Discourse and Inference

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January 8, 2004

Contents

Chapter 4

The Syntax of English in an Abductive Framework

4.1 The Role of Syntax in a Theory of Interpretation

4.1.1 Syntax as the Interpretation of Proximity

To understand our environment we seek the best explanation for the observable features we find there. Among the observable features that we seek to explain are proximities among objects. This generally escapes our notice except when it is out of the ordinary, as when we see a chair on top of a table or a dog in the aisle of a theatre. When things are in their place, the explanation is that that is their place.

A similar problem faces us in discourse. A text is a string of words, and one of the features of the text that requires explanation is the adjacency of pairs of words or larger segments of text.

The simplest example of this is provided by compound nominals. When we see the phrase "turpentine jar" in a text, the interpretation problem we face is finding the most reasonable relationship in the context between turpentine and jars, using what we know about turpentine and jars.

In many compound nominals, the relationship is one conveyed by one of the nouns itself. In "virus replication", the relation between the virus and the replication is precisely the "replication" relation—it is the virus that is replicating.

Syntax and compositional semantics can be seen as arising out of this need to explain adjacency. When we see the pair of words "men work", we need to find some relation between them. The second word itself provides the relation. It is the men who are working. Whereas in the case of "virus replication", "replication" provides a *possible* relation, in the case of "men work", "work" provides an *obligatory* relation. (This is not quite true; metonymy is possible, so that the second word need only provide a relation between the eventuality it denotes and something *functionally related* to the the first word, as in "The office called.")

The hypothesis that sentences have syntactic structure amounts to the acceptance of a set of constraints on the relations that can obtain between two words or larger stretches of text, restricting these relations to be predicate-argument relations (plus metonymy).

The tree structure of sentences arises from the fact that the adjacency relation can be between larger segments of text than simply single words, where the segments have their own internal tree structure resulting from adjacencies. For example, in

John believes men work.

we don't seek to explain the adjacency between "believes" and "men". Rather we first explain the adjacency between "men" and "work", and only then the adjacency between "believes" and "men work" (or the adjacency among "John", "believes", and "men work", depending on your view of the structure of the clause.) This kind of grouping occurs even in the absence of syntactic constraints. Consider the two compound nominals, "Stanford Research Institute" and "Cancer Research Institute". In the latter, we must first find the relationship between cancer and research, and then find the relationship between cancer research and the institute, whereas in the former, we group "Research" with "Institute" and then "Stanford" with "Research Institute".

When a predicate-argument relation is found between adjacent segments, the two together constitute a single segment. Different types of compositions yield different types of segments. "Men work" and "tall men" both encode predicate-argument relations, but one is a sentence (S) and the other a noun phrase (NP). The intermediate structures in the syntactic analysis of a sentence—verb phrases (VP), prepositional phrases (PP), and so on—represent different ways in which the recognition of a predicate-argument relation results in the composition of two segments into a single larger segment.

In order to recognize predicate-argument relations between segments of text larger than one word, we need to know what predicates or arguments are conveyed by the segments. For example, "research institute" refers to an institute rather than research. If this segment provides the argument in larger composed segment, the institute and not the research will be the argument. Similarly, "men work" describes a working event rather than a condition of being men. If we compose it with "today", it is the working that is today. As we compose larger and larger segments of text, we must be able to specify the primary information conveyed by the composite segments.

The rules of syntax and compositional semantics specify how segments of text can be grouped together, what types of segments result from the grouping, and what the primary information conveyed by the composite segment is. They increase the precision and decrease the ambiguity with which information can be conveyed, and they therefore allow more complex messages to be communicated. This increases the possibility of saying new and unexpected things, something of obvious utility in a world that is not always predictable.

4.1.2 The Foci of This Chapter

In Chapter 3 a brief indication was given of how syntax could be integrated into the overall interpretation process, but only with the most trivial of grammars. In this chapter, a much more substantial grammar of English is presented in a form appropriate for the abductive framework.

There has been, of course, an immense amount of research on syntax, and it is impossible here to give even the most cursory overview of this work. Instead the focus is on three phenomena—the composition of segments into larger segments, the predicate-argument relations conveyed by these compositions, and "agreement" phenomena, broadly construed, that constrain the possibilities for composition. The particular syntactic constructions that are discussed are those required for handling the six target texts,[1] together with several other constructions of traditional linguistic interest. However, what is discussed is a fair sampling of what has to be accounted for in a treatment of English syntax in general.

In Section 4.2 the fundamental syntactic predicate *Syn* is described, along with the motivations for the kinds of information it carries. In Section 4.3 the structure of the lexical axioms are described that form the interface between syntax and pragmatics. In Sections 4.4 to 4.16, the bulk of this chapter, the syntactic and lexical rules are given and the treatment of various syntactic constructions is discussed. In Section 4.17 it is shown how several

[1] The book is organized around six target texts from diverse domains. These are given in Appendix I. The role of these texts is this book is to promote broad, domain-independent coverage of linguistic and pragmatic phenomena.

seemingly syntactic problems can be handled in a straightforward manner in this framework as instances of metonymy. In Section 4.18 a plausible story is told about how the analysis of one particular sentence develops and changes as it is processed word-by-word, and some features of a competence-based theory of performance are discussed. In Section 4.19 the treatments of sentence fragments, disfluencies, scrambling, and co-construction are described. In Section 4.20 a plausible incremental account of the evolution of the essential features of syntax is outlined. Finally, in Section 4.21 the issue of the modularity of syntax is examined.

But first a brief statement about ...

4.1.3 Influences and Allegiances

The study of syntax is split and sometimes splintered into contending theories. In this situation it might be useful for me to identify the principal influences on my own work in syntax.

My initial education in syntax was while working for and writing a dissertation under Naomi Sager at New York University. I mastered the details of the Linguistic String Project computer grammar of English (Sager, 19??), still today one of the most extensive computer grammars in existence and the basis for a number of other large grammars. While the details of the grammars I have built since then, including the one given below, bear little resemblance to Sager's Linguistic String Grammar, I remain deeply influenced by her sense of the data that needs to be covered and the careful attention she has paid to the complexity of syntax in written and especially scientific texts.

I was at the margins of early developments in unification grammar at SRI, Stanford, and Xerox PARC in the late 1970s and early 1980s (Pereira and Shieber, 19??; Gazdar, Klein, Pullam, and Sag, 19??; Kay, 19??; Bresnan and Kaplan, 19??). Although in my dissertation work I had arrived at one of the key ideas in unification grammar in a very partial and inelegant form (Hobbs, 1974, Section 5.2), it was lost in the complexities of expressing constraints in an extensive grammar, and my primary interests lay elsewhere during unification grammar's heyday. Nevertheless, the grammar given in this chapter is solidly in the unification grammar camp. Where it differs in formalism from more typical unification grammars, it is because my principal concern is to integrate syntax smoothly with other aspects of interpretation. In the detailed treatments given here, I have been very much influenced by conversations with Ivan Sag and by the account of head-driven phrase structure grammar (HPSG) given in Pollard and Sag (19??); this indebtedness will be obvious to the reader.

As a computational linguist, I have been less influenced by Noam Chomsky and his disciples, particularly the approaches taken since 1980 known as Government and Binding (GB), Principles and Parameters, and Minimalism. However, I am moderately familiar with it, primarily through Haegeman's introduction (19??). Where an explanation of a "principle" of GB can be given naturally in the framework I present, and where I agree with their interpretation of the data, I occasionally discuss the relation between my approach and that of GB. However, since I follow Pollard and Sag rather closely and since they go to great lengths to explicate the relation between HPSG and GB, I take myself to be largely relieved of that obligation. I should say that I don't think the principles of GB are in any way *explanatory*. They strike me rather as abstractly stated characterizations of a broad range of empirical data. I am of course very unsympathetic with their notion of the autonomy of syntax; it is antithetical to the whole aim of this chapter. I discuss this issue in Section 4.21.

Finally, although I am much less familiar with the details of Construction Grammar as developed by Fillmore and Kay (19??), I completely agree with its basic premise—that we know and use very specific large-scale syntactic structures, syntactic idioms, so to speak, that are resident on more general syntactic rules but convey very specific meanings. Thus, although I follow HPSG and GB in presenting a minimun number of rules of composition, I have no compunction about introducing very special purpose versions of them for particular constructions. I have given several examples of this below, such as the analyses of "let's" (Section 4.8) and "take into account" (Section 4.6.5).

4.2 The Structure of *Syn*

4.2.1 Concatenation

The principal predicate used in this development of the syntactic rules is *Syn*. The first argument of *Syn* is a word or a string of words that constitutes a phrase. The variable w, possibly subscripted, is used to designate words and strings of words.

$$Syn(w, \ldots)$$

The most common form of composition rules for phrases is

$$Syn(w_1, \ldots) \wedge Syn(w_2, \ldots) \supset Syn(w_1 w_2, \ldots)$$

This says that if w_1 is a word or phrase of a certain type, conveying certain information, and w_2 is a word or phrase of a certain type, conveying certain information, then the concatenation $w_1 w_2$ is a phrase of a certain type, conveying certain information.

The notation "$w_1 w_2$" is in fact only a convenient abbreviation. The rule should be written

$$Syn(w_1, \ldots) \wedge Syn(w_2, \ldots) \wedge concat(w, w_1, w_2) \supset Syn(w, \ldots)$$

where $concat(w, w_1, w_2)$ means that w is the concatenation of w_1 and w_2. *concat* can be axiomatized in the standard way. The abbreviated form is used in this development, to avoid clutter.

String constants are in Roman type and enclosed in quotes, e.g., "sleep". The empty string is written " ".

The category of a word or phrase also has a place in the argument structure of *Syn*. Because of the other information carried by *Syn*, it will be sufficient to record only the category of the head of a phrase, e.g., "Noun" rather than "NP". Thus, the two rules that in traditional form are expressed

S → NP VP
VP → V NP

and in $\overline{\mathbf{X}}$ syntax are expressed

$$\overline{\overline{\mathbf{V}}} \rightarrow \overline{\overline{\mathbf{N}}}\ \overline{\mathbf{V}}$$
$$\overline{\mathbf{V}} \rightarrow \mathbf{V}\ \overline{\overline{\mathbf{N}}}$$

can in our framework be expressed by the axioms

$$Syn(w_1, \ldots, \mathbf{n}, \ldots) \wedge Syn(w_2, \ldots, \mathbf{v}, \ldots) \supset Syn(w_1 w_2, \ldots, \mathbf{v}, \ldots)$$
$$Syn(w_3, \ldots, \mathbf{v}, \ldots) \wedge Syn(w_4, \ldots, \mathbf{n}, \ldots) \supset Syn(w_3 w_4, \ldots, \mathbf{v}, \ldots)$$

The first rule says that concatenating a phrase w_1 headed by a noun (with some other conditions) and a phrase w_2 headed by a verb (with some other conditions) results in a phrase headed by a verb. The second rule says that concatenating w_3, a verb or a phrase headed by a verb, (with some other conditions) and a phrase w_4 headed by a noun (with some other conditions) results in a phrase headed by a verb.

These two rules will be elaborated and generalized in subsequent sections as illustrative examples.

By using *Syn* as the predicate and the categories as arguments, it is possible to state composition rules in a more general form than if we were to use categories like NP and VP.

A bit more should be said about the nature of the w's. They in fact represent string instances, or string tokens, or fragments of utterances. When we use a particular string constant, such as "work", in the first argument position of *Syn*, what we really mean is not the abstract string "work", but a particular spoken or written instance of that string. More properly, we should represent this by a variable w, and treat "work" as a property of the string instance, expressed by something like "work"(w), meaning that this particular utterance fragment can be characterized as an instance of the English word "work". Similarly, when we write $concat(w, w_1, w_2)$, we are saying that the specific utterance fragment w would result from the adjacency in time and place of the specific utterance fragments w_1 and w_2. However, this ontological subtlety can safely be ignored for most of this chapter. It is significant only in understanding the treatments of conjunction (Section 4.14) and disfluencies (Section 4.19.4), and, to a lesser extent, adjuncts (Section 4.9).

4.2.2 Arguments of Predicates

The predicate *Syn* relates words and phrases to the information they convey. It expresses a relation between strings of words and eventualities and other entities. The syntax rules have to be specified in a way that insures the correct predicate-argument structure is associated with the various syntactic structures. Included under this heading are the problems of long-distance dependencies, such as filling the gaps in relative clauses correctly. Since one of the principal elements of an abductive interpretation is proving the logical form of the sentence, it is crucial to get the logical form right. Consequently, this is the central issue in the present chapter. The treatment of predicate-argument structure given in this chapter is intended to be complete for the syntactic structures covered.

There are two ways predicate-argument structure could be constructed. The first is to carry partially instantiated predications from the head that provides the predicate up to the elements that provide the arguments.

$$
\begin{aligned}
&Syn(w_1, x, \mathbf{n}, \ldots) \wedge Syn(w_2, \lambda u[p'(e,u,y)], \mathbf{v}, \ldots) \wedge \lambda u[p'(e,u,y)](x) \\
&\quad \supset Syn(w_1 w_2, e, \mathbf{v}, \ldots) \\
&Syn(w_3, p, \mathbf{v}, \ldots) \wedge Syn(w_4, y, \mathbf{n}, \ldots) \\
&\quad \supset Syn(w_3 w_4, \lambda u[p'(e,u,y)], \mathbf{v}, \ldots)
\end{aligned}
$$

Here, the two-argument predicate p associated with the verb w_3 is applied to its object y in the second rule to yield a one-argument predicate represented by the lambda expression. This is then applied to the subject x in the first rule, and the complete predication occurs on the left side of that rule, dictating that it must be proved abductively in order for the sentence to be interpreted. The sentence as a whole describes the eventuality e.

However, the lambda expressions are clumsy to have to carry around, so the opposite approach will be taken in this chapter. We will pass the arguments from the elements that provide them *down* to the head of the phrase that provides the predicate, for application there. Suppose again the verb w_3 conveys the predicate p. Then the rules become

$$\begin{array}{l} Syn(w_1, x, \mathbf{n}, \ldots) \wedge Syn(w_2, e, \mathbf{v}, x, \ldots) \\ \quad \supset Syn(w_1 w_2, e, \mathbf{v}, \ldots) \\ Syn(w_3, e, \mathbf{v}, x, \ldots, y, \ldots) \wedge Syn(w_4, y, \mathbf{n}, \ldots) \\ \quad \supset Syn(w_3 w_4, e, \mathbf{v}, x, \ldots) \\ p'(e, x, y) \supset Syn(w_3, e, \mathbf{v}, x, \ldots, y, \ldots) \end{array}$$

The subject argument x is passed as an argument of *Syn* down through the verb phrase to the verb. The object argument y is also passed down to the verb. Both x and y occur as arguments of the "lexical predicate" p for the verb w_3. The requirement to prove this fragment of the logical form is then associated with the verb w_3. The third axiom says, essentially, that if e is the eventuality of p being true of x and y, then w_3 is a verb describing e and having x and y as the referents of its subject and object, respectively. The requirement to prove this fragment of the logical form is captured by having $p'(e, x, y)$ on the left-hand side of this "lexical axiom".

An advantage of this approach is that in lexical axioms like the third one, the predicate-argument structure of a word, its lexical realization, and, as we will see below, its agreement and subcategorization features and its selectional constraints can all be captured in a single axiom. This idea is summarized in Section 4.3.

The next property of *Syn* to be introduced is an unfortunate artifact of the variety of predicate calculus we are using. Predicates must have a fixed number of arguments. But we would like to use the same predicate *Syn* for all phrases and lexical items, regardless of their arity, that is, regardless of how many arguments need to be passed from one part of the sentence to another. Our solution is to assign *Syn* the maximum number of arguments and use a constant symbol, "−", to denote "empty". Thus, the *Syn* predication for the intransitive, transitive, and ditransitive verbs "sleep", "build", and "give" will be, respectively,

$$\begin{array}{l} Syn(\text{“sleep”}, e, \mathbf{v}, x, \ldots, -, \ldots, -, \ldots) \\ Syn(\text{“build”}, e, \mathbf{v}, x, \ldots, y, \ldots, -, \ldots) \end{array}$$

$Syn(\text{“give”}, e, \mathbf{v}, x, \ldots, y, \ldots, z, \ldots)$

The variables x, y, and z, possibly subscripted, will be used for the subject, the first complement, and the second complement, respectively. They will be listed in order of increasing obliqueness, so that they generally reflect the most natural order of saying the corresponding English sentence.[2] For “give”, the order of the arguments is

x gives y to z.

I have assumed that three is the maximum number of arguments. One could argue against this on the basis of verbs like “carry”.

The truck carried the cargo from New York to Chicago.

Here the truck, the cargo, New York, and Chicago could all be viewed as arguments of “carried”. However, as we will see in Section 4.6, it is straightforward to treat arguments signalled by prepositions as adjuncts and have them end up in the right place in the logical form anyway. “From New York” and “to Chicago” can be treated as though they were adverbials, so that in specifying the subcategorization patterns for “carry” we would only need to worry about the subject and direct object.

The one commonly cited verb that is often alleged to have four arguments not signalled by prepositions is “bet”, as in

John bet George five dollars that the Giants would win.

“John”, “George”, “five dollars” and “that the Giants would win” all seem to be arguments of “bet”. However, one could argue that “five dollars” is a measure phrase. “John bet George five dollars” has the same structure as “John carried George five miles.” It is true that the amount phrase passivizes out of some “bet” constructions.

$1000 was bet on the game.

But it does not seem to passivize out of the “four-argument” construction.

* $5 was bet George that the Giants would win.

Moreover, just as measure phrases in clauses correspond in nominalizations to a very special prenominal measure phrase

John ran three miles. ⇒ John’s three-mile run

[2] In this I follow Pollard and Sag, 1994, p. 24

so does the ammount argument in bet constructions.

John bet George five dollars ⇒ John's five-dollar bet with George

In any case, I will assume that analysis here, primarily because I don't want to carry around extra argument places throughout the whole book, just to handle one verb.[3]

There is one construction we will have to deal with in this chapter that, under the analysis we adopt, involves a predicate with four arguments. It is the "so *Adj* a $\overline{\mathbf{N}}$ that *S*" construction, as in

Speech is so familiar a phenomenon that we never think about it.

This is analyzed as the predicate *so* applied the subject of the clause, to a scale determined by *Adj*, to the further qualifying property $\overline{\mathbf{N}}$ and to an eventuality conveyed by the "that" clause. Rather than carrying around extra argument places throughout the whole book, we will, when discussing this example, do violence to the *Syn* predicate.

The *Syn* predication for NPs is generally as in

$$Syn(\text{“the chair”}, x, \mathbf{n}, -, \ldots, -, \ldots, -, \ldots)$$

The phrase "the chair" refers to x, has a head of category Noun, and has no other complements.

The *Syn* predication for constituent phrases in NPs is a bit more complicated and is explicated in Section 4.10.

The basic rules can now be written

$$\begin{array}{l} Syn(w_1, x, \mathbf{n}, -, \ldots, -, \ldots, -, \ldots) \wedge Syn(w_2, e, \mathbf{v}, x, \ldots, -, \ldots, -, \ldots) \\ \quad\quad \supset\ Syn(w_1 w_2, e, \mathbf{v}, -, \ldots, -, \ldots, -, \ldots) \\ Syn(w_3, e, \mathbf{v}, x, \ldots, y, \ldots, -, \ldots) \wedge Syn(w_4, y, \mathbf{n}, -, \ldots, -, \ldots, -, \ldots) \\ \quad\quad \supset\ Syn(w_3 w_4, e, \mathbf{v}, x, \ldots, -, \ldots, -, \ldots) \\ p'(e, x, y)\ \supset\ Syn(w_3, e, \mathbf{v}, x, \ldots, y, \ldots, -, \ldots) \end{array}$$

When an argument has a value of "−", we will say that it is saturated, and, more commonly, when it has some other value, we will say that it is unsaturated. So the first of these rules says that a fully saturated phrase w_1

[3] An alternative that would allow any number of arguments would be to have the logical form consist of a predicatication for the verb—$love'(e)$—and one for each predicate-argument relation—$Subject(J, e)$, $Object(M, e)$. See Section 2.3.1. I occasionally use this mode of representation, but in general feel it makes the logical forms too strung out to comprehend easily.

referring to x and headed by a noun can be concatenated with a phrase w_2 describing the eventuality e, headed by a verb, and with all but its subject argument saturated and expecting a subject referring to x, to produce a phrase describing e, headed by a verb, and having all its arguments saturated. The statement of the second rule is similar. The third rule says that if an eventuality e is the eventuality of p being true of x and y, then it can be expressed by the word or phrase w_3, describing e, headed by a verb, and having phrases referring to x as it subject and y as its object.

We now see why it is not necessary to record the bar level with the category in these rules (e.g., $\overline{\mathbf{v}}$, $\overline{\overline{\mathbf{v}}}$). It is implicit in the number of the x, y and z arguments that are saturated. In this, we follow Pollard and Sag (1994, pp. 39-40).

4.2.3 Agreement

The sentence

Flying planes can be dangerous.

is ambiguous. "Flying planes" can be a singular activity or a plural set of objects. The sentence

(4.1) Flying planes is dangerous.

is not ambiguous. "Flying planes" can only be the activity. Number agreement with the verb "is" forces this reading. The sentence

Sleeping students can be disconcerting.

is also unambiguous. "Sleep" does not subcategorize for a noun phrase object, so "sleeping students" can only mean a plural set of students who are sleeping.

Agreement phenomena, broadly enough construed to include subcategorization, function primarily as a way of constraining what adjacency or proximity relations can be interpreted as predicate-argument relations. They help us arrive at the right logical form, although they themselves do not contribute to the logical form. They have the effect of eliminating ambiguities. If English had no number agreement, and if, say, sentence (4.1) were instead

Flying planes be dangerous.

the logical form of the correct interpretation would be the same, but we would have more difficulty in deriving it. Agreement phenomena take some of the load off of adjacency for conveying predicate-argument relations and consequently allow freer word order. The effect of this is not great in English, but in languages with much richer and more pervasive agreement features, the result can be a word order that is highly unconstrained.

If getting the predicate-argument relations right in syntax is like fitting tenons into mortices in cabinet-making, then the analog of agreement constraints is the shape of the mortices and tenons. They restrict what can be connected with what.

In the approach that is presented here, as in most approaches to syntax, agreement features are associated with every word. As the words are composed into phrases, the phrases are assigned features in various ways depending on the features of their constituents. For any given phrase, the features come in two varieties. There are those that constrain the possible subject and complements of the head of the phrase, and there are those that constrain what other heads this head can itself be a subject or complement of. That is, if the predication $p'(e, x, y, z)$ is constructed in the lexical axiom for the head of a phrase, there are constraints on what other elements in the sentence can provide the x, y, and z arguments, and there are constraints on what e can be an argument of. For example, the verb "eats" will have a singular NP as its subject because it is singular, an accusative NP as its object because it is transitive, and because it is tensed, a clause it heads can be a full sentence or part of a "that" clause, but it cannot be an infinitive clause. Thus, a feature or complex of features will be associated with the eventuality variable e, constraining where it can be an argument, and features will be associated with each of the entity variables x, y, and z, constraining what phrases can supply these arguments.

For clarity, we will be as consistent as possible in the letters that are used for the agreement features associated with the different variables. Paired with the eventuality e that corresponds to the head of the phrase will be the agreement feature f. Paired with the arguments x, y and z will be their agreement features a, b, and c, respectively. The agreement feature variables will have the same subscripts as their eventuality and entity variables. The agreement feature variables will appear immediately after their respective eventuality and entity variables in the list of arguments of Syn.

$$Syn(w, e, f, x, a, y, b, z, c, \ldots)$$

Agreement feature constants will be written in roman bold-face characters, such as **n**, **v**, and **sing**.

Agreement features typically come in small sets of mutually exclusive properties, and each category of word or phrase typically has a very small number of these sets of properties associated with it. The details of the feature system for each category are explicated below as the various phenomena are discussed and they are summarized in Section 4.16. All words and phrases have a feature for their category, coming from the feature set *CAT*. Verbs have the *CAT* feature of **v**; nouns **n**. Verbs in addition have a feature set called *TNS* that classifies verb instances as tensed (**tnsd**), tenseless (**tnsless**), a present participle (**ing**), a past participle (**en**), or infinitive (with the word "to")(**inf**). The agreement structure of verbs can then be represented as an ordered pair, in which the first element is the category **v**, the second element is **tnsd**, **tnsless**, **ing**, **en**, or **inf**. For example, the feature variable f for "sleeps" would be <**v**, **tnsd**>, indicating that it is a tensed verb.

The two primary agreement feature sets associated with nouns and NPs are number—**sing** and **pl**—and case—**nom** and **acc**. The agreement structure of nouns and NPs can then be represented as a triple, in which the first element is the category **n**, the second element is **sing** or **pl**, and the third element is **nom** or **acc**. For example, the feature variable a for "the man" would be <**n**, **sing**, a_3 >, indicating that its head is a singular noun and of indeterminate case.

The subject of the verb "sleeps" must be singular and nominative and be headed by a noun. Thus, the a argument for "sleeps" will be <**n**, **sing**, **nom**>.

Very often, most of the elements of the feature n-tuple in a given rule will be variables, indicating that the word or phrase is neutral with respect to that feature in that rule. Rather than carrying these variables along in the notation, we will eliminate them, specifying only the constant feature values. Where more than one feature constant appears in the feature n-tuple, they will be concatenated, with a period between them. For example, the verb "slept" is neutral with respect to number, so the feature triple for its a argument would be <**n**, a_2, **nom**>, and this will be abbreviated **n.nom**.

In composition rules we will need both to restrict the values of some features and to enforce identity of features in different *Syn* predications. Enforcing identity is done by shared variables. Thus, we need to indicate the variable in both places and indicate the restrictions on the values of the variable that each *Syn* predication imposes. We will do this by writing the variable, followed by a colon, followed by the constant feature values the variable is restricted to. For example,

a:**n.sing**

indicates the feature variable a whose *CAT* feature is restricted to be **n**, whose *NUM* feature is **sing**, and whose *CASE* feature is indeterminate.

If all the elements of the feature n-tuple are variables, it will be expressed with a single variable, say, just a.

The S → NP VP rule can now be written

$$\begin{aligned} & Syn(w_1, x, a, -, -, -, -, -, -, \ldots) \\ & \quad \wedge\, Syn(w_2, e, f{:}\mathbf{v.tnsd}, x, a{:}\mathbf{n.nom}, -, -, -, -, \ldots) \\ & \quad \supset\, Syn(w_1 w_2, e, f, -, -, -, -, -, -, \ldots) \end{aligned}$$

This says that if the string w_1 is a phrase denoting x and having the agreement feature structure a, and the string w_2 is a phrase describing the eventuality e, having the agreement feature structure f, where the *CAT* feature of f is **v** and the *TNS* feature is **tnsd**, and furthermore having x as its subject argument, requiring its subject to have agreement feature structure a, where the *CAT* feature of a is **n** and the *CASE* feature of a is **nom**, then the concatenation $w_1 w_2$ is a clause describing the eventuality e and having the agreement feature structure f. Forcing the identity of the a arguments in the two conjuncts of the antecedent restricts w_1 to be an NP and enforces number and case agreement. The identity of the feature f in the second and third *Syn* predications means that the composite string is headed by a **v** and since it has no unsaturated arguments, it is a $\overline{\overline{\overline{\mathbf{V}}}}$ or an S. An easier way to say all this is that if w_1 is an NP referring to x, and w_2 is a tensed verb phrase describing e and having x as its subject, then $w_1 w_2$ is a tensed clause describing e.

When the NP "the man" ($a =$<**n**, **sing**, a_3 > or **n.sing**) is composed with the VP "slept" ($a =$<**n**, a_2, **nom**> or **n.nom**), the rule will require that the two a arguments be the same. They will be, since **n** unifies with **n**, **sing** unifies with the variable a_2, and the variable a_3 unifies with **nom**.

The VP → V NP rule can now be stated

$$\begin{aligned} & Syn(w_3, e, f{:}\mathbf{v}, x, a{:}\mathbf{n.nom}, y, b{:}\mathbf{n.acc}, -, -, \ldots) \\ & \quad \wedge\, Syn(w_4, y, b, -, -, -, -, -, -, \ldots) \\ & \quad \supset\, Syn(w_3 w_4, e, f, x, a, -, -, -, -, \ldots) \end{aligned}$$

This says that a verb w_3 taking a nominative NP referring to x as its subject and an accusative NP referring to y as its object can be concatenated with an accusative NP w_4 referring to y to produce a VP taking a nominative NP referring to x as its subject.

A lexical axiom of the form

$$p'(e, x, y) \supset Syn(w_3, e, \mathbf{v}, x, \mathbf{n.nom}, y, \mathbf{n.acc}, -, -, \ldots)$$

says that if e is the eventuality of p being true of x and y, then e can be described or conveyed by a verb w_3 taking a nominative NP referring to x as its subject and an accusative NP referring to y as its object. It is not necessary to specify the agreement variables here since we do not need to force any identities among agreement features in different *Syn* predications in this rule, there being only one.

Strictly speaking, agreement features are properties of word and phrase instances, that is, of specific utterances of the word or phrase. So, an utterance of the word "deer" might be singular or might be plural on different occasions. Our strings w similarly denote word and phrase instances. Thus, properly, we should express the agreement features by expressions like $\mathbf{sing}(w)$ and $\mathbf{n}(w)$. Agreement constraints would then be encoded as explicit conjuncts in the syntactic composition rules.

All of this is useful for ontological clarity. However, it would make the conposition and/or lexical axioms a nightmare to write.[4] This is why I have introduced the agreement feature arguments in the *Syn* predications, and the various abbreviations.

Some agreement features are, in a sense, "subfeatures" of other features. For example, time nouns like "Saturday" form a subclass of nouns, and the feature **ntime** is a subfeature of **n** in the feature set *CAT*. Strictly speaking, such relations should be encoded as independent implications of the form

$$\mathbf{ntime}(w) \supset \mathbf{n}(w)$$

In our abbreviated treatment, however, we will allow subfeatures to unify with the features they are subfeatures of. The feature **ntime** will unify with **n** to yield **ntime**. As we specify the agreement feature structures for the various categories, we will indicate what features are subfeatures of what.

Four more abbreviation conventions need to be introduced. First, very often corresponding feature structures in two different *Syn* predications in a rule must be identical except for one feature. For example, in the rule relating actives and passives, the feature structures corresponding to the logical object must be the same except in the *CASE* feature:

$$Syn(w, e, \ldots, x, a, y, b{:}\mathbf{n.acc}, -, -, \ldots)$$

[4] Briefly, in each lexical axiom, one would have to include predications of the form $Syn(w, x, \ldots)$ in the antecedent for each argument x of p, and the a, b, and c features would be included in the antecedent as properties of the w's. The f features would be included in the consequent of the lexical axiom. The composition axioms would have to pass up features from the head to the composite phrase explicitly.

$$\supset Syn(w, e, \ldots, y, b{:}\mathbf{nom}, -, -, -, -, \ldots)$$

In this rule, the logical object y is moved to the subject position, and its feature structure b remains the same, except that the *CASE* feature is changed from **acc** to **nom**. In terms of feature tuples, b:**n.acc** abbreviates the tuple <**n**,b_2,**acc**>, while b:**n.nom** abbreviates <**n**,b_2,**nom**>.

Second, if we wish to change the feature from a specific value to an indeterminate value, we can indicate this by using a variable subscripted by the name of the feature set. Thus, we could have written the passive transformation as

$$Syn(w, e, \ldots, x, a, y, b{:}\mathbf{n.acc}, -, -, \ldots)$$
$$\supset Syn(w, e, \ldots, y, b{:}b_{CASE}, -, -, -, -, \ldots)$$

This says that the agreement feature structure associated with y is the same in the two predications, except that whereas in the active form the *CASE* feature is **acc**, in the passive form it is indeterminate. (This would allow passivization to apply, for example, in small clauses.) In this rule, b:**n.acc** abbreviates the tuple <**n**,b_2,**acc**>, while $b{:}b_{CASE}$ abbreviates <**n**,b_2, b_{CASE} >.

Third, when we wish to enforce agreement on only one feature in a feature structure, we will repeat the same variable subscripted by the name of the feature set, as in

$$Syn(w_1, \ldots, e_1, f_1{:}f_{CAT}, \ldots) \wedge Syn(w_2, e_2, f_2 : f_{CAT}, \ldots) \ldots$$

This forces the *CAT* feature of f_1 and f_2 to be the same. In this expression $f_1{:}f_{CAT}$ abbreviates $< f_{CAT}, f_{12}, f_{13} >$ and $f_2{:}f_{CAT}$ abbreviates $< f_{CAT}, f_{22}, f_{23} >$. Only the f_{CAT} variables need to unify.

Finally, for many features there are natural names, such as **in** for prepositional phrases whose preposition is "in" and **of** for prepositional phrases whose preposition is "of". But there may be no natural name for the feature that exactly subsumes both, e.g., the feature that holds of prepositional phrases whose preposition is either "in" or "of". When we need such features, rather than making up an unnatural name, I will use a "disjunctive" feature notation, such as **in/of**. This is just another name of a feature and is related to its two disjunct features by the axiom

$$\mathbf{in/of}(w) \equiv \mathbf{in}(w) \vee \mathbf{of}(w)$$

While the abbreviatory notation developed in this section borrows much from feature logics, its use is much more restricted. It is used only for agreement phenomena, broadly construed. We are not using it to encode the tree structure of sentences; that is encoded in the proof graph. And we are not using it to capture the predicate-argument structure underlying sentences; that is handled directly in the arguments of the *Syn* predicate.

Since agreement phenomena are not as crucial to abductive interpretation as predicate-argument relations, the treatment of it will be somewhat looser. The approach will be illustrative with no attempt at completeness. As a result, the reader will no doubt be able to find numerous examples of ungrammatical sentences that are not ruled out by the axioms presented.

4.2.4 Gaps

One final augmentation to the structure of the predicate *Syn* is required for long-distance dependencies, as exemplified in relative clauses. To get the predicate-argument structure right, the gap in the relative clause must be linked to the NP or other element that fills it. In GB, this work is done by the "Move α" rule; in HPSG it is handled by identity of variables. The approach taken here will resemble HPSG.

First, let us consider the problem ignoring agreement constraints. A number of phrase types can contain gaps, including Ss, VPs, and NPs, as in

John owns the boat that $[_S$ Mary painted $()]_S$.
John owns the boat that Mary $[_{VP}$ painted $()]_{VP}$.
John owns the boat that Mary saw $[_{NP}$ a picture of $()]_{NP}$.

We will handle this by introducing a gap argument at the end of *Syn*. It will be a variable indicating the entity that the filler refers to; we will use the letter v to express the gap variable. If there is no gap, that argument will be equal to the empty constant $-$. The argument structure of *Syn* is now

$$Syn(w, e, f, x, a, y, b, z, c, v, \ldots)$$

One way to introduce a gap in the object position of a verb phrase would be to have a rule

$$(4.2) \quad Syn(w, e, f{:}\mathbf{v}, x, a{:}\mathbf{n}, y, \mathbf{n}, -, -, -, \ldots) \supset Syn(w, e, f, x, a, -, -, -, -, y, \ldots)$$

A transitive verb—one with a y argument of category $\mathbf{n}$—by itself, with no object, constitutes a verb phrase with a gap, where the filler of the gap will be the object of the verb.

The gap and the filler could then be identified with each other in a rule, for example, that attached relative clauses to NPs.

$$
\begin{aligned}
&Syn(w_1, , x, a{:}\mathbf{n}, -, -, -, -, -, -, -, \ldots)\\
&\qquad \wedge\, Syn(w_2, -, \mathbf{relpro}, -, -, -, -, -, -, -, \ldots)\\
&\qquad \wedge\, Syn(w_3, e_3, \mathbf{v}, -, -, -, -, -, -, x, \ldots)\\
&\quad \supset\, Syn(w_1 w_2 w_3, x, a, -, -, -, -, -, -, -, \ldots)
\end{aligned}
$$

That is, an NP without a gap can be concatenated with a relative pronoun and an S with a gap. The entity x referred to by the NP is identical to the entity that is to fill the gap.

The approach to wh-movement taken in Section 4.13 below will be somewhat more complex to be more general and to handle such phenomena as pied-piping, but the treatment given here is adequate for motivating the presence of the v argument.

It is furthermore necessary to link agreement features of the filler with those of the gap, since the filler must often agree with the verb in the relative clause, as in

? This is the man who John saw ().
This is the man whom John saw ().
This is the man who John believes () knows the answer.
These are the men who John believes () know the answer.

Just as the x, y and z arguments have their corresponding agreement features a, b and c, the gap variable v will have a corresponding agreement feature argument. The letter g will be used to express the agreement features of the gap variable. We thus arrive at the final argument structure for the predicate *Syn*:

$$Syn(w,\ e, f,\ x, a,\ y, b,\ z, c,\ v, g)$$

The nonstring arguments come in pairs, indicated here (and only here) by spaces.

Words and many types of phrases cannot have gaps. In these cases, the last two arguments are always the empty constant $-$.

With the addition of the v and g arguments, the basic grammar rules take on the following form:

(4.3) $Syn(w_1, x, a, -, -, -, -, -, -, -, -)$
$\wedge Syn(w_2, e, f{:}\mathbf{v.tnsd}, x, a\ {:}\mathbf{n.nom}, -, -, -, -, v, g)$
$\supset Syn(w_1w_2, e, f, -, -, -, -, -, -, v, g)$

(4.4) $Syn(w_3, e, f{:}\mathbf{v}, x, a{:}\mathbf{n.nom}, y, b{:}\mathbf{n.acc}, -, -, -, -)$
$\wedge Syn(w_4, y, b, -, -, -, -, -, -, v, g)$
$\supset Syn(w_3w_4, e, f, x, a, -, -, -, -, v, g)$

(4.5) $p'(e, x, y) \supset Syn(w_3, e, \mathbf{v}, x, \mathbf{n.nom}, y, \mathbf{n.acc}, -, -, -, -)$

In Section 4.4 more abstract versions of these rules are introduced, and it is these that will be the basis of the development in this chapter.

