Lexical Semantics

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1.1 Introduction

Lexical semantics is the study of what words mean and how their meanings contribute to the compositional interpretation of natural language utterances. The lexicon can be seen as that component of the grammar that encodes both the information required for composition in the syntax, as well as the knowledge for multiple levels and types of semantic interpretation. Lexical entries are richly structured objects that act as both triggers to semantic operations as well as signatures to entailments and implicatures in the context of larger discourses. Because any semantic interpretation requires access to knowledge about words, the lexicon of a grammar must provide a systematic and efficient way of encoding the information associated with words in a language.

Four key questions arise when determining how to model the meanings conveyed by words: (i) What are the semantic components that constitute word meaning? (ii) How are word meanings differentiated and how are they related to each other? (iii) How does the meaning of individual words drive the compositional process to make semantically coherent sentences? and (iv) When is a component of word meaning considered "lexical" rather than "world" knowledge?

As the linguistic phenomena associated with lexical semantics become better understood, several theoretical assumptions have emerged across most current models of word meaning. These can be summarized roughly as follows:

1. Lexical meaning involves a kind of componential analysis, either through predicative primitives or a system of types.
2. The selectional properties of verbs must be explained in terms of the lexical semantics of the predication;
3. The role of event semantics and the event structure of a lexical item are critical in determining the meaning of linguistic expressions.

As we will see below, the first point makes an explicit connection between predicate decomposition theories (such as Lakoff, 1970, Levin and Hovav-Rapoport, 1995) and type-theoretic approaches to lexical semantics (Dowty, 1979, Pustejovsky, 1995, Davis and Koenig, 2000, Asher and Pustejovsky, 2006). This in turn directly influences the manner in which selectional constraints are encoded. Finally, we will observe the central role of Aktsionarten and event typing in the determination of sentence meaning in composition.

There are essentially four strategies to lexical specification that have been adopted in the literature. These approaches can be defined in terms of how, or whether, they provide an interface from expressions in the object language to their denotations in the metalanguage. The interface defines the logical forms associated with lexical items in the object language, and it is these expressions which are interpreted in the metalanguage. The four approaches can be defined as follows:

(1) a. Atomic Predication: No interface language is provided, and there is direct interpretation of an object expression into the metalanguage;
b. Relational Models: The interface is a relational structure, which is interpreted in the metalanguage;
c. Feature-based Decomposition: Component-based features are used to classify an expression in the object language into distinct concepts in the metalanguage;
d. Structural Decomposition: Component-based features are organized as a graph structure, with associated compositional interpretations in the metalanguage.

Atomic predication refers to non-decompositional approaches to lexical semantic interpretation, such as the early type-theoretic semantics of Montague (1968), where the lexical items are primitives in the object language, or the "language of thought" proposed by Fodor (1975, 2002). This view assumes a very tight coupling between the lexical semantics of a word and the syntactic projection associated with it. One consequence of this position, is that there are as many lexical entries for a word as there are senses for it in the object language. We discuss this view in Section XX below.

Relational models also start with the assumption that words are treated as primitives, but unlike atomic predication theory, they can have arbitrarily complex relational structures that facilitate semantic inferences. Such approaches are not as strict about introducing arguments that are visibly expressed in the syntax of the language, as is done with atomic predication models. Perhaps the best known example of this strategy is Davidson's addition of the event variable to action predicates (Davidson, 1967), as well as most subsequent work

assuming an event variable for eventuality predicates in language. Computational models for linguistic inference also often invoke this strategy in order to perform reasoning within established logical systems. Hobbs et al. (1993), for example, working within a framework of first-order abductive inference, adds any additional parameters to the argument structure of a predicate that are needed for an inference.

Feature-based decomposition has been used for discriminative analysis of natural language semantics since the 1960s, when the Katz and Fodor (1963) and Katz and Postal (1964) models within early generative grammar gained the greatest currency within the field. All expressions in the object language are decomposed into sets of binary-valued features, distinguishing concepts such as gender, number, age, marital status, and so on. Recently, vector-based representations of word meaning have emerged as a way to handle some long-standing problems in the computational interpretation of language. These distributional semantic models utilize far more sophisticated techniques for identifying word distributions and computing similarity and relatedness with them (Schütze, 1993, Padó and Lapata, 2007, Erk and Padó, 2008).

Finally *structural decomposition* is the approach currently adopted by many lexical semanticists working in the interface between syntax and semantics. Words are defined as restricted algebraic structures, with primitive predicates as atomic elements. This approach has been adopted broadly, from Dowty (1979), in his model-theoretic interpretation of generative semantics (Lakoff, 1965/1970), to van Valin (2005), Jackendoff's Conceptual Structure (Jackendoff, 1983, 2002), and variants of this model (Levin and Hovav-Rappoport, 1995, 2005). Both Generative Lexicon Theory (Pustejovsky and Boguraev, 1993, Pustejovsky, 1995) and semantic interpretations for HPSG (Davis and Koenig, 2000, Ginzburg and Sag, 2000) can also be seen as assuming a rich, structural decomposition as the foundation for their models.

In this entry, after a brief history of research in lexical semantics, we review the major issues confronting models of word meaning. Then we examine more closely the meaning components of individual words, beginning with word classes and types, and moving on to different strategies for encoding lexical meaning. We then consider the role played by event semantics in the determination of meaning. We conclude with an examination of the ways that word meanings contribute to the compositional mechanisms responsible for building sentence meanings. As part of this discussion, we look briefly at recent distributional models of semantics, as they have become influential in computational approaches to lexical disambiguation strategies, as well as several other areas in lexical semantics.

1.2 The History of Lexical Semantics

Interest in the meaning of words goes back as far as philosophical thought and speculation about the natural world. Aristotle, for example, in his *de Interpretatione* (McKeon, 1968) outlines a broad theory of language meaning, framed within a context of determining truth in the service of reasoning. As part of his general characterization of nature, Aristotle proposes a classification of thoughts and the words that convey them using a systematic set of dimensions called *aitia*. Applied to verbs and their corresponding activities, this allows one to distinguish between telic (goal-completive) or atelic (non-goal completive) eventualities. This has influenced both work in lexical aspect and Aktionsarten within linguistics, as well as provided much of the conceptual background for *Qualia Structure*.

With the exception of Locke (1690), Hume (1740), and Reid (1764), there was very little in the way of serious or systematic theorizing about word meaning until late in the 19th century. At this time, language researchers in Germany and France began focusing on lexical semantics from a psychological perspective, looking at the relation between words and concepts. Bréal, for example, considered polysemy (a term he coined) to be a necessary creative component of language, claiming that this phenomenon better than most others in semantics illustrates the cognitive and conceptualizing force of the human species (cf. Bréal, 1897). Similarly, German semasiologists viewed the lexicon, word meaning, and mechanisms of polysemy as illustrative of the "life force" of human language (cf. Erdman, 1900).

In the early 20th Century, European Structuralists introduced the distinction between syntagmatic and paradigmatic processes. Syntagmatic processes refer to the influence of "horizontal" elements on a word or phrase, in contradistinction to paradigmatic processes, which refer to "vertical" or alternative substitutions in a phrase. The term had significant currency in early and mid-twentieth century linguistics from Saussure on, and helped to define the formal study of syntax as widely practiced today. The Structuralists saw paradigmatic relations encoded in the various lexical systems of a language, and this was elaborated into a framework of componential analysis for language meaning (Jakobson, 1970). Componential analysis, used by anthropologists to study kinship terminology, is a method for breaking down the meanings of lexical items into a set of features, thereby illustrating similarities and differences of meaning between the items. The goal of such analysis was simply to classify the lexical items in the language with some finite set of features, its ultimate contrastive elements. These contrastive elements are structured in a matrix, allowing for dimensional analysis and generalizations to be made about lexical sets occupying the cells

in the matrix. Hjelmslev (1953), for example, decomposed lexical items into 'paradigms' which pattern the same way distributionally in the language. The componential analysis of lexical items entails a decomposition into distinctive features: *man* as [+adult, +male], *woman* as [+adult, -male], *girl* as [-adult, -male], and so forth.

