features are attached. It is referred to as the basic level, and the nominal concepts at this level are called basic-level categories or generic concepts (Berlin, Breedlove, and Raven, 1966, 1973). Rosch (1975; Rosch, Mervis, Gray, Johnson, and Boyes-Braem, 1976) extended this generalization: for concepts at the basic level, people can list many distinguishing features. Above the basic level, descriptions are brief and general. Below the base level, little is added to the features that distinguish basic concepts. These observations have been made largely for the names of concrete, tangible objects, but some psycholinguists have argued that a base or primary level should be a feature of every lexical hierarchy (Hoffman and Ziessler, 1983).

Although the overall structure of noun hierarchies is generated by the hyponymy relation, details are given by the features that distinguish one concept from another. For example, a canary is a bird that is small, colorful, sings, and flies, so not only must *canary* be entered as a hyponym of *bird*, but the attributes of small size and bright color must also be included, as well as the activities of singing and flying. Moreover, *canary* must inherit from *bird* the fact that it has a beak and wings with feathers. In order to make all of this information available when *canary* is activated, it must be possible to associate *canary* appropriately with at least three different kinds of distinguishing features (Miller, in press):

(1) Attributes: *small, yellow*

(2) Parts: *beak, wings*

(3) Functions: *sing, fly*

Each type of distinguishing feature must be treated differently.

Note that attributes are given by adjectives, parts by nouns, and functions by verbs. If the association of *canary* with each of these features is to be represented in WordNet by labeled pointers, then pointers will be required from nouns to adjectives and from nouns to verbs. As this is written, allowance has been made for including such pointers in WordNet, but the possibility has not yet been coded by the lexicographers; only the pointers to parts, which go from nouns to nouns, have been implemented.

When WordNet was first conceived, it was not intended to include information about distinguishing features. It was assumed that WordNet would be used in close conjunction with some on-line dictionary, and that the distinguishing features of a lexical concept would be available from that source. As the coverage of WordNet increased, it became increasingly obvious that alternative senses of a word could not always be identified by the use of synonyms. Rather late in the game, therefore, it was decided to include distinguishing features in the same way that conventional dictionaries do, by including short explanatory glosses as a part of synsets containing polysemous words. These are marked off from the rest of the synset by parentheses. For example, the {*artifact*} hierarchy in WordNet contains eight different senses of the highly polysemous noun *case*:

{*carton, case0, box,@* (a box made of cardboard; opens by flaps on the top)}

{*case1, bag,@* (a portable bag for carrying small objects)}

{*case2, pillowcase, pillowslip, slip2, bed linen,@* (a removable and washable cover for a pillow)} {*bag1, case3, grip, suitcase, traveling bag*,@ (a portable rectangular traveling bag for carrying clothes)}

{*cabinet, case4, console, cupboard*,@ (a cupboard with doors and shelves)}

{*case5, container*,@ (a small portable metal container)}

{*shell, shell plating, case6, casing1, outside surface*,@ (the outer covering or housing of something)}

{*casing, case7, framework*,@ (the enclosing frame around a door or window opening)}

The parenthetical glosses serve to keep the several senses distinct, but a certain redundancy is apparent between the superordinate concepts, indicated by '@,' and the head words of the defining gloss. As more distinguishing features come to be indicated by pointers, these glosses should become even more redundant. An imaginable test of the system would then be to write a computer program that would synthesize glosses from the information provided by the pointers.

At the present time, however, attributive and functional features are not available for many words, and where they are available, it is in the form of defining glosses, not labeled pointers to the appropriate adjectives or verbs. But part-whole relations are available in WordNet; experience with these distinguishing features should provide a basis for the future implementation of cross-part-of-speech pointers.

Attributes and Modification

Values of attributes are expressed by adjectives. For example, size and color are attributes of canaries: the size of canaries can be expressed by the adjective *small*, and the usual color of canaries can be expressed by the adjective *yellow*. There is no semantic relation comparable to synonymy or hyponymy that can serve this function, however. Instead, adjectives are said to modify nouns, or nouns are said to serve as arguments for attributes: Size(*canary*) = *small*.

Although the possibility has not yet been implemented in WordNet, the fact that a canary is small could be represented by a labeled pointer in much the same way as the fact that a canary is a bird is represented. Formally, the difference is that there would be no return pointer from *small* back to *canary*. That is to say, although people will list *small* when asked for the features of canaries, when asked to list small things they are unlikely to group together canaries, pygmies, ponies, and closets. The pointer from *canary* to *small* is interpreted with respect to the immediate superordinate of *canary*, i.e., *small for a bird*, but that anchor to a head noun is lost when *small* is accessed alone.