One more point about gaps. Consider

> This is the man that John introduced Mary to ().
> This is the man that John introduced () to Mary.

Often when composing two phrases into a larger phrase, either component phrase can have a gap in it, but not both, and the composite phrase has the same gap. To handle this fact, many rules will have the form

$$Syn(w_1, \ldots, v_1, g_1) \wedge Syn(w_2, \ldots, v_2, g_2) \wedge gap(v, g, v_1, g_1, v_2, g_2)$$
$$\supset Syn(w_1w_2, \ldots, v, g)$$

The meaning of $gap(v, g, v_1, g_1, v_2, g_2)$ is that either all of v, v_1, and v_2 are the empty element, or v is the same as v_1 or v_2 while the other is the empty element. In axioms,

$$\supset gap(-, -, -, -, -, -)$$
$$\supset gap(v, g, v, g, -, -)$$
$$\supset gap(v, g, -, -, v, g)$$

That is, either there is no gap, or there is a gap in the first constituent or the the second constituent only and it is the same as the gap in the composite phrase.

4.2.5 Summary

To summarize, the structure of the basic syntactic predicate is

$$Syn(w, e, f, x, a, y, b, z, c, v, g)$$

where

w:	the word or string of words that constitutes the phrase.
e:	the variable representing the eventuality corresponding to the head of the phrase.
f:	the agreement features associated with eventuality e.
x, y, z:	the variables representing the entities that are the first, second, and third arguments, respectively, of the predication associated with the head.
a, b, c:	the agreement features associated with entities x, y, and z, respectively.
v:	the variable representing the entity that fills a gap.
g:	the agreement features associated with entity v.

Variables and agreement features are always paired.

The variables x, y, and z will be referred to as *arguments*. The phrase that supplies x will be referred to as the *subject*. The phrases that supply y and z will be called the *first* and *second complements*. The argument of a predication that is supplied by the subject will sometimes be called the *logical subject* of the predication. I will sometimes say "the subject x" where I mean "the argument x supplied by the subject".

The variables a, b, and c will be referred to as *feature variables*, and each individually will be called a *feature structure*. A feature structure is an n-tuple of *features*, such as **v** and **tnsd**, that come from *feature sets* like *CAT* and *TNS*.

4.3 Lexical Axioms

The process of interpreting a sentence is a process of proving that the string of words *is* a sentence with a particular interpretation. This involves back-chaining along axioms involving the *Syn* predicate and, in effect, "deconcatenating" strings into smaller units. This process bottoms out in what can be called "lexical axioms". These are axioms of the form

$$p'(e, x, y, z) \supset Syn(w_3, e, f, x, a, y, b, z, c, -, -)$$

There is at least one of these axioms for each word sense. They encode the lexical information about word senses. They can be thought of as lexicon entries. They constitute the interface between syntax and world knowledge.

Let us examine three such axioms more closely.

$$like'_1(e, x, y)$$
$$\supset Syn(\text{“likes”}, e, \mathbf{v.tnsd}, x, \mathbf{n.sing.nom}, y, \mathbf{n.acc}, -, -, -, -)$$
$$like'_2(e, x, y) \supset Syn(\text{“like”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc}, -, -, -, -)$$

$$green'(e, x) \supset Syn(\text{"green"}, e, \mathbf{adj}, x, \mathbf{n}, -, -, -, -, -, -)$$

In each case the left side of the axiom is the logical form that corresponds to the morpheme. The arguments in the logical form also appear on the right side of the axiom as arguments of *Syn*, so that their referents can be picked up from the correct elements in the rest of the sentence during the course of what corresponds to parsing in this framework. The spelling or phonology of the word is specified in the first argument of *Syn*. Agreement features are expressed in the f, a, b, and c arguments.

The lexical axioms for nouns is a bit more complex and will be motivated and developed in Section 4.10.

One other facet of typical lexical entries is selectional constraints on the arguments. The lexical axioms are the natural place to encode the selectional constraints. Suppose, for example, we want to insist that the subject of "likes" be animate. The above axiom can be expanded to

$$\begin{aligned}&like'_1(e, x, y) \wedge animate(x)\\ &\quad \supset Syn(\text{"likes"}, e, \mathbf{v.tnsd}, x, \mathbf{n.sing.nom}, y, \mathbf{n.acc}, -, -, -, -)\end{aligned}$$

That is, if e is the liking by x of y where x is animate, then e can be expressed by the tensed verb "likes", which takes a singular nominative NP referring to x as its subject and an accusative NP referring to y as its object. Because $animate(x)$ is in the antecedent, it must be verified in the course of interpreting the text.

The selectional constraints need not be simple type specifications as above, but, as we will see in numerous examples in this book, they can be arbitarily complex conditions on all the the variables at once.

In Hobbs (1982) and Hobbs et al. (1993), an approach to lexical ambiguity was proposed in which a predicate neutral among the meanings was generated in the logical form of the sentence, and more specific predicates corresponding to the different word senses were linked to that predicate and used in the knowledge base. Thus, for the word "fair", there would be a predicate $fair$ that is true both of entities that are even-handed and of entities that are mediocre, a predicate $fair_1$ that is true of entities that are even-handed, and a predicate $fair_2$ that is true of entities that are mediocre. Knowledge about even-handedness and mediocrity would have axioms involving the predicates $fair_1$ and $fair_2$, respectively. This approach would use the three following axioms.

$$\begin{aligned}&fair'(e, x) \supset Syn(\text{"fair"}, e, \mathbf{adj}, x, \mathbf{n}, -, -, -, -, -, -)\\ &fair'_1(e, x) \supset fair'(e, x)\\ &fair'_2(e, x) \supset fair'(e, x)\end{aligned}$$

That is, if something is fair_1 it is fair, if something is fair_2 it is fair, and fairness can be expressed by the adjective "fair".

However, it is just as easy to use the predicates $fair_1$ and $fair_2$ directly in the lexical axioms.

$$fair_1'(e,x) \supset Syn(\text{“fair”}, e, \textbf{adj}, x, \textbf{n}, -, -, -, -, -, -)$$
$$fair_2'(e,x) \supset Syn(\text{“fair”}, e, \textbf{adj}, x, \textbf{n}, -, -, -, -, -, -)$$

That is, both fairness_1 and fairness_2 can be expressed by the adjective "fair".

The latter method will be used in this book, for the most part.

Three main types of axiom will be used in this chapter. Lexical axioms specify the canonical way predications pick up their arguments from other elements in the sentence. Composition axioms, such as (4.3), actually pick up those arguments from other elements, in the course of concatenating strings into larger units. The third type of axiom rearranges the arguments in the *Syn* predication, so that the composition axioms can pick up the arguments in a noncanonical manner. These axioms will be called "alternation axioms", and will typically have the form

$$Syn(w, e, f, \ldots) \supset Syn(w, e, f, \ldots)$$

where the dots in the second *Syn* predication stand for a permutation or other modification of the dots in the first. Rule (4.2) in Section 4.2.4 is such an axiom. A number of diverse phenomena will be handled in this way, including passivization, Aux-inversion, and metonymy.

In all three types of axioms, a *Syn* predication occurs in the consequent. In composition axioms, two or three *Syn* predications occur in the antecedent. In alternation axioms, one *Syn* predication and perhaps a logical form fragment occurs in the antecedent. In lexical axioms, only logical form fragments occur in the antecedent.

4.4 The Basic Clause-Level Composition Rules

In this section four basic clause-level composition rules will be presented. Most of the work of composition in this treatment of syntax will use these rules in conjunction with lexical axioms and alternation axioms.

The first rule corresponds to the rule

$$\text{S} \rightarrow \text{NP VP}$$

in traditional grammars, the $\overline{\overline{\mathbf{X}}}$ rule in $\overline{\mathbf{X}}$ syntax, and Schema 1 in HPSG (Pollard and Sag, 1994, p. 38). It handles external arguments to the left of the head, and could be called the Subject Rule. It is stated as follows:

(4.6) $$\begin{aligned} & Syn(w_1, x, a, -, -, -, -, -, -, v_1, g_1) \\ & \quad \wedge Syn(w_2, e, f, x, a\text{:}\mathbf{sb}, -, -, -, -, v_2, g_2) \\ & \quad \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ & \quad \supset Syn(w_1 w_2, e, f, -, -, -, -, -, -, v, g) \end{aligned}$$

A phrase of type a, usually a noun phrase but more generally any type of phrase that the verb or other head specifies as a possible subject, is followed by a phrase of type f, and the concatenation is a phrase of type f. Number agreement is enforced by the identity of a in the two *Syn* predications in the antecedent. The referent x of the subject is passed down to the head by making it an argument of the second *Syn* predication in the antecedent. The eventuality e described by the combined phrase as a whole is the one that is constructed by the second component phrase. The use of the *gap* predication here is as described in Section 4.2.4.

Rule (4.6) is intended to cover the application of a subject to ordinary verb phrases, predicate complement constructions, and several other kinds of complements.

The feature **sb** restricts the application of this rule to heads w_2 that subcategorize for it. The feature comes from the feature set *COMPRULE*, whose other members are **ob**, **sc**, **oc**, and **tf**, used in the other clause-level composition rules.

The remaining rules are for attaching verbs and other operators to their complements. There are separate rules for ordinary objects, subject control constructions, and object control constructions. These rules correspond to the $\overline{\mathbf{X}}$ rule of $\overline{\mathbf{X}}$ Theory and Schema 2 of HPSG (Pollard and Sag, 1994, p. 38).

The first of these rules corresponds to the traditional rules

VP → V NP
PP → P NP

It may be called the Object Rule and is stated as follows:

(4.7) $$\begin{aligned} & Syn(w_1, e, f, x, a, y, b\text{:}\mathbf{ob}, z, c, v_1, g_1) \\ & \quad \wedge Syn(w_2, y, b, -, -, -, -, -, -, v_2, g_2) \\ & \quad \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ & \quad \supset Syn(w_1 w_2, e, f, x, a, z, c, -, -, v, g) \end{aligned}$$

If a head word or phrase w_1 describing eventuality e with agreement features f and having arguments x, y and z with agreement features a, b and c, respectively, is concatenated with a phrase w_2, often but not necessarily an NP, referring to y and having agreement features b, then the result w_1w_2 is a phrase of type f describing eventuality e, and having as its unsaturated arguments the subject x and a possible remaining complement z, which have agreement features a and c respectively. The composite phrase has a gap v with agreement features g if and only if exactly one of its constituents does too. Since the z argument moves over to y's place, the complements get consumed one by one. When none remains, it will match the pattern of Rule (4.6), so that the subject can be attached.

The syntactic part of the interpretation, that is, the "parse", of the sentence "John likes Mary" is illustrated in Figure 4.1. From the top down, the Subject Rule is first applied to split off "John". Then the Object Rule is applied to split apart "likes" and "Mary". Finally, lexical axioms introduce the fragments of the logical form. The analysis of the verb will be complicated somewhat below, in Section 4.6. In the remaining illustrations in this chapter, the *gap* predications will not be shown if they play no significant role.

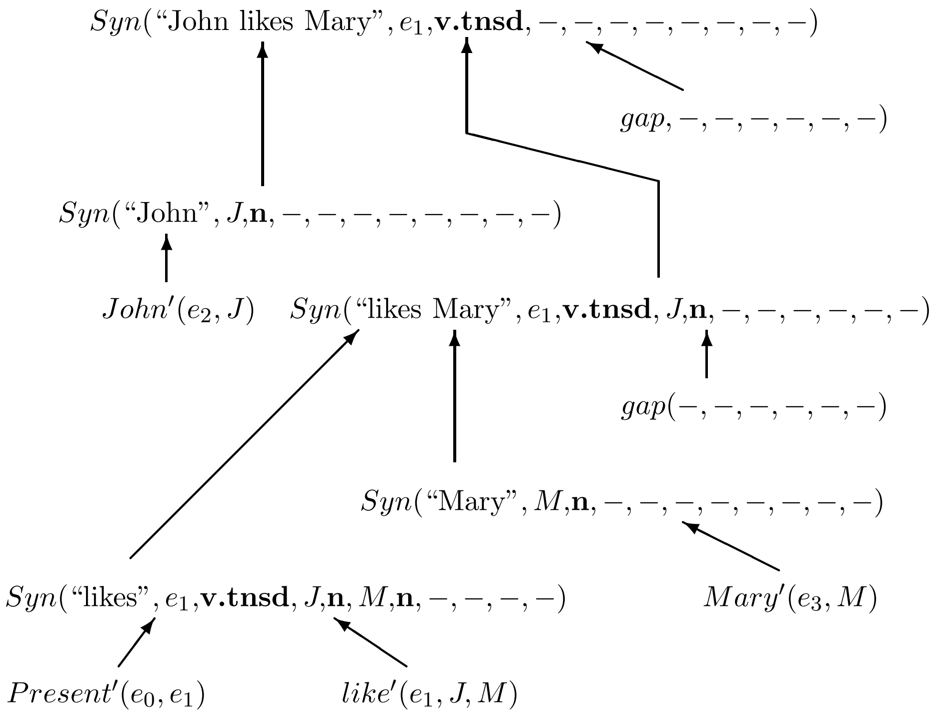

Figure 4.1: Parse of "John likes Mary."

The next rule for complements covers complements that share their subject with their heads. This includes the cases traditionally known as Raising, or Subject Control, and we will refer to this as the Subject Control Rule. It is stated as follows:

$$\text{(4.8)} \quad \begin{aligned} & Syn(w_1, e_1, f_1, x, a, e_2, f_2{:}\mathbf{sc}, z, c, v_1, g_1) \\ & \quad \wedge Syn(w_2, e_2, f_2, x, a, -, -, -, -, v_2, g_2) \\ & \quad \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ & \supset Syn(w_1 w_2, e_1, f_1, x, a, z, c, -, -, v, g) \end{aligned}$$

This is the same as rule (4.7) except that the subject of the complement is the same as the subject of the head. Since the complement is sentential, I have used the variables e_2 and f_2 instead of y and b.

The next rule is intended to handle Object Control verbs like "persuade". In

John persuaded Mary to leave early.

Mary is both an argument of the persuading and the leaving. The composition rule must pick up "Mary" as the first complement of "persuade" and the infinitive as the second complement, while specifying the latter's subject to be "Mary".

The rule, which may be called the Object Control Rule, is as follows:

$$\text{(4.9)} \quad \begin{aligned} & Syn(w_1, e_1, f_1, x, a, y, b, e_3, f_3{:}\mathbf{oc}, -, -) \\ & \quad \wedge Syn(w_2, y, b, -, -, -, -, -, -, v_2, g_2) \\ & \quad \wedge Syn(w_3, e_3, f_3, y, b, -, -, -, -, v_3, g_3) \\ & \quad \wedge gap(v, g, v_2, g_2, v_3, g_3) \\ & \supset Syn(w_1 w_2 w_3, e_1, f_1, x, a, -, -, -, -, v, g) \end{aligned}$$

That is, if w_1 is a word or phrase of type f_1 describing e_1 and having x, y, and e_3 as its arguments with feature structures a, b, and f_3, respectively, w_2 is a word or phrase of type b referring to y, and w_3 is a phrase of type f_3 describing e_3, then the concatenation of the three is a phrase of type f_1 describing e_1 and having subject x with feature structure a. The concatenation has a gap if and only if exactly one of w_2 or w_3 has a gap. The subject of the embedded clause w_3 is identical to the first complement of the matrix.

In the application of this rule, it doesn't matter what the *COMPRULE* feature of b is.

Note that in this treatment of clause-level composition, the subject and the complements receive very similar treatment. They differ only in the rule that attaches them to the verb. Agreement constraints on the subject are imposed by features associated with the verb. In this, the approach is like that in HPSG (Pollard and Sag, 1994, pp. 29-30) rather than that in GB.

In all of these rules the f feature structure of the head is carried up to the composite phrase. This captures Pollard and Sag's Head Feature Principle (1994, p. 34). The content of the two, the e argument, is also identical, capturing Pollard and Sag's Semantics Principle (p. 48). The Subject Composition Rule applies only to verb phrases whose only unsaturated argument is the subject and results in a composite phrase all of whose arguments are saturated. This ensures that in a complete S, all arguments will have been consumed. This captures Pollard and Sag's Subcategorization Principle (p. 34). Pollard and Sag argue that together the Head Feature Principle and the Subcategorization Principle subsume the Projection Principle of GB (p. 35). In the present framework then, the principles can be seen as moderately abstract characterizations of a few composition axioms.

Sections 4.5 to 4.15 present an analysis of English syntax, including clause-level phenomena, VP structures, predicate complements, small clauses, adjuncts, the structure of the NP, reflexive pronouns, long-distance dependencies, conjunctions, and comparatives.

4.5 Clause-Level Phenomena

4.5.1 Moods

The declarative, interrogative, and imperative moods are surface speech acts that are signalled by the syntactic form of the sentence. These speech act characterizations mediate between the syntactic structure of the sentence and the role played by the utterance of the sentence in the world of the speaker and hearer. They convey, or at least purport to convey, a relation between the informational content of the sentence and the mental states of the speaker and hearer. Assertions, or sentences in the indicative mood, express, at least on the surface, the speaker's goal that the hearer believe that content. Questions convey the speaker's goal of knowing or believing a specialization of the information content of the sentence. Imperatives express the speaker's goal that the hearer perform the action described by the sentence.

Axiomatic characterizations of the three moods will thus relate *Syn* predications with epistemic and communicative predications like *goal*, *believe*, and *utter*, involving the speaker and hearer. The axiom linking declarative sentences to the speaker's and hearer's epistemic states and communicative intentions is as follows:

(4.10) $Syn(w, e, \mathbf{v.tnsd}, -, -, -, -, -, -, -, -) \quad \wedge \quad goal(i, e_1) \quad \wedge$
$believe'(e_1, u, e)$
$\supset utter'(e_2, i, u, w)$

This axiom is used when one is in the position of having to find an explanation for an act e_2 of someone i uttering a sequence of words w to someone else u. One possible explanation is that i has the goal e_1 that u believe e, where w is a tensed clause without gaps or unsaturated arguments that describes the situation e. The speaker i says sentence w to a hearer u because she wants u to believe the content e of the sentence. Less direct goals of the utterance are reasoned about with this as the base.

Yes-no questions require a preposed auxilliary, as in

Has John left?
Is John here?
Can John go?

One's first guess of how to do this would be to have auxilliary verbs subcategorize for tenseless clauses, including small clauses made up of a subject and a predicate complement. This is adequate for auxilliaries that convey only a property of the eventuality described by the clause, such as "is" which only specifies that the eventuality is true in the present. However, for epistemic modals such as "can" (in the sense of "is able to" rather than "is possible"), this approach is not adequate, for the auxilliary conveys a relation between the subject and the verb phrase of the tenseless clause, and the subject is no longer available once the clause has been composed. That is, we would need to have as a lexical axiom for "can" something like

$can'(e, ??, e_1)$
$\supset Syn(\text{“can”}, e, \mathbf{modal}, e_1, \mathbf{v.tnsless}, -, -, -, -, -, -)$

But we have no way to reach inside the tenseless clause to get its subject.

Pollard and Sag's (1994) approach to this difficulty is to appeal to a rule that is essentially of a VSO character (their Schema 3). A head can be composed with an arbitrary number of complements to its left. We can achieve the same effect, however, with the composition rules already presented, if we employ a simple alternation on auxilliaries applied at the lexical level. An invertable auxilliary taking an NP subject and a tenseless

VP as its first complement can also be subjectless and take an NP and a tenseless VP as its two complements. Since the NP needs to be the subject of the tenseless VP, the Object Control Rule (4.9) would apply. In "Can John go?" "can" is viewed as taking two complements, "John" and "go", where "John" is moreover the subject of "go". The following axiom achieves this alternation:

$$Syn(w, e, \mathbf{aux.tnsd}, x, a{:}\mathbf{n.sb}, e_1, f_1{:}\mathbf{v.tnsless.sc}, -, -, v, g)$$
$$\supset\ Syn(w, e, \mathbf{ynq}, -, -, x, a, e_1, f_1{:}\mathbf{oc}, v, g)$$

That is, if a word w is a tensed (or modal) auxilliary taking an NP subject and a tenseless clause complement having the same subject, then it can also take the NP and tenseless clause as its first and second complements, with no subject, where the first complement provides the subject of the second complement. The resulting clause is given the attribute **ynq** to restrict its occurrence to the top level of the sentence and to wh-questions,[5] and to govern its interpretation, as described below.

The feature **aux** is a subfeature of **v** in the feature set CAT.

Interpreting yes-no questions requires us to take seriously the information conveyed by the question mark or the rising intonation. We will represent this information by means of the predicate ?. We will take $?'(e_0, e)$ to mean that e_0 is a judgment on the truth or falsity of e. In the next section we will see *yes*, *no* and *maybe* treated as properties of eventualities, conveying their truth, falsity and possibility, respectively. They are related to ? by the axioms

$$yes(e) \supset ?(e)$$
$$no(e) \supset ?(e)$$
$$maybe(e) \supset ?(e)$$

That is, they are each judgments on the truth or falsity of e.

The rule for interpreting yes-no questions is then as follows:

$$Syn(w, e, \mathbf{ynq}, -, -, -, -, -, -, -, -) \wedge goal(i, e_1) \wedge believe'(e_1, i, e_0)$$
$$\wedge\, ?'(e_0, e)\ \supset\ utter'(e_2, i, u, w)$$

That is, one explanation for an uttering e_2 by i to u of a string of words w is that i has the goal e_1 that i believe a judgment e_0 on the truth or falsity of e, where w is a yes-no question without gaps or unsaturated arguments that describes the situation e.

[5]And possibly to a few other constructions, such as "Only recently has he gone back to college".

As described below in Section 4.13, wh-questions can be formed by concatenating a wh-phrase with a yes-no question having a gap. We give the rule here without explanation.

$$\begin{aligned}&Syn(w_1, v_2, g_2{:}\mathbf{n/p}, y, b, -, -, -, -, v_1, g_1{:}\mathbf{whq})\\ &\qquad \wedge Syn(w_2, e_2, \mathbf{ynq}, -, -, -, -, -, -, v_2, g_2) \wedge wh'(e_1, v_1)\\ &\quad \supset Syn(w_1w_2, e_1, \mathbf{whq}, -, -, -, -, -, -, -, -)\end{aligned}$$

As described in Chapter 2, $wh'(e, x)$ says that e is a context-dependent essential property of x. It becomes the primary content of the wh-question. When a wh-question is asked, the speaker is saying that she wants to know or believe such a context-dependent essential property.

$$\begin{aligned}&Syn(w, e, \mathbf{whq}, -, -, -, -, -, -, -, -) \wedge goal(i, e_1) \wedge believe'(e_1, i, e)\\ &\quad \supset utter'(e_2, i, u, w)\end{aligned}$$

That is, one explanation for an uttering e_2 by i to u of a string of words w is that that i has the goal e_1 that i believe e, where e is the content of a wh-question w without gaps or unsaturated arguments.

An imperative consists of a tenseless, gapless VP.

$$\begin{aligned}&Syn(w, e, \mathbf{v.tnsless}, u, a, -, -, -, -, -, -) \wedge goal(i, e)\\ &\quad \supset utter'(e_2, i, u, w)\end{aligned}$$

That is, one explanation for an uttering e_2 by i to u of a string of words w is that that i has the goal e of u doing something, where w is a tenseless VP and e is the eventuality it conveys. Note the identity of the subject of the sentence and the recipient of the utterance.

We can now see with particular clarity the mediating role syntax plays between the intentions of the participants in the conversation and the world knowledge that underlies its content. This is illustrated in Figure 4.2

The mutual influence of inference about plans and inference about world knowledge is effected by shared predications and shared variables. The search for a minimal proof of the logical form and the *goal* and *believe* predications often determines the best syntactic analysis.

4.5.2 On What is Said and Presuppositions

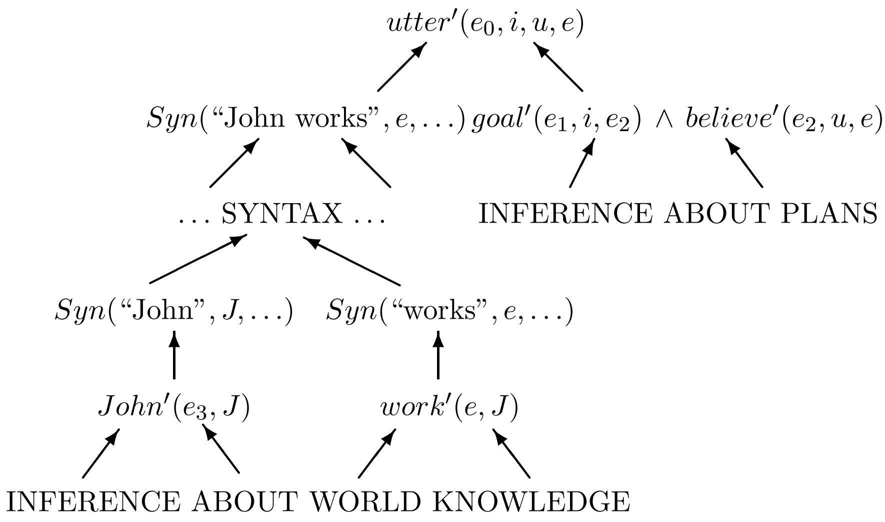

Figure 4.2: Syntax Mediates Between Plans and World Knowledge

In “Logic and Conversation” Grice (19??) distinguishes between what is said and implicatures. In his analysis of the example

He is in the grip of vice.

we can see that what he means by “what is said” includes the predication made by the main verb of the sentence, after pronouns have been resolved, words have been disambiguated, and, to an extent, metaphors have been interpreted.

This is distinguished from conventional implicatures, an illustration of which is in the sentence

He is an Englishman; he is, therefore, brave.

The conventional implicature, conveyed by the word “therefore”, is the causal or implicational relation between being an Englishman and being brave. He also identifies conversational implicatures, which were discussed in Chapter 3.

His motivation for making this distinction is to preserve the philosophy of language’s account of sentences like the first by distinguishing them from sentences like the second, which would cause it problems.

But this is a rather strange way of cutting the pie. There are predications explicit in the sentence, that come from compositional semantics, as described in this chapter; call these “explicit” predications. Then there are predications that come from inference using world knowledge, as described in Chapters 3 and 6; call these “implicit” predications. Grice’s “what is said” includes among the explicit predications the predication from the main verb and among the implicit predications the predications derived in the course of pronoun resolution and lexical disambiguation. Not included in his “what is said” are the explicit predications derived from definite noun phrases and from conjunctions like “therefore”. Also not included are the implicit predications derived in the course of understanding the relation of a sentence to the surrounding discourse and broader context.

For these reasons I do not believe Grice’s analysis is a good basis for the treatment of the assertion-presupposition distinction.

Intuitively, the assertion of a sentence is the predication that we judge to be true or false when we judge the sentence to be true or false. But judgments of the truth or falsity of sentences has played and will play very little role in this account of discourse interpretation. Our concern is rather with the comprehension of the meaning of the sentence, and the account is neutral with respect to truth or falsity. Unlike much of twentieth century philosophy of language, my primary aim is not to determine the conditions under which English sentences are true or false. For the most part, I am only interested in getting at the information conveyed, explicitly or implicitly, by a text.

However, there is a place where judgments of truth or falsity matter—in discourses that contain judgments of truth or falsity. Consider the dialogue fragments

A: The man is tall.
B: True.

and

A: The man is strong.
B: That’s false.

In our account of discourse coherence we have to discover the relation between the two successive utterances. In particular we have to discover that there is an elaboration relation between the sentences in the first example and a contrast relation in the second.

As sketched in Chapter 3 and as developed more deeply in Chapter 6, coherence relations between successive segments of discourse are primarily relations between the principal predications of the two segments. For clauses, that is usually the predication conveyed by the main verb or predicate complement, although as we will see in Section 4.17, this can be displaced to some other predication conveyed by elements of the sentence.

In the first of the above exchanges, the eventuality that is primarily conveyed by A's utterance is e where $tall'(e, x)$. Thus, when we seek its coherence with B's utterance, we have to establish a relation between e and what is conveyed by B's utterance. The most plausibe relation is that it is e which is true. A similar story can be told about the second exchange.

In brief, the reason for making the distinction between assertions and the rest of the information in a sentence is because of the role of assertions in determining coherence. The syntactic analysis of the sentence will reveal the information that would normally be considered the assertion and about which the sentence is making an existential claim, but a number of factors can cause the assertion to be displaced to other information conveyed by the sentence

Traditionally, the defining property of the presuppositions of a sentence is that they survive negation. Both

(4.11) John's dog is barking.

and

(4.12) John's dog isn't barking.

seem to convey that John owns a dog. Nevertheless, these presuppositions are not mere inferences or entailments, the usual story goes (??, 19??), because they are cancellable.

(4.13) John's dog isn't barking, because he doesn't own a dog.

In the present framework, there is a distinction that corresponds to the distinction between presuppositions and assertions, but no special machinery is required for presuppositions. Of the various properties conveyed by a sentence, there are some (generally few) for which the sentence is making an existential claim and these correspond to what is normally the assertion. In (4.11) the sentence claims that the barking event occurs in the real world. In (4.12) it claims that it doesn't. For the majority of conveyed propositions, however, the sentence is simply silent about the existential status of the corresponding eventuality. In the course of interpreting sentences (4.11) and (4.12), we decide that the best interpretation results if we assume John owns a dog. Thus, the assertions are those propositions for which the sentence makes an existential claim; the presuppositions are those for which it doesn't.

The syntactic axioms presented in this chapter would generate a logical form for (4.11) that contained

$$own'(e_1, j, d) \wedge bark'(e_2, d)$$

and for sentence (4.12) would generate in addition the predication

$$not'(e_3, e_2)$$

In sentence (4.11) we would have $Rexist(e_2)$,[6] so the barking would exist. In sentence (4.12) we would have $Rexist(e_3)$, so the barking would not exist. Neither sentence claims $Rexist(e_1)$. That is an assumption we make to get the best interpretation of the overall text.

The cancellability of presuppositions is not a special process. Rather it is just a case where we gain new information which makes our existential assumption inconsistent. The best interpretation of the entire sentence (4.13) does not include the proposition that John's owning the dog obtains in the real world, because this is explicitly contradicted by the second clause.

4.5.3 Lexical Sentences

Certain words function as entire sentences. This fact can be captured in axioms of the form

$$okay'(e, e_1) \supset Syn(\text{“okay”}, e, \mathbf{v.tnsd}, -, -, -, -, -, -, -, -)$$
$$no'(e, e_1) \supset Syn(\text{“no”}, e, \mathbf{v.tnsd}, -, -, -, -, -, -, -, -)$$
$$sure'(e, e_1) \supset Syn(\text{“sure”}, e, \mathbf{v.tnsd}, -, -, -, -, -, -, -, -)$$
$$yeah'(e, e_1) \supset Syn(\text{“yeah”}, e, \mathbf{v.tnsd}, -, -, -, -, -, -, -, -)$$

What the words are asserting or denying, namely e_1, is contextually determined.

[6] Assuming the larger discourse does not embed this sentence in some opaque operator, e.g., as in an extended hypothetical, indirect proof, or other fiction

Words like "correct" and "right" can be seen as being in the process of becoming lexicalized sentences, from being elided instances of full sentences with a predicate adjective—"That is correct." The full interpretation of "Correct", viewed as ellipsis, is shown in Figure 4.3.

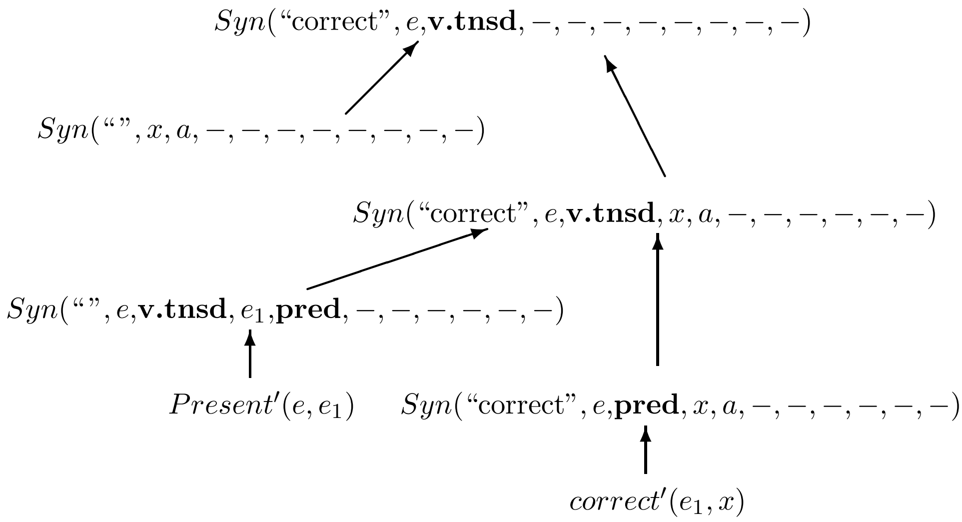

Figure 4.3: Parse of "Correct."

$Syn(\text{" "}, x, a, -, -, -, -, -, -)$ is assumed, as described in Section 4.19.2 as one method for dealing with sentence fragments.

This proof becomes the conventionalized interpretation and the proof is collapsed into the single axiom:

$$\begin{aligned}&Present'(e, e_1) \wedge correct'(e_1, x)\\ &\quad \supset Syn(\text{"correct"}, e, \mathbf{v.tnsd}, -, -, -, -, -, -, -, -)\end{aligned}$$

This has the same form as the other lexical sentences.

4.6 Verb Phrase Rules

4.6.1 Verb Morphology

Tensed verbs typically convey at least two predications, one for the stem and one for the tense. The following axiom pulls the stem and morphology apart:

$$VMorph(w_1, w, e_1, f{:}\mathbf{v}, e_2, a) \wedge VStem(w, e_2, f, x, a, y, b, z, c) \\ \supset Syn(w_1, e_1, f, x, a, y, b, z, c, -, -)$$

VMorph specifies the actual form of the word w_1, the stem w, and the eventuality e_1 associated with the tense, if any. The last of these usually takes the stem's predication e_2 as its argument. The arguments of the verb x, y, and z are required only by the stem, but the agreement feature on the subject is determined in part by morphology, e.g., number, and in part by the stem (see the treatment of "there" in Section 4.7). Thus, *VMorph* and *VStem* must share the variable a. Similarly, the feature f associated with the verb is often a combination of information from both the morphology, e.g., tense, and the stem, e.g., whether the verb is a form of "be".

This approach is illustrated most clearly for irregular verbs. The tenses of "go" and their meanings are captured by the following axioms.

$$Present'(e_1, e_2) \supset VMorph(\text{“goes”}, \text{“go”}, e_1, \mathbf{v.tnsd}, e_2, \mathbf{n.sing.nom})$$
$$Present'(e_1, e_2) \supset VMorph(\text{“go”}, \text{“go”}, e_1, \mathbf{v.tnsd}, e_2, \mathbf{n.pl.nom})$$
$$Past'(e_1, e_2) \supset VMorph(\text{“went”}, \text{“go”}, e_1, \mathbf{v.tnsd}, e_2, \mathbf{n.nom})$$
$$\supset VMorph(\text{“gone”}, \text{“go”}, e_2, \mathbf{v.en}, e_2, \mathbf{n})$$

These axioms specify the relation between the inflected form and the base form, and generate the logical form fragment associated with the inflection. The past participle morphology adds no information to a sentence except in combination with other elements; thus, the last axiom has no antecedent. The two e arguments are identical in this case; the highest level eventuality associated with the past participle will be the going.

In treating tense in this way, I am following the current fashion of separating tense from stem at the lexical level. The alternative, more common in earlier times (e.g., Chomsky, 1957), is to separate tense from the VP. The axiom would be

$$VMorph(w_1, w, e_1, f{:}\mathbf{v}, e_2, a) \wedge Syn(ww_2, e_2, f, x, a, -, -, -, -, -, -) \\ \supset Syn(w_1w_2, e_1, f, x, a, -, -, -, -, -, -)$$

A tensed verb w_1 followed by the rest of the VP w_2 can be analyzed as a tense added to the stem w of w_1 followed by w_2. This treatment of tense is analogous to the treatment of modals, which seems appropriate.

The arguments for which approach to take are not strong. There is no argument from the constraints that the tense imposes on the subject. These are enforced in both treatments by *VMorph*'s contribution to the f feature structure.

Getting the predicate-argument relations right for the stem's predication is also not an argument; things work out in both approaches. In the first approach, x, y and z are correctly associated with e_2 at the $VStem$ level, and that is all that is required, even though they are associated with e_1 above that level. In the second approach, only x is incorrectly associated with e_1 and then only above the VP level, Below the VP level, all three arguments are correctly associate with e_2, as required.

The only potential problem concerns adverbials. In the first approach, in the sentence

John walked slowly.

by the time "slowly" is composed with "walked", the tense's eventuality e_1, the past-ness of the walking, is the head eventuality, and that is what will be taken to be the logical subject of *slow*. But it is the walking, not the past-ness of the walking that should be the logical subject.

In the second approach, this particular problem does not arise. "Slowly" would be composed with the stem VP "walk", whose head eventuality would be e_2, the walking, and the logical subject of *slow* would correctly be e_2.

But even in the second approach, the problem arises when the adverbial appears to the left of the verb. In

Slowly John walked.

the adverbial must be composed with the full clause, and at that point the head eventuality will be e_1, the past-ness of the walking, in both approaches. A mechanism is needed for handling this class of examples in any case, and once we have such a mechanism, it can be used in the first approach for all adverbials.

The mechanism is metonymy, as described in Section 4.17. The logical form produced by the lexical and composition axioms is

$$walk'(e_2, J) \wedge Past'(e_1, e_2) \wedge slow'(e_3, e_1)$$

The eventuality e_1 is not the sort of thing that can be slow, so this argument must be coerced into something that can. The tense itself provides the coercion relation—$Past'(e_1, e_2)$—coercing e_1 into e_2.

