1 Introduction

This book deals with natural language semantics, and in particular the semantics of words, both alone and in combination, i.e. the problem of compositionality. Lexical semantics is the study of how and what the words of a language denote. Computational and theoretical linguists have largely treated the lexicon as a static set of word senses, tagged with features for syntactic, morphological, and semantic information. Under this view, different word senses have been generally associated with distinct lexical items. Nevertheless, formal theories of natural language semantics have done little to address two important issues:

- the creative use of words in novel contexts;
- an evaluation of lexical semantic models on the basis of compositionality.

In this study I examine the interaction of word meaning and compositionality as they relate to these concerns. I will argue that, by adequately accounting for the problem of creative word senses, we directly address the issue of compositionality. Our theory of lexical meaning will affect the general design of a semantic theory in several ways. If we view the goal of a semantic theory as being able to recursively assign meanings to expressions, accounting for phenomena such as synonymy, antonymy, polysemy, and metonymy, then compositionality depends ultimately on what the basic lexical categories of the language denote. The traditional view has been that words behave as either active functors or passive arguments. But we will see that if we change the way in which categories can denote, then the form of compositionality itself changes. Hence, if studied comprehensively, lexical semantics can be a means to reevaluate the very nature of semantic composition in language, in order to satisfy the goals of semantic theory.

First, I review some basic issues in lexical representation and present the current view on how to represent lexical ambiguity, both in theoretical and computational models. This view, incorporating "sense enumerative techniques," distinguishes word senses on the basis of finite feature distinctions. As I argue in chapter 3, however, such an approach, makes no distinction between what Weinreich (1964) calls *contrastive* and *complementary ambiguity*.[1] The former is basic homonymy, where a lexical item accidently carries several distinct and unrelated meanings, whereas

the latter refers to logically related word senses of the same lexical item. I then turn to some further problems with the enumeration method for lexical description illustrated in chapter 3. It will be shown that the representations assumed by current theories are inadequate to account for the richness of natural language semantics.

As I show in chapters 2 and 3, most of the careful representation work has been done on verb classes (e.g., Levin, 1993). In fact, the semantic weight in both lexical and compositional terms usually falls on the verb. This has obvious consequences for how lexical ambiguity has been treated. In chapter 4, I discuss several devices which simplify our semantic description, but which fall outside the conception of enumerative lexical semantics. Looking at these devices closely, we notice that they point to a very different view of lexical semantics and how word meanings are combined.

Given the discussion in these chapters, the following conception of lexical semantic systems emerges. Under such a theory, a core set of word senses, typically with greater internal structure than is assumed in previous theories, is used to generate a larger set of word senses when individual lexical items are combined with others in phrases and clauses. I will refer to such an organization as a *generative lexicon*, and the operations which generate these "extended senses" as *generative devices*, including operations such as *type coercion* and *co-composition*. I discuss how this view supports an explanatory view of semantic modeling. I then examine the goals of linguistic theory in general and lexical semantics in particular. I argue that our framework of knowledge for lexical items must be guided by a concern for semanticality in addition to grammaticality. The model of semantic interpretation we construct should reflect the particular properties and difficulties of natural language, and not simply be an application of a ready-to-wear logical formalism to a new body of data. I will view natural languages as positioned on a hierarchy of semantic descriptions, characterized in terms of their underlying polymorphic generative power. I argue that natural languages fall within the *weakly polymorphic* languages, more expressive than *monomorphic*, but well below the power of unrestricted polymorphic languages. This particular characterization is rich enough to capture the behavior of logical polysemy as well as effects of co-compositionality.

Next, in chapter 5, I outline the type system for our semantics. A generative theory of the lexicon includes multiple levels of representation for

the different types of lexical information needed. Among such levels are Argument Structure (for the representation of adicity information for functional elements), Event Structure (for the representation of information related to Aktionsarten and event type, in the sense of Vendler, 1967, and related work), Qualia Structure (for the representation of the defining attributes of an object, such as its constituent parts, purpose and function, mode of creation, etc.), and Inheritance Structure (for the representation of the relation between the lexical item and others in the lexicon). Chapter 6 presents in more detail the structure of qualia, and the role they play in distributing the functional behavior of words and phrases in composition.

Chapter 7 presents the application of the mechanisms outlined in chapters 5 and 6 to the polymorphic behavior of language. A variety of polymorphic types is studied and I consider what operations are needed to adequately account for the syntactic expressiveness of semantic types. In particular, I examine the role of coercion in the grammar as well as the need for other generative devices, such as selective binding and co-composition. There is no single form of polymorphism; rather, polysemy and type ambiguity are a result of several semantic phenomena in specific interaction.

Chapter 8 examines briefly what the consequences of qualia structure are for the semantics of nominals. Nouns can be formally characterizable in terms of three dimensions of analysis, involving argument structure, event type, and qualia structure. An analysis of nominal polysemy is presented, making use of the type system outlined in the previous chapters, and explaining in more detail the distinction between unified types and dot objects.