The semantic structure of adjectival concepts is discussed by Gross and Miller (this volume). Here it is sufficient to point out that the attributes associated with a noun are reflected in the adjectives that can normally modify it. For example, a canary can be hungry or satiated because hunger is a feature of animals and canaries are animals, but *a stingy canary* or *a generous canary* could only be interpreted metaphorically, since generosity is not a feature of animals in general, or of canaries in particular. Keil (1979, 1983) has argued that children learn the hierarchical structure of nominal concepts by observing what can and cannot be predicated at each level. For example, the important semantic distinction between animate and inanimate nouns derives from the fact that the adjectives *dead* and *alive* can be predicated of one class of nouns but not of the other. Although such selectional restrictions on adjectives are not represented explicitly in WordNet, they did motivate the partitioning of the nouns into the twenty-five semantic components listed above.

Parts and Meronymy

The part-whole relation between nouns is generally considered to be a semantic relation, called meronymy (from the Greek *meros*, part; Cruse, 1986), comparable to synonymy, antonymy, and hyponymy. The relation has an inverse: if W_m is a meronym of W_h, then W_h is said to be a holonym of W_m.

Meronyms are distinguishing features that hyponyms can inherit. Consequently, meronymy and hyponymy become intertwined in complex ways. For example, if *beak* and *wing* are meronyms of *bird*, and if *canary* is a hyponym of *bird*, then, by inheritance, *beak* and *wing* must also be meronyms of *canary*. Although the connections may appear complex when dissected in this manner, they are rapidly deployed in language comprehension. For example, most people do not even notice the inferences required to establish a connection between the following sentences: *It was a canary*. *The beak was injured*. Of course, after *canary* has inherited *beak* often enough, the fact that canaries have beaks may come to be stored redundantly with the other features of *canary*, but that possibility does not mean that the general structure of people's lexical knowledge is not organized hierarchically.

The connections between meronymy and hyponymy are further complicated by the fact that parts are hyponyms as well as meronyms. For example, {*beak, bill, neb*} is a hyponym of {*mouth, muzzle*}, which in turn is a meronym of {*face, countenance*} and a hyponym of {*orifice, opening*}. A frequent problem in establishing the proper relation between hyponymy and meronymy arises from a general tendency to attach features too high in the hierarchy. For example, if *wheel* is said to be a meronym of *vehicle*, then sleds will inherit wheels they should not have. Indeed, in WordNet a special synset was created for the concept, {*wheeled vehicle*}.

It has been said that distinguishing features are introduced into noun hierarchies primarily at the level of basic concepts; some claims have been made that meronymy is particularly important for defining basic terms (Tversky and Hemenway, 1984). Tests of these claims, however, have been concerned primarily with words denoting physical objects, which is where meronyms tend to occur most frequently. In WordNet, meronymy is found primarily in the {*body, corpus*}, {*artifact*}, and {*quantity, amount*} hierarchies. For concrete objects like bodies and artifacts, meronyms do indeed help to define a basic level. No such level is apparent for terms denoting quantities, however, where small units of measurement are parts of larger units at every level of the hierarchy. Since attributes and functions have not yet been coded, no attempt has been made to see whether a basic level can be defined for the more abstract hierarchies.

The ‘‘part of’’ relation is often compared to the ‘‘kind of’’ relation: both are asymmetric and (with reservations) transitive, and can relate terms hierarchically (Miller and Johnson-Laird, 1976). That is to say, parts can have parts: a finger is a part of a hand, a hand is a part of an arm, an arm is a part of a body: the term *finger* is a meronym of the term *hand*, *hand* is a meronym of *arm*, *arm* is a meronym of *body*. But the ‘‘part of’’ construction is not always a reliable test of meronymy. A basic problem with meronymy is that people will accept the test frame, ‘‘W_m is a part of W_h,’’ for a variety of part-whole relations.

In many instances transitivity seems to be limited. Lyons (1977), for example, notes that *handle* is a meronym of *door* and *door* is a meronym of *house*, yet it sounds odd to say ‘‘The house has a handle’’ or ‘‘The handle is a part of the house.’’ Winston, Chaffin, and Hermann (1987) take such failures of transitivity to indicate that different part-whole relations are involved in the two cases. For example, ‘‘The branch is a part of the tree’’ and ‘‘The tree is a part of a forest’’ do not imply that ‘‘The branch is a part of the forest’’ because the *branch/tree* relation is not the same as the *tree/forest* relation. For Lyons’ example, they suggest, following Cruse (1986), that ‘‘part of’’ is sometimes used where ‘‘attached to’’ would be more appropriate: ‘‘part of’’ should be transitive, whereas ‘‘attached to’’ is clearly not. ‘‘The house has a door handle’’ is acceptable because it negates the implicit inference in ‘‘The house has a handle’’ that the handle is attached to the house.