In the early days of generative linguistics, many of the ideas of the Structuralists found there way into the first formulations of lexical knowledge for transformational grammars. Of particular importance was Katz and Fodor's (1963) and Katz and Postal's (1964) theory of feature-based semantics, where the meanings of words were composed entirely of sets of features with Boolean values. In line with Chomsky, the role of the semantics was limited: to detect semantic anomalies and determine the number of readings associated with a sentence. The theory offered proposals for the decomposition of sentences and lexical items, with explicit rules for linking items to syntactic structure While influential in the short term, this theory had no adequate theory of compositionality, and was seen to be too weak as a model for natural language semantics (Weinreich, 1965).

At the same time as features were being introduced into linguistic analyses, the role of a predicate's *valence* in relation to syntactic expressibilty began to be studied. Valence, a term introduced by Tesnière (1959), is a characterization of the number and semantic nature of arguments carried by a verb or other predicative expressions. In the late 1960s and early 1970s, alternatives to the Katz and Fodor model began to emerge that incorporated many of the characteristics and principles of valence-based grammars. These theories (Fillmore, 1965, Lakoff, 1965/1970, Gruber, 1965, Jackendoff, 1972) attempt to respect the relational structure of sentence meaning while encoding the named "semantic functions" of the arguments in the lexical entries for predicates.

Fillmore (1965,1968), for example, uses an enriched notion of valence to account for how arguments bind to syntactic positions in the sentence. From these early accounts of *case grammar*, Fillmore and colleagues developed a broader notion of *frame semantics* (Fillmore, 1976, 1982), where human activities are conceptualized as lexically encoded frames. A semantic frame specifies the conditions under which a predicate combines with its possible arguments, seen as the participants in the event which that predicate denotes.

Some of these ideas were incorporated into lexically-rich, feature-based semantics, in an attempt to explain how the semantic properties of predicates predict syntactic expressibility and behavior. One version of this grew into the framework known as *generative semantics* (Lakoff, 1970, McCawley, 1976), where the input to semantic interpretation was the deep structure of a sentence. While this started as an attempt to explain the selectional preferences imposed

by verbs on their arguments, the scope of the theory expanded to account for all semantic interpretation from deep structure.[1]

This view changed with Chomsky's and Jackendoff's *lexicalist* work in the 1970s, where the role of the lexicon became more central to grammatical processes, and generalizations could be made in terms of what properties were shared by lexical items. While the *Aspects*-model of selectional features restricted the relation of selection to that between lexical items, work by Jackendoff (1972) and McCawley (1968), showed that selectional restrictions must be available to computations at the level of derived semantic representation rather than at deep structure. Later work by Bresnan (1982), Gazdar et al. (1985), and Pollard and Sag (1994) extend the range of phenomena that can be handled by the projection and exploitation of lexically derived information in the grammar. In these frameworks, the lexicon plays a central part in the way compositional processes are carried out in the grammar.

Before the mid-twentieth century, there was little interest in word meaning within traditional philosophy. While linguistic semantics can trace its roots back to both Frege (1892) and Russell (1905), these and other authors were less interested in word meaning and linguistic behavior, than they were in how words were used as the medium through which judgments can be formed and inferences made. Frege's focus lay in formulating the rules which create meaningful expressions in a compositional manner, while also introducing an important distinction between an expression's sense and its reference. However, because of the descriptive bias in linguistics at the time, linguists largely failed to appreciate the role that systematic models of compositionality might play in language generally. Not until mid-century, with Montague's synthesis of grammatical description and intensional type theory were these issues addressed in a comprehensive (and influential) manner.

Montague (1968) introduces a bold new program for semantic interpretation in natural language, based on formal logic with a model-theoretic interpretation. Some of the most influential contemporary work on lexical semantics is based on this foundation, as we shall see in the sections below.

In Dowty (1979), a model-theoretic interpretation of the decompositional techniques introduced by Lakoff, McCawley, and Ross was developed. Dowty's work, together with Partee's (1975) seminal article on how Montague semantics was compatible with syntactic models familiar to linguists at the time, helped introduce formally grounded approaches to semantics to the mainstream of the field.

Over the past two decades there have been serious efforts to create an syn-

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thesis of lexical semantics and compositional mechanisms within linguistic theory. What has emerged is a new view of the role played by the lexicon regarding how composition is directed. Further, there is a new understanding of how contextualized aspects of interpretation impact the design decisions for what semantics is attributed to lexical items.

Examples of this approach are Generative Lexicon Theory (Pustejovsky, 1995, Bouillon and Busa, 2001), and construction grammar (Goldberg, 1995, Jackendoff, 1997, 2002). These developments have helped to characterize the approaches to lexical design in terms of a hierarchy of semantic expressiveness. There are at least three such classes of lexical description, defined as follows: *Sense Enumerative Lexicons*, where lexical items have a single type and meaning, and ambiguity is treated by multiple listings of words; *Polymorphic Lexicons*, where lexical items are active objects, contributing to the determination of meaning in context, under well-defined constraints; and *Unrestricted Sense Lexicons*, where the meanings of lexical items are determined mostly by context and conventional use. It seems clear that the most promising directions seems to be a careful and formal elucidation of the *polymorphic lexicons*, and this will form the basis of our subsequent discussion.

1.3 Issues in Lexical Semantics

In this section, we look more closely at a set of phenomena in language that are of particular relevance to how lexical meaning is encoded and applied through compositional mechanisms in the grammar. We focus on three specific problems here: (a) the semantic distinctions between lexical ambiguity and systematic polysemy; (b) the nature of selectional preferences in verb-argument composition; and (c) the polymorphic behavior of argument selection by predicates.

1.3.1 Ambiguity versus Polysemy

Given the compactness of a lexicon relative to the number of objects and relations referred to in the world, lexical ambiguity would seem inevitable for any language. Furthermore, the cultural, historical, and linguistic blending that contributes to the meanings of our words tends to make lexical ambiguity appear arbitrary as well. Hence, *homonymy* — where one lexical form has many meanings — is to be expected in a language. Examples of homonyms are illustrated in the sentences below:

(2) a. Mary strolled along the *bank* of the river.

b. This company is the largest *bank* in the city.

(3) a. The doctor *treated* the woman with antibiotics.
b. He always *treats* his guests well.

(4) a. First we leave the gate, then we *taxi* down the runway.
b. John saw the *taxi* on the street.

(5) a. The judge asked the defendant to approach the *bar*.
b. The defendant was in the pub at the *bar*.

Such lexical distinctions are called *contrastive ambiguities* (cf. Weinreich, 1968), where it is usually clear that the distinct senses associated with a word are unrelated. For this reason, it is assumed that homonyms are represented as separate lexical entries within the organization of the lexicon. Words with multiple senses are simply listed separately in the lexicon, but this does not seem to compromise or complicate the compositional process of how words combine in the interpretation of a sentence.

We can compare this to the phenomenon known as *polysemy* (cf. Apresjan, 1973). Polysemy is the relationship that exists between related senses of a word, rather than arbitrary ones, as in the above examples. For example, the noun *book* is polysemous, and can refer to either a physical object or the information contained in it, as illustrated in (**??**) below.

(6) a. Mary carried *the book* home.
b. Mary doesn't agree with *the book*.

Unlike the homonyms above, these two senses are logically related to each other by the very concept of *book*. Similarly, the noun *lunch* can refer to the food intended for consumption at a meal or the actual meal itself, as seen in (**??**).

(7) a. Mary has *her lunch* in her backpack.
b. The phone rang during *my lunch* yesterday.

In (**??**), a similar logical relation exists between the two senses of *flight*; in (**??**a), it refers to the event of flying, while in (**??**b) it refers to the plane engaged in flying.

(8) a. *The flight* lasted three hours.
b. *The flight* landed on time in Los Angeles.

While the two senses of the noun *bank* in (**??**) are not related (except by phonological form), each of these examples indicates a formal relation between the lexical senses. It is the role of the lexicon to distinguish such ambiguities, and to establish what this logical relation is.

Polysemy is not an isolated phenomenon in language, but rather is associated with every major category in the lexicon, within all languages. For example, adjectives such as *good*, *dangerous*, and *fast* can be viewed as polysemous, where the sense is modulated slightly, depending on the noun being modified.

(9) a. John is a *a good teacher*.
b. *A good meal* is what we need now.
c. Mary took *a good umbrella* with her into the rain.

In each of these sentences, *good* is a manner modifier whose interpretation is dependent on the noun it modifies; in (**??**a) it means "to teach well", in (**??**b), it means a "tasty meal", and in (**??**c), it means "something keeping you dry." Similar remarks hold for the adjective *dangerous*.