In the next two chapters, I outline some areas of grammar that can be greatly simplified if we apply to them principles of generative lexical analysis through the use of the generative devices and the type system presented in chapter 5. In particular, I treat argument selection as driven by semantic types, modulated by constraints on coercion rules, selective binding, and co-composition operations in the grammar. This approach will permit us to explain the polymorphic nature of verbs taking multiple syntactic types. In chapter 9, I discuss the role that qualia and event structure have in describing the way causal relations are lexicalized in language. Specifically, I look at the semantics of causative/inchoative verbs, aspectual predicates, experiencer predicates, and *modal causatives*

such as *risk*.

Finally, I discuss how this view of lexical organization relates to current theories of metaphor and pragmatically-induced metonymy. I argue, on methodological grounds, for a strong distinction between commonsense knowledge and lexical structure, although the issue is clearly an empirical one. The types of creative polysemy examined in this work exhibit a regularity and systematicity across languages that is absent from patterns of pragmatic sense extension or modes of metaphor.

2 The Nature of Lexical Knowledge

Only a few years ago, it was conventional practice in both theoretical and computational linguistics textbooks to cover all that needed to be said regarding the lexicon in one quick chapter, before getting to the more interesting and substantive topics of syntactic form and semantic interpretation. Such an impoverished coverage today would scarcely reflect the vibrancy of the field of lexical research or the central role played by lexical knowledge in linguistic theory and processing models. It is now standardly assumed by most linguistic frameworks (both computational and theoretical) that much of the structural information of a sentence is best encoded from a lexicalized perspective.[1]

The most pressing problems for lexical semantics, I believe, are the following:

(a) Explaining the *polymorphic nature* of language;

(b) Characterizing the *semanticality* of natural language utterances;

(c) Capturing the *creative use of words* in novel contexts;

(d) Developing a richer, *co-compositional* semantic representation.

I believe we have reached an interesting turning point in research, where linguistic studies can be informed by computational tools for lexicology as well as an appreciation of the computational complexity of large lexical databases. Likewise, computational research can profit from an awareness of the grammatical and syntactic distinctions of lexical items; natural language processing (NLP) systems must account for these differences in their lexicons and grammars. The wedding of these disciplines is so important, in fact, that I believe it will soon be difficult to carry out serious computational research in the fields of linguistics and NLP without the help of electronic dictionaries and computational lexicographic resources (cf. Zampolli and Atkins, 1994, Boguraev and Briscoe, 1988). Positioned at the center of this synthesis is the study of word meaning, lexical semantics.

Before addressing these questions, I would like to discuss two assumptions that will figure prominently in my suggestions for a lexical semantics framework. The first is that, without an appreciation of the syntactic structure of a language, the study of lexical semantics is bound to fail. There is no way in which meaning can be completely divorced from the structure that carries it. This is an important methodological

point, since grammatical distinctions are a useful metric in evaluating competing semantic theories.

The second point is that the meanings of words should somehow reflect the deeper conceptual structures in the cognitive system, and the domain it operates in. This is tantamount to stating that the semantics of natural language should be the image of nonlinguistic conceptual organizing principles, whatever their structure.

Computational lexical semantics should be guided by the following principles. First, a clear notion of semantic well-formedness will be necessary in order to characterize a theory of possible word meaning. This may entail abstracting the notion of lexical meaning away from other semantic influences. For instance, this might suggest that discourse and pragmatic factors should be handled differently or separately from the semantic contributions of lexical items in composition.[2] Although this is not a necessary assumption and may in fact be wrong, it will help narrow our focus on what is important for lexical semantic descriptions.

Secondly, lexical semantics must look for representations that are richer than thematic role descriptions (cf. Gruber, 1965, Fillmore, 1968). As argued in Levin and Rappaport (1986), named roles are useful at best for establishing fairly general mapping strategies to the syntactic structures in language. The distinctions possible with thematic roles are much too coarse-grained to provide a useful semantic interpretation of a sentence. What is needed, I will argue, is a principled method of lexical decomposition. This presupposes, if it is to work at all, (1) a rich, recursive theory of semantic composition, (2) the notion of semantic well-formedness mentioned above, and (3) an appeal to several levels of interpretation in the semantics (cf. Scha, 1983).

Thirdly, and related to the preceding point, lexical semantics must study all syntactic categories in order to characterize the semantics of natural language. That is, contrary to the recent trends in semantic representation, the lexicon must encode information for categories other than verbs. Recent work has done much to clarify the nature of verb classes and the syntactic constructions that each allows (cf. Levin 1985, 1993). Yet it is not clear whether we are any closer to understanding the underlying nature of verb meaning, why the classes develop as they do, and what consequences these distinctions have for the rest of the lexicon and grammar. The curious thing is that there has been little attention paid to the other lexical categories (but cf. Miller and Johnson-Laird,

1976, Miller and Fellbaum, 1991). That is, we have little insight into the semantic nature of adjectival predication, and even less into the semantics of nominals. Not until all major categories have been studied can we hope to arrive at a balanced understanding of the lexicon and the methods of composition.

Stepping back from the lexicon for a moment, let me say briefly what I think the position of lexical research should be within the larger semantic picture. Ever since the earliest attempts at real text understanding, a major problem has been that of controlling the inferences associated with the interpretation process. In other words, how deep or shallow is the understanding of a text? What is the unit of well-formedness when doing natural language understanding; the sentence, utterance, paragraph, or discourse? There is no easy answer to this question because, except for the sentence, these terms are not even formalizable in a way that most researchers would agree on.