Such observations raise questions about how many different ‘‘part of’’ relations there are. Winston et al. (1987) differentiate six types of meronyms: component-object (*branch/tree*), member-collection (*tree/forest*), portion-mass (*slice/cake*), stuff-object (*aluminum/airplane*), feature-activity (*paying/shopping*), and place-area (*Princeton/New Jersey*). Chaffin, Hermann, and Winston (1988) add a seventh: phase-process (*adolescence/growing up*). Meronymy is obviously a complex semantic relation—or set of relations. Only three of these types of meronymy are coded in WordNet:

W_m #p→ W_h indicates that W_m is a component part of W_h;

W_m #m→ W_h indicates that W_m is a member of W_h; and

W_m #s→ W_h indicates that W_m is the stuff that W_h is made from.

Of these three, the ‘is a component of’ relation ‘#p’ is by far the most frequent.

The stuff-object relation demonstrates the limits of folk theories of object composition. With the help of modern science it is now possible to analyze ‘‘stuff’’ into smaller and smaller components. At some point, this analysis loses all connection with the object being analyzed. For example, since all concrete objects are composed of atoms, having atoms as a part will not distinguish one category of concrete objects from any other. *Atom* would be a meronym of every term denoting a concrete object. Something has gone wrong here. For commonsense purposes, the dissection of an object terminates at the point where the parts no longer serve to distinguish this object from others with which it might be confused. Knowing where to stop requires commonsense knowledge of the contrasts that need to be drawn.

This problem arises for many parts other than atoms, of course. Some components can serve as parts of many different things: think of all the different objects that have gears. It is sometimes the case that an object can be two kinds of thing at the same time—a piano is both a kind of musical instrument and a kind of furniture, for example—which results in what is sometimes called a tangled hierarchy (Fahlman, 1979). Tangled hierarchies are rare when hyponymy is the semantic relation. In meronymic hierarchies, on the other hand, it is common; *point*, for example, is a meronym of *arrow, awl, dagger, fishhook, harpoon, icepick, knife, needle, pencil, pin, sword, tine*; *handle* has an even greater variety of holonyms. Since the points and handles involved are so different from one holonym to the next, it is remarkable that this situation causes as little confusion as it does.

Functions and Predication

The term 'function' has served many purposes, both in psychology and linguistics, so anyone who uses it is obligated to explain what sense they attach to it in this context. A functional feature of a nominal concept is intended to be a description of something that instances of the concept normally do, or that is normally done with or to them. This usage feels more natural in some cases than in others. For example, it seems natural to say that the function of a pencil is to write or the function of a knife is to cut, but to say that the function of a canary is to fly or to sing seems a bit forced. What is really intended here are all the features of nominal concepts that are described by verbs or verb phrases. Nominal concepts can play various semantic roles as arguments of the verbs that they co-occur with in a sentence: instruments (*knife-cut*), materials (*wool-knit*), products (*hole-dig; picture-paint*), containers (*box-hold*), etc.

There does not seem to be an obvious term for this type of distinguishing feature. They resemble the functional utilities or action possibilities that Gibson (1979) called 'affordances.' Gardner (1973), borrowing a term from Jean Piaget, spoke of 'operativity'; operative concepts are acquired by interaction and manipulation, whereas figurative concepts are acquired visually, without interaction. Lacking a better term, function will serve, although the possibility should not be overlooked that a more precise analysis might distinguish several different kinds of functional features.

The need for functional features is most apparent when attempting to characterize a concept like {*ornament, decoration*}. An ornament can be any size or shape or composition; parts and attributes fail to capture the meaning. But the function of an ornament is clear: it is to make something else appear more attractive. At least since Dunker (1945) described functional fixedness, psychologists have been aware that the uses to which a thing is normally put are a central part of a person's conception of that thing. To call something a box, for example, suggests that it should function as a container, which blocks the thought of using it for anything else.

There are also linguistic reasons to assume that a thing's function is a feature of its meaning. Consider the problem of defining the adjective *good*. A good pencil is one that writes easily, a good knife is one that cuts well, a good paint job is one that covers completely, a good light is one that illuminates brightly, and so on. As the head noun changes, *good* takes on a sequence of meanings: writes easily, cuts well, covers completely, illuminates brightly, etc. It is unthinkable that all of these different meanings should be listed in a dictionary entry for *good*. How should this problem be handled?