(10) a. This is *a dangerous road* at night.
b. She used *a dangerous knife* for the turkey.

That is, the road is dangerous in (**??**a) when "one drives on it", and the knife is dangerous in (**??**b) when "one cuts with it". Finally, the adjective *fast* in the sentences below acts as though it is an adverb, modifying an activity implicit in the noun; that is, *programming* in (**??**a), and *driving* in (**??**b).

(11) a. Mary is *the fastest programmer* we have on staff.
b. The turnpike is *a faster road* than Main Street.

The exact nature of how the adjective is interpreted relative to the head will be discussed in Section XX below.

A somewhat related phenomenon involving adjectival scope instead of true polysemy can be seen in the sentences in (**??**), where the adjective can modify the agentive nominal activity or the nominal as an individual.

(12) a. Mary is *a beautiful dancer*.
b. Frances is *a Czech polka dancer.*

This problem has been studied by a number of researchers (Larson, Pustejovsky, others), and while not involving polysemy, it does highlight the need for a potentially richer semantic content of agentive nominals than is typically assumed.

As mentioned above, polysemy is a phenomenon exhibited by all the major categories in language, including verbs. Because verbal polysemy is perhaps

the most common form of systematic sense relatedness, we cover it in more detail in a separate section below (cf. 1.3.3).

What is important to realize from the data shown here, for both nouns and adjectives, is that simply listing the senses of these words will not always account for their creative use in novel contexts in language. Accounting for the behavior of polysemy in language is one of the most difficult problems facing a theory of the lexicon, and we take up the solutions to this problem in Section XX.

1.3.2 Selectional Constraints

To demonstrate the interaction of the lexicon with the other components of grammar, let us examine how lexical information is accessed and exploited by syntactic and semantic operations, a process generally referred to as *selection*.

By far, the most widely studied type of selection process involves the constraints imposed on neighboring phrases by a word, by virtue of its lexical properties. One of the most important properties of a verb is an encoding of what phrases it can appear with in the language. In general, this is the problem of determining how many arguments a verb can appear with in the syntax, and is referred to as *argument selection*. There is a general rule of thumb that the number of arguments that the predicate allows in the syntax corresponds to the number of participants an event has.[2] That is, the argument structure of a word loosely reflects the underlying relational meaning associated with that word.

For example, consider the behavior of one-argument (intransitive), two-argument (transitive), and three-argument (ditransitive) verbs in English. The *arity* (number of arguments) information is encoded in the verb's *argument structure*. The verbs *laugh*, *see*, and *give* are simple examples in English.

(13) a. The man *laughed*.
b. The girl *saw* a bird.
c. The boy *gave* a treat to the dog.

The argument structure for the verbs in these sentences can be represented as follows:

(14) a. *laugh*(arg_1)
b. *see*(arg_1,arg_2)
c. *give*(arg_1,arg_2,arg_3)

[2] We'll see below that this is not always the case, however, and there are more complex relations between semantic representations and the syntactic structures that may appear.

The lexicon plays an important role in determining whether a linguistic expression in a language is well-formed, and selection is the mechanism through which this is accomplished. For example, it is because of the argument structures in (**??**) that these verbs do not appear in the wrong grammatical contexts, such as (**??**) below.

(15) a. *The storm *laughed* the man.
b. *A bird *saw*.
c. *A treat *gave* to the dog.

One of the most important themes when studying the lexicon is to establish just what role lexical information plays in determining whether an expression is well-formed or not.

Although the argument structure indicates how many arguments to expect with a verb in the syntax, it says nothing about what *kind* of arguments these should be. This can be accomplished by adding *selectional constraints* to the arguments of the verb. A selectional constraint is a requirement on an argument that must be satisfied for the verb to be interpreted properly. The most important constraint imposed on an argument by a predicate is its *syntactic category*, that is, whether it is an Noun Phrase (NP), Verb Phrase (VP), Adjective Phrase (AP), or sentence (S). For example, both *love* and *think* are transitive verbs and have the argument structure

(16) V(arg_1,arg_2)

but their arguments have different syntactic requirements, as we can easily see in (**??**).

(17) a. The girl *loves* [$_{NP}$ books].
b. The girl *thinks* [$_{S}$ her brother is funny].

This can be encoded as part of the argument structure for that verb if we make a list of features for each argument. In our representation, this list will be shown directly following the argument it is associated with. So, for example, let `cat` be the feature for the category of the argument; then we have the following distinct argument structures for these two verbs.

(18) a. *love*(arg_1[cat=NP],arg_2[cat=NP])
b. *think*(arg_1[cat=NP],arg_2[cat=S])

Thus far, the lexical information needed to interface to the syntax is of two sorts:

(19) Lexical Information Impacting the Grammar:
   a. *Argument structure* of a verb: this determines the number of phrases in the syntactic construction associated with the verb;
   b. *Syntactic category* of each argument; this identifies the actual syntactic phrase associated with the argument;

There are other selectional phenomena captured by constraints. For example, observe the differences in the sentences below.

(20) a. The man / *the rock laughed.
   b. The man / the rock fell.

The constraints imposed on the subject by a verb such as *laugh* would include the feature of `animacy`, while a verb like *fall* does not. Since this is a lexical property of these verbs, their argument structures should reflect this distinction. Hence, the verb *laugh* has a selectional constraint indicating that the subject must be animate, as shown in (**??**).

(21) a. *laugh*(arg_1[cat=NP,animacy=+])

Similarly, the feature of `number` is important for selecting the appropriate subject for verbs such as *assemble*, *gather*, and *disperse*; namely, the subject must be plural.

(22) a. The students *gathered* in the courtyard.
   b. The children *assembled* in the gym.
   c. The fans *dispersed* from the stadium.

Notice, that it can be either *grammatically* plural, as in (**??**) above, or *semantically* plural, as with the subjects in (**??**).

(23) a. The class *gathered* in the courtyard.
   b. The team *assembled* in the gym.
   c. The crowd *dispersed* from the stadium.

That is, the nouns *class*, *team*, and *crowd* can all be considered as plural, from the point of view of the verb and the grammar. Hence, the argument structure for these verbs must reflect this phenomenon by adding a selectional constraint referring to `number`, ranging over the values ‘singular’ and ‘plural’.

(24) a. *assemble*(arg_1[cat=NP,num=plural])

It is interesting to ask whether these selectional constraints are independent or whether they interact with one another. Let us look a little more carefully at the verbs in (**??**) and (**??**) above. We saw that the subject for each of these verbs must be plural. How does the feature `number` interact with `animacy`? Notice that both *disperse* and *gather* allow non-human subjects, while *assemble* does not.

(25) a. The clouds *gathered* in the sky.
b. *The clouds *assembled.*
c. The clouds *dispersed* quickly.

To ensure that a structure such as (**??**b) is not licensed by the grammar, there must an encoding of how the structural conditions are being violated. Notice that this can already be done using the constraints we've discussed, namely the combination of `number` and `animacy`, as illustrated in (**??**) below.

(26) a. *assemble*(arg_1[cat=NP,num=plural, animacy=+])

It would appear then, that the verb *assemble* requires the plural subject to be animate, while the very similar verbs *gather* and *disperse* do not.

Selectional constraints, in fact, can determine the acceptability of arguments in any positions in the grammar; consider the distinction between the verbs *force* and *convince*. Although they are synonyms in many contexts, *force* and *convince* have different selectional properties, the latter requiring that the "convinced" be a cognitive agent.

(27) a. John *forced* the guest to leave.
b. John *convinced* the guest to leave.

(28) a. John *forced* the door to open.
b. *John *convinced* the door to open.

Verbs select for different spatial prepositions as well; verbs involving spatial manner descriptions, for example, are quite specific for the kinds of prepositions they allow. Consider, for example, *on* and *in* versus *over* in the sentences below, when selected by the verb *lie* .

(29) The cat is lying on the floor / in the box / *over the floor / ....

Selectional constraints can also be enlisted to determine the appropriate selection of *manner adverbials* for verbs, as well. Notice that in (**??**), without some sort of adverbial phrase associated with the verbs *behave* and *perform*, the sentences below are ungrammatical.

(30) a. Mary *behaved* *(well).

b. John *performed* *(admirably).