It is my opinion that the representation of the context of an utterance should be viewed as involving many different *generative factors* that account for the way that language users create and manipulate the context under constraints, in order to be understood. Within such a theory, where many separate semantic levels (e.g., lexical semantics, compositional semantics, discourse structure, temporal structure) have independent interpretations, the global meaning of a "discourse" is a highly flexible and malleable structure that has no single interpretation. The individual sources of semantic knowledge compute local inferences with a high degree of certainty (cf. Hobbs *et al.*, 1988, and Charniak and Goldman, 1988). When integrated together, these inferences must be globally coherent, a state which is accomplished by processes of cooperation among separate semantic modules. The basic result of such a view is that semantic interpretation proceeds in a principled fashion, always aware of what the source of a particular inference is, and what the certainty of its value is. Such an approach allows the reasoning process to be both tractable and computationally efficient. The representation of lexical semantics, therefore, should be seen as just one of many levels in a richer characterization of contextual structure.[3]

Given what I have said, let us examine the questions presented above in more detail. First, let us turn to the issue of methodology. In this chapter, I shall review the most common methods used for semantic classification of lexical items, and characterize the richness of the problem

of representing lexical semantic information.

It is the goal of any lexical semantic theory to adequately classify the lexical items of a language into classes predictive of their syntactic and semantic expression. Furthermore, such a theory should not merely map the meanings of lexical items per sentence, on an individual basis. Rather, it should capture the semantic relations between words in such a way which facilitates this mapping.

2.1 Semantic Classes and Categorial Alternation

Within the tradition of formal semantics, the most fundamental aspect of a word's meaning is perhaps its semantic type. On this view, categorial or type information determines not only how a word behaves syntactically, but also what the elements of the category refer to. For example, the verbs *love* and *hate* would be viewed as relations between individuals in the world, whereas the noun *woman* would pick out the set of all individuals in the world who are women. Logical operators such as *the* and *or* might be viewed as set-theoretic operations over sets of individuals in the world (cf. Montague, 1974, for example) or as procedural instructions (cf. Woods, 1975). Because type distinctions are generally so broad, lexical semantics further distinguishes selectional subsets of members of these categories. Conventionally, this is accomplished by applying standard distributional analysis on the basis of collocation and cooccurrence tests (cf. Chomsky, 1955, Harris, 1951). For example, the nouns *dog* and *book* partition into different selectional classes due to contexts involving *animacy*, while the nouns *book* and *literature* partition into different selectional classes due at least to a mass/count distinction (cf. Verkuyl, 1972, Pelletier and Schubert, 1989).

2.1.1 Verbal Alternations

A recently developed linguistic methodology for grouping the meanings of words into semantic classes is to study the syntactic patterns that words participate in (e.g., common grammatical alternations). For example, work begun in the MIT Lexicon Project and recently codified in Levin (1993), outlines a broad classification of verb argument alternations in English, in order to classify verbs into semantically unique classes. For example, the verbs *sink*, *roll*, and *break* all have both tran-

sitive and intransitive forms, where the lexical senses are related by the interpretive feature of causation. There are of course, numerous examples of intransitive verbs which have no zero-derived causative forms, e.g., *arrive*, *die*, *fall* (cf. Fillmore, 1968, Lakoff, 1970, Hale and Keyser, 1986, 1993, and Kunze, 1991):

(1) a. The boat sank in stormy weather.
b. The plane sank the boat in stormy weather.

(2) a. The ball rolled down the hill.
b. Bill rolled the ball down the hill.

(3) a. The bottle broke suddenly.
b. Mary broke the bottle suddenly.

(4) a. The letter arrived on time.
b. *The mailman arrived the letter on time.

(5) a. My terminal died last night.
b. *The storm died my terminal last night.

(6) a. The block tower fell.
b. *Zachary fell the block tower.
c. Zachary felled the block tower.

While the sentences in (4b)–(6b) are ungrammatical, they are certainly understandable. The lexical semantics should specify what it is that these two classes share, such that they have grammatical intransitive forms, but equally important is the characterization of how they differ, such that the latter class permits no transitive form.

Other useful alternation patterns include the conative, as illustrated below in (7)–(10):[4]

(7) a. Mary shot the target.
b. Mary shot at the target.

(8) a. Mary scraped the window.
b. Mary scraped at the window.

(9) a. The cat touched my leg.
b. *The cat touched at my leg.

(10) a. Mary shot the arrow (at the target).
b. *Mary shot at the arrow.

The question is whether it is possible to identify the semantic discriminants leading to the distinct behavior of the transitive verbs above, while still explaining why (9b)–(10b) are ungrammatical.[5] Perhaps even more interesting is how the polysemy of those verbs taking multiple forms can be represented lexically.

What the examples above clearly show is that participation in one grammatical alternation does not sufficiently determine the semantic class of the verb. In fact, even once a complete cataloguing of participation in alternation classes is achieved, we must ask ourselves just what we have accomplished. Descriptively, we may have achieved a great deal, in terms of how verbs behave according to semantically-labeled classes. But we must realize that explaining the behavior of a verb's semantic class can come only from acknowledging that the syntactic patterns in an alternation are not independent of the information carried by the arguments characterized in the very patterns themselves. In other words, the diversity of complement types that a verb or other category may take is in large part also determined by the semantics of the complements themselves. One of the methodological points I will argue is that alternation classifications do not constitute theory. Indeed, as Levin (1993) herself points out, the theoretical mechanisms which give rise to the descriptive distribution of syntactic behavior are not transparent in the classes by themselves.