One solution is to define (one sense of) *good* as ‘performs well the function that its head noun is intended to perform’ (Katz, 1964). A good pencil is one that performs well the function that pencils are intended to perform; a good knife is one that performs well the function that knives are supposed to perform; and so on. This solution puts the burden on the head noun. If an object has a normal function, the noun denoting it must contain information about what that function is. Then when the noun is modified by *good*, the functional feature of the noun’s meaning is marked ‘+’; when it is modified by *bad*, the functional feature is marked ‘-’. If an object has no normal function, then it is inappropriate to say it is good or bad: *a good electron* is semantically anomalous. If something serves several functions, a speaker who says it is good or bad can be misunderstood.

A surprising consequence of this formulation is that an object that is not an *X* can be said to be *a good X* if it performs well the function that *X*’s normally perform. For example, calling a box a chair does not make it one, yet a person who sits on a box can say ‘‘This box is a good chair’’ and so indicate that the box is performing well the function that chairs are expected to perform. Such a sentence would be unintelligible if the function that a chair normally serves were not included as part of the meaning of *chair*.

In terms of the present approach to lexical semantics, functional information should be included by pointers to verb concepts, just as attributes are included by pointers to adjective concepts. In many cases, however, there is no single verb that expresses the function. And in cases where there is a single verb, it can be circular. For example, if the noun *hammer* is defined by a pointer to the verb *hammer*, both concepts are left in need of definition. More appropriately, the noun *hammer* should point to the verb *pound*, because it usually plays the semantic role of instrument and is used for pounding; the verb *hammer* is a conflation of its superordinate *hit* and the instrument used to do it. The semantic role of nouns like *hammer*, *wallpaper*, or *box* tend to be the same wherever they occur in sentences, independent of their grammatical role. That is to say, in both *John hit the mugger with a hammer* and *The hammer hit him on the head*, the semantic role of *hammer* is that of an instrument. Similarly, *wool* is a semantic material in each of the following sentences: *She knitted the wool into a scarf, She knitted a scarf out of the wool*, and *This wool knits well*. This consistency in mapping onto the same semantic role independently of syntax is not a feature of all nominal concepts, however: what is the function of *apple* or *cat*?

Although functional pointers from nouns to verbs have not yet been implemented in WordNet, the hyponymic hierarchy itself reflects function strongly. For example, a term like *weapon* demands a functional definition, yet hyponyms of *weapon—gun, sword, club,* etc.—are specific kinds of things with familiar structures (Wierzbicka, 1984). Indeed, many tangles in the noun hierarchy result from the competing demands of structure and function. Particularly among the human artifacts there are things that have been created for a purpose; they are defined both by structure and use, and consequently earn double superordinates. For example, {*ribbon, band*} is a strip of cloth on structural grounds, but an adornment on functional grounds; {*balance wheel*} is structurally a wheel, but functionally a regulator; {*cairn*} is a pile of stones that functions as a marker; etc. Functional pointers from these nominal concepts to the verbal concepts {*adorn*}, {*regulate*}, {*mark*}, etc. could eliminate many of these tangles. At this time it is not obvious which representation (if not both) has the greater psycholinguistic validity.

The details are obviously complicated and it is hard to feel that a satisfactory understanding of these functional attributes of nominal concepts has yet been achieved. If support for the continued development of WordNet is forthcoming, the exercise of adding pointers from nouns to the verbs that express their functions should lead to deeper insight into the problem.

Antonymy

The strongest psycholinguistic indication that two words are antonyms is that each is given on a word association test as the most common response to the other. For example, if people are asked for the first word they think of (other than the probe word itself) when they hear ‘‘victory,’’ most will respond ‘‘defeat’’; when they hear ‘‘defeat,’’ most will respond ‘‘victory.’’ Such oppositions are most common for deadjectival nouns: *happiness* and *unhappiness* are noun antonyms because they derive from the antonymous adjectives *happy* and *unhappy*.

Semantic opposition is not a fundamental organizing relation between nouns, but it does exist and so merits its own representation in WordNet. For example, the synsets for *man* and *woman* would contain:

{ [*man, woman*,!], *person,@* . . . (a male person) }
{ [*woman, man*,!], *person,@* . . . (a female person) }

where the symmetric relation of antonymy is represented by the ‘!’ pointer, and square brackets indicate that antonymy is a lexical relation between words, rather than a semantic relation between concepts. This particular opposition echoes through the kin terms, being inherited by *husband/wife, father/mother, son/daughter, uncle/aunt, brother/sister*, *nephew/niece*, and even beyond: *king/queen, duke/duchess, actor/actress*, etc.

When all three kinds of semantic relations—hyponymy, meronymy, and antonymy—are included, the result is a highly interconnected network of nouns. A graphical representation of a fragment of the noun network is shown in Figure 2. There is enough structure to hold each lexical concept in its appropriate place relative to the others, yet there is enough flexibility for the network to grow and change with learning.

Figure 2. Network representation of three semantic relations among an illustrative variety of lexical concepts