We see from this brief discussion, that selection is an important part of how lexical information is conveyed to the syntactic operations in the grammar. From what we discussed, there are at least three types of lexical information which interface to the syntax:

(31) Lexical Information Impacting the Grammar:
a. *Argument structure* of a verb: this determines the number of phrases in the syntactic construction associated with the verb;
b. *Syntactic category* of each argument; this identifies the actual syntactic phrase associated with the argument;
c. *Selectional constraints* of each argument; these identify specific grammatical and semantic features of the argument being selected by the verb.

Selectional constraints have been used to encode all manner of lexical and syntactic restrictions in grammar. As such, they are part of the meaning of words and have direct effects on the syntax, morphology, and semantics of the language.

1.3.3 Verb Meaning and Mapping to Syntax

We saw in the previous section the role that the lexicon plays in ensuring that a linguistic expression is well-formed. Recall that it is the argument structure that prevents verbs from ending up in the wrong syntactic contexts in sentences (cf. Levin, 1993). That is, if the lexicon says it is so, then the grammar follows.

(32) a. *laugh*(arg_1) $\Longrightarrow$
The man *laughed*.
b. *see*(arg_1,arg_2) $\Longrightarrow$
The girl *saw* a bird.
c. *give*(arg_1,arg_2,arg_3) $\Longrightarrow$
The boy *gave* a treat to the dog.

Or does it? Notice that there are contexts for each of the verbs in (**??**), which exploit properties of the verb, giving rise to constructions not allowed by the original argument structure.

(33) a. The man *laughed* himself sick.
b. The girl *saw* a bird fly into the room.
c. The man *gave* at the office.

In each of these sentences, the argument structure for the verb has been violated in some way. In (**??**a), there is an additional NP object to the verb *laugh*, and a predicate modifying the object NP *himself*. In (**??**b), what the girl saw was not just a bird, but what the bird did; namely, "flying into the room", described as an additional VP. Finally, in (**??**c), both of the expected arguments are missing, and presumably inferred from the context of the utterance.

These illustrate one aspect of the phenomenon of *verbal polysemy* . Polysemy, as defined in the previous section, is the term given to an ambiguity where the different meanings of the word are logically related to each other. Many verbs can appear in multiple contexts taking a different number of arguments in each, a phenomenon known as an *alternation*. For example, the verbs *break*, *roll*, and *sink* all have intransitive and transitive forms, as shown in the sentences below.

(34) a. The glass *broke*.
b. Mary *broke* the glass.

(35) a. The ball *rolled* down the slide.
b. The boy *rolled* the ball down the slide.

(36) a. The ship *sank*.
b. The torpedo *sank* the ship.

How does the lexicon represent such ambiguities? The simplest way would be to list the different argument structures for each verb, as shown in (**??**).

(37) a. $break_1(\text{arg}_1)$; $break_2(\text{arg}_1,\text{arg}_2)$
b. $roll_1(\text{arg}_1)$; $roll_2(\text{arg}_1,\text{arg}_2)$
c. $sink_1(\text{arg}_1)$; $sink_2(\text{arg}_1,\text{arg}_2)$

But recall from our previous discussion, that the semantic role of the intransitive subject is the same as the transitive object NP in each one of these verbs. That is, it is the *undergoer* or *patient*.

This kind of alternation does not apply to all intransitive verbs, of course, and the lexicon must somehow prevent verbs like *arrive* and *die* from becoming transitive.

(38) a. Your package *arrived*.
b. *The mailman *arrived* your package.

(39) a. My computer *died* yesterday.
b. *The storm *died* my computer yesterday.

The question arising from such cases is this: what allows for an alternation to occur for some verbs while not for others? Is this part of the lexicon or some other rule or strategy in the grammar?

Verb alternations are quite prevalent in language and pose a difficult problem to lexicon designers. For example, how many different argument structures do we have for a verb like *sweep*?

(40) a. John *swept*.
b. John *swept* the floor.
c. John *swept* the dirt into the corner.
d. John *swept* the dirt off the sidewalk.
e. John *swept* the floor clean.
f. John *swept* the dirt into a pile.

Such alternating patterns typically apply to more than just one verb; hence, it would be more efficient to have a general strategy for how these word senses are related rather than simply listing the different senses for each verb.

Lexical information is sensitive both to the syntax and the discourse context. Although a verb may be lexically specified to have a certain number of arguments, there are many situations in which this can be violated. We saw this above in (**??**c) with the verb *give*. In fact, this is quite common, but appears to be governed by systematic rules, and not just pragmatic information. For example, while (**??**c) is grammatical, (**??**b) below is not.

(41) a. The woman *donated* her car to the foundation.
b. *The woman *donated*.

Similarly, *eat* and *drink* can appear without their direct objects, but *devour* and *gulp* cannot.

(42) a. The girl *ate* her lunch quickly.
b. The girl *ate* quickly.

(43) a. The dog *devoured* the bone.
b. *The dog *devoured*.

(44) a. The boy *drank* his milk quietly.
b. The boy *drank* quietly.

(45) a. The boy *gulped* his milk quietly.
b. *The boy *gulped* quietly.

This type of alternation is typically called *indefinite NP deletion*, and is related to other "pragmatic deletions", such as those shown below.

(46) a. John *tried* to call his mother yesterday.
b. John *tried* yesterday.

(47) a. John *attempted* to call his mother yesterday.
b. *John *attempted* yesterday.

The ability to ignore part of the argument structure in the syntax seems to be a lexical property, one which is idiosyncratic to each verb.

Finally we consider a kind of verbal polysemy not involving argument alternation, but a *syntactic category alternation*. Recall from our discussion above (cf. (**??**)) that we motivated a way to distinguish between different syntactic types for an argument; that is, *love* and *think* have different category values associated with their second arguments:

(48) a. *love*(arg_1[cat=NP],arg_2[cat=NP])
b. *think*(arg_1[cat=NP],arg_2[cat=S])

What happens, however, when the syntactic distinction involves the same verb? Consider the sentences below, where the verb *begin* appears in three distinct syntactic contexts.

(49) a. Mary *began* to read the novel.
b. Mary *began* reading the novel.
c. Mary *began* the novel.

Verbs like *hate* and *love* in English can appear in even more contexts, as seen in (**??**) below.

(50) a. John would *hate* Bill to leave.
b. John *hates* (it) that Bill left.
c. John *hated* to lose the game.
d. John *hated* losing the game.
e. John *hated* that he lost the game.

The examples above in (**??**) and (**??**) bring up the issue of how to make generalizations in the lexicon; that is, is there a "compact" manner in which to express that the verb *begin* means the same thing in each sentence in (**??**), and likewise for the verb *hate* in (**??**).

1.4 Event Semantics

In this section, we look at the notion of event in lexical semantics. There are two traditions to examine when studying the role of events in the semantics of language:

(51) a. *Event Argument*: Predicates in language have an *event variable* that can be treated as a first-order individual in the semantics, to enable logical inference; Davidson (1967)
b. *Aktionsarten*: Predicates in language can be classified according to their event type or aspectual class, in order to specific capture grammatical and semantic behaviors; Vendler (1967)

The move by Davidson to introduce a first-order event variable in the representation was mainly motivated by the need to provide a coherent analysis of adverbial modification in the interpretation of sentences. Under this proposal, two-place predicates such as *eat* and three-place predicates such as *give* contain an additional argument, the event variable, e, as depicted below.

(52) a. $\lambda y \lambda x \lambda e[\text{eat}(e)(y)(x)]$
b. $\lambda z \lambda y \lambda x \lambda e[\text{give}(e)(z)(y)(x)]$

In this manner, Davidson is able to capture the appropriate entailments between propositions involving action and event expressions through the conventional mechanisms of logical entailment. For example, to capture the entailments between (**??**b-d) and (**??**a) below,

(53) a. Mary ate the soup.
b. Mary ate the soup with a spoon.
c. Mary ate the soup with a spoon in the kitchen.
d. Mary ate the soup with a spoon in the kitchen at 3:00pm.

In this example, each more specifically described event entails the one above it by virtue of and-elimination (conjunctive generalization) on the expression.