Separating tense and stem at the lexical level thus raises no special problems, and that approach will be followed here.

The regular verb endings can be captured by specifying the string deconcatenations. The following set of axioms is indicative rather than exhaustive of English regular verb morphology. For the relation between "walks" and the base form "walk":

$$Present'(e_1, e_2) \supset VMorph(w\text{“s”}, w, e_1, \mathbf{v.tnsd}, e_2, \mathbf{n.sing.nom})$$

For “possesses” and “possess”:

$$Present'(e_1, e_2) \supset VMorph(w\text{“ses”}, w\text{“s”}, e_1, \mathbf{v.tnsd}, e_2, \mathbf{n.sing.nom})$$

For “teaches” and “teach”:

$$Present'(e_1, e_2) \supset VMorph(w\text{“ches”}, w\text{“ch”}, e_1, \mathbf{v.tnsd}, e_2, \mathbf{n.sing.nom})$$

For regular present plural verb forms:

$$Present'(e_1, e_2) \supset VMorph(w, w, e_1, \mathbf{v.tnsd}, e_2, \mathbf{n.pl.nom})$$

For “walked” and “walk”:

$$Past'(e_1, e_2) \supset VMorph(w\text{“ed”}, w, e_1, \mathbf{v.tnsd}, e_2, \mathbf{n.nom})$$

For “liked” and “like”:

$$Past'(e_1, e_2) \supset VMorph(w\text{“ed”}, w\text{“e”}, e_1, \mathbf{v.tnsd}, e_2, \mathbf{n.nom})$$

For “have walked” and “walk”:

$$\supset VMorph(w\text{“ed”}, w, e_1, \mathbf{v.en}, e_2, \mathbf{n})$$

For “have liked” and “like”:

$$\supset VMorph(w\text{“ed”}, w\text{“e”}, e_1, \mathbf{v.en}, e_2, \mathbf{n})$$

For “walking” and “walk”:

$$Progressive'(e_1, e_2) \supset VMorph(w\text{“ing”}, w, e_1, \mathbf{v.ing}, e_2, \mathbf{n})$$

For “liking” and “like”:

$$Progressive'(e_1, e_2) \supset VMorph(w\text{“ing”}, w\text{“e”}, e_1, \mathbf{v.ing}, e_2, \mathbf{n})$$

For “running” and “run”:

$$Progressive'(e_1, e_2) \supset VMorph(w\text{“nning”}, w\text{“n”}, e_1, \mathbf{v.ing}, e_2, \mathbf{n})$$

The meaning of the predicate *Progressive* is discussed in Chapter 5.

These rules allow interpretion of incorrect forms like “goed” and “likeed”, which may seem like an advantage since we really can interpret them, but of course they also overgenerate to produce those forms. Optimality constraints built into abduction-driven generation should force the generation of the most specific, highly constrained form, however. In any case, to specify these rules more tightly would take us into tedious details well outside the scope of this book.

Person, as an agreement feature set, is largely invisible in modern English and can very nearly be subsumed under Number. For the most part, we can simply classify "I", "we" and "you" as having plural number. The only place where the distinction shows up is with forms of the verb "be". The morphology for "be" requires three extra rules, for "I am", "I was" and "it was". The pronoun "I" is conveniently classified as having a *NUM* feature of **pl** see Section 4.10.11). But the forms of "be" require us to divide this feature into two subfeatures—**ego** and **pln**. The pronoun "I" has the *NUM* feature **ego**, and genuinely plural nouns and pronouns have the *NUM* feature **pln**. Whereas the plural forms of other verbs require their subject to have the feature **pl**, the plural forms of "be" require them more specifically to have **pln**. A further discussion of this move will be found in Section 4.10.

The axioms for "be" are as follows:

$$Present'(e_1, e_2) \supset VMorph(\text{“am”}, \text{“be”}, e_1, \textbf{v.aux.tnsd}, e_2, \textbf{n.ego.nom})$$

$$Present'(e_1, e_2) \supset VMorph(\text{“is”}, \text{“be”}, e_1, \textbf{v.aux.tnsd}, e_2, \textbf{n.sing.nom})$$

$$Present'(e_1, e_2) \supset VMorph(\text{“are”}, \text{“be”}, e_1, \textbf{v.aux.tnsd}, e_2, \textbf{n.pln.nom})$$

$$Past'(e_1, e_2) \supset VMorph(\text{“was”}, \text{“be”}, e_1, \textbf{v.aux.tnsd}, e_2, \textbf{n.ego.nom})$$

$$Past'(e_1, e_2) \supset VMorph(\text{“was”}, \text{“be”}, e_1, \textbf{v.aux.tnsd}, e_2, \textbf{n.sing.nom})$$

$$Past'(e_1, e_2) \supset VMorph(\text{“were”}, \text{“be”}, e_1, \textbf{v.aux.tnsd}, e_2, \textbf{n.pln.nom})$$

$$\supset VMorph(\text{“been”}, \text{“be”}, e_1, \textbf{v.aux.en}, e_2, \textbf{n})$$

The other irregular verb forms for verbs in our target texts are as follows:

$$Past'(e_1, e_2) \supset VMorph(\text{“cut”}, \text{“cut”}, e_1, \textbf{v.tnsd}, e_2, \textbf{n.nom})$$

$$\supset VMorph(\text{“cut”}, \text{“cut”}, e_1, \textbf{v.en}, e_2, \textbf{n})$$

$$Past'(e_1, e_2) \supset VMorph(\text{“found”}, \text{“find”}, e_1, \textbf{v.tnsd}, e_2, \textbf{n.nom})$$

$$\supset VMorph(\text{“found”}, \text{“find”}, e_1, \textbf{v.en}, e_2, \textbf{n})$$

$$Past'(e_1, e_2) \supset VMorph(\text{“got”}, \text{“get”}, e_1, \textbf{v.tnsd}, e_2, \textbf{n.nom})$$

$$\supset VMorph(\text{“got”}, \text{“get”}, e_1, \textbf{v.en}, e_2, \textbf{n})$$

$$\supset VMorph(\text{“gotten”}, \text{“get”}, e_1, \textbf{v.en}, e_2, \textbf{n})$$

$$Present'(e_1, e_2)$$

$\supset VMorph(\text{"has"}, \text{"have"}, e_1, \mathbf{v.aux.tnsd}, e_2, \mathbf{n.sing.nom})$

$Present'(e_1, e_2)$
$\supset VMorph(\text{"hath"}, \text{"have"}, e_1, \mathbf{v.aux.tnsd}, e_2, \mathbf{n.sing.nom})$

$Past'(e_1, e_2) \supset VMorph(\text{"had"}, \text{"have"}, e_1, \mathbf{v.aux.tnsd}, e_2, \mathbf{n.nom})$

$\supset VMorph(\text{"had"}, \text{"have"}, e_1, \mathbf{v.aux.en}, e_2, \mathbf{n})$

$Past'(e_1, e_2) \supset VMorph(\text{"said"}, \text{"say"}, e_1, \mathbf{v.tnsd}, e_2, \mathbf{n.nom})$

$\supset VMorph(\text{"said"}, \text{"say"}, e_1, \mathbf{v.en}, e_2, \mathbf{n})$

$Past'(e_1, e_2) \supset VMorph(\text{"taught"}, \text{"teach"}, e_1, \mathbf{v.tnsd}, e_2, \mathbf{n.nom})$

$\supset VMorph(\text{"taught"}, \text{"teach"}, e_1, \mathbf{v.en}, e_2, \mathbf{n})$

In this development I have taken the syntactic approach to number agreement, by taking **sing**, **pl**, and so on, to be properties of the word instances. An alternative is the semantic approach, which views nouns, determiners, and present tense verbs as conveying information about entities. This issue is discussed in Section 4.10 on the structure of NPs.

4.6.2 Intransitives, Transitives, and Ditransitives

As in most unification grammar approaches, subcategorization will be handled entirely in the lexicon. This section presents the lexical axioms for all the words that are used as intranstive, transitive, or ditransitive verbs in the target texts. Most words have multiple subcategorization patterns; in our approach, there will be one lexical axiom for each pattern.

An example of an intransitive verb is

We pause.

Its lexical axiom is as follows:

$$pause'(e, x) \supset VStem(\text{"pause"}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$$

That is, if e is the eventuality of x pausing, then e can be described by the verb "pause" taking an NP subject referring to x. Since there are no complements, the subject and the verb can be concatenated immediately (after the verb stem has been combined with its morphology), using the Subject Rule (4.6).

Prepositional and adverbial arguments can be treated as though they were adjuncts, as described in the next section. Hence, the verbs in the following examples can also be subsumed under the intransitive case:

I feel strongly about that.
Antibodies appear in the blood serum.
The tenants come in.
We will go from twelve to one.

The remaining lexical axioms for the intransitive verbs in the target texts are as follows:

$appear'(e,x) \supset VStem(\text{“appear”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$
$come'(e,x) \supset VStem(\text{“come”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$
$develop'(e,x) \supset VStem(\text{“develop”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$
$eat'(e,x) \supset VStem(\text{“eat”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$
$feel'(e,x) \supset VStem(\text{“feel”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$
$go'(e,x) \supset VStem(\text{“go”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$
$last'(e,x) \supset VStem(\text{“last”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$
$live'(e,x) \supset VStem(\text{“live”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$
$ruminate'(e,x) \supset VStem(\text{“ruminate”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$
$see'(e,x) \supset VStem(\text{“see”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$
$weep'(e,x) \supset VStem(\text{“weep”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$
$win'(e,x) \supset VStem(\text{“win”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$

Some examples of transitive verbs are as follows:

We define language.
We can isolate the virus.
Inspection revealed metallic particles.
We will discuss that.

In addition, since prepositional arguments can be treated as adjuncts, the verbs in the following examples will also be specified as transitive:

An individual is infected with HIV-1.
Virus is found in the blood.
Low viral replication is interspersed with minor upsurges of viremia.
The lube oil is saturated with metallic particles.
The town is estranged from all other places in the world.
Time will take my love away.
We can use the hour for discussion.
We can get some information from him.

The lexical axioms for transitive verbs have the following form:

$$define'(e, x, y) \supset VStem(\text{“define”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

That is, if e is the eventuality of x defining y, then e is describable by the verb “define” when it takes an NP referring to x as its subject and an NP referring to y as its object. The object is attached by means of the Object Rule (4.7) and must be in the accusative. The subject is attached by means of the Subject Rule (4.6). We do not specify the case or number of the subject in this axiom, since they are specified by the morphological rule.

The other lexical axioms for the transitive verbs in the target texts are as follows:

$$bend'(e, x, y) \supset VStem(\text{“bend”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$characterize'(e, x, y) \supset VStem(\text{“characterize”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$confound'(e, x, y) \supset VStem(\text{“confound”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$deface'(e, x, y) \supset VStem(\text{“deface”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$define'(e, x, y) \supset VStem(\text{“define”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$discuss'(e, x, y) \supset VStem(\text{“discuss”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$do'(e, x, y) \supset VStem(\text{“do”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$eat'(e, x, y) \supset VStem(\text{“eat”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$estrange'(e, x, y) \supset VStem(\text{“estrange”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$find'(e, x, y) \supset VStem(\text{“find”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$gain'(e, x, y) \supset VStem(\text{“gain”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$get'(e, x, y) \supset VStem(\text{“get”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$have'(e, x, y) \supset VStem(\text{“have”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$infect'(e, x, y) \supset VStem(\text{“infect”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$intersperse'(e, x, y) \supset VStem(\text{“intersperse”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$isolate'(e, x, y) \supset VStem(\text{“isolate”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$keep'(e, x, y) \supset VStem(\text{“keep”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$$know'(e, x, y) \supset VStem(\text{“know”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

$lose'(e,x,y) \supset VStem(\text{“lose”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$mean'(e,x,y) \supset VStem(\text{“mean”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$mind'(e,x,y) \supset VStem(\text{“mind”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$need'(e,x,y) \supset VStem(\text{“need”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$observe'(e,x,y) \supset VStem(\text{“observe”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$raise'(e,x,y) \supset VStem(\text{“raise”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$reduce'(e,x,y) \supset VStem(\text{“reduce”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$request'(e,x,y) \supset VStem(\text{“request”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$reveal'(e,x,y) \supset VStem(\text{“reveal”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$saturate'(e,x,y) \supset VStem(\text{“saturate”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$schedule'(e,x,y) \supset VStem(\text{“schedule”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$show'(e,x,y) \supset VStem(\text{“show”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$spend'(e,x,y) \supset VStem(\text{“spend”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$squeeze'(e,x,y) \supset VStem(\text{“squeeze”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$take'(e,x,y) \supset VStem(\text{“take”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$use'(e,x,y) \supset VStem(\text{“use”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$
$wait'(e,x,y) \supset VStem(\text{“wait”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$

The verbs in the following examples are ditransitive:

Bring us some sandwiches.
Give him the demo.

The lexical axioms for ditransitive verbs have the following form:

$give'(e,x,y,z)$
$\quad \supset VStem(\text{“give”}, e, \mathbf{v}, x, \mathbf{n.sb}, z, \mathbf{n.acc.ob}, y, \mathbf{n.acc.ob})$

That is, if e is the eventuality of x giving y to z (i.e., giving z y), then e is describable by the verb "give" when it takes an NP referring to x as its subject, an NP referring to z as its indirect object, and an NP referring to y as its direct object. The indirect and direct objects are both attached to the verb by means of the Object Rule (4.7) and must be in the accusative. The subject is attached by means of the Subject Rule (4.6). Note that the canonical order of arguments for the predicate *give* is

Subject > Direct Object > Object of "to" rather than

Subject > Indirect Object > Direct Object

This is in line with our decision to order the arguments of predicates by obliqueness.

The lexical axiom for "bring" is similar.

$$bring'(e, x, y, z) \supset VStem(\text{“bring”}, e, \mathbf{v}, x, \mathbf{n.sb}, z, \mathbf{n.acc.ob}, y, \mathbf{n.acc.ob})$$

Benefactive ditransitives, as in

John baked Mary a cake.

can be generated systematically by the alternation axiom

$$VStem(w, e, f{:}\mathbf{v}, x, a{:}\mathbf{n.sb}, y, b, -, -) \wedge for'(e_1, e, z) \supset VStem(w, e, f, x, a, z, c{:}\mathbf{n.ob}, y, b)$$

That is, if w is a verb taking a direct object and describing eventuality e and e is for the benefit of z, then w is also a ditransitive verb whose indirect object is an NP referring to z.

4.6.3 Prepositional Arguments

There are two nearly equivalent ways of treating arguments that are labeled by prepositions. The first is to treat them exactly like adjuncts, as described in Section 4.9, as expressing properties of the eventuality conveyed by the main verb. Consider, for example, the verb "go" as in

John will go from New York to Chicago.

Treating "go" as an intransitive verb expressing a three-argument predicate, the logical form generated from the verb stem will be

$$go'(e, J, y, z)$$

where J is John, the subject of the sentence, and y and z are existentially quantified variables with no further known properties. The part of the logical form generated from the prepositional phrases will include

$$from'(e_1, e, NY) \wedge to'(e_2, e, C)$$

where e is the going, NY is New York, and C is Chicago.

Axioms in the knowledge base will relate the arguments of predicates corresponding to verbs with their associated prepositions, as in

$$go'(e, x, y, z) \supset from'(e_1, e, y)$$
$$go'(e, x, y, z) \supset to'(e_2, e, z)$$

That is, if e is a going by x from y to z, then there is a "from" condition e_1 in which e is from y and a "to" condition e_2 in which e is to z.

In the course of abductive interpretation of the logical form, we backchain from $from'(e_1, e, NY)$ to $go'(e, x_3, NY, z_3)$, from $to'(e_2, e, C)$ to $go'(e, x_4, y_4, C)$, unify these with $go'(e_2, J, y, z)$, thereby identifying the y argument of go with New York NY and the z argument of go with Chicago C.

One reason for treating PP arguments as adjuncts in this fashion is that prepositions do not unambiguously signal arguments of the verbs that subcategorize for them. For example, "from" can signal cause as well as source, as in

John is going to his new job in Chicago from frustration.

All of the verbs with PP arguments in the target texts, with one possible exception, could plausibly be classified as intransitives or transitives taking PP adjuncts, and as shown above, any PP argument treated as an adjunct can be recovered as an argument during inferencing, so the incorporation of PP arguments into the grammar may not be not essential to our purposes. However, it is an important enough issue in its own right that I will sketch a more syntactic approach that could be taken.

Two pieces of information must be tranmitted from the PP to the VP in these cases—the variable representing the NP's referent and the preposition. The verb is subcategorized for the particular preposition and the variable must take a place in the predicate-argument structure associated with the verb. Thus, the NP supplies information about the argument and the preposition is relevant to agreement. We may therefore view the various prepositions that signal arguments as features indicating "case" and varying with the features **nom** and **acc** in the feature set *CASE*. The prepositions are few, and those that signal arguments are even fewer; for example, "during" and "across" never signal an argument. Thus, this move does not greatly increase the number of features we have.

A verb such as "rely", which takes one prepositional object, will use the Object Rule (4.7), but its y argument, instead of being in the accusative, will have the *CASE* feature **on**.

$$rely'(e, x, y) \supset VStem(\text{“rely”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.on.ob}, -, -)$$

The verb “rely” expresses a relation e between an agent x conveyed by an NP in the subject position and an object y conveyed by an NP preceded by the “signal” “on”.

For each preposition that can signal an argument, there must be a lexical axiom of the following form:

$$\supset Syn(\text{“on”}, y, \mathbf{n.on}, -, -, y, \mathbf{n.acc.ob}, -, -, -, -)$$

That is, the word “on” can be concatenated with an accusative NP object referring to y to form an “NP” with a *CASE* feature of **on**, also referring to y. There is no antecedent because in this approach, “on” is only a grammatical signal as the the syntactic role of the noun phrase.

The verb “rely” is a good candidate for this treatment, because its “on” argument is obligatory. The only verb in the target texts whose prepositional argument seems obligatory is “intersperse”.

* Low viral replication is interspersed.
Low viral replication is interspersed with minor upsurges of viremia.

The axiom for “intersperse” is

$$intersperse'(e, x, y) \supset VStem(\text{“intersperse”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.with.ob}, -, -)$$

and the axiom for this use of the preposition “with” is

$$\supset Syn(\text{“with”}, y, \mathbf{n.with}, -, -, y, \mathbf{n.acc.ob}, -, -, -, -)$$

This approach to prepositional arguments parallels the most natural approach to noun case endings in languages that inflect nouns for case. In a sense, we view the preposition as a prefix to the NP indicating case.

The two methods of handling prepositional arguments are illustrated in Figures 4.4 and 4.5. In the adjunct approach (Figure 4.4), because of the Adjunct Composition Rule (4.18) of Section 4.9, what is asserted by the sentence is the “on” condition e_3, but the relying e can be immediately inferred from this. This analysis depends on having the axiom

$$rely'(e, x, y) \supset on'(e_1, e, y)$$

relating the predicate to the preposition.

For completeness, lexical axioms are given for the other prepositions in the target texts that could be viewed as case markers.

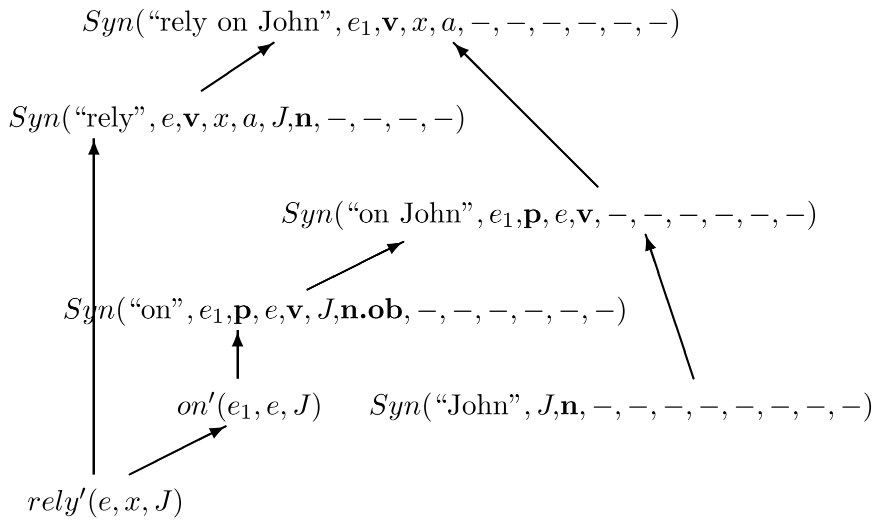

Figure 4.4: Adjunct parse of "rely on John"

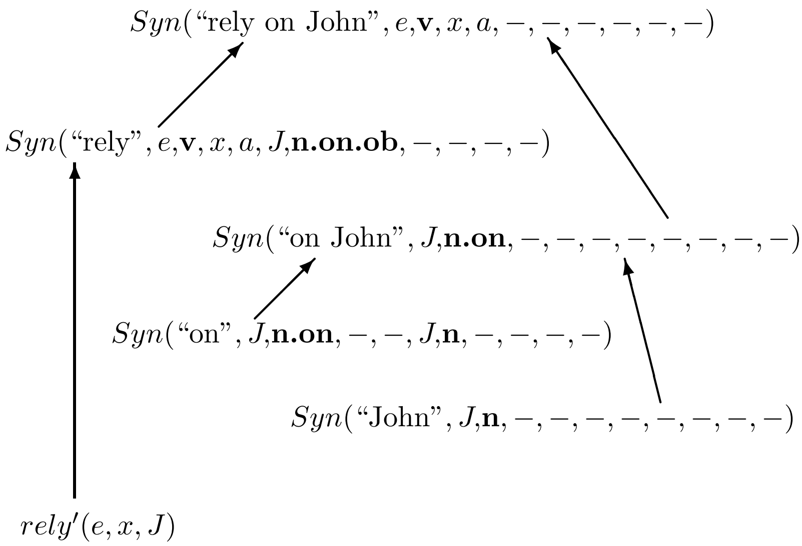

Figure 4.5: Argument parse of "rely on John"

$\supset$ $Syn(\text{"from"}, y,\mathbf{n.from}, -, -, y,\mathbf{n.acc.ob}, -, -, -, -)$
$\supset$ $Syn(\text{"for"}, y,\mathbf{n.for}, -, -, y,\mathbf{n.acc.ob}, -, -, -, -)$
$\supset$ $Syn(\text{"in"}, y,\mathbf{n.in}, -, -, y,\mathbf{n.acc.ob}, -, -, -, -)$
$\supset$ $Syn(\text{"of"}, y,\mathbf{n.of}, -, -, y,\mathbf{n.acc.ob}, -, -, -, -)$
$\supset$ $Syn(\text{"to"}, y,\mathbf{n.to}, -, -, y,\mathbf{n.acc.ob}, -, -, -, -)$

The features **from**, **for**, **in**, **of**, **on**, **to**, and **with** are all subfeatures of the feature **pcase**.

Two-complement verbs, such as "bring", "give", and "go", that take at least one PP argument, also yield to this approach.

$$bring'(e,x,y,z)$$
$$\supset\ VStem(\text{“bring”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, z, \mathbf{n.to.ob})$$
$$give'(e,x,y,z)\ \supset\ VStem(\text{“give”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, z, \mathbf{n.to.ob})$$
$$go'(e,x,y,z)\ \supset\ VStem(\text{“go”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.from.ob}, z, \mathbf{n.to.ob})$$

In the first axiom e is the bringing by x of y to z. In the second, e is the giving by x of y to z. That is, y is the direct object, and z represents the object of "to". In the third axiom, e is the going by x from y to z.

Prepositional arguments are freer in order than are NP arguments. We can say

John went to Chicago from New York.
Mary gave to John every book she no longer needed.

This phenomenon can be handled by the two following rules that permute the PP arguments:

$$(4.14)\quad Syn(w,e,f,x,a,y,\mathbf{n.pcase},z,c,v,g)$$
$$\supset\ Syn(w,e,f,x,a,z,c,y,\mathbf{n.pcase},v,g)$$
$$(4.15)\quad Syn(w,e,f,x,a,y,b,z,\mathbf{n.pcase},v,g)$$
$$\supset\ Syn(w,e,f,x,a,z,\mathbf{n.pcase},y,b,v,g)$$

The feature **pcase** is a superfeature of **from**, **for**, **in**, and so on, in the feature set *CASE*. The first rule moves a PP argument to the right, the second to the left. Either rule can be used in the case of two PP arguments.

The omissability of PP arguments can be captured by the axioms

$$Syn(w,e,f,x,a,y,\mathbf{n.pcase},z,c,v,g)$$
$$\supset\ Syn(w,e,f,x,a,z,c,-,-,v,g)$$
$$Syn(w,e,f,x,a,y,b,z,\mathbf{n.pcase},v,g)$$
$$\supset\ Syn(w,e,f,x,a,y,b,-,-,v,g)$$

with a suitably constrained to avoid verbs like "rely" where the PP argument is obligatory. If we were to adopt the position that the obligatory character of the PP is what defines it as an argument, then we would not have these axioms, we would not have **pcase** lexical axioms for verbs whose PP "complements" were not obligatory, and we would only have **pcase** lexical axioms for verbs, like "rely", whose PP complements were obligatory, To summarize, both the adjunct and argument treatments of prepositional arguments have natural realizations in this framework, so it is not very important whether we decide upon one or the other. In the rest of this book I will be driven by convenience, usually taking the adjunct approach.

4.6.4 Separable Particles

In the following examples, the verbs have separable particles:

Find that out.
Total it up.
Block it out.
Put that off.

The verb and particle together constitute a single lexical item, as seen by the facts that finding out does not imply finding, blocking out does not imply blocking, and so on.

The easiest way to handle verb-particle constructions is to treat the particle as a complement that does not contribute an argument to the predication but influences what the predicate is. The following lexical axiom accomplishes this for "find out":

$$\begin{array}{l} \textit{find-out}'(e,x,y) \\ \quad \supset VStem(\text{“find”}, e,\mathbf{v}, x,\mathbf{n.sb}, y,\mathbf{n.acc.ob}, -,\mathbf{p.out.ob}) \end{array}$$

If e is a finding out by x of y, then e can be described by the verb "find" taking an NP subject referring to x, an accusative NP referring to y as its first complement and the particle "out" as its second complement. The z argument is "$-$" because the particle does not refer.

I have made the "separated" case the default because of the strong preference for postposed particles when the NP is a pronoun.

The following alternation axiom moves the particle to the left of the NP object.

VStem(w,e,f: **v**,x,a: **n**.**sb**,y,b: **n**.**acc**.**ob**,-,c: **p**.**ob**)
  ⊃ VStem(w,e,f,x,a,-,c,y,b)

Here are three more lexical axioms for verb-particle constructions.

$$\begin{array}{l} \textit{block-out}'(e,x,y) \\ \quad \supset VStem(\text{“block”}, e,\mathbf{v}, x,\mathbf{n.sb}, y,\mathbf{n.acc.ob}, -,\mathbf{p.out.ob}) \\ \textit{put-off}'(e,x,y) \\ \quad \supset VStem(\text{“put”}, e,\mathbf{v}, x,\mathbf{n.sb}, y,\mathbf{n.acc.ob}, -,\mathbf{p.off.ob}) \end{array}$$

$total\text{-}up'(e, x, y)$
$\quad \supset VStem(\text{“total”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, \mathbf{p.up.ob})$

The following lexical axioms classify prepositions as possible separable particles.

$\supset Syn(\text{“off”}, -, \mathbf{p.off}, -, -, -, -, -, -, -, -)$
$\supset Syn(\text{“out”}, -, \mathbf{p.out}, -, -, -, -, -, -, -, -)$
$\supset Syn(\text{“up”}, -, \mathbf{p.up}, -, -, -, -, -, -, -, -)$

The features **off**, **out**, and **up** are members of the feature set *PART* associated with prepositions.

Because *Syn* has only room for two complements, this approach does not handle ditransitive verb-particle constructions, as in

Mary always mixes John up with George.

4.6.5 Sentential Complements

One sense of the word "that" turns a clause whose verb is tensed or tenseless into a "that"-clause, which can then be the subject or object of various verbs.

That Mary left early distressed John.
John thought that Mary left early.

When the clause is in the subject position, the word "that" is obligatory. There must be some indication in *Syn* that "that" is present. We can do this by writing a lexical axiom for "that" as follows:

$\supset Syn(\text{“that”}, e, \mathbf{thats}, -, -, e, \mathbf{v.tnsd.ob}, -, -, -, -,)$

Since the word "that" has no semantic content, the left side of the implication is empty. (In an approach that distinguished propositions from eventualities, the relation between the two would be introduced here.) Its function is to take an immediately following S (a fully saturated **v**) with a tensed verb, describing the eventuality e, and turn it into a fully saturated phrase of the category **thats**, describing the same eventuality.

The clause can be tenseless for operators that subcategorize for the subjunctive. The rule for that is

$\supset Syn(\text{“that”}, e, \mathbf{thatsubjunct}, -, -, e, \mathbf{v.tnsless.ob}, -, -, -, -,)$

The verb "distress" which takes a tensed "that" clause as subject has the following lexical axiom:

$$distress'(e, e_1, y)$$
$$\supset VStem(\text{"distress"}, e, \mathbf{v}, e_1, \mathbf{n/thats.sb}, y, \mathbf{n.acc.ob}, -, -, -, -)$$

If e is the eventuality of the situation e_1 distressing y, then e can be described by the verb "distress" having an NP or a "that" clause referring to e_1 as its subject and an accusative NP referring to y as its object.

The examples of sentential complements in the target texts are as follows:

I mean it's not critical.
Let's say we block that out for lunch.
I think we probably want to do it.

One thing immediately obvious from the examples is that the complementizer "that" is optional and often missing when the clause is in object position. The following alternation axioms accommodate this phenomenon:

$$Syn(w, e, \mathbf{v.tnsd}, -, -, -, -, -, -, -, -)$$
$$\supset Syn(w, e, \mathbf{thats.ob}, -, -, -, -, -, -, -, -)$$
$$Syn(w, e, \mathbf{v.tnsless}, -, -, -, -, -, -, -, -)$$
$$\supset Syn(w, e, \mathbf{thatsubjunct.ob}, -, -, -, -, -, -, -, -)$$

If the string w is a tensed or tenseless clause, then it is also a "that" clause that can occur only in object position.

The lexical axioms for verbs taking sentential complements are subcategorized for phrases of type **thats**.

$$believe'(e, x, e_1) \supset VStem(\text{"believe"}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{thats.ob}, -, -)$$

That is, if e is the eventuality of x believing e_1, then e is describable by the verb "believe" when it takes an NP referring to x as its subject and a "that" clause describing e_1 as its object. The object is attached by means of the Object Rule (4.7). The subject is attached by means of the Subject Rule (4.6).

The lexical axioms for verbs with "that" complements in the target texts are as follows:

$$mean'(e, x, e_0) \supset VStem(\text{"mean"}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{thats.ob}, -, -)$$
$$say'(e, x, e_0) \supset VStem(\text{"say"}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{thats.ob}, -, -)$$
$$say'(e, x, e_0) \supset VStem(\text{"say"}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{thatsubjunct.ob}, -, -)$$
$$think'(e, x, e_0) \supset VStem(\text{"think"}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{thats.ob}, -, -)$$

The verb "tell" takes an NP indirect object and a sentential complement, as in

John told George that Mary left early.

The lexical axiom for this use of "tell" is

$$tell'(e, x, e_0, z) \supset VStem(\text{"tell"}, e, \mathbf{v}, x, \mathbf{n.sb}, z, \mathbf{n.ob}, e_1, \mathbf{thats.ob})$$

A special conventionalized form that we need for the target texts is "take into account that ...", meaning "consider". The source interpretation for this idiom is shown, in the past tense, in Figure 4.6. The phrase "into account" is an adjunct on "take ...", indicating the destination of the taking. The link between the two *Syn* expressions for the phrase "into account" represents a tense coercion from the past-ness e to the taking e_0. The "parse" bottoms out in the predicates $take'$, $into'$, and $account'$. This combination, for whatever reason, is interpreted as $consider'$.

The portion of this proof within the dashed lines is then collapsed and conventionalized into the axiom

$$\begin{aligned} & consider'(e_0, x, e_1) \\ & \quad \supset VStem(\text{"take"}, e_0, a{:}\mathbf{v}, x, \mathbf{n}, e_1, \mathbf{n/thats}, -, -) \\ & \quad\quad \wedge Syn(\text{"into account"}, e_2, \mathbf{p}, e_0, a, -, -, -, -, -, -) \end{aligned}$$

That is, one way to describe an eventuality e_0 of considering by x of the eventuality e_1 is to say a form of the verb "take", modified by the PP "into account" and having an NP or a "that" clause describing e_1 as its complement. Within the dashed lines, the bold arrows show the construction; the dotted arrows show the analysis that underlies the construction. This rule permits "into account" to precede or follow the complement. (However, it is underconstrained in that it also allows "into account" to precede "take", since adjuncts can appear anywhere.)

4.6.6 Subject and Object Control Verbs

Verbs that take infinitival complements are typically subject control verbs. That is, the implicit subject of the infinitival complement is the same as the subject of the embedding verb. In

John tried to run.

John is the subject of both the trying and the (unsuccessful) running. The lexical axiom for "try" is as follows:

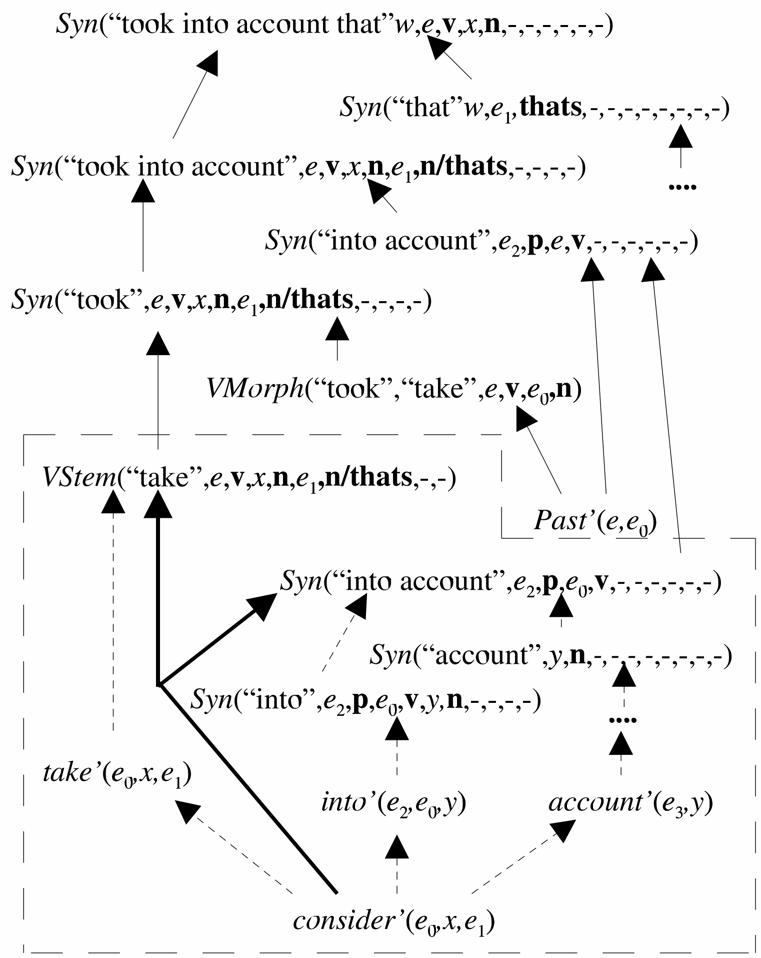

Figure 4.6: Parse of "took into account that ..."

$$try'(e, x, e_1) \supset VStem(\text{"try"}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{v.inf.sc}, -, -, -, -)$$

If eventuality e is a trying by x to do e_1, then e can be described by the verb stem "try" taking an NP referring to x as its subject and an infinitive VP describing e_1 as its complement. The agreement feature **sc** specifies that the Subject Control Rule (4.8) applies, and therefore the logical subject of the infinitival complement will also be x.

The verbs "fear" and "want" are also subject control verbs.

$$fear'(e, x, e_1) \supset VStem(\text{“fear”}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{v.inf.sc}, -, -, -, -)$$
$$want'(e, x, e_1) \supset VStem(\text{“want”}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{v.inf.sc}, -, -, -, -)$$

Many verbs take two complements, the first an NP and the second an infinitival VP. These verbs come in two flavors. The first, exemplified by "promise", is subject control. The subject of the embedding verb is the same as the subject of the infinitival complement. In

John promised Mary to leave early.

it is John who will leave early. The lexical axiom for such verbs is very similar to that of verbs like "try".

$$promise'(e, x, y, e_1) \supset$$
$$VStem(\text{“promise”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, e_1, \mathbf{v.inf.sc})$$

An application of the Object Rule (4.7) consumes the indirect object y. Then an application of Subject Control Rule (4.8) consumes the infinitival complement while identifying its logical subject with the subject of "promise". Finally an application of the Subject Rule (4.6) consumes the subject x.

Another example of a subject control verb with an indirect object is "strike" as in

John struck Mary as a genius.

The lexical axiom for this sense of "strike" is similar to that for "promise", differing only in the type of complement it takes.

$$strike'(e, x, y, e_1)$$
$$\supset VStem(\text{“strike”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, e_1, \mathbf{as.sc})$$

This sense of the word "as" is dealt with in Section 4.7.

These subject control verbs are traditionally known as Equi verbs, because their subjects are equivalent to the logical subjects of their embedded sentential complements. The second variety of subject control operators are the Raising verbs, exemplified by "seem". In

John seems to be happy.

it is John's happiness that is at issue, but the predicate *seem* does not take John as one of its arguments. Its only argument is John's happiness. John is "raised" out of the infinitival complement into the subject position of the main clause.