Still another kind of syntactic diagnostic that seems to have some theoretical utility is polyadicity more narrowly construed. As Bresnan (1982), Fillmore (1986), and Levin (1993) point out, there are not only argument changing alternations such as those discussed above, but also argument dropping alternations as well. The rule of "indefinite NP deletion" is the term for the following alternation paradigm:

(11) a. The woman ate her meal quickly.
b. The woman ate quickly.

(12) a. The dog devoured the cookie.
b. *The dog devoured.

(13) a. John drank his beer feverishly.

b. John drank feverishly.

(14) a. John gulped his beer feverishly.
b. *John gulped feverishly.

(15) a. Mary hummed a song while she walked.
b. Mary hummed while she walked.

(16) a. Mary performed a song while she ate her dinner.
b. *Mary performed while she ate her dinner.

In the examples here one might attribute the possibility of object-drop to an aspectual difference between the verbs being contrasted. That is, while *eat* denotes an activity of unbounded duration (at least lexically), *devour*, one might argue, denotes a transition. Although *devour* is generally considered a manner specification of the verb *eat*, it carries a completive implicature that is absent from *eat*. Similar remarks hold for the other two pairs above: while *drink* is an activity, *gulp* carries the implicature of completive aspect; and finally, while *hum* is an activity, *perform* has a completive aspect lexically.[6]

If this were a complete account of the above data, we might expect it to explain the patterns of deletion for the other cases of complement-dropping. This would seem difficult for many of the verbs entering into this alternation. For example, as Fillmore (1986) points out, there are cases where near synonyms seem to behave differently with respect to licensing of complement-drop (cf. (17) and (18)).

(17) a. Mary tried to start her car in the morning.
b. Mary tried in the morning.

(18) a. Mary attempted to start her car in the morning.
b. * Mary attempted in the morning.

As we can see, no one semantic parameter will be sufficient to explain all complement drop cases.[7]

In addition to transitive-intransitive polyadicity, there are well-documented ditransitive-transitive shifts such as those shown in (19)–(24) below (cf. Pustejovsky, 1992):

(19) a. John gave a book to Mary.

b. *John gave a book.

(20) a. John gave a lecture to the academy.
b. John gave a lecture.

(21) a. John mailed a book to his brother.
b. *John mailed a book.

(22) a. John mailed a letter to his brother.
b. John mailed a letter.

(23) a. Bill showed a book to Mary.
b. *Bill showed a book.

(24) a. Bill showed a movie to the audience.
b. Bill showed a movie.

Thus, in certain cases, the otherwise obligatory expression of the goal argument is dropped and the verb becomes a simple transitive. What allows the alternation, I will argue in later chapters, is the interaction of the verbal semantics with semantic information from the complement itself.

Such grammatical alternations can be used throughout the grammar of a language to make semantic distinctions on the basis of syntactic behavior. Using category and selectional information as well as grammatical alternation data, words can be grouped into semantic classes following more or less predictable syntactic behaviors. Nevertheless, it is still necessary to explain why these and just these grammatical forms are part of a certain alternation class. This is addressed in chapter 9 below.

Finally, let us consider briefly one of the oldest semantic classifications for verbs, that of aspectual class or *Aktionsarten*. The essential idea behind this classification is that verbs and verb phrases differ in the kinds of eventualities in the world they denote. It is normally assumed that there are at least three aspectual types: *state*, *activity*, and *event*, where the last class is itself sometimes broken down into *accomplishment*, and *achievement* events.[8] For example, the verb *walk* in sentence (25) denotes an activity of unspecified duration. That is, the sentence itself does not convey information regarding the temporal extent of the activity, although deictically it is an event in the past which did terminate.[9]

(25) a. Mary walked yesterday.
b. Mary walked to her house yesterday.

Such a sentence as (25a) is said to denote an *activity* (cf. Kenny, 1963, Vendler, 1967, Ryle, 1949, Mourelatos, 1978, Verkuyl, 1972, 1993, Dowty, 1979). Other examples of activity verbs are *sleep*, *run*, *work*, and *drink*. Sentence (25b) conveys the same information as (25a), with the additional constraint, however, that Mary terminated her activity of walking at her house. Although not making explicit reference to the temporal duration of the activity, (25b) does assert that the process has a logical culmination, whereby the activity is over when Mary is at home. This type of sentence is said to denote an *accomplishment* event.

Just as the verb *walk* seems to lexically default to an activity, there are verbs which seem to lexically denote accomplishments. For example, the verbs *build* and *destroy*, in their typical transitive use, denote accomplishment events because there is a logical culmination to the activity performed.

(26) a. Mary built a house.
b. Mary destroyed the table.

In (26a) the existence of the house is the culmination of Mary's act, while in (26b), the nonexistence of something denotable as a table is the direct culmination or consequence of her act.

Creation-verbs are only the best example of accomplishments. *Performance*-verbs such as *play* permit both activity usage (27a) and accomplishment usage (27b), depending on the complement structure:[10]

(27) a. Mary played the piano (for hours).
b. Mary played the sonata in 15 minutes.