(54) a. $\exists e[\text{eat}(e, m, \text{the-soup})]$
b. $\exists e[\text{eat}(e, m, \text{the-soup}) \wedge \mathit{with}(e, \text{a\_spoon})]$
c. $\exists e[\text{eat}(e, m, \text{the-soup}) \wedge \mathit{with}(e, \text{a\_spoon}) \wedge \mathit{in}(e, \text{the\_kitchen})]$
d. $\exists e[\text{eat}(e, m, \text{the-soup}) \wedge \mathit{with}(e, \text{a\_spoon}) \wedge \mathit{in}(e, \text{the\_kitchen}) \wedge \mathit{at}(e, \text{3:00pm})]$

There are of course many variants of the introduction of events into predicative forms, including the identification of arguments with specific named roles (or

partial functions, cf. Dowty, 1989, Chierchia, 1989) such as thematic relations over the event. Such a move is made in Parsons (1980).
In lexical semantic analysis, it is standard practice to create component-based classifications using linguistic data that demonstrate pairwise distinctions for grammatical or semantic well-formedness judgments. One of the most enduring and productive of such an approach is the determination of aspectual class or *Aktionsart*. This is essentially a characterization of the different kinds of eventualities that verbs and event nominals denote. There have been several influential distinctions proposed in the literature, but the best known are those introduced by Kenny (1963) and Vendler (1967). Kenny assumed that there are three basic aspectual types: *state*, it activity, and *performances*. Vendler proposes a similar distinction for states and processes, but splits the last class (his *events*) into two categories, *accomplishments*, and *achievements*. His classification as well as his terminology have been the starting point for much of the work in aspect and event semantics in the field. These even classes are summarized briefly below.

(55) a. *State*: an unchanging situation that holds at a time or over an interval, with no endpoints.
b. *Activity*: a dynamic event with no endpoints (an *atelic* event).
c. *Accomplishment*: an incrementally changing event with a culminating endpoint (a *telic* event).
d. *Achievement*: an instantaneous change of state.

Examples of states are seen in simple attributive predications, such as (**??**a-b), as well as with non-dynamic relations, such as (**??**c-d).

(56) a. Mary is *happy*.
b. Marc is *Dutch*.
c. Jan *loves* Bill.
d. Mary *believes* Jan is happy.

States can be distinguished from activities by virtue of certain grammatical diagnostics, many of which Vendler introduced into the literature. Consider a verb such as *swim* in sentence (**??**a). This denotes an activity of unspecified duration, and the sentence does not convey information regarding a culmination of this activity. With the addition of a goal *to*-PP, however, as in sentence (**??**b), the swimmng activity is bounded, and the resulting event denotes an accomplishment.

(57) a. Jan *swam* yesterday.
b. Jan *swam* to the dock yesterday.

c. Jan *is swimming*.

Hence, we can analyze the verb *swim* as lexically denoting an activity, which can be interpreted contextually as an accomplishment, through the appropriate compositional modification. Finally, notice that sentence (**??**c) denotes a "snapshot" of the swimming process. Both of these aspectual *coercions* are known to distinguish processes from states.

In a similar fashion, there are verbs which lexically denote accomplishments, such as *build* and *destroy*. These verbs encode the logical culmination to the activity performed during the event, as illustrated in (**??**) below.

(58) a. The children *built* a fort.
b. John *destroyed* the anthill.

Finally, 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 (**??**a-c) 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).

(59) a. The plane *crashed* at noon.
b. John *found* his wallet at 3 pm.
c. The train *arrived* at midnight.

Pustejovsky (1988,1991) extends the decompositional approach presented in Dowty (1979) by explicitly reifying the events and subevents in the predicative expressions. Unlike Dowty's treatment of lexical semantics, where the decompositional calculus builds on propositional or predicative units (as discussed above), a "syntax of event structure" makes explicit reference to quantified events as part of the word meaning. Pustejovsky further introduces a tree structure to represent the temporal ordering and dominance constraints on an event and its subevents (cf. also Moens and Steedman, 1988).

(60) a. EVENT $\rightarrow$ STATE | PROCESS | TRANSITION
b. STATE: $\rightarrow$ e
c. PROCESS: $\rightarrow$ $e_1 \ldots e_n$
d. TRANSITION$_{ach}$: $\rightarrow$ STATE STATE
e. TRANSITION$_{acc}$: $\rightarrow$ PROCESS STATE

For example, the accomplishment denoted by "building a house" consists of the building process, followed by the state representing the result of there now existing the object built. Grimshaw (1990) adopts this theory in her work on

argument structure, where complex events such as *break* are given a similar representation. In such structures, the process consists of what x does to cause the breaking, and the state is the resultant state of the broken item. The process corresponds to the outer causing event as discussed above, and the state corresponds in part to the inner change of state event. Both Pustejovsky and Grimshaw differ from the authors above in assuming a specific level of representation for event structure, distinct from the representation of other lexical properties. Furthermore, they follow Davidson (1967), Parsons (1990), and Higginbotham (1986) in adopting an explicit reference to the event place in the verbal semantics.

Recently, Levin and Rappaport (2001, 2005) have adopted a large component of the event structure model for their analysis of the resultative construction in English; and event decomposition has also been employed for properties of adjectival selection, the interpretation of compounds, and stage and individual-level predication.

Research done by Tenny (1987), Dowty (1991), Krifka (1992, 1998), and others, enriches this typology by developing a theory of how the event is shaped by the incremental unfolding of the theme object. The central aspect of this view is that an accomplishment is defined as involving a homomorphism from parts of the event to parts of the incremental theme. The problem of incrementality can be illustrated with the following examples.

(61) a. John ate a hamburger.
b. Mary wrote a novel.

The process of eating something is an incremental activity, resulting in an accomplishment described by reference to the quantized unit appearing in the direct object (theme) position.

Starting from a quite different perspective, Krifka (1989, 1992) presents an interpretation of Aktionsart using an lattice-theoretic interpretation of event structure. Using the sum operation from lattice theory, where a complex event $e_1 \sqcup e_2$ can be formed from any two events, e_1 and e_2, Krifka introduces a part/whole relation, $e_1 \sqsubset e_2$, iff $e_2 = e_1 \sqcup e_2$. This allows for a distinction to be made between *quantized* and *cumulative* predicates. Processes of undifferentiated activity, such as *walking* or *singing*, are cumulative, and are closed under the sum operator, while an accomplishment, such as *build a house*, are not.

(62) a. $\forall P[\mathrm{CUM}(P) \leftrightarrow \forall x \forall y[[P(x) \wedge P(y)] \rightarrow P(x \sqcup y)]]$
b. $\forall P[\mathrm{QUA}(P) \leftrightarrow \forall x \forall y[[P(x) \wedge P(y)] \rightarrow x \not\sqsubset y]]$

These two classes map nicely to the well-known categories of *atelic* and *telic* predicates, mentioned above. For example, no part of building a house is a

complete house-building; the event is quantized by the relationship to the result, i.e., the house (cf. Krifka (1991)). The activity of walking, on the other hand, is cumulative, and any event of walking is composed of subevents of walking.

Recent work on scalar change (cf. Beaver 2008, Levin and Rappaport Hovav 2010) and dynamic event semantics (Naumann 2001) suggests a new understanding of the interplay between verb meaning, event semantics and argument structure with these predicates, by focusing on the measurement of the change in value over the properties of the participants in each intermediate state during the event.

1.5 Lexical Decomposition

Lexical decomposition is concerned with the internal semantic structure of lexical and conceptual items within a lexicon. The focus of lexical decomposition is on how the lexical items are semantically similar and distinct by virtue of shared knowledge structures or semantic primitives. While numerous different sorts of structure (e.g., frames and prototypes) and primitives (e.g., semantic features and semantic markers) have been proposed, we limit our discussion here to the most currently relevant theories, all of them *structural decomposition* models, as introduced above.

The goal of lexical decomposition has traditionally been to provide the necessary and sufficient conditions for the meaning of every lexical item in a subject domain or language. In many ways, this goal is similar to that of the syntactic analysis of sentences in a language. If primitives and structures are taken as an exhaustive set on top of which all expressions in the language are expressed, then the meaning of any lexical item in the language will have to be derived from these terms.

Perhaps the first significant framework of structural decomposition was generative semantics (cf. Lakoff 1965/1970). It emerged just as Katz and Fodor's feature-based decomposition model was shown to be both incomplete and inadequate (cf. Weinreich, 1972) as a model for language semantics. Generative semanticists argued that deep structure be the semantic structure and that only transformational rules need operate on that structure. Lexical items are decomposed into a set of abstract components and transformations are done on those components (see Lakoff, 1965; Ross, 1970). For example, the lexical item 'kill' is decomposed into the predicate DEAD and two higher level predicates CAUSE and BECOME. The terminal nodes of deep semantic structure are these semantic components.