In our approach, the difference between Equi and Raising verbs is very slight. In the lexical axiom for the verb, the right-hand side is identical. The left-hand side differs only in that the subject does not appear as an argument. Thus, the lexical axiom for "seem" is

$$seem'(e, e_1) \supset VStem(\text{“seem”}, e, \mathbf{v}, x, \mathbf{nx.sb}, e_1, \mathbf{v.inf.sc}, -, -)$$

That is, if e is the eventuality that eventuality e_1 seems to be the case, then e can be described by the verb "seem", whose subject x is the logical subject of e_1 and whose infinitival complement describes e_1. The agreement feature **sc** on the argument e_1 ensures that x will be the logical subject of the infinitive, and the absence of x on the left-hand side of the rule means that x will not be the logical subject of the seeming. The expletives "there" and "it" can occur as the subject of "seem", so the subject has to be subcategorized for **nx** rather than **n**, as described in Section 4.7.

We will encounter both types of subject control verbs in the next section on auxilliaries.

Pollard and Sag (1994, p. 140) propose the "Raising Principle", according to which any subject that is not an argument of the main predication is an argument of a complement. That is, if x does not appear on the left side of the lexical axiom, then there must be a complement with the feature **sc**.

The second flavor of control verbs is exemplified by "persuade". These are object control verbs. The indirect object is the logical subject of the infinitival complement. In

John persuaded Mary to leave early.

it is Mary who will leave early. The lexical axiom for such a verb looks like the following:

$$persuade'(e, x, y, e_1) \\ \supset VStem(\text{“persuade”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc}, e_1, \mathbf{v.inf.oc})$$

First the Object Control Rule (4.7) is applied to consume the two complements, identifying y as e_1's subject. Then an application of the Subject Rule (4.6) consumes the subject x.

4.6.7 Auxilliaries

An example of the most complex form of auxilliaries that we will want to handle is

This mess could have been being cleaned up while I was gone.

A form of the verb “to be” can be applied to a past participle to produce a passive. A form of the verb “to be” can be applied to a present participle to form the progressive. A form of the verb “to have” can be applied to a past participle to produce the perfect, and finally a modal can be applied to a tenseless form of a verb.

I follow Pollard and Sag (1994) and others in treating auxilliaries as subject control verbs. Using the Subject Control Rule (4.8), all of the necessary information can be built into the lexical axioms for the auxilliary verbs.

The treatment of passives and progressives will be given in Section 4.7 below, with the treatment of predicate complements.

The rule for the perfect tense is as follows:

$$\begin{array}{l} Perfect'(e_1, e_2) \\ \quad \supset VStem(\text{“have”}, e_1, \mathbf{have}, x, \mathbf{nx.sb}, e_2, \mathbf{v.en.sc}, -, -) \end{array}$$

The agreement feature **v.en** constrains the auxilliary “have” to apply only to past participles. Because of the agreement feature **sc**, the subject of the past participle will be identical to the subject x of “have”. The auxilliary “have” is a Raising verb, rather than an Equi verb, as indicated by the fact that the subject x does not occur in the predication $Perfect'(e_1, e_2)$. The meaning of *Perfect* is discussed in Chapter 5. The subject of the clause can be an expletive “there” or “it” as well as an NP; that is why the perfect tense is subcategorized for **nx** rather than **n**, as explained in Section 4.7.

The feature **have** is a subfeature of **aux**, which is a subfeature of **v** in the feature set *CAT*.

The modal “can”, meaning ability rather than possibility, is handled by the lexical axiom

$$\begin{array}{l} can'(e_1, x, e_2) \\ \quad \supset Syn(\text{“can”}, e_1, \mathbf{modal.tnsd}, x, \mathbf{n.sb}, e_2, \mathbf{v.tnsless.sc}, -, -, -, -) \end{array}$$

Modals have no morphology, so the lexical axiom can be stated directly in terms of *Syn*. The word “can” applies to tenseless verb phrases, and conveys that x can do the action or event e_2. Because of the attribute feature **sc**, the verb is subject control, and the subject of the tenseless verb will be identical to the subject x of “can”. The modal “can” is Equi, rather than Raising, as indicated by the fact that the subject x occurs in the predication $can'(e_1, x, e_2)$. Epistemic or Equi modals cannot have an expletive “there” or “it” for their subject, since the underlying predication needs a logical subject x; hence, this sense of “can” is subcategorized for an **n** subject rather than an **nx**.

The feature **modal** is a subfeature of **aux**. The modal is classed as **tnsd** since a VP that it heads can occur in any context in which tensed verbs can occur.

Other modals are handled with similar lexical axioms. The Equi sense of "could" is given, and the Raising senses of the other modals.

$$could'(e_1, x, e_2)$$
$$\supset Syn(\text{"could"}, e_1, \mathbf{modal.tnsd}, x, \mathbf{n.sb}, e_2, \mathbf{v.tnsless.sc}, -, -, -, -)$$
$$may'(e_1, e_2)$$
$$\supset Syn(\text{"may"}, e_1, \mathbf{modal.tnsd}, x, \mathbf{nx.sb}, e_2, \mathbf{v.tnsless.sc}, -, -, -, -)$$
$$might'(e_1, e_2)$$
$$\supset Syn(\text{"might"}, e_1, \mathbf{modal.tnsd}, x, \mathbf{nx.sb}, e_2, \mathbf{v.tnsless.sc}, -, -, -, -)$$
$$will'(e_1, e_2)$$
$$\supset Syn(\text{"will"}, e_1, \mathbf{modal.tnsd}, x, \mathbf{nx.sb}, e_2, \mathbf{v.tnsless.sc}, -, -, -, -)$$
$$would'(e_1, e_2)$$
$$\supset Syn(\text{"would"}, e_1, \mathbf{modal.tnsd}, x, \mathbf{nx.sb}, e_2, \mathbf{v.tnsless.sc}, -, -, -, -)$$

The use of the word "do" as an auxilliary is captured by the lexical axiom

$$do'(e_1, x, e_2) \supset VStem(\text{"do"}, e_1, \mathbf{do}, x, \mathbf{n.sb}, e_2, \mathbf{v.tnsless.sc}, -, -)$$

It applies to tenseless verb phrases and conveys an intensification of the assertion that the action e_2 occurred by asserting redundantly that the agent x did it. Because of the attribute feature **sc**, the verb is subject control, and the subject of the tenseless verb will be identical to the subject of "do". It is an Equi verb.

The feature **do** is also a subfeature of **aux**.

In negative and question contexts, the auxilliary "do" has lost its semantic force. The axiom given does not capture this fact.

Nonnegative contractions as in

He'd gone.
He'd go.
He'll go.
They're typically late.
We've done that.

are captured in axioms that on backchaining expand the string:

$$Syn(\text{"have"}, e_1, f_1{:}\textbf{have.tnsd}, x, a, e_2, f_2{:}\textbf{v.en}, -, -, -, -)$$
$$\supset Syn(\text{"'ve"}, e_1, f_1, x, a, e_2, f_2, -, -, -, -)$$
$$Syn(\text{"had"}, e_1, f_1{:}\textbf{have.tnsd}, x, a, e_2, f_2{:}\textbf{v.en}, -, -, -, -)$$
$$\supset Syn(\text{"'d"}, e_1, f_1, x, a, e_2, f_2, -, -, -, -)$$
$$Syn(\text{"is"}, e_1, f_1{:}\textbf{be.tnsd}, x, a, e_2, f_2, -, -, -, -)$$
$$\supset Syn(\text{"'s"}, e_1, f_1, x, a, e_2, f_2, -, -, -, -)$$
$$Syn(\text{"are"}, e_1, f_1{:}\textbf{be.tnsd}, x, a, e_2, f_2, -, -, -, -)$$
$$\supset Syn(\text{"'re"}, e_1, f_1, x, a, e_2, f_2, -, -, -, -)$$
$$Syn(\text{"will"}, e_1, f_1{:}\textbf{modal.tnsd}, x, a, e_2, f_2{:}\textbf{v.tnsless}, -, -, -, -)$$
$$\supset Syn(\text{"'ll"}, e_1, f_1, x, a, e_2, f_2, -, -, -, -)$$
$$Syn(\text{"would"}, e_1, f_1{:}\textbf{modal.tnsd}, x, a, e_2, f_2{:}\textbf{v.tnsless}, -, -, -, -)$$
$$\supset Syn(\text{"'d"}, e_1, f_1, x, a, e_2, f_2, -, -, -, -)$$

Note that in American English the contractions of "have" and "had" are restricted to the auxilliary sense.

Negative contractions such as "can't" could be handled similarly.

$$Syn(w_1, e_1, f_1{:}\textbf{aux.}, x, a, y, b, -, -, -, -)$$
$$\wedge\, Syn(\text{"not"}, e_2, \textbf{adv}, e_1, f_1, -, -, -, -, -, -)$$
$$\supset Syn(w_1\text{"n't"}, e_2, f_1, x, a, y, b, -, -, -, -)$$

That is, in backchaining the contracted form is expanded and treated like any other adverbial adjunct, as described in Section 4.9.

However, these are common enough forms to deserve special treatment, especially since they are themselves invertible auxilliaries.

Can't John leave earlier?

All negative contractions that function as invertible auxilliaries will have on the left-hand side of their lexical axioms a predication embedding the eventuality of the auxilliary in negation. For certain negative contractions, including "don't", "doesn't", "didn't", "haven't", "hasn't", and "hadn't", we will want to be able to invert the auxilliary but retain the possibility of interpreting it compositionally by relying on the rules above for analyzing verb morphology. Thus, these rules have a *Syn* predication on their left-hand side for the positive word form.

$$Syn(\text{"does"}, e_1, f_1{:}\textbf{do.pres}, x, a, e_2, f_2, -, -, -, -) \wedge not'(e_0, e_1)$$
$$\supset Syn(\text{"doesn't"}, e_0, f_1, x, a, e_2, f_2, -, -, -, -)$$

$$Syn(\text{"do"}, e_1, f_1{:}\textbf{do.pres}, x, a, e_2, f_2, -, -, -, -) \wedge not'(e_0, e_1)$$
$$\supset Syn(\text{"don't"}, e_0, f_1, x, a, e_2, f_2, -, -, -, -)$$

$$Syn(\text{"did"}, e_1, f_1{:}\textbf{do}, x, a, e_2, f_2, -, -, -, -) \wedge not'(e_0, e_1)$$

$$\supset Syn(\text{“didn't”}, e_0, f_1, x, a, e_2, f_2, -, -, -, -)$$

$$Syn(\text{“has”}, e_1, f_1{:}\mathbf{have.pres}, x, a, e_2, f_2, -, -, -, -) \wedge not'(e_0, e_1) \\ \supset Syn(\text{“hasn't”}, e_0, f_1, x, a, e_2, f_2, -, -, -, -)$$

$$Syn(\text{“have”}, e_1, f_1{:}\mathbf{have.pres}, x, a, e_2, f_2, -, -, -, -) \wedge not'(e_0, e_1) \\ \supset Syn(\text{“haven't”}, e_0, f_1, x, a, e_2, f_2, -, -, -, -)$$

$$Syn(\text{“had”}, e_1, f_1{:}\mathbf{have}, x, a, e_2, f_2, -, -, -, -) \wedge not'(e_0, e_1) \\ \supset Syn(\text{“hadn't”}, e_0, f_1, x, a, e_2, f_2, -, -, -, -)$$

Figure 4.7 illustrates the parse of the yes-no question “Hasn't John left?” From the top down, first the Object Control Rule splits the string into “hasn't”, “John”, and “left”. Then the Aux Inversion alternation axiom is applied, turning “hasn't” into a normal auxilliary. Then the contraction “hasn't” is pulled apart. Then the morphology of “has” is analyzed.

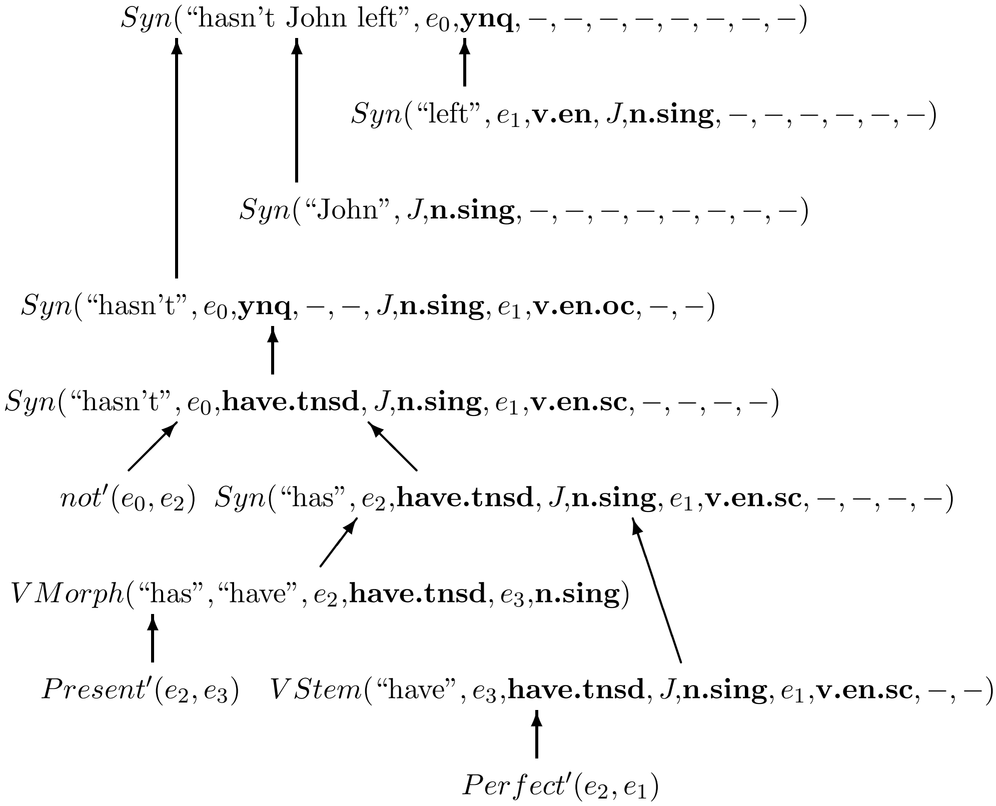

Figure 4.7: Parse of “Hasn't John left?”

Negative contractions with modals can simply have the modal predication and its negation on the left-hand side, since there is no morphological analysis to be done.

$can'(e_1, x, e_2) \wedge not'(e_0, e_1)$
$\quad \supset Syn(\text{“can't”}, e_0, \mathbf{modal.tnsd}, x, \mathbf{n.sb}, e_2, \mathbf{v.tnsless.sc}, -, -, -, -)$

$could'(e_1, x, e_2) \wedge not'(e_0, e_1)$
$\quad \supset Syn(\text{“couldn't”}, e_0, \mathbf{modal.tnsd}, x, \mathbf{n.sb}, e_2, \mathbf{v.tnsless.sc}, -, -, -, -)$

$will'(e_1, e_2) \wedge not'(e_0, e_1)$
$\quad \supset Syn(\text{“won't”}, e_0, \mathbf{modal.tnsd}, x, \mathbf{nx.sb}, e_2, \mathbf{v.tnsless.sc}, -, -, -, -)$

$would'(e_1, e_2) \wedge not'(e_0, e_1)$
$\quad \supset Syn(\text{“wouldn't”}, e_0, \mathbf{modal.tnsd}, x, \mathbf{n.sb}, e_2, \mathbf{v.tnsless.sc}, -, -, -, -)$

I follow Pollard and Sag (1994, p. 125), Pullum (1982), and others in treating the infinitival particle “to” as an auxilliary verb:

$$\supset Syn(\text{“to”}, e, \mathbf{v.inf}, x, \mathbf{nx.sb}, e, \mathbf{v.tnsless.sc}, -, -, -, -)$$

This axiom has no antecedent on the assumption that the infinitival particle adds no semantic content. Those who would argue that it does can add the appropriate antecedent.

The “for”-“to” construction, as in

Mary planned for John to leave early.

can be handled by treating this sense of “for” as an Object Control operator.

$$\supset Syn(\text{“for”}, e, \mathbf{v.inf}, -, -, y, \mathbf{nx.acc}, e, \mathbf{v.inf.oc}, -, -)$$

The word “for” can take as its complements an accusative NP referring to y and an infinitive VP describing eventuality e, and the result is a fully saturated infinitive referring to e whose logical subject is y.

Special cases of auxilliaries involving infinitival complements are the “have to” and “have got to” constructions. Let us assume that these both just mean “must” and write the axioms as follows:

$must'(e, x, e_1) \supset VStem(\text{“have”}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{v.inf.sc}, -, -, -, -)$

$must'(e, x, e_1)$
$\quad \supset VStem(\text{“have”}, e, \mathbf{aux.pres}, x, \mathbf{n.sb}, e_1, \mathbf{v.got.en.sc}, -, -, -, -)$

The “have” in “have to” is not an invertible auxilliary in American English, and so does not take the **aux** feature.

* Has John to leave early?

The "have got to" construction can only be used in very specific contexts. It can only be used in the present tense.

John has got to leave early.
* John had got to leave early.
* John has had got to leave early.
* John will have got to leave early.
* John doesn't want to have got to leave early.

Its "have" is invertible. The word "got" is a past participle; it either adds no meaning or at best is an intensifier. It cannot covary with the alternate past participle "gotten" of "get" without changing the meaning.

* John has gotten to leave early.

Since this "got" is so constrained in its contexts, we need not write the lexical axiom for "got" in terms of $VStem$; Syn will do.

$$\supset Syn(\text{“got”}, e_1, \mathbf{v.got.en}, x, \mathbf{nx.sb}, e_1, \mathbf{v.inf.sc}, -, -, -, -)$$

The word "got" can be attached to an infinitive VP describing eventuality e_1 to produce a VP of type **en**. The word is classified as a nonauxilliary verb of subtype **got**, preventing it from being inverted and restricting it to this one construction.

4.7 Predicate Complements

4.7.1 The Copula

In the sentence

John is tall.

I will call "tall" the predicate complement and "is tall" the verb phrase (VP). Among possible predicate complements are adjectives and adjective phrases,

This painting is *similar to that one*.

prepositional phrases,

This painting is *by Van Gogh*.

and noun phrases,

> This is *a painting by Van Gogh.*

In addition, passives will be treated as predicate complements, as we will see below.

> This was *painted by Van Gogh.*

Weak nominalizations can function as predicate complements.

> My desire is *to paint like Van Gogh.*

The first issue that must be dealt with for predicate complements is what the logical form should be in the various cases. In particular, are forms of the verb "to be" expressed explicitly as a *be* predicate, or is the copula just an empty verb and a carrier of tense? I will come down on both sides of this issue. For some predicate complements, namely, PPs, adjectives, and passives, the copula will be treated as an empty verb.

> John is in New York. $\Rightarrow Present'(e_0, e) \wedge in'(e, J, NY)$
>
> John is tall. $\Rightarrow Present'(e_0, e) \wedge tall'(e, J)$
>
> John was fired. $\Rightarrow Past'(e_0, e) \wedge fire'(e, x, J)$

For NP predicate complements, it will be treated as expressing the relation *be*.

> John is a man. $\Rightarrow Present'(e_0, e) \wedge be'(e, J, x) \wedge man'(e_1, x)$

The alternative would be

> John is a man. $\Rightarrow Present'(e_0, e) \wedge man'(e, J)$

The differences are not great, since the most common interpretation of "be" is identity. But it will occasionally be useful to have the explicit predication of *be* available to further interpretation processes. For example, in

> An elephant is a mammal.

one could argue that "is" conveys implication.

Weak nominalizations are clauses functioning as noun phrases.

> *That he visited Venice* is wonderful.
> *To visit Venice* would be wonderful.
> *For him to visit Venice* would be wonderful.

. Weak nominalizations can occur in the predicate complement position.

> The trouble is *that I don't know the answer.*
> To think is *to exist.*

When they do, we will also use the *be* predicate. For these examples as well, it it questionable whether "be" conveys identity.

Predicate complement constructions behave in many ways like verb phrases. They have one unsaturated argument, the subject, and the subject can be applied to them directly, without a verb, as in small clauses.

First we consider non-nominal predicate complements. These predicate complements will have the feature **pred**. The feature **nominal** covers both noun phrases and weak nominalizations. Then the Subject Control Rule (4.8) already accommodates the application of the copula to a predicate complement. It causes the subject of the sentence to become the logical subject of the predicate complement:

$$\supset VStem(\text{"be"}, e, \mathbf{be}, x, \mathbf{nominal.sb}, e, \mathbf{pred.sc}, -, -)$$

This says the auxilliary verb stem "be" may be applied to a predicate complement describing an eventuality e to yield a verb phrase which can take a nominal referring to x as its subject. Moreover, the logical subject of e will be identified with x, and the eventuality e described by the predicate complement will be the eventuality described by the whole verb phrase. The verb "be" adds no content, so the antecedent of this lexical axiom is empty.

Now consider the nominal case—NP predicate complements. The feature **nppred** is a subfeature of **pred**. The following alternation axiom will turn any NP or nominalization into a potential predicate complement, thereby making the nominal case yield to our treatment of the non-nominal one.

$$(4.16)\quad \begin{array}{l} Syn(w, y, \mathbf{nominal}, -, -, -, -, -, -, -, -) \wedge be'(e, x, y) \\ \quad \supset Syn(w, e, \mathbf{nppred}, x, \mathbf{nominal.sb}, -, -, -, -, -, -) \end{array}$$

That is, an NP or other nominal referring to y can function as a predicate complement, of subtype **nppred**, describing a *be* relation between x and y, where x will be provided by the nominal subject of the predicate complement. The eventuality e conveyed by the predicate complement is that *be* relation.

The last two axioms combine to yield an analysis of the phrase "be a man" as a VP conveying a *be* relation.

A special variety of copular sentences involve "there" or the expletive "it". These words occur in highly restricted contexts. Essentially, they cannot appear in clauses where their presence as the subjects would force them to be the logical subject of the underlying predication. These words will not be considered nouns (**n**) but rather special categories, **it** and **there**, under a supercategory **nx** that subsumes them and ordinary nouns (Figure 4.8). The lexical axioms for "it" and "there" are as follows:

$\supset Syn(\text{"it"}, -, \textbf{it.sing}, -, -, -, -, -, -, -, -)$
$\supset Syn(\text{"there"}, -, \textbf{there}, -, -, -, -, -, -, -, -)$

That is, "it" and "there" can be used as expletives.

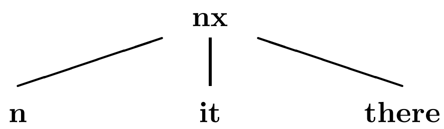

Figure 4.8: The category of nouns and expletives.

Existential "there" clauses, as in

There is a problem.
There are problems.

can be treated as arising from a special sense of the verb "to be", explicated in the lexical axiom

$$exist'(e, y) \supset VStem(\text{"be"}, e, \textbf{be}, -, \textbf{there.}a_{NUM}, y, \textbf{n.}a_{NUM}, -, -, -, -)$$

If e is the eventuality of y existing, then e can be described by a form of the auxilliary verb "be" taking the expletive "there" as subject and an NP referring to y as its complement. By assuming that the expletive "there" has an unexpressed number agreement feature that must agree with the number feature on the y argument, we can enforce the latter's number agreement constraint with the verb. The empty x argument with the feature **there** forces the subject of the clause to be the word "there".

Several verbs other than "be" can take predicate complements. The lexical axioms for such verbs in our target texts are as follows:

$$come\text{-}about'(e, e_1) \supset VStem(\text{"become"}, e, \textbf{v}, x, \textbf{n.sb}, e_1, \textbf{adj/nppred.sc}, -, -)$$

John becomes tired. $\Rightarrow come\text{-}about'(e, e_1) \wedge tired'(e_1, J)$

$$\textit{come-about}'(e, e_1) \supset \textit{VStem}(\text{“get”}, e, \mathbf{v}, x, \mathbf{nx.sb}, e_1, \mathbf{adj/pp.sc}, -, -)$$
John gets tired. $\Rightarrow \textit{come-about}'(e, e_1) \wedge \textit{tired}'(e_1, J)$

$$\textit{seem}'(e, e_1) \supset \textit{VStem}(\text{“seem”}, e, \mathbf{v}, x, \mathbf{nx.sb}, e_1, \mathbf{adj.sc}, -, -)$$
John seems tired. $\Rightarrow \textit{seem}'(e, e_1) \wedge \textit{tired}'(e_1, J)$

$$\textit{sound}'(e, e_1) \supset \textit{VStem}(\text{“sound”}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{adj.sc}, v, g)$$
John sounds tired. $\Rightarrow \textit{sound}'(e, e_1) \wedge \textit{tired}'(e_1, J)$

I have assumed here that “become” and “get” mean *come-about*. The verb “become” only occurs with adjectives and noun phrase predicate complements, “get” occurs with adjectives and PPs, and “seem” and “sound” with adjectives alone. Passives are classified as adjectives, as discussed below.

The verb “to seem” subcategorizes for two other structures.

$$\textit{seem}'(e, e_1) \supset \textit{VStem}(\text{“seem”}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{v.inf.sc}, -, -)$$
John seems to be tired. $\Rightarrow \textit{seem}'(e, e_1) \wedge \textit{tired}'(e_1, J)$

$$\textit{seem}'(e, e_1) \supset \textit{VStem}(\text{“seem”}, e, \mathbf{v}, -, \mathbf{it.sing}, e_1, \mathbf{thats.ob}, -, -)$$
It seems that John is tired. $\Rightarrow \textit{seem}'(e, e_1) \wedge \textit{tired}'(e_1, J)$

In the latter axiom, by making the x argument of Syn empty (“$-$”), we avoid the introduction of an existentially quantified variable with no referent, and by making its agreement feature **it**, we enforce the use of the expletive “it” as the subject of the sentence.

4.7.2 Adjectival Complements

One-argument adjectives can be handled by defining the feature **adj** as a subfeature of **pred**. A typical lexical axiom for a one-argument adjective is as follows:

$$\textit{correct}'(e, x) \supset \textit{Syn}(\text{“correct”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$$

That is, if e is the eventuality of x being correct, then e can be described by the adjective “correct”, when it has as its subject an NP referring to x.

Lexical axioms for the other one-argument adjectives in the target texts are as follows:

$$\textit{constant}'(e, x) \supset \textit{Syn}(\text{“constant”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$$
$$\textit{current}'(e, x) \supset \textit{Syn}(\text{“current”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$$
$$\textit{deep}'(e, x) \supset \textit{Syn}(\text{“deep”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$$
$$\textit{dreary}'(e, x) \supset \textit{Syn}(\text{“dreary”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$$
$$\textit{eternal}'(e, x) \supset \textit{Syn}(\text{“eternal”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$$

$excessive'(e,x) \supset Syn(\text{“excessive”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$fell'(e,x) \supset Syn(\text{“fell”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$firm'(e,x) \supset Syn(\text{“firm”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$good'(e,x) \supset Syn(\text{“good”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$happy'_1(e,x) \supset Syn(\text{“happy”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$high'(e,x) \supset Syn(\text{“high”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$hot'(e,x) \supset Syn(\text{“hot”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$hungry'(e,x,y) \supset Syn(\text{“hungry”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$lofty'(e,x) \supset Syn(\text{“lofty”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$lonesome'(e,x) \supset Syn(\text{“lonesome”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$long'(e,x) \supset Syn(\text{“long”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$low'(e,x) \supset Syn(\text{“low”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$minor'(e,x) \supset Syn(\text{“minor”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$miserable'(e,x) \supset Syn(\text{“miserable”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$nearby'(e,x,y) \supset Syn(\text{“near-by”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$new'(e,x) \supset Syn(\text{“new”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$ongoing'(e,x) \supset Syn(\text{“ongoing”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$outworn'(e,x) \supset Syn(\text{“outworn”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$primary'(e,x) \supset Syn(\text{“primary”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$proud'(e,x) \supset Syn(\text{“proud”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$raw'(e,x) \supset Syn(\text{“raw”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$rich'(e,x) \supset Syn(\text{“rich”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$right'(e,x) \supset Syn(\text{“right”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$sad'(e,x) \supset Syn(\text{“sad”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$short'(e,x) \supset Syn(\text{“short”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$transient'(e,x) \supset Syn(\text{“transient”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$variable'(e,x) \supset Syn(\text{“variable”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$
$white'(e,x) \supset Syn(\text{“white”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$

The predicate *nearby* has an implicit argument that interpretation must generally resolve but is not expressed explicitly.

For many two-argument adjectives, the second argument is signalled by a preposition, as in “late for”, “natural to”, and “visible to”. Prepositional arguments of adjectives, just as of verbs, may be treated as adjuncts or as arguments. The axioms presented here take the latter approach. A typical axiom is

$$acceptable'(e,x,y)$$
$$\supset Syn(\text{“acceptable”}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.to.ob}, -, -, -, -)$$

That is, if e is the eventuality of x being acceptable to y, then e can be described by the adjective “acceptable”, taking as subject an NP referring to x and as complement a PP with the preposition "to" and an NP referring to y.

Lexical axioms for the other adjectives with PP complements in the target texts are as follows:

$adequate'(e, x, y)$
$\quad \supset Syn(\text{"adequate"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.for}, -, -, -, -)$
$available'(e, x, y)$
$\quad \supset Syn(\text{"available"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.for/to}, -, -, -, -)$
$critical'(e, x, y)$
$\quad \supset Syn(\text{"critical"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.for/to}, -, -, -, -)$
$easy'(e, x, y) \supset Syn(\text{"easy"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.for}, -, -, -, -)$
$estranged'(e, x, y)$
$\quad \supset Syn(\text{"estranged"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.from}, -, -, -, -)$
$familiar'(e, x, y) \supset Syn(\text{"familiar"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.to}, -, -, -, -)$
$far\text{-}off'(e, x, y) \supset Syn(\text{"far off"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.from}, -, -, -, -)$
$first'(e, x, s) \supset Syn(\text{"first"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.in/of}, -, -, -, -)$
$happy'_2(e, x, y) \supset Syn(\text{"happy"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.for}, -, -, -, -)$
$late'(e, x, y) \supset Syn(\text{"late"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.for}, -, -, -, -)$
$local'(e, x, y) \supset Syn(\text{"local"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.to}, -, -, -, -)$
$natural'(e, x, y) \supset Syn(\text{"natural"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.to}, -, -, -, -)$
$near'(e, x, y) \supset Syn(\text{"near"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.to}, -, -, -, -)$
$necessary'(e, x, y)$
$\quad \supset Syn(\text{"necessary"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.for/to}, -, -, -, -)$
$peripheral'(e, x, y)$
$\quad \supset Syn(\text{"peripheral"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.to}, -, -, -, -)$
$visible'(e, x, y) \supset Syn(\text{"visible"}, e, \mathbf{adj}, x, \mathbf{n.sb}, y, \mathbf{n.to}, -, -, -, -)$

Two-argument adjectives can always omit arguments other than their subjects. Rather than doubling the number of lexical axioms to accommodate this fact, we may write the single alternation axiom

$$Syn(w, e, f{:}\mathbf{adj}, x, a, y, b, -, -, -, -)$$
$$\quad \supset Syn(w, e, f, x, a, -, -, -, -, -, -)$$

If w is an adjective taking a subject x and a complement y, then it can appear with only its subject. In backchaining, this rule will introduce an existentially quantified variable for y. This rule holds for both prepositional and sentential complements.

Two-argument adjectives whose second arguments are infinitival or sentential can have their subcategorization constraints expressed in the b argument of *Syn*. A typical adjective taking an infinitival complement is "able", and its lexical axiom is

$$able'(e, x, e_1) \supset Syn(\text{"able"}, e, \textbf{adj}, x, \textbf{n.sb}, e_1, \textbf{v.inf.sc}, -, -, -, -)$$
John is able to leave early.

That is, if e is the eventuality of x being able to do e_1, then e can be described by the adjective "able" taking an NP referring to x as its subject and an infinitive VP as its complement, where the subject of "able" is the same as the subject of the infinitive.

Lexical axioms for the other adjectives with infinitival complements in the target texts are as follows:

$$available'(e, x, e_1) \supset Syn(\text{"available"}, e, \textbf{adj}, x, \textbf{n.sb}, e_1, \textbf{v.inf.sc}, -, -, -, -)$$
John is available to go.

$$happy'(e, x, e_1) \supset Syn(\text{"happy"}, e, \textbf{adj}, x, \textbf{n.sb}, e_1, \textbf{v.inf.sc}, -, -, -, -)$$
John is happy to leave early.

$$proud'(e, x, e_1) \supset Syn(\text{"proud"}, e, \textbf{adj}, x, \textbf{n.sb}, e_1, \textbf{v.inf.sc}, -, -, -, -)$$
John is proud to represent his country.

$$sad'(e, x, e_1) \supset Syn(\text{"sad"}, e, \textbf{adj}, x, \textbf{n.sb}, e_1, \textbf{v.inf.sc}, -, -, -, -)$$
John is sad to leave early.

$$willing'(e, x, e_1) \supset Syn(\text{"willing"}, e, \textbf{adj}, x, \textbf{n.sb}, e_1, \textbf{v.inf.sc}, -, -, -, -)$$
John is willing to leave early.

These are all Equi adjectives, in that x is an argument of the predication. The word "likely" is a Raising adjective. In

John is likely to go.

John is the logical subject of the going, but John's going rather than John is the logical subject of "likely". The lexical axiom for "likely" is

$$likely'(e, e_1) \supset Syn(\text{"likely"}, e, \textbf{adj}, x, \textbf{nx.sb}, e_1, \textbf{vp.inf.sc}, -, -, -, -)$$

If e is the eventuality of eventuality e_1 being likely, then e can be described by the adjective "likely" where the subject of "likely" is the logical subject of e_1 and the complement is an infinitive VP describing e_1.

There are two cases of adjectives with sentential complements. In the first, the subject of the sentence has content and usually refers to the experiencer.

$correct'_2(e, x, e_1)$
$\supset Syn(\text{“correct”}, e, \textbf{adj}, x, \textbf{n.sb}, e_1, \textbf{thats.ob}, -, -, -, -)$
John is correct that we left early.

If e is the eventuality of x being correct that e_1 is true, then e can be described by the adjective “correct” taking an NP referring to x as its subject and a “that” clause describing e_1 as its object. Note the use of the predicate $correct_2$ as opposed to *correct*. The knowledge base would have to have an axiom relating these two concepts.

The lexical axioms for the other adjectives of this type in the target texts that take sentential complements are as follows:

$happy'_2(e, x, e_1) \supset Syn(\text{“happy”}, e, \textbf{adj}, x, \textbf{n.sb}, e_1, \textbf{thats.ob}, -, -, -, -)$
John is happy that we left early.

$miserable'_2(e, x, e_1)$
$\supset Syn(\text{“miserable”}, e, \textbf{adj}, x, \textbf{n.sb}, e_1, \textbf{thats.ob}, -, -, -, -)$
John is miserable that we left early.

$proud'(e, x, e_1) \supset Syn(\text{“proud”}, e, \textbf{adj}, x, \textbf{n.sb}, e_1, \textbf{thats.ob}, -, -, -, -)$
John is proud that we left early.

$right'_2(e, x, e_1) \supset Syn(\text{“right”}, e, \textbf{adj}, x, \textbf{n.sb}, e_1, \textbf{thats.ob}, -, -, -, -)$
John is right that we left early.

$sad'_2(e, x, e_1) \supset Syn(\text{“sad”}, e, \textbf{adj}, x, \textbf{n.sb}, e_1, \textbf{thats.ob}, -, -, -, -)$
John is sad that we left early.

In the second case, there is no experiencer and the subject of the clause is the content-free, expletive “it”.

$acceptable'(e, e_1)$
$\supset Syn(\text{“acceptable”}, e, \textbf{adj}, -, \textbf{it.sb}, e_1, \textbf{thats.ob}, -, -, -, -)$
It is acceptable that John left early.

If e is the eventuality of the condition e_1 being acceptable, then e can be described by the adjective “acceptable” having the expletive “it” as its subject and a “that” clause describing e_1 as its complement.

The other adjectives in the target texts exhibiting this pattern are characterized as follows:

$correct'_1(e, e_1)$
$\supset Syn(\text{“correct”}, e, \textbf{adj}, -, \textbf{it.sb}, e_1, \textbf{thats.ob}, -, -, -, -)$
It is correct that John left early.

$good'(e, e_1) \supset Syn(\text{“good”}, e, \textbf{adj}, -, \textbf{it.sb}, e_1, \textbf{thats.ob}, -, -, -, -)$

It is good that John left early.

$likely'(e, e_1) \supset Syn($"likely"$, e,$**adj**$, -,$**it.sb**$, e_1,$**thats.ob**$, -, -, -, -)$
It is likely that John left early.

$natural'(e, e_1)$
$\supset Syn($"natural"$, e,$**adj**$, -,$**it.sb**$, e_1,$**thats.ob**$, -, -, -, -)$
It is natural that John left early.

$possible'(e, e_1)$
$\supset Syn($"possible"$, e,$**adj**$, -,$**it.sb**$, e_1,$**thats.ob**$, -, -, -, -)$
It is possible that John left early.

$right'_1(e, e_1) \supset Syn($"right"$, e,$**adj**$, -,$**it.sb**$, e_1,$**thats.ob**$, -, -, -, -)$
It is right that John left early.

$sad'_1(e, e_1) \supset Syn($"sad"$, e,$**adj**$, -,$**it.sb**$, e_1,$**thats.ob**$, -, -, -, -)$
It is sad that John left early.

The adjective "necessary" exhibits the same pattern, except that it takes a subjunctive "that" clause.

$necessary'(e, e_1, y)$
$\supset Syn($"necessary"$, e,$**adj**$, -,$**it.sb**$, e_1,$**thatsubjunct.ob**$, -, -, -, -)$
It is necessary that we leave early.