As illustrated in (27b) above, one classic diagnostic for testing whether a verb or verb phrase denotes an accomplishment is modification by temporal adverbials such as *in an hour*, i.e., the so-called frame adverbials. Notice in (28) that both derived and lexical accomplishments license such modification, while activities (29) do not.

(28) a. Mary walked to the store in an hour.
b. Mary built a house in a year.

(29) a. *John drank in 20 minutes.
b. *Mary worked in an hour.

The frame adverbial seems to require that the verb or verb phrase make reference to an explicit change of state, a precondition missing in (29a) and (29b).

The last conventional aspectual classification is that of achievement. An achievement is an event that results in a change of state, just as an accomplishment does, but where the change is thought of as occurring instantaneously. For example, in sentences (30a), (30b), and (30c) the change is not a gradual one, but something that has a point-like quality to it. Hence, modification by *point adverbials* such as *at 3 pm* is suggestive that a sentence denotes an achievement (cf. Dowty, 1979).

(30) a. John died at 3 pm.
b. John found his wallet at 3 pm.
c. Mary arrived at noon.

Of course, point adverbial modification is not restricted to achievements, as the examples with accomplishment verbs below show:

(31) a. She swam the channel at 10:00 am.
b. The pianist performed the sonata at noon.
c. James taught his 3 hour seminar at 2:30 pm. d. He delivered his lecture at 4:00 pm.

Here the point-adverbial indicates the starting time of an event of some specific duration.

What are apparently lexical properties of the verb can be affected by factors that could not possibly be lexical. For instance, consider the sentences in (32), where we see a shift in the meaning of *eat* from an activity as in (32a) to an accomplishment as in (32b). Similarly, the lexically specified accomplishment verb *build* mentioned above can appear with either a bare plural object or mass term, thereby assuming an activity reading (cf. (33a) and (33b)).

(32) a. Mary ate cookies. (*activity*)
b. Mary ate a cookie. (*accomplishment*)

(33) a. Brown and Root Inc. built the runway in Tehran.

b. Brown and Root Inc. builds runways in Southwest Asia.

The presence of a bare plural object shifts the interpretation of a typically telic (or completive) event to an unbounded process (cf. Bach, 1986, Verkuyl, 1993, and Krifka, 1989 for details).

Another indication of an aspectual shift resulting from pluralization of the subject of achievement predicates comes from complementation patterns with aspectual predicates such as *begin* and *finish*. Normally, achievements are not grammatical as complements of these verbs, as illustrated in (34), but the same predicates with plural subjects suggests an aspectual distinction.

(34) a. *John began finding a flea on his dog.
b. *The guest began to arrive.

(35) a. John began finding fleas on his dog.
b. The guests began to arrive.

Finally, let us examine the behavior of *states*. Following Carlson (1977) and Kratzer (1989), we can distinguish two kinds of stative predicates *individual-level* and *stage-level*. Predicates such as *tall*, *intelligent*, and *overweight* might be thought of as properties that an individual retains, more or less, throughout its lifetime, and can be identified with the individual directly. These are *individual-level* predicates. Properties such as *hungry*, *sick*, and *clean* are usually identified with non-permanent states of individuals, and have been called *stage-level* predicates.[11] It is this class which typically appears in forms of the resultative construction as the culminating predicate, as shown in the sentences in (36).

(36) a. John drank himself sick with that cheap brandy.
b. Watching the commercial on TV made John hungry.
c. Bill wiped the counter clean before serving us our coffee.

None of these constructions typically permit individual-level predicates, as (37) clearly illustrates.

(37) a. *Bill ate himself overweight over the years.
b. *John read himself intelligent with the *Great Books*.

One final characteristic for distinguishing activities from accomplishments, known as the "imperfective paradox" (cf. Bach, 1986, Dowty, 1979), involves the possible entailments from the progressive aspect. To illustrate the nature of this paradox, consider the sentences in (38).

(38) a. John is running. (Therefore, John has run.)
b. John is building a house. (*Therefore, John has built a house.)

What this difference in entailment indicates is whether an action is homogeneous in nature or has a culmination of some sort. Sentence (38a) is an activity and entails the statement *John has run*. That is, John has already engaged in some running. Sentence (38b), on the other hand, does not allow the entailment *John has built a house* because building is not a homogeneous process, but rather culminates in a changed state, i.e., it is an accomplishment. Thus, if *x is ϕing* entails *x has ϕed*, then either the verb or the predicate is an activity. A theory of lexical semantics should be able to account for this behavior, and not just use it to classify propositions into aspectual types.

Summarizing, we have considered the following categorization of aspectual types for verbs, verb phrases, and sentences: ACTIVITIES: *walk*, *run*, *swim*, *drink*; ACCOMPLISHMENTS: *build*, *destroy*, *break*; ACHIEVEMENTS: *die*, *find*, *arrive*; and STATES: *sick*, *know*, *love*, *resemble*, *think*, *be*. Membership in an aspectual class determines much of the semantic behavior of a lexical item, but it should be noted that the aspectual properties of a sentence may change as the result of other factors, such as adverbial modification (both durative and frame), the structure of the NP in an argument position (e.g., definite vs. bare plural), or the presence of a prepositional phrase. Such non-lexical issues are problems in compositional semantics and are discussed in the context of "type-shifting" phenomena in Bach (1986), Link (1983), Krifka (1989), and Verkuyl (1993). In the discussion that follows, I will restructure the above classification slightly, by making reference to subevents and to an event focusing mechanism called *event headedness*.