While the framework of generative semantics is no longer generally adopted, many aspects of the theory can be seen in contemporary lexical theories, owing to some significant generalizations the theory made about semantic structure in language. For example, the sentences in (**??**) form a sort of paradigm for the concept 'dead', related by the application of abstract predicates, which systematically change the meaning of the words associated with it (cf. Lakoff, 1965, McCawley, 1968, Carter, 1976).

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

For example, assuming that the underlying form for a verb like *kill* encodes the stative predicate in (**??**c) and the relation of causation, generative semanticists posited representations such as (**??**) below.

(64) (CAUSE (x, (BECOME (NOT (ALIVE y))))

Here the predicate CAUSE is represented as a relation between an individual causer *x* and an expression involving a change of state in the argument *y*. Although there is an intuition that the cause relation involves a causer and an event, neither Lakoff nor Carter make this commitment explicitly (a point we return to below).

In a very influential work, Dowty (1979) presents a model-theoretic interpretation of the ideas from generative semantics, but with one important difference: Dowty associates complex decompositional expressions such as the one in (**??**) with the lexical items directly, without the syntactic machinery of predicate reduction that was required in a generative semantics derivation from deep to surface structure. Hence, the lexicon in Dowty's theory is far richer than normally envisioned.

Another significant contribution made by Dowty's study of word meaning is his re-interpretation of Vendler's classification of the Aktionsarten, mentioned in Section XX, in model-theoretic terms. Thus, states, activities, accomplishments, and achievements, are given a formal treatment within an intensional logic.

Pursuing a similar line of reasoning to the generative semanticists concerning lexical decomposition, Jackendoff (1972) built on Gruber's (1967) thesis to argue that predicates such as [+cause] and [+inchoative] are encoded in the meaning of the word itself.[3] In Jackendoff's later work (1983, 1990, 1997,

[3] Jackendoff (1972), following Chomsky (1970), was philosophically at odds with the claims made by generative semantics. Interpretive semantics took semantics to be a process of interpretation over the derived surface form of the sentence, rather than the deep structure.

2002), the approach to lexical decomposition makes claims for cognitive relevance that are not important motivations for many researchers. However, Jackendoff believes in the cognitive primacy of the primitives used within his system, and the role of these primitives in performing inferences. We examine Jackendoff's semantic representation briefly here, as it pertains to lexical decomposition.

The spatial predicates which Jackendoff employs can be seen as one dimension of decompositional analysis. Another dimension Jackendoff employs could be called the causal dimension. These include two predicates, CAUSE and LET, each of which takes an agent and event as arguments. To illustrate, let us take the sentence from above, and embed it within a causative construction.

(65) a. John flew the plane from New York to Boston.
b. CAUSE(John, GO(plane, New York, Boston))

Although these predicates are spatial in origin, Jackendoff, like many others interested in the nature of semantic extension, explores the idea that the predicates within the spatial domain may be used to analyze concepts within other semantic domains. The basic idea here is that for different semantic fields such as possession, identification, circumstantial, and temporal, a verb from the spatial field can acquire a new meaning using the same primitives because it is being evaluated relative to a new field. Examples of this include:

(66) a. *Possessional*: John will take the house and Mary the kids.
b. *Identificational*: John turned into a great father.
c. *Circumstantial*: Mary lead me to believe she was younger than I.
d. *Temporal*: The seminar has been moved to Wednesdays.

Regardless of the decompositional approach adopted, there are many questions that remain: do its primitives provide a complete and exhaustive description of the concepts of natural language? How open-ended is the system? What is the additional information which distinguishes the meaning of one lexical item from another? That is, the primitives do allow for generalizations, but what allows for the discrimination of concepts (the function filled by distinguishers in Katz and Fodor's theory), and how many features are necessary to that end?

More recent versions of lexical representations inspired by generative semantics and Jackendoff's decomposition model can be seen in the Lexical Relational Structures of Hale and Keyser (1993), where syntactic tree structures are employed to capture the same elements of causation and change of state as in the representations of Carter, Jackendoff, and Dowty. The work of Levin and Rappaport, building on Jackendoff's Lexical Conceptual Structures, has

likewise been influential in further articulating the internal structure of verb meanings (see Levin and Rappaport 1995).

Generative Lexicon can be seen as a hybrid theory, incorporating aspects of Jackendoff's and Dowty's work with the event semantics of Davidson and Parsons. It has taken several decades for Davidson's (1967) observations regarding the role of events in the determination of verb meaning to find their way convincingly into the major linguistic frameworks. Over the past two decades, a synthesis has emerged which attempts to model verb meanings as complex predicative structures with richer event structures (cf. Parsons, 1990, Pustejovsky, 1991, 1995, Levin and Rappaport, 1995). This research has developed the idea that the meaning of a verb can be analyzed into a structured representation of the event that the verb designates, and has furthermore contributed to the realization that verbs may have complex, internal event structures.

1.6 Semantic Roles

While decomposition aims to define lexical meaning in terms of a word's internal features, theories of semantic roles can be seen as *partial decomposition* models, focusing on articulating the function or role that the arguments of a predicate play in the determination of sentence meaning. Hence, as mentioned above in Section 2.0, we can view semantic roles as enhanced argument structure specifications.

Argument structure is the syntactic encoding of the functional behavior of an expression in the object language. In linguistically motivated models of lexical semantics, one of the basic semantic distinctions between nouns and verbs is stated in terms of their selectional behavior in syntax (the valence properties discussed in section 2.0). The argument structure for a word can be seen as the simplest specification of its semantics, indicating the number and type of parameters associated with the lexical item as a predicate. For example, the verb *sleep* can be represented as a predicate taking one argument, *love* as taking two arguments, while the verb *buy* takes two, three, or four arguments, depending on the context.

(67) a. **sleep**(x)
b. **love**(x,y)
c. **build**(x,y,z)

The first theory of semantic roles within a generative model was *Case Grammar*, a semantically oriented grammar developed by Fillmore (1968) and others, e.g., Anderson (1971, 1977) and Starosta (1989). Case was first used for

the morphological analysis of noun endings in, e.g., German and Russian. Fillmore showed that these noun endings serve the same purpose as the positioning of nouns and prepositions in lexical surface structures. Fillmore (1968) introduced the notion of case grammar and a case frame, a predicate containing arguments that are a set of obligatory and optional cases. Implicit in the theory is that each NP in a sentence can be assigned only one case and that the cases assigned by a verb can be realized only once in a sentence. He defined a number of cases including:

(68) a. Agentive (A): an animate perceived instigator of the action identified by the verb.
b. Instrumental (I): an inanimate force or object causally involved in the action or state identified by the verb.
c. Dative (D): an animate being affected by the action identified by the verb.
d. Objective (O): the semantically most neutral case.

For example, the verb 'open' requires that its objective role be filled: something must open or be opened. In (**??**a), only the objective role is filled. In (**??**b) and (**??**c), both agentive and objective roles are filled. In (**??**d), the instrumental and objective roles are filled. In (**??**e), the agentive, objective, and instrumental roles are filled.

(69) a. The door opened.
b. Mary opened the door.
c. The door was opened by Mary.
d. The key opened the door.
e. Mary opened the door with the key.

Fillmore noted that different case roles can occupy the same grammatical function, e.g., the grammatical subject is 'door' in (**??**a) and (**??**c) which occupies the objective role, 'Mary' in (**??**b) and (**??**c) which has the agentive role, and 'key' in (**??**d) and (**??**e) which has an instrumental role.

Fillmore's theory attempts to explain how the arguments of a predicate are assigned to particular syntactic structures and is not concerned with establishing an independent level of semantic representation. To handle assignment, Fillmore assumed a principle of a case hierarchy, which allowed the selection of grammatical subject and object in default configurations. As an example of case assignment, consider the verb 'break' which assigns both obligatory and optional cases. Obligatory cases include the objective, while optional cases include both the agentive and instrumental cases.

(70) John broke the window with a rock.

In sentence (**??**), by default assignment, agentive is assigned to the subject, objective to the object, and instrumental to the phrase within the prepositional phrase. This is a type of default selection which can be violated if the verbal morphology indicates a structure such as a passive as in (**??**c).