In Section 4.10 an alternation axiom is presented for converting predicate adjectives (**adj**) into prenominal adjectives. Some adjectives can only occur in predicate complement position, and they can be specified directly as of category **pred**.

$alone'(e, x) \supset Syn($"alone"$, e,$**pred**$, x,$**n.sb**$, -, -)$

The word "so" by itself can be an adjectival predicate complement, as in "Say it isn't so."

$so'_1(e, x) \supset Syn($"so"$, e,$**pred**$, x,$**n.sb**$, -, -, -, -, -, -)$

Adjectives in predicate complement position can be modified by operators like "so" and "too", as in

John was so tired that he fell.
John was too tired to sleep.
John is too old for the job.

The logical form of these sentences will involve the predicates so_2 and too_2. The predicate so_2 locates an entity (John) on a scale (tiredness) and says that the entity falls in a region high enough that some condition is true (that he left early). The predicate so_2 thus takes three arguments—the entity, the scale, and the condition. Both the scale and the condition will be represented by eventualities. The logical form of the first sentence thus includes

$$so_2'(e, J, e_1, e_2) \wedge tired'(e_1, z) \wedge Past'(e_2, e_3) \wedge fall'(e_3, x)$$

where x is the referent for the so far unresolved "he". This logical form will be generated if a lexical axiom for "so" is written as follows:

$$so_2'(e, x, e_1, e_2) \\ \quad \supset Syn(\text{“so”}, e,\mathbf{pred}, x,\mathbf{n.sb}, e_1,\mathbf{adj.ob}, e_2,\mathbf{thats.ob}, -, -)$$

That is, if e is the condition of x being so e_1 that e_2, then e can be described by the word "so" taking an NP subject referring to x, an adjectival complement describing e_1, and a "that" complement describing e_2. If we wanted the subject of the sentence to be an argument of the scale, replacing z in the logical form above, we would classify the e_1 argument as **sc** instead of **ob**. However, that is not how comparisons will be handled in this book.

The predicate too_2 has a similar meaning. It locates an entity (John) on a scale (tiredness) and says that the entity falls in the region above the region where some condition is true (John's sleeping). The lexical axioms for this sense of "too" are

$$too_2'(e, x, e_1, e_2) \\ \quad \supset Syn(\text{“too”}, e,\mathbf{pred}, x,\mathbf{n.sb}, e_1,\mathbf{adj.ob}, e_2,\mathbf{v.inf.sc}, -, -)$$

$$too_2'(e, x, e_1, z) \supset Syn(\text{“too”}, e,\mathbf{pred}, x,\mathbf{n.sb}, e_1,\mathbf{adj.ob}, z,\mathbf{n.for}, -, -)$$

Both "so" and "too" have variants in which the second complement is omitted.

The predicates so_2 and too_2 will be further explicated in the discussion of scales in Chapter 5.

A very intriguing syntactic structure occurs in one of the target texts.

> Speech is so familiar a feature of daily life that ...

It is first of all not clear whether the "so Adj an $\overline{\mathbf{N}}$ that S" is an NP or an adjective phrase. Without the "that" clause it can appear as the subject of a sentence, suggesting that it is an NP.

So diligent a worker should be paid more.

However, with the "that" clause it cannot, suggesting it is an adjective phrase.

* So diligent a worker that he completes everything ahead of time should be paid more.

The closely related "too Adj an $\overline{\mathbf{N}}$" cannot appear as the subject of a sentence, with or without a "that" clause, suggesting that that too is an adjective phrase. In any case, I will assume both constructions to be adjective phrases.

The next question is what is its bracketing, its constituent structure. If it were an NP, we might say that "so diligent a" is a complex determiner phrase, paralleling "such a" and perhaps "many a". If it is an adjective phrase, we might want to say that "diligent" and "a worker" somehow combine into an adjective phrase defining a scale, so that the previous lexical axiom for "so" would work. The combination certainly defines a scale, but there is no other construction in English like this, combining an adjective and an NP into an adjective phrase.

I will analyze this construction as having "so" as its head. The word "so" takes four arguments—the subject of the sentence, an adjective defining a scale, an indefinite NP refining that scale, and a "that" clause. The underlying predicate will be so_2. Since there are four arguments, we will have to do violence to the *Syn* predicate and slip two more arguments in. I do this with apologies. The lexical axiom for this sense of "so" is

$$so_2'(e, x, e_1\&e_2, e_3) \wedge be'(e_2, x, y)$$
$$\supset Syn(\text{"so"}, e, \mathbf{pred}, x, \mathbf{n.sb}, e_1, \mathbf{adj.sc}, y, \mathbf{n}, e_3, \mathbf{thats.ob}, -, -)$$

That is, if e is the condition of x being so high on a scale defined by the property e_1 and the property e_2 of x being y that the eventuality e_3 occurs, then e can be described by the word "so" taking an NP subject referring to x, an adjectival complement describing e_1, an NP complement referring to y, and a "that" complement describing e_3. Here I have taken the subject x of the sentence to be the defining argument of the scale.

The NP in this axiom is insufficiently constrained. It must have the determiner "a". The machinery for expressing this constraint will not be developed here; it would be straightforward but tedious and diversionary.

4.7.3 Tough Movement

Tough Movement is illustrated by the sentence

John is easy to please ().

The subject of the sentence fills the gap in the infinitival complement. This phenomenon requires a new composition rule, the Tough Movement Rule, parallel to the rules for subject and object control.

$$\text{(4.17)} \quad \begin{aligned} & Syn(w_1, e_1, f_1, x, a, e_2, f_2{:}\mathbf{tf}, z, c, v, g) \\ & \qquad \wedge\, Syn(w_2, e_2, f_2, x_2, a_2, -, -, -, -, x, a) \\ & \quad \supset\, Syn(w_1 w_2, e_1, f_1, x, a, z, c, -, -, v, g) \end{aligned}$$

A word or phrase w_1 of type f_1 describing eventuality e_1 and having arguments x, e_2, and z with agreement features a, f_2, and c, respectively, can be concatenated with a phrase w_2 of type f_2 describing eventuality e_2, having a gap, and possibly having an unsaturated subject x_2 with agreement feature a_2, to produce a phrase of type f_1 describing e_1, with unsaturated arguments x and z. The gap in w_2 is filled by x. The resulting phrase inherits its gap from w_1.

Whereas in Subject Control, the subject of the matrix sentence is identified with the subject of the complement, in Tough Movement the subject of the matrix sentence is identified with the gapped element in the complement.

The lexical axiom for this use of “easy” is

$$easy'(e, e_2, y) \supset Syn(\text{“easy”}, e, \mathbf{adj}, x, \mathbf{n.sb}, e_2, \mathbf{v.inf.tf}, -, -, -, -)$$

If e is the condition of eventuality e_2 being easy for y, then e can be described by the adjective “easy” having an NP subject referring to some entity x and an infinitival VP complement describing e_2 and having a gap that is filled by x. Note that x does not appear in the *easy* predication. It only plays a role in the logical subject of *easy*.

In “John is easy to please”, the gap in the VP is introduced as described in Section 4.13. It is passed up to the infinitive by the Subject Control Rule applying to “to”. By the Tough Movement Rule, it is identified with the subject of “easy”, and hence by the Subject Control Rule applying to “is” and the Subject Rule concatenating “John” with the VP, it is identified with the subject of the sentence. This is illustrated in Figure 4.9.

The lexical axiom for the similar sense of “difficult” is

$$\begin{aligned} & difficult'(e, e_2, y) \\ & \quad \supset Syn(\text{“difficult”}, e, \mathbf{adj}, x, \mathbf{n.sb}, e_2, \mathbf{v.inf.tf}, -, -, -, -) \end{aligned}$$

Another construction that can be subsumed under Tough Movement is the use of “too” illustrated in

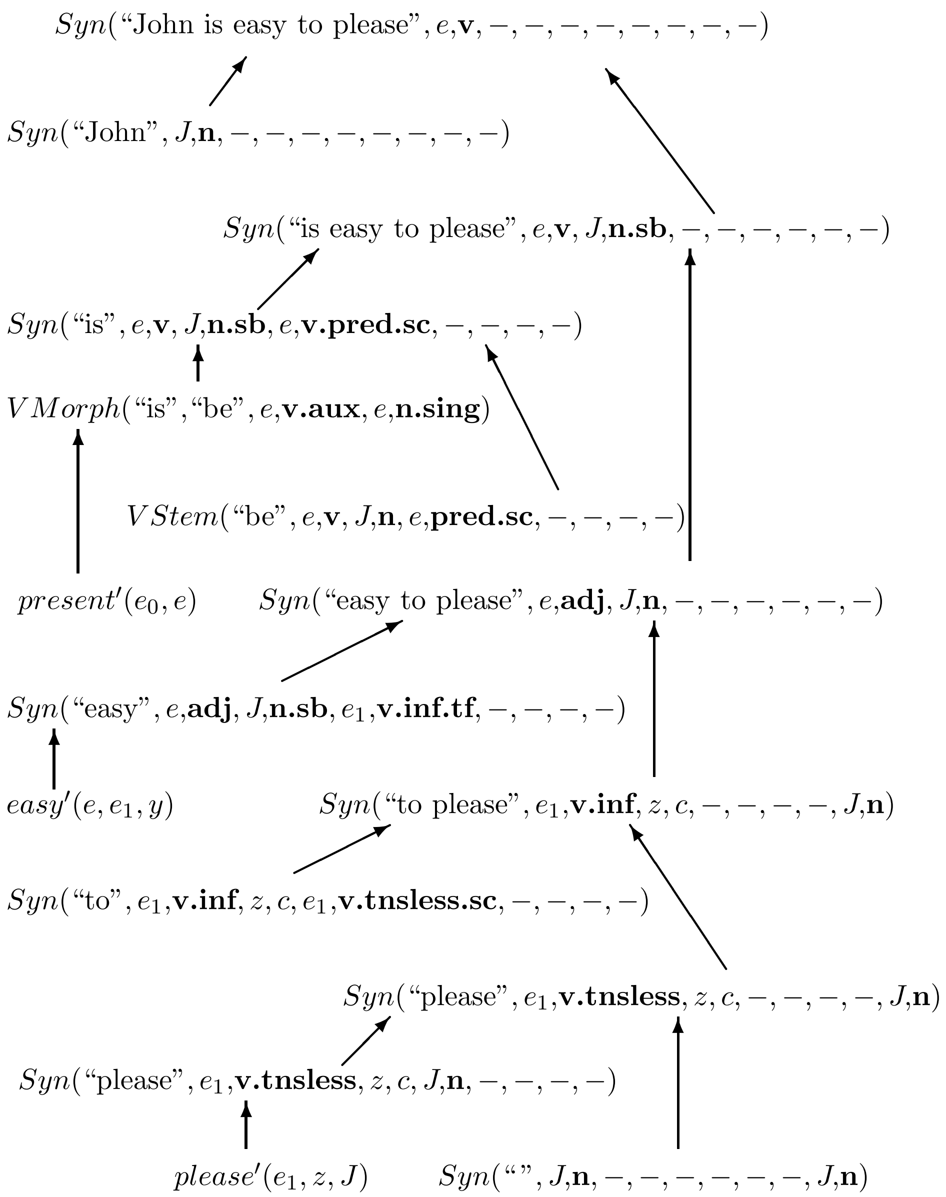

Figure 4.9: Parse of "John is easy to please."

The shelf is too high for John to reach ().

This usage is captured by the lexical axiom

$too'_2(e, x, e_1, e_2)$

$$\supset Syn(\text{“too”}, e, \mathbf{pred}, x, \mathbf{n.sb}, y, \mathbf{adj.ob}, e_2, \mathbf{v.inf.tf}, -, -)$$

The word “for” is applied to “John” and “to reach ()” to produce a fully saturated infinitive with a gap (as described in Section 4.13), the Object Rule consumes the adjective and moves the infinitive into the first complement position, and then the Tough Movement Rule applies to fill the gap in the infinitive with the subject of the sentence.

4.7.4 Passives

Passives behave very much like adjectives. They occur in predicate complement position. They can be the right adjuncts of nouns. They can appear in the adjectival position in the left adjunct of the noun. Some passives, such as “tired”, actually *become* adjectives. All of this suggests a very simple treatment of passives, namely, a single alternation axiom that converts the past participle into an adjective and identifies the subject of the passivized sentence with the logical object of the underlying active predicate.

$$\begin{array}{l} Syn(w, e, \mathbf{v.en}, x, a, y, b{:}\mathbf{nx.acc.ob}, -, -, v, g) \\ \quad \supset Syn(w, e, \mathbf{adj}, y, b{:}b_{CASE}\mathbf{.sb}, -, -, -, -, v, g) \end{array}$$

If w is the past participle of a verb which takes a subject x and an NP or expletive object y, with agreement features a and b, respectively, then w can function as an adjective, taking an NP or expletive subject referring to y. In making this alternation, the b feature associated with y has the composition rule **ob** replaced by **sb**, and the accusative feature **acc** replaced by the indeterminate variable b_{CASE}. The latter allows y to appear in the nominative as the subject of tensed clauses, and in the accusative in small clauses and other contexts.

In backchaining, this rule will introduce the variable x as the existentially quantified logical subject of the underlying “active” predicate (possibly to be identified with the object of a “by” PP adjunct in pragmatics).

We have to be careful when extending this alternation to verbs with a second complement. If the second complement composes with the verb by the Object Rule (4.7), the situation is straightforward.

$$\begin{array}{l} Syn(w, e, \mathbf{v.en}, x, a, y, b{:}\mathbf{nx.acc.ob}, z, c{:}\mathbf{ob}, v, g) \\ \quad \supset Syn(w, e, \mathbf{adj}, y, b{:}b_{CASE}\mathbf{.sb}, z, c, -, -, v, g) \end{array}$$

The second complement z is moved over to be the first complement.

If the verb is Subject Control and the complement calls for rule (4.8), passivization is disallowed. It would eliminate the subject that the complement requires. Thus,

* John was promised () to go.
* John was struck () as a genius.

This is Visser's Generalization, as discussed in Pollard and Sag (1994, Section 7.3.2), following Bresnan (1982).

If the verb is Object Control and the complements call for rule (4.9), the complement of the resulting **adj** must be Subject Control.

$$Syn(w, e, \mathbf{v.en}, x, a, y, b{:}\mathbf{n.acc}, e_1, f_1{:}\mathbf{oc}, v, g)$$
$$\supset Syn(w, e, \mathbf{adj}, y, b{:}b_{CASE}\mathbf{.sb}, e_1, f_1{:}\mathbf{sc}, -, -, v, g)$$

This ensures that y will be retained as the subject of the complement e_1.

These rules handle all the following examples:

John was given () a book.
John was kept () waiting.
The barn was painted () red.
John was treated () as a genius.
John was told () that Mary couldn't attend his lecture.
John was persuaded () to speak more slowly.

They do not cover the sentence

A book was given John

This would require a similar rule moving z to subject position.

These rules would seem to allow

John was made () go.
John was wanted () to go.

These examples are discussed below in Section 4.8 on small clauses.

This treatment of passives is in accord with that of Pollard and Sag (1994, p. 119) in that it admits "movement" only to primary objects of verbs.

The passivization axiom could have been written to rotate the Agent argument into the most oblique argument position, constained to have the *CASE* feature **by**. My view, however, is that the "by" phrase in passive sentences is an adjunct independently conveying the identity of the Agent.

4.7.5 Prepositions and Subordinate Conjunctions

A prepositional phrase is a preposition followed by an NP. The structure is allowed by the Object Rule (4.7), together with lexical axioms for prepositions subcategorizing the prepositions for NP objects. The lexical axiom for "about" is

$$about'(e,x,y) \supset Syn(\text{“about”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -)$$

If e is the eventuality of x being about y, then e can be described by the preposition "about" taking a phrase denoting x as its subject and an accusative NP referring to y as its object.

The lexical axioms for the other prepositions in the target texts are as follows:

$$\begin{array}{l}
after'(e,x,y) \supset Syn(\text{“after”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
as'_1(e,x,y) \supset Syn(\text{“as”}, e, \mathbf{as}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
by'(e,x,y) \supset Syn(\text{“by”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
during'(e,x,y) \supset Syn(\text{“during”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
except'(e,x,y) \supset Syn(\text{“except”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
for'(e,x,y) \supset Syn(\text{“for”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
from'(e,x,y) \supset Syn(\text{“from”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
in'(e,x,y) \supset Syn(\text{“in”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
like'(e,x,y) \supset Syn(\text{“like”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
of'(e,x,y) \supset Syn(\text{“of”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
on'(e,x,y) \supset Syn(\text{“on”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
out\text{-}of'(e,x,y) \supset Syn(\text{“out of”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
til'(e,x,y) \supset Syn(\text{“til”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
to'(e,x,y) \supset Syn(\text{“to”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -) \\
with'(e,x,y) \supset Syn(\text{“with”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -)
\end{array}$$

"As" is usually thought of as a subordinate conjunction rather than as a preposition, but since we will be treating subordinate conjunctions in the same way as prepositions, we have included the "as NP" construction in the lexical axioms above. Its category feature is **as**, which is a subfeature of **p**.

The preposition "between" may seem to be a relation among three things—X is between Y and Z. But the structure of "Y and Z" is a single noun phrase that happens to have a conjunction in it. For that reason, "between" will be treated as a relation between two things, the second of which is a pair of items. Thus, "between" will have the same sort of axiom that the other prepositions do, although we may add a further condition to the antecedent to specify the selectional constraint that the object must have cardinality two.

$between'(e,x,y) \wedge two(y)$
$\supset Syn(\text{“between”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -)$

Certain lexical items function as prepostional phrases. Axioms for these are as follows:

$away\text{-}from'(e,x,y) \supset Syn(\text{“away”}, e, \mathbf{pred}, x, a, -, -, -, -, -, -)$
$here'(e,x) \supset Syn(\text{“here”}, e, \mathbf{pred}, x, a, -, -, -, -, -, -)$
$in'(e,x,y) \supset Syn(\text{“in”}, e, \mathbf{pred}, x, a, -, -, -, -, -, -)$
$someplace'(e,x) \supset Syn(\text{“someplace”}, e, \mathbf{pred}, x, a, -, -, -, -, -, -)$
$there'(e,x) \supset Syn(\text{“there”}, e, \mathbf{pred}, x, a, -, -, -, -, -, -)$

The underlying predicates for “in” and “away” are taken to be relational, and the same as the predicates underlying the prepositions “in” and “away from”.

Subordinate conjunctions are just like prepostions except that they are subcategorized for sentential complements instead of NPs. Subordinate clauses usually occur as adverbials, but they can also appear as predicate complements, as seen in the following examples:

The party was because John was going away to college.
The best part of the party was after John left.
It is as I say.
Moreover, his remarkable achievement was with his leg broken.

They can also appear as postmodifiers of nouns, like other predicate complements, providing the head nouns are event nouns.

The party before John went off to college was a real blast.

The lexical axioms for the subordinate conjunctions in the target texts, plus some other common ones, are as follows:

$as_2'(e,x,y) \supset Syn(\text{“as”}, e, \mathbf{p}, x, a, y, \mathbf{v.tnsd.ob}, -, -, -, -)$
$because'(e,x,y) \supset Syn(\text{“because”}, e, \mathbf{p}, x, a, y, \mathbf{v.tnsd.ob}, -, -, -, -)$
$before'(e,x,y) \supset Syn(\text{“before”}, e, \mathbf{p}, x, a, y, \mathbf{v.tnsd.ob}, -, -, -, -)$
$if'(e,x,y) \supset Syn(\text{“if”}, e, \mathbf{p}, x, a, y, \mathbf{v.tnsd.ob}, -, -, -, -)$
$unless'(e,x,y) \supset Syn(\text{“unless”}, e, \mathbf{p}, x, a, y, \mathbf{v.tnsd.ob}, -, -, -, -)$
$when'(e,x,y) \supset Syn(\text{“when”}, e, \mathbf{p}, x, a, y, \mathbf{v.tnsd.ob}, -, -, -, -)$

All of these subordinate conjunctions take tensed clauses as complements. Some also take gerunds and other complements, but we will not need these. The subordinate conjunction “as” has two other interesting uses that will be covered. First, it can take several kinds of predicate complements. This is more frequent as an adjunct, but can occur as a predicate complement.

> John's role in the group was as manager.
> John's role in the incident was as in April.

This use of "as" is captured by the lexical axiom

$$as_1'(e, x, e_1) \supset Syn(\text{"as"}, e, \mathbf{as}, x, \mathbf{n.sb}, e_1, \mathbf{nppred/p.ob}, -, -, -, -)$$

If e is an "as" relation between x and an eventuality e_1, then e can be described by the "preposition" "as" having as subject an expression referring to x and as its complement an NP or PP predicate complement describing e_1.

The predicate as_1 is something like *be*; the predicate as_2 is something like *while*.

In addition to taking a tensed clause or a predicate complement as its complement, the word "as" can take a clause with a gap in it, and the logical subject of "as" will be identical with the gapped element.

> The problem is as John described ().

This is Tough Movement again. The lexical axiom for this sense of "as" is as follows:

$$as_1'(e, x, e_1) \supset Syn(\text{"as"}, e, \mathbf{as}, x, a, e_1, \mathbf{v.tnsd.tf}, -, -, -, -)$$

The Tough Movement Rule (4.17) will cause the gap in the complement to be identified with the logical subject of "as", so that the logical form of the above sentence will include

$$problem'(e_2, x) \wedge as_1'(e, x, e_1) \wedge describe'(e_1, J, x)$$

4.7.6 Progressives

Like passives, progressives are very similar to adjectival complements in that they can occur in the predicate complement position, as the postmodifier of a noun, and in the prenominal adjectival position.

> John is running from the law.
> A man running from the law is dangerous.
> A rolling stone gathers no moss.

The progressive aspect invites us to examine the event at a finer granularity, not as an undecomposable, point-like event but as an event with duration and internal structure. This is true in all three of the above examples. Thus we can say that the *Progressive* predication is introduced by the "ing" ending, rather than the verb "to be". The latter carries no content beyond its tense. It is for this reason that the *Progressive* predicate was associated with the "ing" ending in the discussion in Section 4.6 on verb morphology.

All of this suggests that progressives be treated like adjectives. On the other hand, many verbs that subcategorize for predicate complements admit adjectives but not progressives.

John became tired.
* John became sleeping.
John got tired.
* John got sleeping.
John seems tired.
* John seems sleeping.
John sounds tired.
* John sounds sleeping.

For this reason we will introduce another subfeature of **pred**, called **prog**. It is related to the "-ing" form of verbs by the following alternation axiom:

$$Syn(w, e, \mathbf{v.ing}, x, a, y, b, z, c, v, g) \supset Syn(w, e, \mathbf{prog}, x, a, y, b, z, c, v, g)$$

Note that even though it is treated in a manner similar to adjectives, it can nevertheless take NP objects, because it inherits the subcategorization features of the verb.

4.8 Small Clauses

Some verbs are subcategorized for small clauses, which are formed by concatenating an NP with a predicate complement or an infinitive or nontensed VP, as in

John had the papers available.
John made the papers available.

There are two possible treatments of small clauses. The first is to attach the NP to the complement by the Subject Rule (4.6) to create a fully saturated clause of the type of the complement, which the matrix verb is then subcategorized for:

$$have'_3(e, x, e_1) \supset VStem(\text{"have"}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{pred.ob}, -, -)$$

If e is the situation of x's having the condition e_1 hold, then e can be described by the nonauxilliary verb "have" taking an NP subject referring to x and a fully saturated predicate complement describing e_1 as its complement. The stipulation that the Object Rule (4.7) be used ensures that the predicate complement will have been fully saturated by having its logical subject adjoined to it.

The second approach is to treat the matrix verb as an Object Control verb.

$$make'(e, x, e_1) \supset VStem(\text{"make"}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc}, e_1, \mathbf{pred.oc})$$

If e is the situation of x's making the condition e_1 hold, where the logical subject of e_1 is y, then e can be described by the nonauxilliary verb "make" taking an NP subject referring to x, an indirect object NP referring to y, and an incompletely saturated predicate complement describing e_1 as its second complement. The stipulation that the Object Control Rule (4.9) be used ensures that y will be passed down to the predicate complement to be its subject.

Note that the logical forms in these two approaches are the same.

The principal difference in the two approaches is that the second allows passivization according to the rules already given, whereas the first doesn't. For these two verbs, this difference in fact is appropriate.

* The papers were had available.
The papers were made available.

It seems reasonable therefore to use the first approach for verbs that do not passivize and the second for those that do.

Pollard and Sag (1994, Section 3.2) point out that verbs must be able to subcategorize for the category of the predicate complement. This is possible in both approaches described here, since **adj**, **p**, and so on, are all subfeatures of **pred**.

Two more verbs that take a small clause complement and passivize (though for the first, not always comfortably) are "see" and "keep".

I saw the building destroyed.
The building was seen destroyed.
We kept the discussion to half an hour.
The discussion was kept to half an hour.

Their lexical axioms are

$$keep'(e, x, e_1) \supset VStem(\text{“keep”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc}, e_1, \mathbf{pred.oc})$$
$$see'(e, x, e_1) \supset VStem(\text{“see”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc}, e_1, \mathbf{pred.oc})$$

Small clauses can also be formed by attaching a subject to an infinitive VP:

John wanted Mary to leave.

For “want” the second NP does not passivize, so the lexical axiom is

$$want'(e, x, e_1) \supset VStem(\text{“want”}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{v.inf.ob}, -, -)$$

If e is the situation of x's wanting the condition e_1 to hold, then e can be described by the verb “want” taking an NP subject referring to x and a fully saturated infinitive VP describing e_1 as its complement. The stipulation that the Object Rule (4.7) be used ensures that the predicate complement will have been fully saturated by having its logical subject “Mary” adjoined to it.

Small clauses can also be formed by attaching a subject to a tenseless VP:

Let us go.
Have the secretaries bring sandwiches.

The first of these passivizes and the second doesn't.

John was let go.
* The secretaries were had bring sandwiches.

Thus, the lexical axioms for these word senses are

$$let'(e, x, e_1) \supset VStem(\text{“let”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc}, e_1, \mathbf{v.tnsless.oc})$$
$$have'_3(e, x, e_1) \supset VStem(\text{“have”}, e, \mathbf{v}, x, \mathbf{n.sb}, e_1, \mathbf{v.tnsless.ob}, -, -)$$

The contraction “let's” has a particular meaning, subsumed by, but much more specific than, “let us”. “Let us go.” could mean the same as “Let's go,” although it sounds stilted. But it could also be something kidnap victims say to the kidnapper.

“Let's” can be viewed as a conventionalization of one specific interpretation of “let us”. The source interpretation is this: “Let's” is a contraction for “let us”. “Let's” is only used in an imperative sentence, and the implied subject is thus “you”. The verb “to let” means “to not cause not”. Thus, “Let us go.” means “Don't you cause us not to go.” The set of people designated by "us" may or may not include you in general, but in this interpretation it does. One way for *you* to cause *us* not to go, provided you are a part of us, is for you not to go yourself. The sentence "Let's go." tells you not to cause us not to go in this fashion. Figure 4.10 illustrates this interpretation.

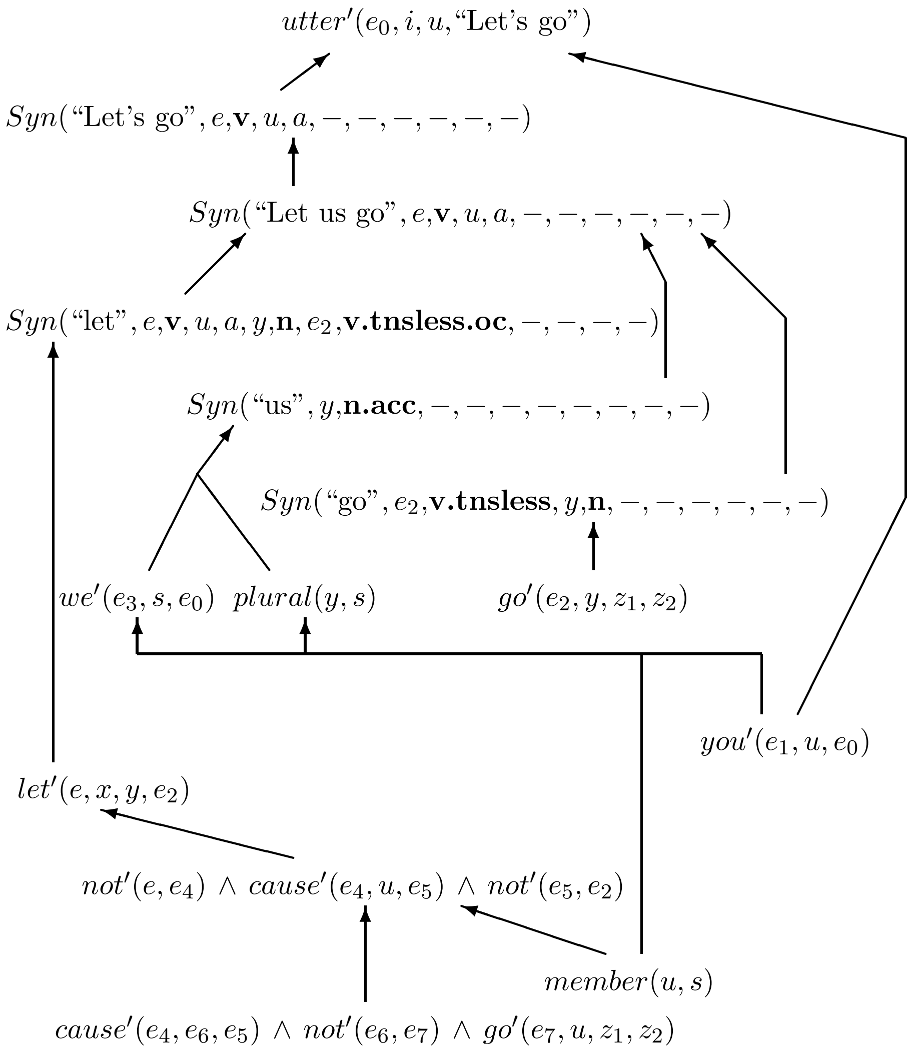

Figure 4.10: Parse of "Let's go."

When this is conventionalized it is compressed into the following two axioms, one to take care of its syntax and the other its meaning:

$$let\text{'}s'(e, e_2) \supset Syn(\text{"let's"}, e, \mathbf{v.tnsless}, -, -, e_2, \mathbf{v.tnsless}, -, -, -, -)$$

$$\begin{aligned} & not'(e, e_4) \wedge cause'(e_4, e_6, e_5) \wedge not'(e_6, e_7) \wedge not'(e_5, e_2) \\ & \quad \wedge we'(e_3, s, e_0) \wedge plural(y, s) \wedge you'(e_1, u, e_0) \wedge member(u, s) \\ & \quad \wedge Subst(u, e_7, y, e_2) \\ & \supset let's'(e, e_2) \end{aligned}$$

The first rule says that if e is a "let's-ing" of an event e_2, then e can be conveyed by the tenseless VP formed by concatenating "let's" with a tenseless VP conveying e_2.

The second rule unpacks the meaning of $let\text{'}s'$. The condition e of e_2 being "let's-ed" is the condition of the nonoccurrence of a causal event e_4. In e_4, the cause is the nonoccurrence e_6 of an event e_7, and the effect is the nonoccurrence e_5 of the event e_2. If u is the "you" of the utterance event e_0 and the set s with typical member y is the "we" of e_0 and includes u, then the event e_7 is what results from substituting u for y in e_2. A needed paraphrase: Don't *you* cause *us* not to do e_2 by not doing it yourself.

In "Let's go", e_2 is our going, e_7 is your going, e_5 is our not going, e_6 is your not going, e_4 is the causal relation from your not going to our not going, and e is the negation or nonoccurrence of that causing.

4.9 Adjuncts

4.9.1 Adjunct Placement

From the standpoint of predicate-argument relations, there are two patterns for clause-level adjuncts, illustrated by the examples

John spoke slowly.
John spoke reluctantly.

In the first, "slowly" expresses a property of the speaking. In the second, "reluctantly" expresses a relation between John and the speaking. Thus, the subject of the sentence must be passed into the adjunct.

The placement of adjuncts within a sentence can be quite free. This is essentially a fact about concatenation, and it will be accommodated in the first argument position of *Syn*.

Adjunct Composition Rule 1 is as follows:

(4.18)
$$\begin{aligned} & Syn(w_1w_3, e_1, f_1, x, a, y, b, z, c, v_1, g_1) \\ & \quad \wedge Syn(w_2, e_2, f_2{:}\mathbf{adjunct1}, e_1, f_1, -, -, -, -, v_2, g_2) \\ & \quad \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ & \supset Syn(w_1w_2w_3, e_2, f_1, x, a, y, b, z, c, v, g) \end{aligned}$$

There are several things to note about this rule. First, it says that the adjunct w_2 can intervene anywhere in a matrix phrase w_1w_3. Either w_1 or w_3 could be empty, since the constraint that they consitute a phrase is only on their concatenation; there are no constraints on w_1 or w_3 independently. The rule thus covers all of

Slowly John spoke.
John slowly spoke.
John spoke slowly.

Which may be distressing, this rule is somewhat underconstrained. The adjunct phrase can appear anywhere in the, in general, matrix phrase. We could limit this by specifying constraints on w_1 and w_3 in the rule, in particular to disallow a noun group (the part of an NP from the determiner through the head noun) to span the break between w_1 and w_3, and moreover in some cases to restrict particular kinds of adjuncts to only initial or final positions in the matrix phrase. But since ruling out the generation of clumsy expressions is not a focus of this chapter, no more will be said about this issue.

The adjunct predicates a property e_2 of the eventuality e_1 described by the matrix phrase. The former becomes the "head eventuality" of the composite phrase. This is because many such adjuncts are opaque. In

John almost spoke.

the primary property asserted by the sentence is not the speaking but the "almost-ness" of the speaking. For transparent adjuncts, like "slowly", the existence of the eventuality of the matrix clause can be inferred directly from the transparency of the adjunct, so in this case it is at worst harmless to pick the adjunct eventuality as head.

On the other hand, the "head agreement feature structure" of the composite phrase is inherited from matrix, not the adjunct. In

Mary believes that John almost spoke.

what Mary believes is the almost-ness, but it is the agreement properties of "John spoke" that determines its acceptability as a complement of "believes". For these reasons, the composite phrase in the Adjunct Composition Rule has e_2 as its e argument and f_1 as its f argument.

The eventuality e_1 becomes the logical subject of the adjunct. Whatever unsaturated arguments the phrase w_1w_3 has will be inherited by the composite phrase $w_1w_2w_3$. The gap in the composite phrase is inherited from either the matrix or the adjunct.

A wrinkle: Recall from Section 4.6 that the head eventuality for tensed verbs is the eventuality from the tense. But adjuncts almost always are intended to predicate a property of the eventuality deriving from the verb stem—the speaking was slow, not its past-ness. As I pointed out there, if tense predications are considered easy coercions, then they themselves function to coerce the argument of the adjunct to the desired verb stem eventuality. I will refer to these coercions as "tense coercions". The logical form of "John spoke slowly" before tense coercion is

$$Past'(e, e_1) \wedge speak'(e_1, J) \wedge slow'(e_2, e)$$

and after tense coercion is

$$Past'(e, e_1) \wedge speak'(e_1, J) \wedge slow'(e_2, e_1)$$

where the predication $Past'(e, e_1)$ effects the coercion from e to e_1.

Adjunct Composition Rule 2 is as follows:

$$\begin{array}{lll} (4.19) & & Syn(w_1w_3, e_1, f_1, x, a, y, b, z, c, v_1, g_1) \\ & & \quad \wedge\, Syn(w_2, e_2, f_2{:}\textbf{adjunct2}, x, a, e_1, f_1, -, -, v_2, g_2) \\ & & \quad \wedge\, gap(v, g, v_1, g_1, v_2, g_2) \\ & & \supset\; Syn(w_1w_2w_3, e_2, f_1, x, a, y, b, z, c, v, g) \end{array}$$

This rule is identical to Rule (4.18) except that the subject x of the matrix phrase w_1w_3 becomes an argument of the adjunct phrase w_2 as well, so that the adjunct predicates a relation between the subject of the matrix phrase and the eventuality described by the matrix phrase. This rule covers the sentence "John spoke reluctantly," whose logical form (after tense coercion) is

$$Past'(e, e_1) \wedge speak'(e_1, J) \wedge reluctant'(e_2, J, e_1)$$

where e_2 is what is asserted by the sentence as a whole.

By contrast, the logical form for "John was reluctant to speak" is

$Past'(e, e_2) \wedge speak'(e_1, J) \wedge reluctant'(e_2, J, e_1)$

where the assertion of the sentence is e. In both cases e_2 is a relation of reluctance between John and a (possible) speaking event. In the first case the speaking event is asserted to have been in the past, so we know it occurred. In the second, only the reluctance is asserted to have been in the past, so we cannot know whether the speaking actually occurred.

4.9.2 Predicate Complements as Adjuncts

Nearly anything that can be a predicate complement can also be an adjunct, as illustrated by the following examples:

PP: John spoke in Chicago.
Subordinate Clause: After John left the party, Mary was angry.
Adjective Phrase: More important than that, Mary stayed until the end.
Progressive VP: John left the party early, suggesting he was angry.

Even appositive NPs can appear as adverbial adjuncts on clauses, as in

John fell down the stairs, a real jolt to the system.

In certain specialized genres, NPs can occur in adjunct roles playing other functions. For example, in

Virus is typically found in the blood (viremia).

"viremia" gives a name to the condition described in the clause. Both of these examples are comfortably seen as instances of a *be* relation. However, in

The proportion of infected cells in peripheral blood is 100 to 1000 times higher in AIDS patients than in asymptomatic individuals (12).

"12" refers to the bibliographic entry of an article that describes the experiment that resulted in the eventuality that the matrix sentence conveys. This is less comfortably described as a kind of *be* relation, but we could perhaps see it as a combination of *be* and a metonymy.