2.1.2 Nominal Alternations

Nouns also have characteristic grammatical behaviors, depending on semantic category. For nouns as well, studying the behavior of grammatical alternations has certainly been the point of departure for the

semantic classification of nominal types. Probably the most studied distinction for nominal semantics is that of *count* versus *mass*. This is a distinction which dates back to Aristotle, and more recently has played an integral role in the structuring of the semantic model for language (cf. Pelletier and Schubert, 1989, Link, 1983). How "stuff" is individuated will determine how we talk about it; hence, *sand*, although in fact composed of individual grains, is a mass noun and refers to undifferentiated stuff in our daily experience of it.[12] A *house*, on the other hand, is obviously perceivable as an individuated object and is classified as a count noun. As is well-documented, count nouns and mass nouns select for different quantifier types and allow very different patterns of predication.

(39) a. MASS NOUNS: much sand, more water;
b. COUNT NOUNS: several houses, every child.

Not surprisingly, however, there are nouns that have both mass and count interpretations, and these will figure in our later investigations quite prominently. They include nouns such as *beer*, where we can talk about amounts of (40a) or quantities of (40b) the substance. Similarly, nouns such as *e-mail* refer either to the mass of correspondences I have or have sent, as in (41), or to the individual transaction or correspondence, seen in (42).

(40) a. Texans drink a lot of beer.
b. Patsy relished every beer she drank.

(41) a. More e-mail is arriving every day.
b. Is there any e-mail for me today?

(42) a. The last e-mail I sent you was yesterday.
b. Every e-mail I send gets bounced.

A semantic distinction related to count and mass is that between individual and group nouns, and this is also differentiated by predicability. For example, group nouns satisfy semantic plurality requirements on selection, as shown in (43) below:

(43) a. The committee met for lunch.
b. The crowd dispersed after the police introduced tear gas.

For purposes of anaphoric binding, group nouns do not parallel plural NPs completely, however.

So far, all the noun classes we have discussed have been *predicative* in a fairly direct way. That is, both *woman* and *water*, when used in full NPs, refer independently to something out in the world. *Relational* nouns, on the other hand, are dependent on another referent in terms of how they themselves denote. For example, *neighbor* and *brother* denote individuals standing in relation to at least one other individual in specific ways. The grammatical consequences of this semantic distinction have been long recognized, and give rise to the following interesting distinction;

(44) a. The men arrived yesterday.
b. ?The neighbor arrived yesterday.
c. The neighbors arrived yesterday.

(45) a. *The brother came home.
b. The brothers came home together.

As Bierwisch (1983) and Eschenbach (1993) have pointed out, the two types of relational nouns can be distinguished with respect to pluralization behavior. Nouns such as *neighbor* and *sister* denote "horizontal relations," while *father* and *daughter* denote hierarchical relations. Within the latter class, the noun *daughter* is the dependent object in the relation, and behaves differently from *father*, which is the independent individual. Note that contextual salience will improve the acceptability of these NPs.

(46) a. *The daughter is in the house.
b. ?The daughters are gathering upstairs.
c. The fathers are meeting tomorrow.

Explicit mention of the independent variable in the relation, of course, results in fully acceptable sentences:

(47) a. My daughter phoned me.
b. John's brother is in town.
c. My neighbor lent me a chainsaw.

The distinctions between count/mass, individual/group, and predicative/relational, are motivated by distinct grammatical behaviors as well

as the underlying semantic distinctions perhaps giving rise to these differences. A more traditional method of nominal classification is based on taxonomies of the speaker's intuition or commonsense perspective of what the nouns denote in the world. For example, we might distinguish between "concrete referring" nouns, such as *woman*, *boy*, *horse* (all count nouns), as well as *grass*, *water*, and *gold* (mass nouns), and "abstract referring" nouns such as *time*, *place*, *age*, and *shape*. Such taxonomies of entity types are common in computational treatments of language phenomena, but are largely ignored or seen as irrelevant by the majority of theoretical linguists. The major exception to this is the semantic taxonomic tradition as carried out by Wierzbicka (1988) and Dixon (1991) and their colleagues. This tradition cannot be so quickly dismissed as is so often the case in theoretical circles. Many of the generalizations they hope to capture are legitimate goals for linguistic theory and cognitive science. More to the point, however, much of their work attempts to achieve these goals without always applying the proper tools of analysis.[13]

The structuring of such taxonomic information for nouns (and other categories as well) in computational linguistics and AI is not simply an exercise in domain modeling; it is necessary for driving the inferences that a language reasoning system must perform in order to understand a sentence. From primitives-based inferencing techniques such as Wilks (1975,1978) to commonsense metaphysics reasoning systems applied to language such as Hobbs *et al.* (1987), the taxonomic classification of objects in the world through language can be a serious enterprise and not merely metaphysical play.