Fillmore (1977a) notes some deficiencies and limitations of case grammar. Although case grammar is useful as a guide to decomposition of verb meaning, the theory does nothing to clarify the nature of sense relations like antonymy and hyponymy. Case grammar allows the recognition of sentences as partially synonymous by matching case structures. Because it does not claim to be a complete model for meaning, case grammar avoids the pitfalls of the decomposition model of Katz-Fodor; on the other hand, because of its incompleteness, it is unclear what role such a system of cases might play in a comprehensive semantic theory.

Part of Jackendoff's early work on the theory of lexical decomposition (as discussed above) included a formalization of Gruber's (1967) more limited notion of thematic role. In this view, which is quite similar to Fillmore's conception of cases, Jackendoff (1972) classifies verbs according to which thematic (theta) roles they assign to their arguments. Thus, theta theory, as this view has come to be known, is a minimal decomposition of verb meaning, where features and abstract predicates have been replaced by named functional roles, as in case grammar. The success of theta theory has come not from how well it characterizes verb denotations, but in how "functional" roles interact with other principles of syntax to determine the well-formedness of a sentence.

Thematic relations are now generally defined as partial semantic functions of the event being denoted by the verb or noun, and behave according to a predefined calculus of roles relations (e.g., Carlson, 1984, Dowty, 1989, Chierchia, 1989). For example, semantic roles such as agent, theme, and goal, can be used to partially determine the meaning of a predicate, when they are associated with the grammatical arguments to a verb.

(71) a. **put**<AGENT,THEME,LOCATION>
b. **borrow**<RECIPIENT,THEME,SOURCE>

Thematic roles can be ordered relative to each other in terms of an implicational hierarchy. For example, there is considerable use of a universal subject hierarchy such as shown below (cf. Fillmore, 1968, Comrie, 1981).

(72) AGENT > RECIPIENT/BENEFACTIVE> THEME/PATIENT > INSTRUMENT > LOCATION>

Many linguist have questioned the general explanatory coverage of thematic roles, however, and have have chosen alternative methods for capturing the

generalizations they promised. Dowty (1991) suggests that theta-role generalizations are best captured by entailments associated with the predicate itself. A theta-role can then be seen as the set of predicate entailments that are properties of a particular argument to the verb. Characteristic entailments might be thought of as prototype roles, or **proto-roles**; this allows for degrees or shades of meaning associated with the arguments to a predicate. Others have opted for a more semantically neutral set of labels to assign to the parameters of a relation, whether it is realized as a verb, noun, or adjective.

In the late 1970s, Fillmore began to rethink his views of semantics and developed a "scenes-and-frames" semantics to overcome the deficiencies and limitations he had noted with case grammar. The basic ideas of the new semantics, heavily influenced by Minsky (1975), were that "people associate certain scenes with certain linguistic frames" and that "meanings are relativized to scenes," i.e., lexical items or expressions are understood by placing them within scenes or images in which they have some linguistic functions, e.g., naming.

In the theory, frames are linguistic entities that represent the meanings of lexical items. Scenes can be not only visual but also refer to "interpersonal transactions, standard scenarios, familiar layouts" (Fillmore, 1977b, p. 63) and "body image" (the way we orient and classify linguistic frames such as UP-DOWN and LEFT-RIGHT).

Fillmore's account views scenes-and-frames as offering an alternative to traditional accounts of lexical decomposition issues like lexical ambiguity, synonymy, semantic fields and selection restrictions (Fillmore, 1975, p. 129). Synonymy can be understood as "indistinguishable scenes for which the frame offers lexical options. A selection restriction is viewed as the relation between a frame and a scene. "[The] selection restriction information about the use of a word can be stated as a specification of the nature of the appropriate scene" (p. 71).

Fillmore furthermore argues that the denotations of lexical items is better characterized by a sort of prototype theory; that is, "instead of the meaning of a linguistic form being represented in terms of a checklist of conditions that have to be satisfied in order for the form to be appropriately or truthfully used, it is held that the understanding of meaning requires, at least for a great many cases, an appeal to an exemplar or prototype" (Fillmore, 1975, p. 123). A prototype is an ideal example of some concept to which other instances of the same concept bear a strong (but not necessarily total) resemblance. For example, a prototypical bird might have a beak, wings, feathers, and be able to fly, but an ostrich would still be recognized as a bird. The prototype idea can be seen in Berlin and Kay's (1969) studies of colour terms, in Labov's (1972)

work on the boundary criteria between cups and bowls, and in the work of the psychologist Eleanor Rosch (1975).

1.6.1 Qualia Structure

Thus far, we have focused on the lexical information associated with verb entries. All of the major categories, however, are encoded with syntactic and semantic feature structures that determine their constructional behavior and subsequent meaning at logical form. In Generative Lexicon Theory (Pustejovsky, 1995), it is assumed that word meaning is structured on the basis of four generative factors, or *qualia roles*, that capture how humans understand objects and relations in the world and provide the minimal explanation for the linguistic behavior of lexical items (these are inspired in large part by Moravcsik's (1975, 1990) interpretation of Aristotelian *aitia*). These are: the FORMAL role: the basic category that distinguishes the object within a larger domain; CONSTITUTIVE role: the relation between an object and its constituent parts; the TELIC role : its purpose and function; and the AGENTIVE role: factors involved in the object's origin or "coming into being". Qualia structure is at the core of the generative properties of the lexicon, since it provides a general strategy for creating new types. For example, consider the properties of nouns such as *rock* and *chair*. These nouns can be distinguished on the basis of semantic criteria which classify them in terms of general categories such as `natural_kind`, `artifact_object`. Although very useful, this is not sufficient to discriminate semantic types in a way that also accounts for their grammatical behavior. A crucial distinction between *rock* and *chair* concerns the properties which differentiate `natural_kinds` from *artifacts*: functionality plays a crucial role in the process of individuation of artifacts, but not of natural kinds. This is reflected in grammatical behavior, whereby "a good chair", or "enjoy the chair" are well-formed expressions reflecting the specific purpose for which an artifact is designed, but "good rock" or "enjoy a rock" are semantically ill-formed since for *rock* the functionality (i.e., TELIC) is undefined. Exceptions exist when new concepts are referred to, such as when the object is construed relative to a specific activity, such as in "The climber enjoyed that rock"; *rock* itself takes on a new meaning, by virtue of having telicity associated with it, and this is accomplished by integration with the semantics of the subject NP. Although *chair* and *rock* are both `physical_object`, they differ in their mode of coming into being (i.e., AGENTIVE): artifacts are man-made, *rocks* develop in nature. Similarly, a concept such as *food* or *cookie* has a physical manifestation or denotation, but also a functional grounding, pertaining to the activity of "eating." These distinct aspects of a category are represented by the qualia structure for

that concept, which provides a coherent structuring for different dimensions of meaning.

By analyzing the semantics of objects in terms of qualia, the classic domain of entities from Montague Grammar can be organized as a hierarchical system of subtypes (sorts), structured into three broadly defined types:

(73) a. *Natural types*: Natural kind concepts consisting of reference only to Formal and Constitutive qualia roles;
b. *Artifactual types*: Concepts making reference to Telic (purpose or function), or Agentive (origin).
c. *Complex types*: Concepts integrating reference to the relation between at least two types from the other levels.

Qualia structure has proved to be an expressive representational device and has been adopted by adherents of many other grammatical frameworks. For example, Jensen and Vikner (1994) and Borschev and Partee (2001) both appeal to qualia structure in the interpretation of the genitive relation in NPs, while many working on the interpretation of noun compounds have developed qualia-based strategies for interpretation of noun-noun relations (Johnston and Busa, 1996, 1997, Lehner, 2003, Jackendoff, 2003). Van Valin (2005) has adopted qualia roles within several aspects of RRG analyses where nominal semantics have required finer grained representations.

1.7 Type Theory and the Lexicon

How can lexical semantic information be exploited in the compositional operations responsible for building larger semantic expressions in language? In this section we discuss how the representational strategies and approaches outlined above can be integrated into a uniform framework, one that can interface with the mechanisms we are familiar with within compositional semantics. Specifically, we present a type-theoretic treatment of lexical semantic information, as developed in Asher and Pustejovsky (2006) and Pustejovsky (2006).