Another approach would be to posit a predicate *Appositive*, similar to the predicates *nn*, *of*, and *'s*. *Appositive* will often mean identity but can sometimes be specialized to other relations. Its interpretational possibilities would be somewhat broader than those of *be*. To take an extreme example, in the sentence

> John Smith, Toledo, Ohio, writes to complain of what Andy Rooney said last week.

The phrase "Toledo, Ohio" has the structure of an appositive on "John Smith", and "Ohio" has the structure of an appositive on "Toledo". The first encodes a relation of "resides in" and the second "is located in". To accommodate this kind of use, Rule (4.16) that turns an NP into a Predicate Complement could introduce the predicate $Appositive'$ instead of the predicate be', and be' would be one possible interpretation of $Appositive'$, as provided by the axiom

$$be'(e,x,y) \supset Appositive'(e,x,y)$$

Relative clauses can also function as adjuncts.

> **Relative Clause:** John left the party early, which surprised everyone there.

These facts are accommodated by having the features **pred** and **rels** be subfeatures of the feature **adjunct1** in the feature set CAT.

Frequently, these adjuncts in fact take the *subject* of the matrix clause as their logical subject, rather than the eventuality described by the matrix clause.

> **PP:** In Chicago for the weekend, John dropped in to visit Mary.
> **Adjective Phrase:** Taller than anyone else in his class, Johnny was frequently embarassed.
> **Passive VP:** Broken by misfortune, John had given up trying.
> **Progressive VP:** John had left the party early, driving home by himself.
> **NP:** John left the party early, the rude, arrogant snob!
> **Relative Clause:** Someone left the party early who was very much in a hurry.

Our approach here is to let Adjunct Composition Rule 1 pick up the eventuality of the matrix clause as the logical subject, and then to treat the transfer to the subject of the matrix clause as an example of metonymy. This is explicated further in Section 4.17.2.

Adverbs function as adjuncts. In addition, several constructions signal their role as adjuncts solely by their occurrence in an adjunct position. The ones that will be discussed here are purpose infinitives and time and measure NPs.

4.9.3 Adverbs

Adverbs either express a property of the eventuality described by the phrase or clause they modify (Adjunct Composition Rule 1) or express a relation between that eventuality and the subject of that phrase or clause (Adjunct Composition Rule 2).

Typical of the first class is the adverb "actually", and its lexical axiom is

$$actual'(e, e_1) \supset Syn(\text{“actually”}, e, \mathbf{adv1}, e_1, \mathbf{v}, -, -, -, -, -, -)$$

If e is the eventuality of another eventuality e_1 being actual, then e can be described by the adverb "actually" occurring as an adjunct on a phrase that describes eventuality e_1. The feature **adv1** is a subfeature of the feature **adjunct1**, so Adjunct Composition Rule 1 will apply. The adverb modifies primarily clauses and VPs; hence, e_1's agreement feature is constrained to be of category **v**.

There has been a tradition in linguistics to distinguish between adverbs that modify clauses and those that modify VPs (??, 19??). In

John ran *slowly*.
John spoke *rudely*.
When he *first* gets here, I will talk to him.

the adverbs are seen as modifying the VP. In

John did *not* run.
Rudely, John spoke.
I will go *first*.

they are seen as modifying the clause. However, in our approach, there is no difference in the logical form generated for these two cases. The difference between the two cases is essentially this: Adverbs of manner, purportedly modifying the VP, decompose the action described by the VP (or the event described by the full clause) and look at them at a finer granularity. Other adverbs treat the eventuality as an undecomposed whole and describe their relation to the rest of the world; these adverbs are those traditionally seen as modifying the clause. For example, in "I will go first" the event is undecomposed. In "When he first gets here, ..." it is decomposed, and viewed as something that has internal structure. It is not clear that this distinction is properly captured as a distinction in what structures the adverbs are subcategorized for, and I will not try to capture the distinction in this way. I view it as fundamentally a pragmatics problem, not a syntactic one.

Lexical axioms for adverbs similar to "actually" are as follows:

$$
\begin{aligned}
&\textit{fiery}'(e, e_1) \supset \textit{Syn}(\text{“fiery”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)\\
&\textit{maybe}'(e, e_1) \supset \textit{Syn}(\text{“maybe”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)\\
&\textit{not}'(e, e_1) \supset \textit{Syn}(\text{“not”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)\\
&\textit{of-course}'(e, e_1) \supset \textit{Syn}(\text{“of course”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)\\
&\textit{often}'(e, e_1) \supset \textit{Syn}(\text{“often”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)\\
&\textit{slow}'(e, e_1) \supset \textit{Syn}(\text{“slowly”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)\\
&\textit{strong}'(e, e_1) \supset \textit{Syn}(\text{“strongly”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)
\end{aligned}
$$

Many adverbs realize predicates that crucially involve an extra argument that must be resolved contextually. There are two principal cases of this. In the first, the adverb describes a relation between its logical subject and another, contextually determined eventuality. "Again" is such an adverb. To understand properly what it conveys, we must determine the eventuality that is being repeated.

$$\textit{again}'(e, e_0, e_1) \supset \textit{Syn}(\text{“again”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)$$

If e is an *again* relation between eventualities e_0 and e_1, where e_0 is the first such event and e_1 the second, then e can be described by the adverb "again" occurring as an adjunct on a clause or VP describing the eventuality e_1.

Lexical axioms for similar adverbs are as follows:

$$
\begin{aligned}
&\textit{at-least}'(e, e_0, e_1) \supset \textit{Syn}(\text{“at least”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)\\
&\textit{for-example}'(e, e_0, e_1)\\
&\qquad \supset \textit{Syn}(\text{“for example”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)\\
&\textit{immediate}'(e, e_0, e_1)\\
&\qquad \supset \textit{Syn}(\text{“immediately”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)\\
&\textit{in-fact}'(e, e_0, e_1) \supset \textit{Syn}(\text{“in fact”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)\\
&\textit{then}'(e, e_0, e_1) \supset \textit{Syn}(\text{“then”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)\\
&\textit{thus}'(e, e_0, e_1) \supset \textit{Syn}(\text{“thus”}, e, \textbf{adv1}, e_1, \textbf{v}, -, -, -, -, -, -)
\end{aligned}
$$

"At least" modifies an eventuality e_1 that is being compared to another eventuality e_0. "For example" relates the example e_1 to the thing exemplified e_0. If an eventuality e_1 happens immediately, then it is immediately upon or after some other eventuality e_0. "In fact" relates an eventuality e_1 to an eventuality e_0 that it is an elaboration of. "Then" and "thus" express relations between two eventualities, but occur as adjuncts only on the second.

The second class of adverbs with a crucial, contextually determined extra argument involve a comparison of the eventuality modified with some comparison set. The adverb "even" is an example, and its lexical axiom is

$$even'(e, e_1, s) \supset Syn(\text{"even"}, e, \mathbf{adv1}, e_1, \mathbf{v}, -, -, -, -, -, -)$$

To understand properly a use of the adverb "even" applied to an eventuality, as in

John can even program.

we must recover a set s of similar eventualities and place them along a scale on which e_1 is at a high point. The meaning of *even* is discussed more thoroughly in Chapter 5.

The lexical axiom for "even" says that if e is an *even* relation between the eventuality e_1 and a comparison set s, then e can be described by the adverb "even" occurring as an adjunct on a clause or VP describing the eventuality e_1.

Lexical axioms for similar adverbs are as follows:

$$first'(e, e_1, s) \supset Syn(\text{"first"}, e, \mathbf{adv1}, e_1, \mathbf{v}, -, -, -, -, -, -)$$
$$late'(e, e_1, s) \supset Syn(\text{"late"}, e, \mathbf{adv1}, e_1, \mathbf{v}, -, -, -, -, -, -)$$
$$only'(e, e_1, s) \supset Syn(\text{"only"}, e, \mathbf{adv1}, e_1, \mathbf{v}, -, -, -, -, -, -)$$
$$original'(e, e_1, s) \supset Syn(\text{"originally"}, e, \mathbf{adv1}, e_1, \mathbf{v}, -, -, -, -, -, -)$$
$$rare'(e, e_1, s) \supset Syn(\text{"rarely"}, e, \mathbf{adv1}, e_1, \mathbf{v}, -, -, -, -, -, -)$$

All of the adverbs discussed so far have subcategorized for clauses or VPs. Adverbs such as "about", "at least", and "only" also subcategorize for numbers, as in

About 50 people showed up.
At least 50 people showed up.
Only 50 people showed up.

The adverb "about" also subcategorizes for adjectives, as in

That's about right.

The lexical axioms for these uses differ from the above axioms only in the agreement feature associated with the e_1 argument.

$approximate'(e, e_1)$
$\quad \supset Syn(\text{“about”}, e, \mathbf{adv1}, e_1, \mathbf{number/adj}, -, -, -, -, -, -)$
$at\text{-}least'(e, e_1, s)$
$\quad \supset Syn(\text{“at least”}, e, \mathbf{adv1}, e_1, \mathbf{number}, -, -, -, -, -, -)$
$only'(e, e_1, s) \supset Syn(\text{“only”}, e, \mathbf{adv1}, e_1, \mathbf{number}, -, -, -, -, -, -)$

These predicates are explicated further in Chapter 5.

The only adverb in the target texts that expresses a relation between the subject of the matrix clause and its eventuality is “typically”. In

John typically leaves early.

John’s leaving early is typical for John. The lexical axiom for “typically” is

$$typical'(e, e_1, x) \supset Syn(\text{“typically”}, e, \mathbf{adv2}, x, \mathbf{n}, e_1, \mathbf{v}, -, -, -, -)$$

If e is the property of e_1 being typical of x, then e can be described by the adverb “typically” occurring as an adjunct on a clause or VP describing the eventuality e_1. The feature **adv2** is a subfeature of the feature **adjunct2**, and therefore the x argument of *typical* is provided by the subject of the matrix clause.

Some of the adverbs presented in this section are multiwords—“at least”, “for example”, “in fact”, and “of course”. As with other idioms, their interpretations, though conventionalized, are motivated, and the origin interpretations could be displayed as was done for “let’s” in Section 4.8.

“Like” functions in spoken discourse as an adverbial, in the same class as “y’know”. It conveys something about the way the sentence is being expressed. The lexical axiom for this use of “like” is

$$like'_2(e, e_1) \supset Syn(\text{“like”}, e, \mathbf{adv1}, e_1, \mathbf{v}, -, -, -, -, -, -)$$

Again, we could have displayed its origin interpretation as a preposition.

Some words function by themselves as adjunct phrases, including “now”, “otherwise”, and “well”, generally conveying something about the discourse structure or the speaker’s mental state. Examples from the target texts are

Otherwise the town is lonesome.
Now I, let’s see, um . . .
Well, ah, we could probably make it less than that.

These words can be treated as adverbs. “Otherwise” expresses a relation between the eventuality of the clause modified and another, contextually determined eventuality. “Now” places the eventuality within a temporal sequence, either in the world or in the text. "Well" expresses a relation between the eventuality expressed and the thought the speaker is trying to convey. The lexical axioms for these words are as follows:

$$otherwise'(e, e_0, e_1)$$
$$\supset Syn(\text{"otherwise"}, e, \mathbf{adv1}, e_1, \mathbf{v}, -, -, -, -, -, -)$$
$$now'(e, e_1) \supset Syn(\text{"now"}, e, \mathbf{adv1}, e_1, \mathbf{v}, -, -, -, -, -, -)$$
$$well'(e, e_1) \supset Syn(\text{"well"}, e, \mathbf{adv1}, e_1, \mathbf{v}, -, -, -, -, -, -)$$

The predicates on the left are elucidated in Chapter 5.

4.9.4 Purpose Infinitives

The logical form for the purpose infinitive sentence

John left to sleep.

is, after tense coercion,

$$Past'(e, e_1) \wedge leave'(e_1, J) \wedge in\text{-}order\text{-}to'(e_0, e_1, e_2) \wedge sleep'(e_2, J)$$

The leaving was in order to sleep.

Purpose infinitives have no explicit signal of their relation to their matrix clause. Rather the information about purpose is carried by their occurrence as an adjunct. Thus, the *in-order-to* predication must be introduced by a rule that associates an infinitive with its adjunct role. The following alternation axiom does this.

$$Syn(w, e_2, \mathbf{v.inf}, x, a, -, -, -, -, v, g) \wedge in\text{-}order\text{-}to'(e, e_1, e_2)$$
$$\supset Syn(w, e, \mathbf{adjunct2}, x, a, e_1, f_1, -, -, v, g)$$

An infinitive VP w describing the situation e_2 can function as the purpose of another situation e_1 described by the matrix phrase in which the infinitive is embedded. The logical subject x of the purpose infinitive is the same as the subject of the matrix clause; hence, Adjunct Composition Rule 2 applies.

This rule is an alternation axiom in that the antecedent and consequent describe the same string of words, but as different categories and with different argument structures, and the antecedent introduces a new predication.

4.9.5 Time and Measure NPs

Like purpose infinitives, time and measure NPs convey information simply by their occurrence as adjuncts. There is nothing in their internal structure that expresses a relation between the time or measure and the eventuality timed or measured. For example, ignoring the analysis of “Sunday” and “three miles” and after tense coercion,

John ran Sunday.
$\Rightarrow Past'(e, e_1) \wedge run'(e_1, J) \wedge at\text{-}time'(e_0, e_1, Sunday)$

John ran three miles.
$\Rightarrow Past'(e, e_1) \wedge run'(e_1, J) \wedge measure'(e_0, e_1, 3\text{-}miles)$

The rules that associate the *at-time* and *measure* predications with the occurrence of the NPs as adjuncts parallel the rule for purpose infinitives.

$$Syn(w, x, \mathbf{ntime}, -, -, -, -, -, -, v, g) \wedge at\text{-}time'(e_0, e_1, x) \supset Syn(w, e_0, \mathbf{adjunct1}, e_1, \mathbf{v}, -, -, -, -, v, g)$$
$$Syn(w, x, \mathbf{nmeasure}, -, -, -, -, -, -, v, g) \wedge measure'(e_0, e_1, x, s) \supset Syn(w, e_0, \mathbf{adjunct1}, e_1, \mathbf{v}, -, -, -, -, v, g)$$

In the first, w is a Time NP describing the time x. It can function as an adjunct in a matrix clause or VP, and when it does, it conveys the information e_0 that the eventuality e_1 described by the matrix occurred at time x.

In the second, w is a Measure NP describing the measure x. It can function as an adjunct in a matrix clause or VP, and when it does, it conveys the information e_0 that the eventuality e_1 described by the matrix measures x on some scale s. Normally such statements require further explication at a pragmatic level, as described in Chapter 5.

The agreement features **ntime** and **nmeasure** are subfeatures of **n** in the feature class *CAT*.

4.9.6 Separators

Punctuation has not been discussed in connection with any of the previous rules, in spite of the fact that many adjuncts, especially long ones, can only occur in writing set off by punctuation and in speech set off by timing or intonation. I will not attempt to write rules to prohibit long adjuncts that are not set off. However, rules will be presented to handle the punctuation when it occurs. The following basic rule will allow us to strip off the punctuation when it occurs.

$$Syn(w_2, e, f{:}\mathbf{adjunct}, x, a, y, b, z, c, v, g) \wedge MatchSeps(w_1, w_3) \supset Syn(w_1 w_2 w_3, e, f, x, a, y, b, z, c, v, g)$$

This says that if we encounter the string $w_1w_2w_3$ where w_1 and w_3 are matching separators, then we only need to find an adjunct interpretation for w_2. For example, this turns the string ", for example," into the string "for example". The rule leaves the argument and feature structure of w_2 unchanged. This has the structure of an alternation axiom, except that nothing alternates.

The agreement feature **adjunct** is a superfeature of **adjunct1** and **adjunct2**.

The following rules specify some pairs of matching separators.

$MatchSeps(\text{“,”}, \text{“,”})$
$MatchSeps(\text{“,”}, \text{“ ”})$
$MatchSeps(\text{“,”}, \text{“;”})$
$MatchSeps(\text{“,”}, \text{“.”})$
$MatchSeps(\text{“ ”}, \text{“,”})$
$MatchSeps(\text{“ ”}, \text{“;”})$
$MatchSeps(\text{“—”}, \text{“—”})$
$MatchSeps(\text{“—”}, \text{“.”})$
$MatchSeps(\text{“(”}, \text{“)”})$
$MatchSeps(\text{“[”}, \text{“]”})$

The second, fifth and sixth rules, allowing the empty string terminally and initially, are intended to take care of the case of sentence-final and sentence-initial adjuncts. These rules are of course underconstrained, but the complexities that would be involved in tightening them up would take us well beyond the principal concerns of this book.

It will be convenient in the developments below on adjectives and conjunctions to specify other places for separators in phrases. Many of these will involve the use of separators having a "strength" in a particular range. For example, in some contexts, we can have commas and semicolons but cannot have the absence of a separator, while in other contexts we can have nothing or commas but not semicolons. To deal with these constraints economically, we will say that the empty string is a separator of strength 0, comma 1, semicolon 2, and period 3. The predicate $Sep01$ will be true of the empty string and commas, $Sep012$ will be true of these two plus semicolons, $Sep12$ will be true of commas and semicolons, and $Sep23$ semicolons and periods. These conventions are encoded in the following axioms.

$Sep01(\text{“ ”})$
$Sep01(\text{“,”})$
$Sep012(\text{“ ”})$

$Sep012(“,”)$
$Sep012(“;”)$
$Sep12(“,”)$
$Sep12(“;”)$
$Sep23(“;”)$
$Sep23(“.”)$

Thus a context that allows only a comma or a semicolon will use the predicate $Sep12$.

4.10 Noun Phrase Rules

4.10.1 The Structure of the Noun Phrase

The information about an NP that is available to the rest of the grammar is sparse—only the entity referred to and the agreement features.

(4.20) $Syn(w, x, a, -, -, -, -, -, -, -, -)$

However, our treatment of the internal structure of the English noun phrase will be driven primarily by two issues that will force us to encode substantially more information: the positional constraints on elements in a noun phrase, and a treatment of determiners as expressing relations.

The English noun phrase consists of a determiner phrase and the remainder, which in some linguistic traditions is referred to as $\overline{\mathbf{N}}$ (“N bar”) and in others as CN (“common noun”); I will use the former term. In

the only three large red house boats in the bay

“the only three” is the determiner phrase and “large red house boats in the bay” is the $\overline{\mathbf{N}}$. The $\overline{\mathbf{N}}$ consists of a head noun (“boats”), zero or more prenominal nouns to its left (“house”), zero or more adjectives to the left of that (“large red”), and zero or more noun complements to the right of the head noun (“in the bay”).

The rules for NPs must ensure this order of elements. We will do this by building the $\overline{\mathbf{N}}$ from the inside out, keeping track of what kinds of elements we have added to it so far, both on the left and on the right. The category **n** will have associated with it two features *LEFT* and *RIGHT*, that will encode the structure of the partial $\overline{\mathbf{N}}$. The feature *LEFT* can take on the values **ld**, **la**, **ln**, meaning that the left most element is a determiner, adjective, or noun, respectively. As we will see in Section 4.10.5, we also need a feature that says the leftmost "element" is an empty head; this feature value will be **le**. The feature *RIGHT* can take on the values **rn**, **rc**, or **re**, meaning that the rightmost element is a noun, a noun complement, or an empty head, respectively.

The feature **ln** associated with a phrase means that that the phrase has a head noun, possibly with one or more prenominal nouns prefixed to it, but no adjective or determiner. The feature **la** means that the phrase has had at least one adjective prefixed to it but has no determiners. The feature **ld** means that at least one determiner has been added. The feature **rc** means that the phrase has had at least one noun complement added.

In addition, we can have the disjunctive feature values **ld/la/ln/le**, **ld/la/ln**, **la/ln/le**, **la/ln**, and **ln/le** for the feature *LEFT*, and **rn/rc/re**, **rn/re** and **rn/rc** for the feature *RIGHT*. To save ink, abbreviations will be used for the disjunctive feature values. **ldane** will be used for **ld/la/ln/le**, **ldan** for **ld/la/ln**, **lane** for **la/ln/le**, **lan** for **la/ln**, and **lne** for **ln/le**. **rnce** will be used for **rn/rc/re**, **rnc** for **rn/rc**, and **rne** for **rn/re**.

We will then restrict the attachment of prenominal nouns to only phrases with the feature **ln**, the attachment of adjectives to only phrases with the feature **lan**, the attachment of noun complements to only phrases with the feature **rnc**, and the attachment of determiners to phrases with the feature **ldan**. These constraints will enforce the internal structure of the NP.

Determiners, in the present approach, are generally taken to express relations of various sorts, and they can take as their arguments any of three kinds of information carried by $\overline{\mathbf{N}}$s—the entity referred to, the property of that entity denoted by the $\overline{\mathbf{N}}$, and, in the case of plurals, the set of which that entity is the typical element. Thus, for the noun "boats", there is the typical boat x, the eventuality or condition e of x's being a boat, and the set s of boats that has x as its typical member.

The word "three", for example, describes a property—cardinality—of the set s. The word "the" can be viewed as describing a relation between the entity x referred to and the description e provided by the $\overline{\mathbf{N}}$. The word "most" can be viewed as introducing a new set, whose typical element will be the referent of the NP as a whole, and expressing a relation between that set and the set introduced by the $\overline{\mathbf{N}}$.

Some adjectives also express properties of e or s rather than x. For example, "numerous" is a property of the set rather than the typical element, and "artificial" is a property of the property e.

Hence, as we build up the $\overline{\mathbf{N}}$, we must also build up and carry along in *Syn* all of x, e, and s. The variables e and x have their natural place in the e and x argument positions. For the sake of this development, we will overload the z argument position and use it to store s. This will mean that we cannot subcategorize nouns for more than one argument expressed in noun complement position. This will be harmless, however. Arguments signalled by prepositions can be treated equivalently as relations between the head and argument, as described in Section 4.6, and there is never more than one sentential argument. So in

John's promise to Mary to leave early

"promise" would be subcategorized for an infinitival complement, and "to Mary" would be taken as expressing a *to* relation between the promise and Mary, where pragmatics would take care of identifying Mary with the proper existentially quantified argument of *promise*.

Consequently, the structure of the *Syn* predication for partial $\overline{\mathbf{N}}$s as they are being built from the inside out will be

$$Syn(w, e, f, x, a, y, b, s, -, v, g) \tag{4.21}$$

where w is the phrase so far constructed, e is the description of the entity provided by that string of words, f encodes the *LEFT* and *RIGHT* features, x is the entity the $\overline{\mathbf{N}}$ will refer to, a is its agreement feature structure, y is either the empty constant $-$ or the referent of w's argument to be found in the noun complement, b is its agreement feature structure, and s is the empty constant $-$ for singular nouns and the set referred to for plural nouns. The variables v and g will generally be the empty constant $-$, unless a gap has been introduced in a noun complement, as in

[This is the man I saw] a picture of ().

or, as described in Section 4.13, there is a wh-word in the NP.

For convenience, I will refer to (4.20) as the *external* representation of the NP and to (4.21) as the *internal* representation.

For building up $\overline{\mathbf{N}}$s, we need several new composition rules. The first allows us to add prenominal nouns, adjectives, and determiners to the left of a head noun. It is NP Composition Rule 1.

$$\begin{aligned} & Syn(w_1, e_1, f_1, e_2, f_2, x, a{:}\mathbf{n}, s, -, v_1, g_1) \\ & \quad \wedge Syn(w_2, e_2, f_2, x, a, y, b, s, -, v_2, g_2) \\ & \quad \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ & \supset Syn(w_1 w_2, e_1 \& e_2, f_1, x, a, y, b, s, -, v, g) \end{aligned} \tag{4.22}$$

A word w_1, such as an adjective, conveying the property e_1 can be concatenated with a word or phrase w_2 of category **n** conveying the property e_2 and referring to x. The property conveyed by the composite phrase is the conjunction of e_1 and e_2. The applicability of the rule will be conditioned on the *LEFT* feature pf feature structure f_2 of w_2, and the *LEFT* feature of feature structure f_1 of the composite will be determined by w_1. If w_2 has an extra argument y with its agreement feature structure b, these are inherited by the composite phrase. If w_2 is plural, its associated set s is inherited by the composite phrase. Since noun complements are added before determiners and sometimes before adjectives, w_2 could have a gap v_2 with agreement features g_2; these are inherited by the composite phrase. A relative and interrogative determiner w_1 such as "which" will also have gap arguments v_1 and g_1, as described in Section 4.13, and these are also inherited by the composite phrase. If w_1 is an adjective or prenominal noun, there will be no gap in it.

The typical lexical axiom for nouns will have the following form, for singular and plural nouns:

$$man'(e,x) \supset Syn(\text{"man"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$$
$$man'(e,x) \wedge plural'(e_0, x, s)$$
$$\quad \supset Syn(\text{"men"}, e\&e_0, \mathbf{ln.rn}, x, \mathbf{n.pln}, -, -, s, -, -, -)$$

If e is the condition of x being a man, then x can be described by the singular noun "man", so far unadorned by modifiers (the *LEFT* feature **ln** and the *RIGHT* feature **rn**). If e is the condition of x being a man and e_0 is the condition of x being the typical element of the set s, then s can be described by the plural noun "men", again so far unadorned by modifiers. For plurals, the property conveyed by the word is the conjunction of e and e_0.

We will use an alternation axiom to change ordinary nouns into prenominal nouns that can participate in NP Composition Rule 1 (4.22).

$$Syn(w, e_1, f_1{:}\mathbf{lan}, y, b{:}\mathbf{n}, z, c, s_1, -, -, -) \wedge nn'(e, y, x)$$
$$\quad \supset Syn(w, e_1\&e, f_1{:}\mathbf{ln}, e_2, f_2{:}\mathbf{ln.rn}, x, a, s_2, -, -, -)$$

This rule converts an ordinary noun w, like "house", referring to y, with associated eventuality e_1 (the house-ness of y), and with a possible second argument z and a possible associated set s_1, into a prenominal noun that can be attached to any phrase with *LEFT* feature **ln** to produce a composite phrase referring to some entity x with *LEFT* feature **ln**. The information conveyed by the prenominal noun is the information e_1 conveyed by the original noun, conjoined with an nn relation e between y and x.

Prenominal nouns may themselves be modified by prenominal nouns and by adjectives. For example, in “Stanford Research Institute” “Stanford” and “Research” both modify “Institute”, but in “Cancer Research Institute”, “Cancer” modifies “Research” and “Cancer Research” modifies “Institute”. In

Berkeley Free Speech Movement

the adjective “Free” modifies “Speech”, and “Berkeley” and “Free Speech” both modify “Movement”. In the above axiom, we have allowed the alternation to be applied to any phrase whose *LEFT* feature is **la** or **ln**. Thus, “Free Speech” (**la**) and “Cancer Research” (**ln**) can function as prenominal “nouns”. The resulting phrase, however, is only of type **ln**, and more prenominal nouns can be attached to its left. For this reason, in the consequent of the above axiom, the *LEFT* feature of f_1 is restricted to be **ln**.

The prenominal noun's complement (z), if it has one, is lost.

a promise to be faithful
* promise keepers to be faithful
—* primise-to-be-faithful keepers

Plurals are rare as prenominal nouns. If a plural is used, its associated set (s_1) is lost to the rest of the NP construction in this treatment, although it will still be a part of the logical form.

Of the various elements in the noun phrase, prenominal nouns are attached to the head noun first. The order of attachment for prenominal adjectives and postnominal noun complements can vary, because we want to have available at the time of attachment the semantic material needed for the right logical form, insofar as possible. A problem arises with opaque adjectives, like “former” and “alleged”, which take the property rather than the entity as its argument. This can be described in terms of bracketing. In the phrase

a [former [president of General Motors]]

the word “former” scopes over both the “president” property and the “of” relation. In

a [fake [painting by Rembrandt]]

the word “fake” scopes the whole description “painting by Rembrandt”, not just over “painting”. In

a [[former president] living in New York] the word "former" scopes over "president", not over the "living" relation. In

a [[fake Rembrandt] by Harry Donovan]

the word "fake" scopes over only "Rembrandt", not over the "by" relation. These differences in scope are captured by the order in which prenominal adjectives and postnominal noun complements are attached. In the narrow scope cases, the adjective is added before the noun complement. In wide scope cases, the noun complement is added first. In the case of transparent adjectives, like "red", scope or bracketing is irrelevant and a benign ambiguity will result.

The lexical axioms for adjectives, as seen in Section 4.7.2, were designed for use in predicate complements. But almost every such adjective can appear prenominally as well. We can capture this with an alternation axiom:

$$(4.23) \quad Syn(w, e_1, f_1{:}\mathbf{adj/prog}, x, a, y, b, z, c, -, -) \\ \supset Syn(w, e_1, f_1{:}\mathbf{la.}f_{RIGHT}, e_2, f_2{:}\mathbf{lan.}f_{RIGHT}, x, a{:}\mathbf{n}, s, -, -, -)$$

This rule converts a predicate adjective w, like "red", expressing the property e_1 of its logical subject x, into a prenominal adjective that can be attached to any phrase of category **n** that has not yet acquired determiners (the *LEFT* feature is **lan**), where x is the referent of that phrase. The *RIGHT* feature can be either **rn** or **rc**, and whatever it is is inherited by the composite phrase on composition.

Any complements that the predicate adjective possesses are lost in this alternation.

John was fearful that the dog would attack.
* a fearful man that the dog would attack

Present and passive participles of verbs can also appear in the adjective position of NPs, as freely as can adjectives. We have already subsumed passives under the category **adj** in Section 4.7, so the above axiom only has to allow present participles—category **prog**—in additon to adjectives.

These rules are illustrated in Figure 4.11, which shows the parse of the $\overline{\mathbf{N}}$ "red house boat".

All the structures that can appear as predicate complements can also appear as noun complements, and when they do, their logical subjects are provided by the head nouns.

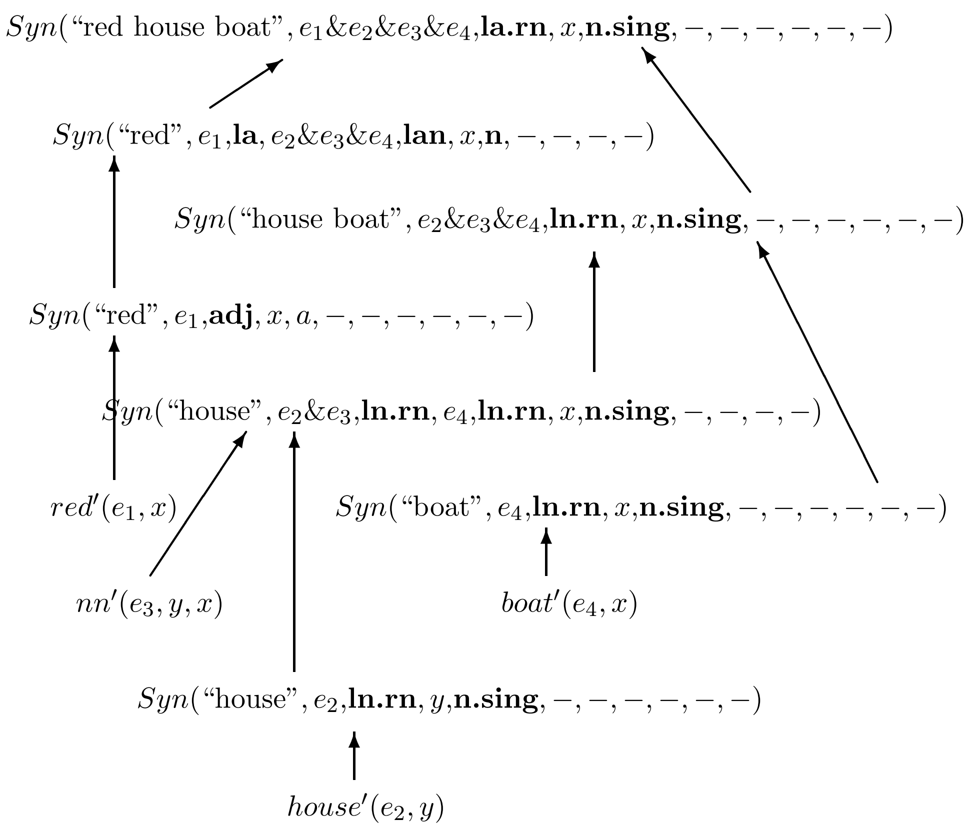

Figure 4.11: Parse of "red house boat"

PP: a meeting in Chicago
Subordinate Clause: the party when John left for college
Adjective Phrase: the people responsible for this mess
Passive VP: a house destroyed by the storm
Progressive VP: a man running to catch the train
NP: John Smith, the new manager,

In addition, relative clauses can and usually do function as noun complements.

the man who came to dinner

Finally, "than" complements can be noun complements in comparative NPs.

a more serious student than George

The second new composition rule, NP Composition Rule 2, is for the attachment of these noun complements to the right of the head noun.

(4.24)
$$\begin{aligned} & Syn(w_1, e_1, f_1{:}\mathbf{rnce}, x, a{:}\mathbf{n}, y, b, s, -, v_1, g_1) \\ & \quad \wedge Syn(w_2, e_2, f_2{:}\mathbf{pred/rels/than}, x, a, -, -, -, -, v_2, g_2) \\ & \quad \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ & \supset Syn(w_1w_2, e_1\&e_2, f_1{:}\mathbf{rc}, x, a, y, b, s, -, v, g) \end{aligned}$$

A partial $\overline{\mathbf{N}}$ w_1 referring to x with agreement features a and conveying the property e_1 can be concatenated with a predicate complement, relative clause, or "than" phrase. The logical subject of the predicate complement or relative clause (that is, the entity that fills the gap in the relative clause; see below) is x. The complement y and associated set s, if any, of the composite phrase are inherited from w_1. The composite phrase has the *RIGHT* feature of **rc** indicating that a complement has been added. There are certain restricted contexts in which a gap can survive from a noun complement to an NP, as in

[This is the man that I saw] a picture of ().

However, only one noun complement can contribute a gap. Enforcing this is the job of the *gap* predication.

That w_1 can have an empty head (**re**) is to handle examples such as "those in charge", as seen below in Section 4.10.5.

In this development of syntax the relevant distinction between restrictive and nonrestrictive noun complements arises with determiners like "the" that take the $\overline{\mathbf{N}}$'s eventuality as one of its arguments. The eventuality associated with a *restrictive* noun complement should be conjoined into that argument, whereas a *nonrestrictive* one should not be. The logical form for

the returning soldiers discouraged by defeat

where the noun complement is restrictive will be

$$\begin{aligned} & the'(e_1, x, e_2\&e_3\&e_4\&e_5) \wedge return'(e_2, x) \wedge soldier'(e_3, x) \\ & \quad \wedge plural'(e_4, x, s) \wedge discourage'(e_5, y, x) \wedge defeat'(e_6, y) \end{aligned}$$

whereas the logical form for

the returning soldiers, discouraged by defeat

where the noun complement is nonrestrictive will be

$$the'(e_1, x, e_2\&e_3\&e_4) \wedge return'(e_2, x) \wedge soldier'(e_3, x) \wedge plural'(e_4, x, s) \\ \wedge discourage'(e_5, y, x) \wedge defeat'(e_6, y)$$

The difference is whether the discouragement e_5 is or is not part of the argument of the predicate *the*. This difference is made possible in NP Composition Rule 2 by not imposing any constraints concerning what the leftmost element of the partial $\overline{\mathbf{N}}$ is. The determiner can be attached before or after the noun complement. When it is attached after the noun complement, a definite or indefinite determiner will take the conjunction of the eventualities so far accumulated as its second argument, including that contributed by the noun complement, and the interpretation will be restrictive. If it is attached before the noun complement, it will not include those eventualities, and the interpretation will be nonrestrictive.

This device does not handle nonrestrictive material in prenominal position, as in one reading of

The intelligent Greeks created a beautiful civilization.

This problem is discussed in Chapter 6 on local pragmatics.

A third composition rule, NP Composition Rule 3, attaches arguments in noun complement position to head nouns.

$$(4.25) \quad Syn(w_1, e_1, f_1{:}\mathbf{ln.rnc}, x, a{:}\mathbf{n}, y, b, s, -, v_1, g_1) \\ \wedge Syn(w_2, y, b, -, -, -, -, -, -, v_2, g_2) \\ \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ \supset Syn(w_1 w_2, e_1, f_1{:}\mathbf{rc}, x, a, -, -, s, -, v, g)$$

A partial $\overline{\mathbf{N}}$ w_1 referring to x with agreement features a and conveying the property e_1 and requiring an argument y with agreement feature structure b can be concatenated with a phrase w_2 of type b referring to y to produce a composite phrase of the same type as w_1, referring to the same entity and conveying the same property. Arguments are added before adjectives (f_1:**ln.rnc**), and the composite phrase is coded as **rc** to indicate that it now has a complement. The gap in the composite phrase is inherited from one or the other of the consitituents, or neither.

Since complements of nouns are always optional, we need an alternation axiom that will delete them.

$$Syn(w_1, e_1, f_1, x, a{:}\mathbf{n}, y, b, s, -, v_1, g_1) \\ \supset Syn(w_1, e_1, f_1, x, a, -, -, s, -, v_1, g_1)$$

Noun complements (except "than" clauses) are frequently set off by commas and other separators. The following axiom strips them off in analysis.

$$\begin{aligned}&Syn(w_2, e, f{:}\mathbf{pred/rels}, x, a, -, -, -, -, v, g)\\&\quad \wedge MatchedSeps(w_1, w_3)\\&\quad \supset Syn(w_1w_2w_3, e, f, x, a, -, -, -, -, v, g)\end{aligned}$$

When an entire NP is built up, it is converted into the form required by the rest of the grammar by the following alternation axiom:

$$\begin{aligned}&Syn(w, e, f{:}\mathbf{ldan.rnc}, x, a{:}\mathbf{n}, -, -, s, -, v, g)\\&\quad \supset Syn(w, x, a, -, -, -, -, -, -, v, g)\end{aligned} \tag{4.26}$$

An NP w, in any state of development, can be "closed off" by throwing away all the information except the entity x that is referred to and its agreement feature structure a. The gap survives for picture nouns and relativizers.