These concerns have received renewed interest in computational approaches to language analysis both in computational linguistics and formal semantics, and point back to the work done on selection restriction from the 1960s and 1970s in the generative tradition. Where selectional features were seen as conditions on lexical insertion in previous theories, sortal specification is viewed in terms of type satisfaction within an interpreted model. I mention this trend because I believe there are important underlying motivations in both computational and theoretical linguistics communities for modeling the conceptual or epistemological ground assumptions for language research. Yet these motivations can differ dramatically and I hope to identify what the goals are for the diverse communities, and then outline what I think the common goals are

for linguistic research in the different approaches.

2.1.3 Adjective Classes

Finally, let us turn briefly to the semantics of adjectives. By their very nature, adjectives are generally taken to denote states. Some of the previous discussion on types of stativity, e.g., the individual-level vs. stage-level distinction, will be a useful device for distinguishing adjectives as well. This is related to but not identical with the oldest distinction applied to adjectives, that of accidental vs. necessary qualities (as used in Aristotle and the scholastics). This distinction gives rise to the classification of properties such as *hungry*, *dirty*, and *broken* as accidental qualities as distinct from necessary qualities such as the properties *bipedal* (of a species), *tall* (of an individual), and *hard* (of a substance). We saw in the previous discussion that there are grammatical distinctions to be made on the basis of this typological difference. One diagnostic we did not consider concerns the progressive aspect, and the ability of most stage-level predicates to enter into predicates with the progressive, while individual-level predicates cannot, as illustrated below.

(48) a. The horse is being gentle with her rider.
b. You're being so angry again!
c. Stop being so impatient.

(49) a. *John is being tall today.
b. *Aren't you being beautiful tonight!
c. *Stop being so intelligent.

There are, of course, other ways to classify adjectives by virtue of syntactically distinct behaviors, including the basic distinction between predicative and attributive position, illustrated in (50)–(51).

(50) a. the alleged criminal
b. *This criminal is alleged.

(51) a. the frightened boy
b. The boy is frightened.

With respect to complementation patterns, there are structurally many similarities between adjectives and verbs. For examples, just as there are

intransitive and transitive verbs, there are unary and binary predicative adjectives, which can be seen as intransitive and transitive forms. An adjective such as *old*, for example, takes no complement, as in (52a), while adjectives such as *envious* and *jealous* as in (52b) are inherently relational, and might be analyzed as transitive.

(52) a. Sophia is not old.
b. John is envious of Mary's position.

Another structural distinction differentiates adjectives allowing movement-like behavior, such as *certain*, from non-alternating adjectives.

(53) a. Mary is certain to be the next President.
b. It is certain that Mary will be the next President.

Perhaps the most celebrated example from this class involves the raising/control distinction seen with adjective pairs such as *easy* and *eager*.[14] Adjectives such as *eager*, *anxious*, and *unwilling* are subject-control predicates, and have no alternating construction, while *tough*-Movement adjectives such as *easy*, *tough*, and *difficult*, enter into the following alternation.

(54) a. It is easy to teach this class.
b. This class is easy to teach.

(55) a. It is dangerous to drive on this road in the winter.
b. This road is dangerous to drive on in the winter.

(56) a. It is interesting to imagine Bill President.
b. Bill President is interesting to imagine.

These are particularly interesting from our perspective because of the underspecified meaning many of these adjectives assume in constructions such as (57) and (58) below:

(57) a. Jim has decided to give an easy exam.
b. We're going to get a difficult exam for the final.

(58) a. Bill has to take a dangerous road to get here.
b. John had an interesting suggestion.

Depending on the nominal, however, interpretation of the "ellipsed" infinitival may depend on local context, as the sentences in (59) illustrates.

(59) a. John is teaching an easy class this semester.
b. Bill is taking an easy class this semester.

What is curious about these sentences is that the "understood predicate" in the NP *an easy class* is determined by the governing predicate in the VP; that is, in (59a) the class is *easy to teach* while in (59b) it is *easy to take*. This is not the case, however, with the NP *an easy/difficult exam*, where the ease or difficulty seems to refer in most cases to the taking of the exam.[15] This seems to depend on the semantics of the noun being modified. I will return to these examples in chapter 10, where local semantic context is able to bring out the appropriate reading compositionally, and the appropriate semantic distinctions are presented for differentiating between nouns such as *exam* and *class*.

Rather than first examining the grammatical behavior of adjectives, it might seem reasonable to look first at what concepts are expressible in a language adjectivally. This is the approach described in Dixon (1982), where he takes a field-descriptive perspective on the taxonomic classification of adjectives. Dixon distinguishes adjectives according to the general semantic field associated with the term. For example, he arrives at the following classes for adjectives from cross-linguistic study:

1. DIMENSION: big, little, large, small, long, short
2. PHYSICAL PROPERTY: hard, soft, heavy, light
3. COLOR: red, green, blue
4. HUMAN PROPENSITY: jealous, happy, kind, proud, cruel, gay
5. AGE: new, old, young
6. VALUE: good, bad, excellent, fine, delicious
7. SPEED: fast, quick, slow
8. DIFFICULTY: difficult, easy
9. SIMILARITY: alike, similar
10. QUALIFICATION: possible, probable, likely

Such classes can be very useful for descriptive purposes, but reveal little about the functional or relational properties of the predicate. For example, the adjectives *difficult* and *easy* are tough-movement predicates and behave the same with respect to this construction. In the class QUALIFICATION, however, the adjective *likely* allows raising while *possible* and *probably* do not. Similarly, the other semantic classes do not reflect a uniform syntactic behavior. What is needed, I believe, is a semantic classification that captures the intuitions listed by Dixon but based on the relational and logical behavior of the predicates and not on their folk-epistemology. I return to this discussion below in chapter 10.