The basic semantic knowledge associated with a lexical item can be split into two categories: its *semantic type* and its *selectional type*. While the former identifies the semantic class that a lexical item belongs to (such as *entities*, *events*, and *attributes*), the latter class specifies the semantic characteristics associated with the arguments to a lexical item. From a type theoretic position, such as that adopted within formal semantics since Montague (1968), these are in fact identical, as the type of a functional expression is determined by the nature of the typing of its arguments (cf. Partee, 1975, 1978, Bach, 1986).

Following standard assumptions within type theoretic semantics (cf. (Chierchia and McConnell-Ginet, 2000), we assume a vocabulary of atomic and derived types. For the present discussion, we let the atomic types be: e the general type of entities; and t the type of truth values. Derived types consist of all *functional types*, formed with the functional infix, $\rightarrow$; hence, for any types σ and τ, then $\sigma \rightarrow \tau$ is a type.

As in Montague Grammar and other standard frameworks, we will take a lexical entry to consist of a lambda term and a type assignment to the variables in the term. This will then determine via the standard interpretation for the lambda term a functional type for the whole expression. Unlike Montague Grammar, however, *Type Composition Logic* (TCL) (cf. Asher and Pustejovsky, 2006, Asher, 2011) has a much richer system of types reflecting the information conventionally associated with a word in the GL approach (its qualia structure), and correspondingly more complex rules for manipulating these types. Such typing knowledge is typically structured by means of some sort of inheritance mechanism (Evans and Gazdar, 1990, Copestake and Briscoe, 1992, Pollard and Sag, 1994), and modeled as a lattice or semi-lattice (Carpenter, 1992). Briscoe, dePaiva, and Copestake (1993) describe a rich system of types for allowing default mechanisms into lexical type descriptions. An example of such an inheritance structure is shown in Figure 1.1.

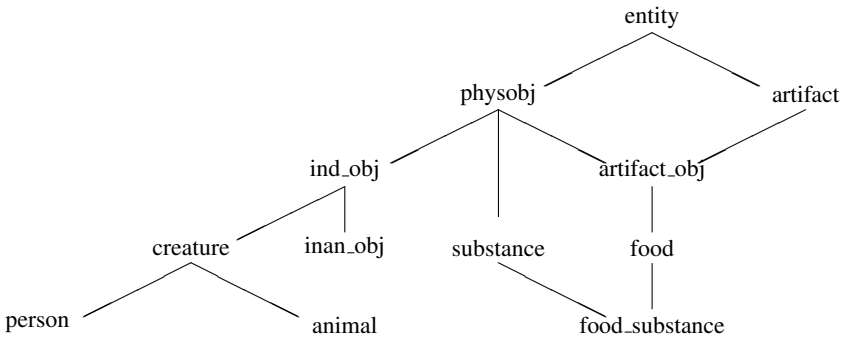

Figure 1.1 Fragment of a Type Hierarchy

As presented in the previous section, the qualia structure is a system of relations that characterizes the semantics of a lexical item, and TCL provides a way to encode this directly in the type associated with a lexeme. Following Asher and Pustejovsky (2006), we adopt two additional type constructors, $\otimes$ and $\bullet$. The constructor $\otimes$ introduces a qualia relation, Q, such that, if σ and

τ are types, then so is $\sigma \otimes_Q \tau$, for Q. The constructor $\bullet$ introduces a *complex type*, such that, if σ and τ are types, then so is $\sigma \bullet \tau$.

To illustrate how a richer lexical semantics is reflected directly in the type structure, notice that a feature structure denoting the qualia structure for an expression, α, reduces to the type $\alpha : (\beta \otimes_A \sigma) \otimes_T \tau$ in TCL.

(74)
$$\begin{bmatrix} \alpha \\ \text{QS} = \begin{bmatrix} \text{FORMAL} = \beta \\ \text{TELIC} = \tau \\ \text{AGENTIVE} = \sigma \end{bmatrix} \end{bmatrix}$$

We can define all three basic types from (**??**) using the qualia and these constructors. The first two classes in (**??**) are defined in terms of qualia; a natural physical object is simply an atomic type: , *man* and *water* satisfy the type *phys*. These are members of the *natural types*, $\mathcal{N}$ The natural entity types are those entities formed from the FORMAL quale and are formally structured as a join semi-lattice (Pustejovsky, 2001), $\langle \mathcal{N}, \sqsubseteq \rangle$. The creation of predicates over the subdomain of natural types follows conventional functional typing assumptions: for any type τ in the subdomain of natural types, $\tau \in \mathcal{N}$, $\tau \rightarrow t$ is a *natural* functional type.

Once we have defined natural type entities, their corresponding functional types are defined. The creation of predicates over the subdomain of natural types follows conventional functional typing assumptions: for any type τ in the subdomain of natural types, $\tau \in \mathcal{N}$, $\tau \rightarrow t$ is a *natural* functional type. This allows us to define natural predicates such as *die* or *touch*, as: $\lambda x{:}e_N[die(\text{x})]$, $\lambda y{:}e_N \lambda x{:}\ e_N[touch(\text{x,y})]$.

The second class of types, *artifactual types*, are defined as any type with an associated TELIC type. For example, the concept of a potable liquid would have the typing, $liquid \otimes_T drink$. Similarly, an artifactual entity such as *bread* would be typed as, $(phys \otimes_A bake) \otimes_T eat$. The creation of functional types over the domain of artifactual types is defined as follows: for any type τ in the domain of artifactual entity types, $\tau \in \mathcal{A}$, $\tau \rightarrow t$ is a *artifactual* functional type. For example, $\lambda x{:}e_A[break(\text{x})]$; $\lambda y{:}e_A \lambda x{:}e_N[fix(\text{x,y})]$.

Finally, *complex types* are constructed through a type-construction operation (the dot, $\bullet$) over the domain of Naturals, Artifactuals, and Complex Types. Consider the noun *book*, a complex type denoting both the informational content and the physical manifestation of that content: $phys \bullet info$. Other examples include the nouns *lunch*, *school*, *lunch*, and *promise*. Constructing functional types over the subdomain of complex types is straightforward: for any type τ in the domain of complex entity types, $\tau \in \mathcal{C}$, $\tau \rightarrow t$ is a *complex* functional type. Examples include verbs such as *read*: $\lambda y{:}phys \bullet info\ \lambda x{:}e_N[read(\text{x,y})]$.

One of the advantage of introducing a finer-grained system of types is the

ability to explain the selectional constraints associated with the arguments to a predicate; that is, *die* selects for an animate entity; *assemble* selects for a semantically plural individual, and so on.

Another advantage of a richer type system, however, is the way that it facilitates new solutions to semantic analyses that were not previously available. For example, consider the problem of verbal polysemy, mentioned in section XX above, where a verb is able to appear in multiple syntactic contexts, with complementary or additional arguments. The examples below illustrate this phenomenon with the verb *enjoy*, an aspectual verb *begin*, and an experiencer causative, *wake up*.

(75) a. Mary enjoyed the movie.
b. Mary enjoyed watching the movie.

(76) a. Mary began a book.
b. Mary began to read a book.

(77) a. The coffee woke John up.
b. John's drinking the coffee woke him up.

What these sentence pairs illustrate is the process of *type coercion*, a semantic operation that converts an argument to the type which is expected by a predicate, where it would otherwise not be accepted (cf. Pustejovsky, 1995). This is an operation in the grammar ensuring that the selectional requirements on an argument to a predicate are satisfied by the argument in the compositional process. The rules of coercion presuppose a typed language such as that outlined above. By allowing lexical items to coerce their arguments, we obviate the enumeration of multiple entries for different senses of a word.

The notion that a predicate can specify a particular target type for its argument is a very useful one, and intuitively explains the different syntactic argument forms for the verbs below. In sentences (**??**) and (**??**), noun phrases and verb phrases appear in the same argument position, somehow satisfying the type required by the verbs *enjoy* and *begin*. Similarly, in sentences (**??**), noun phrases of very different semantic classes appear as subject of the verb *wake*.

If we analyze the different syntactic occurrences of the above verbs as separate lexical entries, following the sense enumeration theory outlined in previous sections, we are unable to capture the underlying relatedness between these entries; namely, that no matter what the syntactic form of their arguments, the verbs seem to be interpreting all the phrases as events of some sort. It is exactly this type of complement selection which type coercion allows in the compositional process.

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