In the following sections we discuss various issues that arise as we build the NP from the inside out.

4.10.2 Noun Morphology

The rule for handling the most common case of regular plural noun morphology is as follows:

$$\begin{aligned}&Syn(w, e, f, x, a{:}\mathbf{n.sing}, y, b, -, -, -, -) \wedge plural'(e_0, x, s)\\&\quad \supset Syn(w\text{"s"}, e\&e_0, f, x, a{:}\mathbf{n.pln}, y, b, s, -, -, -)\end{aligned}$$

If w is a singular noun referring to x, conveying the property e, and possibly having a complement y with agreement feature structure b and e_0 is the eventuality of x being the typical element of a set s, then if the letter "s" is concatenated onto w the result will be a plural noun still referring to x, conveying the conjunction of e and e_0, having y as its complement, and having s as its associated set.

Some rules for other regular plurals of nouns are as follows:

$$\begin{aligned}&Syn(w\text{"s"}, e, f, x, a{:}\mathbf{n.sing}, y, b, -, -, -, -) \wedge plural'(e_0, x, s)\\&\quad \supset Syn(w\text{"ses"}, e\&e_0, f, x, a{:}\mathbf{n.pln}, y, b, s, -, -, -)\\&Syn(w\text{"ch"}, e, f, x, a{:}\mathbf{n.sing}, y, b, -, -, -, -) \wedge plural'(e_0, x, s)\\&\quad \supset Syn(w\text{"ches"}, e\&e_0, f, x, a{:}\mathbf{n.pln}, y, b, s, -, -, -)\\&Syn(w\text{"y"}, e, f, x, a{:}\mathbf{n.sing}, y, b, -, -, -, -) \wedge plural'(e_0, x, s)\\&\quad \supset Syn(w\text{"ies"}, e\&e_0, f, x, a{:}\mathbf{n.pln}, y, b, s, -, -, -)\end{aligned}$$

$$Syn(w\text{“fe”}, e, f, x, a{:}\mathbf{n.sing}, y, b, -, -, -, -) \wedge plural'(e_0, x, s)$$
$$\supset Syn(w\text{“ves”}, e\&e_0, f, x, a{:}\mathbf{n.pln}, y, b, s, -, -, -)$$

The rule for nouns ending in “y” is not quite right, since the previous letter has to be a consonant, but, again, the scope of this book precludes.

Some rules for irregular plurals are as follows:

$$Syn(\text{“child”}, e, f, x, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \wedge plural'(e_0, x, s)$$
$$\supset Syn(\text{“children”}, e\&e_0, f, x, a{:}\mathbf{n.pln}, -, -, s, -, -, -)$$
$$Syn(\text{“man”}, e, f, x, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \wedge plural'(e_0, x, s)$$
$$\supset Syn(\text{“men”}, e\&e_0, f, x, a{:}\mathbf{n.pln}, -, -, s, -, -, -)$$
$$Syn(\text{“woman”}, e, f, x, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \wedge plural'(e_0, x, s)$$
$$\supset Syn(\text{“women”}, e\&e_0, f, x, a{:}\mathbf{n.pln}, -, -, s, -, -, -)$$

Equivalently, we could have written these axioms in the form

$$child'(e, x) \wedge plural'(e_0, x, s)$$
$$\supset Syn(\text{“children”}, e\&e_0, f{:}\mathbf{ln.rn}, x, a{:}\mathbf{n.pln}, -, -, s, -, -, -)$$

As with verb morphology, it will be assumed that optimality constraints built into abduction-driven generation will force the generation of the most specific, highly constrained form in the case of irregulars.

4.10.3 Lexical Axioms for Nouns

The predicates for the simplest nouns have only an eventuality and a single entity argument, as in

$$thing'(e, x)$$

A lexical axiom for such a noun is as follows:

$$thing'(e, x) \supset Syn(\text{“thing”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$$

That is, if e is the eventuality of x being a thing, then the singular noun “thing” can be used to refer to x, conveying the property e. The noun by itself is a partial $\overline{\mathbf{N}}$ to which no adjectives or noun complements have been added (features **ln.rn**).

The lexical axioms for the other words in the target texts with one-argument predicates are as follows:

$$AIDS'(e, x) \supset Syn(\text{“AIDS”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$$
$$antibody'(e, x) \supset Syn(\text{“antibody”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$$
$$antigen'(e, x) \supset Syn(\text{“antigen”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$$

$AZT'(e,x) \supset Syn(\text{"AZT"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$blade'(e,x) \supset Syn(\text{"blade"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$blood'(e,x) \supset Syn(\text{"blood"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$brass'(e,x) \supset Syn(\text{"brass"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$bus'(e,x) \supset Syn(\text{"bus"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$CD4^{+'}(e,x) \supset Syn(\text{"CD4}^{+}\text{"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$cell'(e,x) \supset Syn(\text{"cell"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$chip'(e,x) \supset Syn(\text{"chip"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$church'(e,x) \supset Syn(\text{"church"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$cotton'(e,x) \supset Syn(\text{"cotton"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$farm'(e,x) \supset Syn(\text{"farm"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$HIV\text{-}1'(e,x) \supset Syn(\text{"HIV-1"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$house'(e,x) \supset Syn(\text{"house"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$impellor'(e,x) \supset Syn(\text{"impellor"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$individual'(e,x) \supset Syn(\text{"individual"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$kingdom'(e,x) \supset Syn(\text{"kingdom"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$line'(e,x) \supset Syn(\text{"line"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$lube\text{-}oil'(e,x) \supset Syn(\text{"lube oil"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$lunch'(e,x) \supset Syn(\text{"lunch"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$main'(e,x) \supset Syn(\text{"main"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$man'(e,x) \supset Syn(\text{"man"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$mill'(e,x) \supset Syn(\text{"mill"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$ocean'(e,x) \supset Syn(\text{"ocean"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$oil'(e,x) \supset Syn(\text{"oil"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$one'(e,x) \supset Syn(\text{"one"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$particle'(e,x) \supset Syn(\text{"particle"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$patient'(e,x) \supset Syn(\text{"patient"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$peach'(e,x) \supset Syn(\text{"peach"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$period'(e,x) \supset Syn(\text{"period"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$place'(e,x) \supset Syn(\text{"place"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$project'(e,x) \supset Syn(\text{"project"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$road'(e,x) \supset Syn(\text{"road"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$room'(e,x) \supset Syn(\text{"room"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$start\text{-}air\text{-}compressor'(e,x)$
$\quad \supset Syn(\text{"SAC"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$sandwich'(e,x) \supset Syn(\text{"sandwich"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$secretary'(e,x) \supset Syn(\text{"secretary"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$seroconversion'(e,x)$
$\quad \supset Syn(\text{"seroconversion"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$serum'(e,x) \supset Syn(\text{"serum"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$

$slave'(e,x) \supset Syn(\text{“slave”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$soil'(e,x) \supset Syn(\text{“soil”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$store'(e,x) \supset Syn(\text{“store”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$street'(e,x) \supset Syn(\text{“street”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$summer'(e,x) \supset Syn(\text{“summer”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$time'(e,x) \supset Syn(\text{“time”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$town'(e,x) \supset Syn(\text{“town”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$train'(e,x) \supset Syn(\text{“train”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$tree'(e,x) \supset Syn(\text{“tree”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$tower'(e,x) \supset Syn(\text{“tower”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$unit'(e,x) \supset Syn(\text{“unit”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$viremia'(e,x) \supset Syn(\text{“viremia”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$virus'(e,x) \supset Syn(\text{“virus”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$winter'(e,x) \supset Syn(\text{“winter”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$word'(e,x) \supset Syn(\text{“word”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$worker'(e,x) \supset Syn(\text{“worker”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$world'(e,x) \supset Syn(\text{“world”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
$Zidovudine'(e,x)$
$\quad \supset Syn(\text{“Zidovudine”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$

Several of the nouns from the target texts that have one-argument predicates are unit or time nouns. “Saturday” is a time noun, which means that it can stand alone as a time adverbial.

$Saturday'(e,x)$
$\quad \supset Syn(\text{“Saturday”}, e, \mathbf{ln.rn}, x, \mathbf{ntime.sing}, -, -, -, -, -, -)$

Others are nouns referring to units of measure, which means that they can head NPs that can stand alone as measure adverbials.

$day'(e,x) \supset Syn(\text{“day”}, e, \mathbf{ln.rn}, x, \mathbf{nmeasure.sing}, -, -, -, -, -, -)$
$hour'(e,x) \supset Syn(\text{“hour”}, e, \mathbf{ln.rn}, x, \mathbf{nmeasure.sing}, -, -, -, -, -, -)$
$inch'(e,x) \supset Syn(\text{“inch”}, e, \mathbf{ln.rn}, x, \mathbf{nmeasure.sing}, -, -, -, -, -, -)$
$mile'(e,x) \supset Syn(\text{“mile”}, e, \mathbf{ln.rn}, x, \mathbf{nmeasure.sing}, -, -, -, -, -, -)$
$minute'(e,x)$
$\quad \supset Syn(\text{“minute”}, e, \mathbf{ln.rn}, x, \mathbf{nmeasure.sing}, -, -, -, -, -, -)$
$month'(e,x)$
$\quad \supset Syn(\text{“month”}, e, \mathbf{ln.rn}, x, \mathbf{nmeasure.sing}, -, -, -, -, -, -)$
$second'(e,x)$
$\quad \supset Syn(\text{“second”}, e, \mathbf{ln.rn}, x, \mathbf{nmeasure.sing}, -, -, -, -, -, -)$
$week'(e,x) \supset Syn(\text{“week”}, e, \mathbf{ln.rn}, x, \mathbf{nmeasure.sing}, -, -, -, -, -, -)$

Many nouns, especially nominalizations, correspond to two-argument predicates. For example, "edge":

$$edge'(e, x, y) \supset Syn(\text{“edge”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$$

If e is the eventuality of x being the edge of y, then the singular noun "edge" can be used to refer to x, conveying the property e. I have left y out of the complement structure for "edge". The axiom could have been written

$$edge'(e, x, y) \supset Syn(\text{“edge”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, y, \mathbf{n.of}, -, -, -, -)$$

and NP Composition Rule 3 would apply to pick up the y argument from an "of" PP in noun complement position. However, in this development, all PP complements of head nouns will be treated as adjuncts, adding a new property rather than filling in an argument. As described in Section 4.6, other interpretation processes will normally identify the adjunct relation as an argument relation through factoring, via such axioms as

$$edge'(e, x, y) \supset of'(e_0, e, y)$$

Only the e and x arguments will be filled in by "syntactic" processing, as indicated in the lexical axioms below.

Arguments conveyed by prenominal nouns, possessives, and noun-like adjectives, as in

the cliff edge
the water's edge
the sylvan edge

will be handled similarly.

Non-PP complements will be incorporated into the lexical axioms, since they are not so easily treated as adjuncts.

Two classes of nominalization can be distinguished—action nominalizations and actor nominalizations. In the former, an example of which is "action", the resulting noun refers to the event or eventuality conveyed by the underlying verb ("act"). In the latter, exemplified by "actor", the resulting noun is rather a participant in the eventuality.

Nouns more generally can be classified as describing eventualities or as describing a participant in an eventuality. The noun "edge" is a clear example of the latter; it is more like "actor". The edge and the edge-ness are distinct.

I will first give the lexical axioms for the nouns in the target texts that seem to be in the "actor" class, since those in the "action" class raise a basic representational issue that we must come to a decision about. In the first axiom, if John's age is 40 years, then x is 40 years, y is John, and e is the eventuality of 40 years being John's age.

$age'(e,x,y) \supset Syn(\text{"age"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is the age of y
$advantage'(e,x,y)$
  $\supset Syn(\text{"advantage"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is an advantage of y
$assembly'(e,x,y) \supset Syn(\text{"assembly"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is an assembly of y
$cost'(e,x,y) \supset Syn(\text{"cost"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is the cost of y
$count'(e,x,y) \supset Syn(\text{"count"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is the count of y (as in "cell count")
$feature'(e,x,y) \supset Syn(\text{"feature"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is a feature of y
$goal'(e,x,y) \supset Syn(\text{"goal"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is a goal of y
$hand'(e,x,y) \supset Syn(\text{"hand"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is a hand of y
$information'(e,x,y)$
  $\supset Syn(\text{"information"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is information about y
$inlet'(e,x,y) \supset Syn(\text{"inlet"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is an inlet to y
$level'(e,x,y,z) \supset Syn(\text{"level"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is the level of y on a scale z
$number'(e,x,y) \supset Syn(\text{"number"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is the number of y
$plan'(e,x,y,z) \supset Syn(\text{"plan"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, e_1, \mathbf{v.inf}, -, -, -, -)$
  x is a plan of y to do z
$pressure'(e,x,y,z) \supset Syn(\text{"pressure"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is the pressure of y on z
$purpose'(e,x,y) \supset Syn(\text{"purpose"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is a purpose of y
$stop'(e,x,y) \supset Syn(\text{"stop"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is a stop of y (as in "bus stop")
$tenant'(e,x,y) \supset Syn(\text{"tenant"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
  x is a tenant of y

$thought'(e, x, y, z)$
$\supset Syn(\text{"thought"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, e_1, \mathbf{thats}, -, -, -, -)$
x is a thought by y of/that z

Two treatments of "action" nominalizations are possible. In the first, the lexical axiom would itself unwind the nominalization into its underlying predicate.

$discuss'(e, x, y, z)$
$\supset Syn(\text{"discussion"}, e, \mathbf{ln.rn}, e, \mathbf{n.sing}, -, -, -, -, -, -)$

If e is a discussing by x of y with z, then e is can be described by the singular noun "discussion". The eventuality conveyed by the noun and the entity referred to are identical in this treatment.

The alternative is to treat nominalizations like every other noun.

$discussion'(e_0, e, x, y, z)$
$\supset Syn(\text{"discussion"}, e_0, \mathbf{ln.rn}, e, \mathbf{n.sing}, -, -, -, -, -, -)$

Here e is a discussion by x of y with z and e_0 is the eventuality of e's *being* a discussion. In this approach the relation between *discuss* and *discussion* is expressed in a separate axiom.

$discuss'(e, x, y, z) \equiv discussion'(e_0, e, x, y, z)$

The second approach seems to add an extra layer of "eventuality-hood", that would better be dispensed with. However, this is the approach we will adopt, first, for consistency with our treatment of other nouns, and, second, because many nominalizations, if not all, carry meaning over and above what is conveyed by the underlying verb, and we may want to relate the two by a more complex collection of axioms in the knowledge base.

For consistency with other lexical axioms for nouns, we will use the variable names as in $discussion'(e, x, y, z, v)$ rather than as in $discussion'(e_0, e, x, y, z)$. The x argument will represent an eventuality. The first of these expressions will say that x is a discussion by y of z with v and e is the eventuality of x's being a discussion.

In the glosses of the predications in the lexical axioms below, the e argument will be ignored, since saying "e is x's being a change in y" rather than "x is a change in y" seems very pedantic.

$change'(e, x, y) \supset Syn(\text{"change"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
x is a change in y
$death'(e, x, y) \supset Syn(\text{"death"}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$

x is the death of y
$decay'(e, x, y) \supset Syn($"decay"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the decay of y
$demo'(e, x, y) \supset Syn($"demo"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is a demo of y
$glare'(e, x, y) \supset Syn($"glare"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the glare of y
$incubation'(e, x, y)$
$\supset Syn($"incubation"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the incubation of y
$infection'(e, x, y, z)$
$\supset Syn($"infection"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the infection by y of z
$interchange'(e, x, y, z)$
$\supset Syn($"interchange"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the interchange of y with z
$investigation'(e, x, y, z)$
$\supset Syn($"investigation"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the investigation by y of z
$life'(e, x, y) \supset Syn($"life"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the life of y
$loss'(e, x, y, z) \supset Syn($"loss"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the loss by y of z
$love'(e, x, y, z) \supset Syn($"love"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the love by y of z
$occurrence'(e, x, y)$
$\supset Syn($"occurrence"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the occurrence of y
$operation'(e, x, y)$
$\supset Syn($"operation"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the operation of y, say, of machinery
$presentation'(e, x, y, z, v)$
$\supset Syn($"presentation"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the presentation by y of z to v
$rage'(e, x, y) \supset Syn($"rage"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the rage of y
$replacement'(e, x, y, z, v)$
$\supset Syn($"replacement"$, e,$**ln.rn**$, x,$**n.sing**$, -, -, -, -, -, -)$
x is the replacement by y of z with v
$replication'(e, x, y, z)$

$\supset Syn(\text{“replication”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
x is the replication by y of z
$ruin'(e, x, y, z) \supset Syn(\text{“ruin”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
x is the ruining by y of z
$speech'(e, x, y) \supset Syn(\text{“speech”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
x is the speech of y
$state'(e, x, y) \supset Syn(\text{“state”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
x is the state of y
$talk'(e, x, y, z) \supset Syn(\text{“talk”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
x is the talking by y to z
$trade'(e, x, y, z, v) \supset Syn(\text{“trade”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
x is the trade by y of z with v
$treatment'(e, x, y, z, v)$
$\supset Syn(\text{“treatment”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
x is the treatment by y of z for v
$upsurge'(e, x, y) \supset Syn(\text{“upsurge”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
x is an upsurge by y
$usage'(e, x, y, z) \supset Syn(\text{“usage”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
x is the usage by y of z
$view'(e, x, y, z) \supset Syn(\text{“view”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, z, \mathbf{thats}, -, -, -, -)$
x is the view by y of/that z
$wear'(e, x, y) \supset Syn(\text{“wear”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$
x is y's getting worn

Gerunds can occur anywhere nouns can. The following alternation axiom captures this.

$$Syn(w, e, \mathbf{v.ing}, x, a, y, b, z, c, -, -)$$
$$\supset Syn(w, e, \mathbf{ln.rn}, e, \mathbf{n.sing}, -, -, -, -, -, -)$$

This allows a string w to function as a noun in all noun contexts, and finally be reduced to a gerund. In “giving”, e is the giving, and x, y and z are the giver, the gift, and the gifted. The latter are lost in the gerund usage, and recoverable only pragmatically. I have not included the eventuality of e *being* a giving, as in other action nominalizations, because a general way of stating that is not obvious.

Plurals of gerunds, as in

John's comings and goings

would first be stripped of the “s” by the noun morphology rule and then reduced to the gerund by the above axiom.

4.10.4 Proper Noun Phrases and Personal Pronouns

Proper names function as NPs. As described in Chapter 2, they will be treated as predicates. Their lexical axioms will be expressed in the internal form for NPs rather than the external form, since they can function not only as independent NPs, but also as head nouns in more elaborated NPs, as in

A discouraged Bill Clinton faced the press.
Roger Schank is the Newt Gingrich of artificial intelligence.

Lexical axioms of the following sort relate the predicate to the word.

$$Brian'(e,x) \supset Syn(\text{“Brian”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$$

If e is the condition of x being Brian, then x can be referred to by the singular noun “Brian”, conveying condition e.

Personal pronouns function as NPs and do not normally function as head nouns. Hence, we can use the external form for NPs for the *Syn* predication. The lexical axiom for “he” is

$$he'(e,x) \supset Syn(\text{“he”}, x, \mathbf{n.sing.nom}, -, -, -, -, -, -, -, -)$$

If e is the condition of x being a “he” (i.e., a male human), then x can be referred to by the nominative singular pronoun “he”, conveying condition e. There are also lexical axioms for the accusative and reflexive forms.

$$he'(e,x) \supset Syn(\text{“him”}, x, \mathbf{n.sing.acc}, -, -, -, -, -, -, -, -)$$
$$he'(e,x) \supset Syn(\text{“himself”}, x, \mathbf{n.sing.refl}, -, -, -, -, -, -, -, -)$$

The constraints on the uses of reflexives and nonreflexive pronouns are discussed below.

The predicates for the first and second person pronouns have an extra argument for the utterance with respect to which the entities are the speaker or hearer, as discussed in Chapter 2. The lexical axioms for these pronouns are as follows:

$$I'(e,x,u) \supset Syn(\text{“I”}, x, \mathbf{n.ego.nom}, -, -, -, -, -, -, -, -)$$
$$I'(e,x,u) \supset Syn(\text{“me”}, x, \mathbf{n.ego.acc}, -, -, -, -, -, -, -, -)$$
$$I'(e,x,u) \supset Syn(\text{“myself”}, x, \mathbf{n.ego.refl}, -, -, -, -, -, -, -, -)$$
$$we'(e,s,u) \wedge plural'(e_0,x,s)$$
$$\supset Syn(\text{“we”}, x, \mathbf{n.pln.nom}, -, -, -, -, -, -, -, -)$$
$$we'(e,s,u) \wedge plural'(e_0,x,s)$$
$$\supset Syn(\text{“us”}, x, \mathbf{n.pln.acc}, -, -, -, -, -, -, -, -)$$
$$we'(e,s,u) \wedge plural'(e_0,x,s)$$

$$\supset Syn(\text{“ourselves”}, x, \mathbf{n.pln.refl}, -, -, -, -, -, -, -, -)$$
$$you'(e, x, u) \supset Syn(\text{“you”}, x, \mathbf{n.pln}, -, -, -, -, -, -, -, -)$$
$$you'(e, x, u) \supset Syn(\text{“yourself”}, x, \mathbf{n.pln}, -, -, -, -, -, -, -, -)$$
$$you'(e, s, u) \wedge plural'(e_0, x, s)$$
$$\supset Syn(\text{“you”}, x, \mathbf{n.pln}, -, -, -, -, -, -, -, -)$$
$$you'(e, s, u) \wedge plural'(e_0, x, s)$$
$$\supset Syn(\text{“yourselves”}, x, \mathbf{n.pln.refl}, -, -, -, -, -, -, -, -)$$

The agreement feature **ego** is to ensure that “I” will occur with “am” and “was” rather than “is”, “are” or “were”. Otherwise, **ego** is a subfeature of **pl**, so that “I” will occur with, for example, “go” instead of “goes”. This treatment is discussed further below in Section 4.10.11.

The predicate *we* can be linked to the predicate *I* in the appropriate way by the axiom

$$we'(e_1, s, u) \wedge plural'(e_2, x, s) \supset I'(e_3, y, u) \wedge member'(e_4, y, s)$$

That is, the set designated by “we” for utterance u includes the individual designated by “I” for u.

The pronoun “you” may be either singular or plural, the only difference being that in the latter case the proposition $plural'(e_0, x, s)$ is part of the meaning.

The predications for the third person pronouns do not have the extra argument for the utterance.

$$she'(e, x) \supset Syn(\text{“she”}, x, \mathbf{n.sing.nom}, -, -, -, -, -, -, -, -)$$
$$she'(e, x) \supset Syn(\text{“her”}, x, \mathbf{n.sing.acc}, -, -, -, -, -, -, -, -)$$
$$she'(e, x) \supset Syn(\text{“herself”}, x, \mathbf{n.sing.refl}, -, -, -, -, -, -, -, -)$$
$$it'(e, x) \supset Syn(\text{“it”}, x, \mathbf{n.sing}, -, -, -, -, -, -, -, -)$$
$$it'(e, x) \supset Syn(\text{“itself”}, x, \mathbf{n.sing.refl}, -, -, -, -, -, -, -, -)$$
$$they'(e, s) \wedge plural'(e_0, x, s)$$
$$\supset Syn(\text{“they”}, x, \mathbf{n.pln.nom}, -, -, -, -, -, -, -, -)$$
$$they'(e, s) \wedge plural'(e_0, x, s)$$
$$\supset Syn(\text{“them”}, x, \mathbf{n.pln.acc}, -, -, -, -, -, -, -, -)$$
$$they'(e, s) \wedge plural'(e_0, x, s)$$
$$\supset Syn(\text{“themselves”}, x, \mathbf{n.pln.refl}, -, -, -, -, -, -, -, -)$$

4.10.5 Headless Noun Phrases

Frequently an NP will lack a head noun, as in “that”, “three”, and “the best”. This phenomenon could be handled by abduction. When a head is missing, the proposition

$$Syn(\text{``''}, e, \mathbf{ln.rn}, x, \mathbf{n}, -, -, -, -, -, -)$$

could simply be assumed, supplying the variables, otherwise unconstrained, that the adjective or determiner phrase adds properties to. This process may sometimes be operating, as when we hear "The ..." and know what the speaker is referring to, even if she does not continue.

But headless NPs are really a more regular phenomenon than should be handled by an exception mechanism. The other way to allow them is to define an empty $\overline{\mathbf{N}}$ with the *LEFT* and *RIGHT* features **le.re** and to subcategorize the relevant determiners and adjectives for headless $\overline{\mathbf{N}}$s. The two axioms that define singular and plural empty $\overline{\mathbf{N}}$s are

$$entity'(e, x) \supset Syn(\text{``''}, e, \mathbf{le.re}, x, \mathbf{n}, -, -, -, -, -)$$
$$plural'(e_0, x, s) \supset Syn(\text{``''}, e_0, \mathbf{le.re}, x, \mathbf{n}, -, -, s, -, -)$$

The empty string can function as a noun referring to x, but it is classified as **le.re**, which prevents it from being an NP by itself and restricts the adjectives and determiners with which it can combine. When an appropriate adjective or determiner is attached, the resulting phrase will have the *LEFT* feature **la** or **ld**, and, as we will see, the *RIGHT* feature **rn** or **rc**, and hence it can be converted into an NP.

The antecedent $entity'(e, x)$ is included in the first axiom because the e argument is required by the NP composition rules, and therefore needs to be *something*, albeit semantically empty.

Headless NPs can have noun complements, as in "those in command" and "the three who arrived early". The noun complement has to be attached to the empty head first, since the property it provides has to be one of the conjuncts in the eventuality argument of the determiner. (In other words, the determiner scopes over it.) But the result of concatenating the empty head with the noun complement retains the **le** feature, so that a lone noun complement can't become an NP.

We will see below in lexical axioms for determiners and some adjectives how headless $\overline{\mathbf{N}}$s are made eligible to become NPs.

4.10.6 The Adjective Position

The treatment of prenominal attributive adjectives—the simple case in which the logical subject of the adjective's predication is the entity x referred to by the head noun—was discussed above. But there are a number of other constructions that can appear in the adjective position of the English NP, and some of these are discussed here.

First, opaque adjectives: An artificial flower is not a flower, a fake Rembrandt is not a Rembrandt, an alleged murderer is not necessarily a murderer, and a former president is no longer a president. All of these adjectives provide a property not for the entity x referred to by the head noun but for the eventuality conveyed by the head noun. It is the flower-ness that is artificial, the Rembrandt-ness that is fake, the being a murderer that is alleged, and the being president that is former. The logical subjects of the predicates for these adjectives are not the x arguments but the e arguments. Whereas the logical form of "red flower" is

$$red'(e_1, x) \wedge flower'(e_2, x)$$

the logical form of "artificial flower" is

$$artificial'(e_1, e_2) \wedge flower'(e_2, x)$$

The lexical axiom for "artificial" is as follows:

$$artificial'(e_1, e_2) \supset Syn(\text{“artificial”}, e_1, \mathbf{ls}, e_2, \mathbf{lan}, x, \mathbf{n}, s, -, -, -)$$

If e_1 is the eventuality of another property e_2 being artificial, then e_1 can be conveyed by the adjective "artificial", applied to a partial $\overline{\mathbf{N}}$ conveying the property e_2 and referring to x, possibly with the associated set s.

The lexical axioms for some other opaque adjectives:

$$alleged'(e_1, e_2) \supset Syn(\text{“alleged”}, e_1, \mathbf{la}, e_2, \mathbf{lan}, x, \mathbf{n}, s, -, -, -)$$
$$fake'(e_1, e_2) \supset Syn(\text{“fake”}, e_1, \mathbf{la}, e_2, \mathbf{lan}, x, \mathbf{n}, s, -, -, -)$$
$$former'(e_1, e_2) \supset Syn(\text{“former”}, e_1, \mathbf{la}, e_2, \mathbf{lan}, x, \mathbf{n}, s, -, -, -)$$

I have given the lexical axioms for these adjectives only for their prenominal uses. They are either unacceptable or a bit peculiar when they appear in predicate complement position.

* The murderer is alleged.
* The president is former.
? That flower is artificial.
? That Rembrandt is fake.

We can see those cases where the use is peculiar rather than unacceptable as cases of metonymy (cf. Section 4.17), where the coercion is, say, from the flower x to the flower-hood e via the coercion relation $flower'(e, x)$.

"Set adjectives" are another variety of adjective. A set adjective takes as its logical subject not the entity x referred to by its head noun but the associated set s. "Numerous" is an example. Like the opaque adjectives, they are more comfortable in prenominal position. If we write the lexical axiom directly for the prenominal position, then we can be explicit in making s the logical subject.

$$numerous'(e_1, s) \\ \quad \supset Syn(\text{"numerous"}, e_1,\mathbf{la}, e_2,\mathbf{lan}, x,\mathbf{n}, s, -, -, -)$$

If e_1 is the eventuality of set s being numerous, then e_1 can be conveyed by the adjective "numerous", applied to a partial $\overline{\mathbf{N}}$ conveying the property e_2, referring to the typical element x of the set s.

On the other hand, such adjectives can appear as predicate complement.

The protesters were numerous.
The crowd was numerous.

If the logical subject of the adjective is a collective noun like "crowd", there is no problem; that really is its logical subject. However, if it is a plural NP, then since we are not passing a pointer to s above the level of the NP, we cannot identify the logical subject as s directly in the syntactic rules. The logical subject will be x. However, we can again view the correct logical subject as resulting from the pragmatic process of metonymy, where the coercion from x to s is via the relation $plural'(e, x, s)$ introduced by the plural morpheme. This coercion is promoted if we place the selectional constraint on the logical subject that it be a set. Thus, the lexical axiom for "numerous", as a predicate adjective, would be

$$numerous'(e, x) \wedge set(x) \\ \quad \supset Syn(\text{"numerous"}, e,\mathbf{adj}, x,\mathbf{n}, -, -, -, -, -, -)$$

When x is a collective, the constraint is satisfied. When it is the typical element of a set, it is coerced to the set.

Another variety of adjective is the noun-like adjective. A presidential retreat is not a retreat that is presidential but a retreat that bears some relation to the president. The adjective functions as though it were a prenominal noun.

Although these adjectives are also more comfortable in prenominal than in predicate complement position, we will give their lexical axioms for the latter, since they do occur.

$$president'(e_1, y) \wedge nn'(e_2, y, x) \\ \quad \supset Syn(\text{"presidential"}, e_1\&e_2,\mathbf{adj.nounlike}, x,\mathbf{n}, -, -, -, -, -, -)$$

That is, if e_1 is the condition of y being a president and e_2 is some nn relation between y and x, then the conjunction of e_1 and e_2 can be conveyed by the adjective "presidential" whose subject is an NP referring to x.

The conversion of noun-like adjectives from predicate complement to prenominal position can be accomplished by the alternation axiom (4.23). However, there is a little twist worth mentioning. Noun-like adjectives differ from other adjectives in that they can intermix freely with prenominal nouns, modifying the head noun, as in

> the Gettysburg presidential retreat.

Thus, the alternation axiom for these adjectives would have to specify that the composite phrase is of type **ln** rather than **la**. They can moreover conjoin with prenominal nouns, as in

> the asymptomatic or incubation period.

The lexical axioms for the noun-like adjectives in the target texts are as follows:

$$\begin{array}{l} day'(e_1, y) \wedge nn'(e_2, y, x) \\ \quad \supset Syn(\text{“daily”}, e_1\&e_2, \mathbf{adj.nounlike}, x, \mathbf{n}, -, -, -, -, -, -) \\ metal'(e_1, y) \wedge nn'(e_2, y, x) \\ \quad \supset Syn(\text{“metallic”}, e_1\&e_2, \mathbf{adj.nounlike}, x, \mathbf{n}, -, -, -, -, -, -) \\ die'(e_1, y) \wedge nn'(e_2, y, x) \\ \quad \supset Syn(\text{“mortal”}, e_1\&e_2, \mathbf{adj.nounlike}, x, \mathbf{n}, -, -, -, -, -, -) \\ symptom'(e_1, y) \wedge nn'(e_2, y, x) \\ \quad \supset Syn(\text{“symptomatic”}, e_1\&e_2, \mathbf{adj.nounlike}, x, \mathbf{n}, -, -, -, -, -, -) \\ city'(e_1, y) \wedge nn'(e_2, y, x) \\ \quad \supset Syn(\text{“urban”}, e_1\&e_2, \mathbf{adj.nounlike}, x, \mathbf{n}, -, -, -, -, -, -) \\ virus'(e_1, y) \wedge nn'(e_2, y, x) \\ \quad \supset Syn(\text{“viral”}, e_1\&e_2, \mathbf{adj.nounlike}, x, \mathbf{n}, -, -, -, -, -, -) \\ water'(e_1, y) \wedge nn'(e_2, y, x) \\ \quad \supset Syn(\text{“watery”}, e_1\&e_2, \mathbf{adj.nounlike}, x, \mathbf{n}, -, -, -, -, -, -) \end{array}$$

It should be pointed out that any of these adjectives could have been related in their lexical axioms to a predicate of the same name and the relation to the underlying noun concept expressed as another axiom in the knowledge base.

$$\begin{array}{l} president'(e_1, y) \wedge nn'(e_2, y, x) \supset presidential'(e_3, x) \\ presidential'(e_3, x) \\ \quad \supset Syn(\text{“presidential”}, e_3, \mathbf{adj.nounlike}, x, \mathbf{n}, -, -, -, -, -, -) \end{array}$$

Two more adjectives in the target texts occur only in the prenominal position. Their lexical axioms are

$$main'(e_1, x, s_1) \supset Syn(\text{“main”}, e_1,\mathbf{la}, e_2,\mathbf{lan}, x,\mathbf{n}, s, -, -, -)$$
$$sometime'(e_1, x) \supset Syn(\text{“sometime”}, e_1,\mathbf{la}, e_2,\mathbf{lan}, x,\mathbf{n}, s, -, -, -)$$

The second argument s_1 of *main* is an implicit comparison set.

The logical form for the $\overline{\mathbf{N}}$ in the comparative

a more serious man

is

$$more'(e_1, x, y, e_2) \wedge serious'(e_2, z) \wedge man'(e_3, x)$$

That is, the man x is higher than some unspecified y on a scale defined by the property e_2 of some indefinite z being serious. z can be thought of as a lambda-abstracted variable. Inferences involving comparatives will utilize substitutions for z in the adjective's predication, as seen in Section 4.15 and in Chapter 5.

To see how we should express the lexical axiom for “more”, consider the sentence

John is more serious.

We can view “more” as an operator that takes an adjective phrase, “serious”, as its complement, yielding a composite phrase that is also an adjective phrase—“more serious”—that then takes an NP subject, “John”. Since the subject x of the “more” eventuality does not become the subject of the adjective, the Object Composition Rule is the complement rule that applies, rather than the Subject Control Rule.

$$more'(e_1, x, y, e_2) \supset Syn(\text{“more”}, e,\mathbf{adj}, x,\mathbf{n.sb}, e_2,\mathbf{adj.ob}, -, -, -, -)$$

The rules for “most”, “less”, and “least” are similar.

$$most_2'(e_1, x, s, e_2) \supset Syn(\text{“most”}, e,\mathbf{adj}, x,\mathbf{n.sb}, e_2,\mathbf{adj.ob}, -, -, -, -)$$
$$less'(e_1, x, y, e_2) \supset Syn(\text{“less”}, e,\mathbf{adj}, x,\mathbf{n.sb}, e_2,\mathbf{adj.ob}, -, -, -, -)$$
$$least'(e_1, x, s, e_2) \supset Syn(\text{“least”}, e,\mathbf{adj}, x,\mathbf{n.sb}, e_2,\mathbf{adj.ob}, -, -, -, -)$$

In the lexical axiom for “most”, the predicate $most_2$ is used. The predicate $most_1$ corresponds to the determiner “most”. The second argument s of $most_2$ and *least* is an implicit comparison set.

The treatment of preadjectival adverbs, like “very”, is similar. The lexical axiom for “very” is

$$very'(e_1, e_2) \supset Syn(\text{“very”}, e_1, \mathbf{adj}, x, \mathbf{n.sb}, e_2, \mathbf{adj.sc}, -, -, -, -)$$

“Very” is treated as something like a Raising verb. It takes an adjective as its complement. It passes its subject x down to the complement via the Subject Control Composition Rule, but it does not use the subject in its own predication. The axiom says that if e_1 is the condition of another eventuality e_2 holding to a very great extent, then e_1 can be described by the word “very” taking an adjective denoting e_2 as its complement to produce an adjective phrase that can take an NP as its subject, where the referent x of the NP will be the logical subject of the adjective.

Three interesting compound adjectival constructions occur in the target texts:

a three-foot high fence
a two-room flat
a double-barrelled shotgun

It is not obvious that these constructions are examples of more general patterns, so there seems little to do but to write individual rules for each of them.

The logical form for “three-foot high fence” is

$$three'(e_1, s) \wedge plural'(e_2, y, s) \wedge foot'(e_3, y) \wedge measure'(e_4, x, s, e_5) \\ \wedge high'(e_5, z) \wedge fence'(e_6, x)$$

That is, there is a set s of three feet y such that a fence x has the measure s on the scale defined by the highness e_5 of some indefinite z. This treatment of measures is developed in Chapter 5.