2.2 Interlexical Relations

Besides grouping words into distinct semantic classes, lexical semantics is the study of how words are semantically related to one another. In this section, I will briefly examine five classes of lexical relations:

1. Synonymy
2. Antonymy
3. Hyponymy and Lexical Inheritance
4. Meronymy
5. Entailment and Presupposition

Synonymy is generally taken to be a relation between words rather than concepts. One fairly standard definition states that two expressions are synonymous if substituting one for the other in all contexts does not change the truth value of the sentence where the substitution is made (cf. Lyons, 1977, Cruse, 1986).[16] A somewhat weaker definition makes reference to the substitution relative to a specific context. For example in the context of carpentry, *plank* and *board* might be considered synonyms, but not necessarily in other domains (cf. Miller *et al.*, 1990). It should be noted that if synonymy is defined by substitutability of expressions, then it is an intra-category relation, e.g., nouns for nouns, verbs for verbs, and so on.

Antonymy is a relation characterized in terms of semantic opposition, and, like synonymy is properly defined over pairs of lexical items rather than concepts. Examples of antonymy are *rise/fall*, *heavy/light*,

fast/slow, *long/short* (cf. Cruse, 1986, Miller, 1991). It is interesting to observe that co-occurrence data illustrate that synonyms do not necessarily share the same antonyms. For example, *rise* and *ascend* as well as *fall* and *descend* are similar in meaning, yet neither *fall/ascend* nor *rise/descend* are antonym pairs. For further details see Miller *et al.* (1990).

By far the lexical relation most studied in the computational community is hyponymy, essentially the taxonomic relation defined in inheritance networks. For example, specifying *car* as a hyponym of *vehicle* is equivalent to saying that *vehicle* is a superconcept of the concept *car*, or that the set *car* is a subset of those individuals denoted by the set *vehicle*.

One of the most difficult lexical relations to define and treat formally is that of meronymy, the relation of parts to the whole. The relation is familiar from knowledge representation languages with predicates or slot-names such as `part-of` and `made-of` (cf. Brachman and Schmolze, 1985, Hobbs *et al.*, 1987). Similarly in the domain of planning, the issue of meronymy arises when defining the necessary or optional subparts of a plan or event (cf. Kautz, 1987, and Cohen *et al.*, 1990). For treatments of this relation in lexical semantics, see Miller *et al.* (1990) and Cruse (1986).

Another important respect in which words can be related is through entailment and presupposition. Although there is no complete agreement on how to define these relations, one fairly established distinction is the following. An expression A *semantically entails* an expression B if and only if every situation that makes A true, makes B true. On the other hand, A *semantically presupposes* B if and only if both (a) in all situations where A is true, B is true, and (b) in all situations where A is false, B is true (cf. Strawson, 1952, Keenan, 1972).[17]

To see how important these concepts are for determining lexical meanings, observe how (60a) entails the proposition denoted by sentence (60b).

(60) a. John killed Bill.
b. Bill died.
c. Bill is dead.

That is, if there is a *killing* event, then there is also a *dying* event. Capturing such entailment relations was one of the motivations for lexical

decomposition in linguistics in the 1960s, and still motivates much research (e.g., Jackendoff, 1983, Dowty, 1979).

That *kill* entails rather than presupposes an event associated with *dying*, becomes clear when examining the negation of (60a), where no dying event occurs. This is not the behavior of presupposition, however. Notice in (61)–(63) that the verb *manage* entails the complement event, but also carries a presupposition that the person *attempts* to do the action in the complement, whether it succeeds or not.

(61) a. Mary managed to finish the exam.
b. Mary finished the exam.

(62) a. Mary didn't managed to finish the exam.
b. Mary didn't finish the exam.

(63) Mary attempted to finish the exam.

Thus, the lexical semantics of a verb like *manage* must presuppose that the agent of the managing event also *attempts* to bring this event about (cf. Katz and Fodor, 1963, Karttunen, 1971, 1974, Seuren, 1985).

Similar presuppositions arise with the lexical semantics of verbs such as *sell* and *trade*, where possession or ownership is presupposed by the assertion of the relation.

(64) a. John is selling his piano.
b. John owns a piano.

(65) a. Mary is trading her piano for a computer.
b. Mary owns a piano.

For some lexical items, determining what the presuppositions are is not so straightforward. For example, the verb *forget* in (66a) and (66b) appears to presuppose the truth of the complement (hence, it is called a *factive* verb, cf. Kiparsky and Kiparsky, 1971).

(66) a. John forgot that he locked the door.
b. John didn't forget that he locked the door.

That is, regardless of John's memory, there is a fact in the world that John locked the door. It would furthermore appear that this factivity is associated with the verb *forget*. Notice however, that in (67) there is no factive interpretation associated with the complement.

(67) John forgot to lock the door.

In fact, in some ways it appear to be counterfactive, in that the process of forgetting prevents the event from even occurring. We will return to issues of factivity in chapter 8.