The rule that generates this logical form is the following complicated beast:

$$Syn(w_1, e_1, \mathbf{number}, e_3, f_3{:}\mathbf{ln.rn}, y, b{:}b_{NUM}, s, -, -, -) \\ \wedge Syn(w_2, e_3, f_3, y, b{:}\mathbf{nmeasure.sing}, -, -, -, -, -, -) \\ \wedge Syn(w_3, e_5, \mathbf{adj}, z, \mathbf{n}, -, -, -, -, -, -) \\ \wedge plural'(e_2, y, s) \wedge measure'(e_4, x, s, e_3) \\ \supset Syn(w_1\text{“-”}w_2 w_3, e_1\&e_2\&e_3\&e_4\&e_5, \mathbf{la}, e_6, \mathbf{lan}, x, \mathbf{n}, s_1, -, -, -)$$

The treatment of numbers is described below, but the structure of the first *Syn* predication is the same as for prenominal adjectives. Essentially, it says that w_1 is a number corresponding to a cardinality property e_1 of the set s and that it can be applied to a partial $\overline{\mathbf{N}}$ of structure **nn** referring to y. The set s has typical element y. w_2 is a singular measure noun, regardless of the

NUM feature of w_1, referring to y, and e_3 is the property conveyed by the noun (being a foot). w_3 is an adjective, providing a property e_5 that defines a scale (height). If these three facts about the words hold, and if e_2 is the property of y being the typical element of s and e_4 is the property of some entity x having measure s on the scale defined by e_5, then the concatenation of these three words, with a hyphen, conveys the conjunction of e_1, e_2, e_3, e_4, and e_5, and constitutes a phrase that can function as a prenominal adjective, to be applied to a head noun referring to x (the fence), conveying property e_6 (fence-hood) and possibly having associated set s_1 (as in "three-foot high fences").

The logical form for "two-room flat" is

$$two'(e_1, s) \wedge plural'(e_2, y, s) \wedge room'(e_3, y) \wedge nn'(e_4, s, x) \\ \wedge flat'(e_5, x)$$

That is, there is a set s of two rooms, whose typical element is y, such that a flat x bears some relation *nn* to s. In this case, the relation is *consist-of*, but in other examples other relations are conveyed. In "two-car garage" the garage can contain two cars, and in "two-alarm fire" the fire set off two alarms. I have assumed that the relation encoded is as open as that encoded in compound nominals.

The rule that generates this logical form is the following:

$$Syn(w_1, e_1, \mathbf{number}, e_3, f_3{:}\mathbf{ln.rn}, y, b{:}b_{NUM}, s, -, -, -) \\ \wedge Syn(w_2, e_3, f_3, y, b{:}\mathbf{n.sing}, -, -, -, -, -, -) \\ \wedge plural'(e_2, y, s) \wedge nn'(e_4, s, x) \\ \supset Syn(w_1\text{“-”}w_2, e_1\&e_2\&e_3\&e_4, \mathbf{la}, e_5, \mathbf{lan}, x, \mathbf{n}, s_1, -, -, -)$$

If w_1 is a number expressing the cardinality (property e_1) of a set s whose typical element is y (property e_2), w_2 is a noun referring to y and conveying the property e_3, and e_4 is the *nn* relation between s and x, then the concatenation of the two words, with a hyphen in between, conveys the conjunction of e_1, e_2, e_3, and e_4, and constitutes a phrase that can function as a prenominal adjective, to be applied to a head noun referring to x, conveying property e_5, and possibly having associated set s_1. The noun w_2 is singular regardless of the number of w_1.

The expression "three-foot fence", without the adjective, falls under this rule, where *nn* is interpreted as *measure*.

The logical form of "double-barrelled shotgun" is

$$double'(e_1, y) \wedge barrel'(e_2, y) \wedge inalienable\text{-}possession'(e_3, y, x) \\ \wedge shotgun'(e_4, x)$$

As Davis (19??) argues, the noun that is turned into the past participle of a verb must represent an inalienable possession of the head noun.

a good-hearted man
* an expensive-carred executive

The logical form says that there is a barrel y that is double and that it is the inalienable possession of a shotgun x.

The rule that generates this logical form is the following:

$$\begin{aligned}&Syn(w_1, e_1,\mathbf{adj}, y,\mathbf{n}, -, -, -, -, -, -)\\ &\quad \wedge VMorph(w_2, w, e_2,\mathbf{v.en}, e_2,\mathbf{n})\\ &\quad \wedge Syn(w, e_2,\mathbf{nn}, y,\mathbf{n.sing}, -, -, -, -, -, -)\\ &\quad \wedge \textit{inalienable-possession}'(e_3, y, x)\\ &\supset Syn(w_1\text{"-"}w_2, e_1\&e_2\&e_3,\mathbf{la}, e_4,\mathbf{lan}, x,\mathbf{n}, s_1, -, -, -)\end{aligned}$$

If w_1 is an adjective conveying property e_1 of y, if w_2 would be the past participle form of a noun w were it a verb, if w is a singular noun referring to y and conveying property e_2, and if e_3 is the property of y being an inalienable possession of x, then the concatenation of w_1 and w_2, with a hyphen in between, conveys the conjunction of e_1, e_2, and e_3, and constitutes a phrase that can function as a prenominal adjective, to be applied to a head noun referring to x, conveying property e_4 and possibly having associated set s_1.

4.10.7 Inflectional and Derivational Adjective Morphology

I will not attempt to characterize the complex and surprisingly rare conditions under which an adjective can take an "er" or "est" ending. Of the adjectives in the target texts, only one-syllable adjectives and two-syllable adjectives whose second syllable is unstressed "y" inflect for comparative and superlative. These axioms only handle some of the forms when they do occur.

$$\begin{aligned}&Syn(w, e_1, f{:}\mathbf{adj}, x_1, a{:}\mathbf{n}, -, -, -, -, -, -) \wedge more'(e, x, y, e_1)\\ &\quad \supset Syn(w\text{"er"}, e, f, x, a, -, -, -, -, -, -)\\ &Syn(w\text{"e"}, e_1, f{:}\mathbf{adj}, x_1, a{:}\mathbf{n}, -, -, -, -, -, -) \wedge more'(e, x, y, e_1)\\ &\quad \supset Syn(w\text{"er"}, e, f, x, a, -, -, -, -, -, -)\\ &Syn(w\text{"y"}, e_1, f{:}\mathbf{adj}, x_1, a{:}\mathbf{n}, -, -, -, -, -, -) \wedge more'(e, x, y, e_1)\\ &\quad \supset Syn(w\text{"ier"}, e, f, x, a, -, -, -, -, -, -)\\ &Syn(w, e_1, f{:}\mathbf{adj}, x_1, a{:}\mathbf{n}, -, -, -, -, -, -) \wedge most'(e, x, s, e_1)\\ &\quad \supset Syn(w\text{"est"}, e, f, x, a, -, -, -, -, -, -)\end{aligned}$$

$$Syn(w\text{“e”}, e_1, f{:}\mathbf{adj}, x_1, a{:}\mathbf{n}, -, -, -, -, -, -) \wedge most'(e, x, s, e_1)$$
$$\supset Syn(w\text{“est”}, e, f, x, a, -, -, -, -, -, -)$$
$$Syn(w\text{“y”}, e_1, f{:}\mathbf{adj}, x_1, a{:}\mathbf{n}, -, -, -, -, -, -) \wedge most'(e, x, s, e_1)$$
$$\supset Syn(w\text{“iest”}, e, f, x, a, -, -, -, -, -, -)$$

Axioms like the following handle the irregular cases.

$$Syn(\text{“good”}, e_1, f{:}\mathbf{adj}, x_1, a{:}\mathbf{n}, -, -, -, -, -, -) \wedge more'(e, x, y, e_1)$$
$$\supset Syn(\text{“better”}, e, f, x, a, -, -, -, -, -, -)$$
$$Syn(\text{“good”}, e_1, f{:}\mathbf{adj}, x_1, a{:}\mathbf{n}, -, -, -, -, -, -) \wedge most'(e, x, s, e_1)$$
$$\supset Syn(\text{“best”}w, e, f, x, a, -, -, -, -, -, -)$$

The three following axioms introduce the negation that is conveyed through derivational morphology in “a-”, “non-” and “un-” adjectives, as in “asymptomatic”, “non-metallic”, and “undetectable”.

$$Syn(w, e_1, f{:}\mathbf{adj}, x, a, y, b, z, c, -, -) \wedge not'(e, e_1)$$
$$\supset Syn(\text{“a”}w, e, f, x, a, y, b, z, c, -, -)$$
$$Syn(w, e_1, f{:}\mathbf{adj}, x, a, y, b, z, c, -, -) \wedge not'(e, e_1)$$
$$\supset Syn(\text{“non-”}w, e, f, x, a, y, b, z, c, -, -)$$
$$Syn(w, e_1, f{:}\mathbf{adj}, x, a, y, b, z, c, -, -) \wedge not'(e, e_1)$$
$$\supset Syn(\text{“un”}w, e, f, x, a, y, b, z, c, -, -)$$

For example, since “symptomatic” is a noun-like adjective, the logical form for “asymptomatic patient” is

$$not'(e_1, e_3) \wedge symptom'(e_2, y, z) \wedge nn'(e_3, y, x) \wedge patient'(e_4, x)$$

That is, the negation e_1 of a relation e_3 between a symptom y of z and a patient x holds.

Also from derivational morphology are “able” adjectives, such as “detectable”, derived from transitive verbs.

$$Syn(w, e_1, \mathbf{v.tnsless}, x, a, y, b{:}\mathbf{n}, z, c, -, -) \wedge can'(e, x, e_1)$$
$$\supset Syn(w\text{“able”}, e, \mathbf{adj}, y, b, z, c, -, -)$$

The logical form for “undetectable antigen” is

$$not'(e_1, e_2) \wedge can'(e_2, x, e_3) \wedge detect'(e_3, x, y) \wedge antigen'(e_4, y)$$

That is, the negation e_1 of someone X's ability e_2 to detect an antigen y is conveyed. In backchaining, first the “un” is stripped off to make it “not detectable”, and then the “able” is stripped off to mke it “not able to detect”. The one doing the detecting (x) has to be determined pragmatically, if relevant.

4.10.8 Determiner Phrases

The complexity of the English determiner phrase can be seen from the following examples:

other books
many other books
too many other books
ten too many other books
as few as ten too many other books
not as few as ten too many other books

Determiners can be combined to form very complex phrases.

At the same time, however, there are constraints on which determiners can be combined with which other determiners. For example,

All the forest was destroyed.
* All a forest was destroyed.
the three other books
three other books
the other three books
* other the three books
* other three books
the many other books
? the other many books
any such book
* such any book
* a such book
such a book
as few as five books
* as few as several books
all three books
* both two books
the only book
* this only book

No attempt will be made in this development to account for this pattern of acceptable and unacceptable combinations. No generalizations are apparent, and such an attempt would be mired in unenlightening detail. I will simply assume that determiners can be combined with other determiners.

The structure of the *Syn* predication for determiners is the same as that for prenominal adjectives and nouns.

Numbers and several other determiners such as "several" and "a few", express a property about the cardinality of the set associated with the NP. Here is the lexical axiom for "several":

$$several'(e_1, s)$$
$$\supset Syn(\text{"several"}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.pln}, s, -, -, -)$$

If e_1 is the property of the set s having several elements, then e_1 can be expressed by the determiner "several" applied to a plural partial NP conveying property e_2 and referring to the set s, whose typical element is x. The **ld** option in the *LEFT* feature of the string "several" is attached to is because "several" can sometime precede other determiners, as in "several other".

In addition, "several" can appear with an empty head, with or without a noun complement.

Several were tall.
Several of the men were tall.

The following lexical axiom handles this case.

$$several'(e_1, s)$$
$$\supset Syn(\text{"several"}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.pln}, s, -, -, -)$$

If e_1 is the property of the set s having several elements, then e_1 can be expressed by the determiner "several" concatenated with a plural empty head conveying property e_2 and referring to the set s, whose typical element is x. Because the leftmost element in the partial $\overline{\mathbf{N}}$ must be the empty head (**le**), we rule out examples like "Several old of the men were tall." The resulting string will have *RIGHT* feature of **rnc**, which allows it to be converted into the external reprepresentation for an NP by rule (4.26). This loses the information of whether there is a noun complement, but that is no longer needed at this point.

Other lexical axioms with a similar structure are as follows:

$$a\text{-}few'(e_1, s)$$
$$\supset Syn(\text{"a few"}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.pln}, s, -, -, -)$$
$$a\text{-}few'(e_1, s)$$
$$\supset Syn(\text{"a few"}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.pln}, s, -, -, -)$$
$$many'(e_1, s)$$
$$\supset Syn(\text{"many"}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.pln}, s, -, -, -)$$
$$many'(e_1, s)$$
$$\supset Syn(\text{"many"}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.pln}, s, -, -, -)$$

Numbers will be dealt with below.

The determiner "much" is similar to "many" in that it is a characterization of the quantity of what it modifies, but here the quantity is an aggregate rather than a set, and the NP must be singular. Its lexical axioms are

$$much'(e_1, x) \supset Syn(\text{"much"}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.sing}, -, -, -, -)$$
$$much'(e_1, x) \supset Syn(\text{"much"}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.sing}, -, -, -, -)$$

If e_1 is the property of there being much of a substance x, then e_1 can be expressed by the determiner "much" applied to a singular partial NP conveying property e_2 and referring to x.

The determiner "more" comes in two varieties. It can apply to singular substance nouns, as in "more information", and to plural count nouns, as in "more computers". These two senses are the comparatives of "much" and "many", respectively. The four axioms are

$$much'(e_0, z) \wedge more'(e_1, x, y, e_0) \supset Syn(\text{"more"}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.sing}, -, -, -, -)$$
$$much'(e_0, z) \wedge more'(e_1, x, y, e_0) \supset Syn(\text{"more"}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.sing}, -, -, -, -)$$
$$many'(e_0, z) \wedge more'(e_1, s, y, e_0) \supset Syn(\text{"more"}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.pln}, s, -, -, -)$$
$$many'(e_0, z) \wedge more'(e_1, s, y, e_0) \supset Syn(\text{"more"}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.pln}, s, -, -, -)$$

The first of these axioms says that if e_1 is the property of x being more than some contextually determined y on the scale defined by the property e_0 of there being much of an indefinite entity z (i.e., the scale of much-ness), then e_1 can be expressed by the determiner "more" applied to a singular partial NP conveying property e_2 and referring to x.

The superlative of "much" and "many" is expressed as "the most". Its lexical axioms are as follows:

$$much'(e_0, z) \wedge most'_2(e_1, x, s_1, e_0) \supset Syn(\text{"the most"}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.sing}, -, -, -, -)$$
$$much'(e_0, z) \wedge most'_2(e_1, x, s_1, e_0) \supset Syn(\text{"the most"}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.sing}, -, -, -, -)$$
$$many'(e_0, z) \wedge most'_2(e_1, s, s_1, e_0) \supset Syn(\text{"the most"}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.pln}, s, -, -, -)$$
$$many'(e_0, z) \wedge most'_2(e_1, s, s_1, e_0) \supset Syn(\text{"the most"}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.pln}, s, -, -, -)$$

Here the set s_1 is the contextually determined comparison set for the superlative. x is the highest of all the elements in s_1 on the scale defined by e_0.

The axioms for negative comparatives are similar:

$much'(e_0, z) \wedge less'(e_1, x, y, e_0)$
$\quad \supset Syn(\text{"less"}, e_1,\mathbf{ld}, e_2,\mathbf{ldan}, x,\mathbf{n.sing}, -, -, -, -)$
$much'(e_0, z) \wedge less'(e_1, x, y, e_0)$
$\quad \supset Syn(\text{"less"}, e_1,\mathbf{ld.rnc}, e_2,\mathbf{le}, x,\mathbf{n.sing}, -, -, -, -)$
$many'(e_0, z) \wedge less'(e_1, s, y, e_0)$
$\quad \supset Syn(\text{"fewer"}, e_1,\mathbf{ld}, e_2,\mathbf{ldan}, x,\mathbf{n.pln}, s, -, -, -)$
$many'(e_0, z) \wedge less'(e_1, s, y, e_0)$
$\quad \supset Syn(\text{"fewer"}, e_1,\mathbf{ld.rnc}, e_2,\mathbf{le}, x,\mathbf{n.pln}, s, -, -, -)$
$much'(e_0, z) \wedge least'_2(e_1, x, s_1, e_0)$
$\quad \supset Syn(\text{"least"}, e_1,\mathbf{ld}, e_2,\mathbf{ldan}, x,\mathbf{n.sing}, -, -, -, -)$
$much'(e_0, z) \wedge least'_2(e_1, x, s_1, e_0)$
$\quad \supset Syn(\text{"least"}, e_1,\mathbf{ld.rnc}, e_2,\mathbf{ld}, x,\mathbf{n.sing}, -, -, -, -)$
$many'(e_0, z) \wedge least'_2(e_1, s, s_1, e_0)$
$\quad \supset Syn(\text{"fewest"}, e_1,\mathbf{ld}, e_2,\mathbf{ldan}, x,\mathbf{n.pln}, s, -, -, -)$
$many'(e_0, z) \wedge least'_2(e_1, s, s_1, e_0)$
$\quad \supset Syn(\text{"fewest"}, e_1,\mathbf{ld.rnc}, e_2,\mathbf{le}, x,\mathbf{n.pln}, s, -, -, -)$

Like the comaparatives, the determiner "enough" has an implicit, contextually determined argument. It has singular and plural versions.

$enough'(e_1, x, y)$
$\quad \supset Syn(\text{"enough"}, e_1,\mathbf{ld}, e_2,\mathbf{ldan}, x,\mathbf{n.sing}, -, -, -, -)$
$enough'(e_1, x, y)$
$\quad \supset Syn(\text{"enough"}, e_1,\mathbf{ld.rnc}, e_2,\mathbf{le}, x,\mathbf{n.sing}, -, -, -, -)$
$enough'(e_1, s, y)$
$\quad \supset Syn(\text{"enough"}, e_1,\mathbf{ld}, e_2,\mathbf{ldan}, x,\mathbf{n.pln}, s, -, -, -)$
$enough'(e_1, s, y)$
$\quad \supset Syn(\text{"enough"}, e_1,\mathbf{ld.rnc}, e_2,\mathbf{le}, x,\mathbf{n.pln}, s, -, -, -)$

The first axioms says that if e_1 is the property of there being enough of a substance x for some often contextually determined purpose y, then e_1 can be expressed by the determiner "enough" applied to a singular partial NP conveying property e_2 and referring to x.

A number of determiners express a relation between an entity and the description of the entity given by the rest of the NP. The determiner "the" is one of these, and its lexical axiom is

$$the'(e_1, x, e_2)$$
$$\supset Syn(\text{“the”}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n}, s, -, -, -)$$

If e_1 is the property of x being *the* entity describable in the current context by the property e_2, then e_1 can be expressed by the determiner “the” applied to a partial NP conveying property e_2 and referring to x, possibly with associated set s. The predicate *the* conveys the information that x is mutually uniquely identifiable in context by the description e_2; this semantics for *the* is developed in Chapter 5.

The determiners “a” and “an” have similar lexical axioms:

$$a'(e_1, x, e_2)$$
$$\supset Syn(\text{“a”}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.sing}, -, -, -, -)$$
$$a'(e_1, x, e_2)$$
$$\supset Syn(\text{“an”}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.sing}, -, -, -, -)$$

If e_1 is the property of x being *an* entity describable in the current context by the property e_2, then e_1 can be expressed by the determiners “a” or “an” applied to a partial NP conveying property e_2 and referring to x. The predicate a conveys the information that x is *not* mutually uniquely identifiable in context by the description e_2. There are two ways that this can happen. First, the entity x may be new to the discourse; this gives us the use of “a” in indefinite NPs. Second, the property e_2 may not be mutually known. This gives us the use of “a” in predicate complements, but also uses illustrated by “a discouraged Bill Clinton”; the predicate a conveys the information that some property, either e_2 or some part of it, is not mutually known. This semantics for a is developed in Chapter 5. The treatment of the restriction of “an” to pre-vowel positions is beyond the scope of this book.

The determiners “a” and “the” cannot appear in headless NPs.

The lexical axioms for demonstratives are similar, except that they can appear in headless NPs.

$$this'(e_1, x, e_2)$$
$$\supset Syn(\text{“this”}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.sing}, -, -, -, -)$$
$$this'(e_1, x, e_2)$$
$$\supset Syn(\text{“this”}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.sing}, -, -, -, -)$$
$$that'(e_1, x, e_2)$$
$$\supset Syn(\text{“that”}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.sing}, -, -, -, -)$$
$$that'(e_1, x, e_2)$$
$$\supset Syn(\text{“that”}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.sing}, -, -, -, -)$$

$$
\begin{aligned}
& this'(e_1, x, e_2) \wedge plural'(e_0, x, s) \\
& \quad \supset Syn(\text{“these”}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.pln}, s, -, -, -) \\
& this'(e_1, x, e_2) \wedge plural'(e_0, x, s) \\
& \quad \supset Syn(\text{“these”}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.pln}, s, -, -, -) \\
& that'(e_1, x, e_2) \wedge plural'(e_0, x, s) \\
& \quad \supset Syn(\text{“those”}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.pln}, s, -, -, -) \\
& that'(e_1, x, e_2) \wedge plural'(e_0, x, s) \\
& \quad \supset Syn(\text{“those”}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.pln}, s, -, -, -)
\end{aligned}
$$

The determiners “these” and “those” introduce $plural'(e_0, x, s)$ redundantly, since it will also be introduced by the plural head noun. But this is harmless as the two will factor.

Two other determiners that express properties between the entity x and the property e_2 supplied by the rest of the NP have the following lexical axioms.

$$
\begin{aligned}
& any'(e_1, x, e_2) \\
& \quad \supset Syn(\text{“any”}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n}, s, -, -, -) \\
& any'(e_1, x, e_2) \\
& \quad \supset Syn(\text{“any”}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n}, s, -, -, -) \\
& such'(e_1, x, e_2) \\
& \quad \supset Syn(\text{“such”}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n}, s, -, -, -)
\end{aligned}
$$

“Any” specifies that x is a random entity satisfying the description e_2.

The determiner “most”—represented by the predicate $most_1$—expresses a relation between two sets s_1 and s_2, saying that s_1 is most of s_2. The set s_2 is defined by the rest of the NP that “most” is applied to. The set s_1 is the set that the entire NP refers to. Thus for the phrase “most people” s_2 is the set of all people and s_1 is a subset containing most of them. The lexical axioms for “most” are as follows:

$$
\begin{aligned}
& most'(e_1, s_1, s_2) \wedge dset'(e, s_2, x_2, e_2) \wedge plural'(e_0, x_1, s_1) \\
& \qquad \wedge Syn(w, e_2, f{:}\mathbf{ldan}, x_2, a{:}\mathbf{n.pln}, -, -, s_2, -, -, -) \\
& \quad \supset Syn(\text{“most”}w, e_1 \& e \& e_0 \& e_2, f{:}\mathbf{ld}, x_1, a, -, -, s_1, -, -, -) \\
& most'(e_1, s_1, s_2) \wedge dset'(e, s_2, x_2, e_2) \wedge plural'(e_0, x_1, s_1) \\
& \qquad \wedge Syn(w, e_2, f{:}\mathbf{le}, x_2, a{:}\mathbf{n.pln}, -, -, s_2, -, -, -) \\
& \quad \supset Syn(\text{“most”}w, e_1 \& e \& e_0 \& e_2, f{:}\mathbf{ld.rnc}, x_1, a, -, -, s_1, -, -, -)
\end{aligned}
$$

These axioms are rather complicated because they introduce a new set s_1 with its typical element x_1, and they tighten the interpretation of the $\overline{\mathbf{N}}$ from a not necessarily complete set to the complete set defined by the property conveyed by the $\overline{\mathbf{N}}$. That is, the NP "people" does not necessarily refer to all people, but in "most people", the $\overline{\mathbf{N}}$ "people" does.

The first axiom says that if e_1 is the property of the set s_1 being most of the set s_2, where s_2 is the set (property e) with typical element x_2 and defined by the property e_2, e_0 is the property of x_1 being the typical element of s_1, and w is a partial plural NP referring to set s_2 with typical element x_2 and conveying property e_2, then the concatenation of the word "most" with w is a plural NP referring to x_1 with associated set s_1 conveying the conjunction of e_1, e, e_0, and e_2.

These axioms do not look like ordinary lexical axioms in that a *Syn* predication occurs in the antecedent. But in fact we could view them as lexical axioms with complex selectional constraints. The content of the word "most" is the *most* predication, which is a relation between sets s_1 and s_2. The selectional constraint on s_2 is that it is a defined set referred to and described by the $\overline{\mathbf{N}}$ that "most" will modify.

"Most" also has a mass noun use, in the singular. Here the predication

$$daggregate'(e, x_2, e_2)$$

means that x_2 is the aggregate of all the substance defined by property e_2. For "coffee" x_2 is the aggregate of all coffee. The axioms for this use of "most" are as follows:

$$\begin{aligned}
&most'(e_1, x_1, x_2) \wedge daggregate'(e, x_2, e_2) \\
&\qquad \wedge Syn(w, e_2, f{:}\mathbf{ldan}, x_2, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \\
&\quad \supset Syn(\text{"most"}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld}, x_1, a, -, -, -, -, -, -) \\
&most'(e_1, x_1, x_2) \wedge daggregate'(e, x_2, e_2) \\
&\qquad \wedge Syn(w, e_2, f{:}\mathbf{le}, x_2, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \\
&\quad \supset Syn(\text{"most"}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld.rnc}, x_1, a, -, -, -, -, -, -)
\end{aligned}$$

The determiner "half" has the same two uses. In addition, "all" can be viewed as a limiting case. The axioms for these words are as follows:

$$\begin{aligned}
&all'(e_1, s_1, s_2) \wedge dset'(e, s_2, x_2, e_2) \wedge plural'(e_0, x_1, s_1) \\
&\qquad \wedge Syn(w, e_2, f{:}\mathbf{ldan}, x_2, a{:}\mathbf{n.pln}, -, -, s_2, -, -, -) \\
&\quad \supset Syn(\text{"all"}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld}, x_1, a, -, -, s_1, -, -, -) \\
&all'(e_1, s_1, s_2) \wedge dset'(e, s_2, x_2, e_2) \wedge plural'(e_0, x_1, s_1) \\
&\qquad \wedge Syn(w, e_2, f{:}\mathbf{le}, x_2, a{:}\mathbf{n.pln}, -, -, s_2, -, -, -) \\
&\quad \supset Syn(\text{"all"}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld.rnc}, x_1, a, -, -, s_1, -, -, -) \\
&all'(e_1, x_1, x_2) \wedge daggregate'(e, x_2, e_2) \\
&\qquad \wedge Syn(w, e_2, f{:}\mathbf{ldan}, x_2, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \\
&\quad \supset Syn(\text{"all"}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld}, x_1, a, -, -, -, -, -, -)
\end{aligned}$$

$$
\begin{aligned}
& all'(e_1, x_1, x_2) \wedge daggregate'(e, x_2, e_2) \\
& \quad\quad \wedge Syn(w, e_2, f{:}\mathbf{le}, x_2, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \\
& \quad \supset Syn(\text{“all”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld.rnc}, x_1, a, -, -, -, -, -, -) \\
& half'(e_1, s_1, s_2) \wedge dset'(e, s_2, x_2, e_2) \wedge plural'(e_0, x_1, s_1) \\
& \quad\quad \wedge Syn(w, e_2, f{:}\mathbf{ldan}, x_2, a{:}\mathbf{n.pln}, -, -, s_2, -, -, -) \\
& \quad \supset Syn(\text{“half”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld}, x_1, a, -, -, s_1, -, -, -) \\
& half'(e_1, s_1, s_2) \wedge dset'(e, s_2, x_2, e_2) \wedge plural'(e_0, x_1, s_1) \\
& \quad\quad \wedge Syn(w, e_2, f{:}\mathbf{le}, x_2, a{:}\mathbf{n.pln}, -, -, s_2, -, -, -) \\
& \quad \supset Syn(\text{“half”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld.rnc}, x_1, a, -, -, s_1, -, -, -) \\
& half'(e_1, x_1, x_2) \wedge daggregate'(e, x_2, e_2) \\
& \quad\quad \wedge Syn(w, e_2, f{:}\mathbf{ldan}, x_2, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \\
& \quad \supset Syn(\text{“half”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld}, x_1, a, -, -, -, -, -, -) \\
& half'(e_1, x_1, x_2) \wedge daggregate'(e, x_2, e_2) \\
& \quad\quad \wedge Syn(w, e_2, f{:}\mathbf{le}, x_2, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \\
& \quad \supset Syn(\text{“half”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld.rnc}, x_1, a, -, -, -, -, -, -)
\end{aligned}
$$

The determiner “some” has two senses. In

Some idiot broke this.

“some” is more like “a”. It conveys a relation between the referent of “some idiot” and the property of being an idiot. In

I need some nails.

“some” expresses a relation between two sets, the set of all nails and the set I need. It is similar to “most”. The first of these senses will have the predicate $some_1$ and the second $some_2$. The lexical axiom for the first sense is

$$
\begin{aligned}
& some'_1(e_1, x, e_2) \\
& \quad \supset Syn(\text{“some”}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.sing}, -, -, -, -)
\end{aligned}
$$

The second sense, $some_2$, has plural count and singular mass cases—“some nails” and “some coffee”.

$$
\begin{aligned}
& some'_2(e_1, s_1, s_2) \wedge dset'(e, s_2, x_2, e_2) \wedge plural'(e_0, x_1, s_1) \\
& \quad\quad \wedge Syn(w, e_2, f{:}\mathbf{ldan}, x_2, a{:}\mathbf{n.pln}, -, -, s_2, -, -, -) \\
& \quad \supset Syn(\text{“some”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld}, x_1, a, -, -, s_1, -, -, -) \\
& some'_2(e_1, s_1, s_2) \wedge dset'(e, s_2, x_2, e_2) \wedge plural'(e_0, x_1, s_1) \\
& \quad\quad \wedge Syn(w, e_2, f{:}\mathbf{le}, x_2, a{:}\mathbf{n.pln}, -, -, s_2, -, -, -) \\
& \quad \supset Syn(\text{“some”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld.rnc}, x_1, a, -, -, s_1, -, -, -) \\
& some'_2(e_1, x_1, x_2) \wedge daggregate'(e, x_2, e_2)
\end{aligned}
$$

$$\begin{array}{l} \quad \wedge\, Syn(w, e_2, f{:}\mathbf{ldan}, x_2, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \\ \supset\, Syn(\text{“some”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld}, x_1, a, -, -, -, -, -, -) \\ some_2'(e_1, x_1, x_2) \wedge daggregate'(e, x_2, e_2) \\ \quad \wedge\, Syn(w, e_2, f{:}\mathbf{le}, x_2, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \\ \supset\, Syn(\text{“some”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld.rnc}, x_1, a, -, -, -, -, -, -) \end{array}$$

Note that the second sense of “some”, but not the first, can occur with an empty head.

The treatment of monotone decreasing quantifiers such as “little”, “few” and “no” was sketched in Chapter 2, Section 2.4.6, and is addressed again below in Section 4.17.6. They raise the problem that the logical form for sentences involving them cannot adequately be constructed from information in the NP alone. Our approach to this problem is to generate a logical form in the lexical axioms that parallels those of “most”. In Chapter 6 (and in Hobbs (1995)) it is shown how this can then be strengthened into the required logical form.

$$\begin{array}{l} few'(e_1, s_1, s_2) \wedge dset'(e, s_2, x_2, e_2) \wedge plural'(e_0, x_1, s_1) \\ \quad \wedge\, Syn(w, e_2, f{:}\mathbf{ldan}, x_2, a{:}\mathbf{n.pln}, -, -, s_2, -, -, -) \\ \supset\, Syn(\text{“few”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld}, x_1, a, -, -, s_1, -, -, -) \\ few'(e_1, s_1, s_2) \wedge dset'(e, s_2, x_2, e_2) \wedge plural'(e_0, x_1, s_1) \\ \quad \wedge\, Syn(w, e_2, f{:}\mathbf{le}, x_2, a{:}\mathbf{n.pln}, -, -, s_2, -, -, -) \\ \supset\, Syn(\text{“few”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld.rnc}, x_1, a, -, -, s_1, -, -, -) \\ little'(e_1, x_1, x_2) \wedge daggregate'(e, x_2, e_2) \\ \quad \wedge\, Syn(w, e_2, f{:}\mathbf{ldan}, x_2, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \\ \supset\, Syn(\text{“little”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld}, x_1, a, -, -, -, -, -, -) \\ little'(e_1, x_1, x_2) \wedge daggregate'(e, x_2, e_2) \\ \quad \wedge\, Syn(w, e_2, f{:}\mathbf{le}, x_2, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \\ \supset\, Syn(\text{“little”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld.rnc}, x_1, a, -, -, -, -, -, -) \\ no'(e_1, s_1, s_2) \wedge dset'(e, s_2, x_2, e_2) \wedge plural'(e_0, x_1, s_1) \\ \quad \wedge\, Syn(w, e_2, f{:}\mathbf{ldan}, x_2, a{:}\mathbf{n.pln}, -, -, s_2, -, -, -) \\ \supset\, Syn(\text{“no”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld}, x_1, a, -, -, s_1, -, -, -) \\ no'(e_1, x_1, x_2) \wedge daggregate'(e, x_2, e_2) \\ \quad \wedge\, Syn(w, e_2, f{:}\mathbf{ldan}, x_2, a{:}\mathbf{n.sing}, -, -, -, -, -, -) \\ \supset\, Syn(\text{“no”}w, e_1\&e\&e_0\&e_2, f{:}\mathbf{ld}, x_1, a, -, -, -, -, -, -) \end{array}$$

“Few” and “little” can occur with empty heads; “no” cannot.

The word “other” can occur as the sole determiner, it can be added after any other determiner phrase, and it can occur before numbers. The conditions under which it can occur in headless NPs are complex, as indicated by the examples,

* other
other books
* other three
* other three books
the other
the other three
the other three books

I will not attempt to rule out the bad examples, but will allow "other" to be applied to headed and headless $\overline{\mathbf{N}}$s.

$$other'(e_1, x, y)$$
$$\supset Syn(\text{"other"}, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n}, s, -, -, -)\ other'(e_1, x, y)$$
$$\supset Syn(\text{"other"}, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n}, s, -, -, -)$$

If e_1 is the eventuality of x being other than some y, often contextually determined, then e_1 can be expressed by the determiner "other" applied to a partial and possibly headless NP conveying eventuality e_2 and referring to x, possibly with associated set s.

In Section 4.9 the lexical axiom for the adverb "not" was given, where "not" was subcategorized for phrases of category **v**. It can also occur with determiners, as in "not much information". The following axiom, in conjunction with Adjunct Composition Rule 1 will allow this use of "not".

$$not'(e, e_1) \supset Syn(\text{"not"}, e, \mathbf{adv1}, e_1, \mathbf{dn}, -, -, -, -, -, -)$$

If e is the condition of e_1 not being true, then e can be expressed by the adverb "not" applied to a determiner conveying the eventuality e_1.

Possessive NPs also function as determiners. They convey a contextually determined relation we will indicate by $'s$. The axiom that adds "'s" to an NP (in its internal representation) to convert it into a determiner is the following:

$$Syn(w, e_1, \mathbf{rn}, y, \mathbf{n}, -, -, s_1, -, -, -) \wedge {}'s'(e_0, y, x)$$
$$\supset Syn(w\text{"'s"}, e_1\&e_0, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n}, s_2, -, -, -)$$
$$Syn(w, e_1, \mathbf{rn}, y, \mathbf{n}, -, -, s_1, -, -, -) \wedge {}'s'(e_0, y, x)$$
$$\supset Syn(w\text{"'s"}, e_1\&e_0, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n}, s_2, -, -, -)$$

If w is an NP with a head and without a noun complement, referring to y and conveying the property e_1 of y, possibly with associated set s_1, and e_0 is the eventuality of x being y's, then the conjunction of e_1 and e_0 can be expressed by concatenating w with "'s" to form a determiner that can apply to a partial NP expressing e_2 and referring to x, possibly with associated set s_2. The internal representation of the NP w is used rather than the external representation, because that makes it possible to state the condition that w cannot have a noun complement or be headless. It also prevents pronouns from taking an "'s".

This rule does not cover NPs like "the queen of England's sister", but this is not a very productive pattern.

The above axiom is almost an alternation axiom, in that it modifies the word's argument structure and agreement features, but is like a composition axiom in that it concatenates w with "'s". A purely lexical alternative would be to give "'s" the lexical axiom

$$\text{'}s'(e_0, y, x) \supset Syn(\text{"'s"}, x, \mathbf{n}, y, \mathbf{n.sb}, x, \mathbf{n.ob}, -, -, -, -)$$

The possessive relation e_0 between y and x can be conveyed by the morpheme "'s" preceded by an NP referring to y and followed by an NP referring to x. The composite phrase is an NP referring to x. This rule does not capture the structural constraints on the first NP, however.

The axioms for possessives handle possessives of irregular plural NPs, like "men's". The axioms for the possessive of regular plural NPs are

$$\begin{aligned}
&Syn(w\text{"s"}, e_1, \mathbf{rn}, y, \mathbf{n.pln}, -, -, s_1, -, -, -) \wedge \text{'}s'(e_0, y, x) \\
&\quad \supset Syn(w\text{"'"}, e_1\&e_0, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n}, s_2, -, -, -) \\
&Syn(w, e_1, \mathbf{rn}, y, \mathbf{n.pln}, -, -, s_1, -, -, -) \wedge \text{'}s'(e_0, y, x) \\
&\quad \supset Syn(w\text{"'"}, e_1\&e_0, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n}, s_2, -, -, -)
\end{aligned}$$

The lexical axioms for the possessive pronoun "his" are as follows:

$$\begin{aligned}
&he'(e_1, y) \wedge \text{'}s'(e_0, y, x) \\
&\quad \supset Syn(\text{"his"}, e_1\&e_0, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n}, s_2, -, -, -) \\
&he'(e_1, y) \wedge \text{'}s'(e_0, y, x) \\
&\quad \supset Syn(\text{"his"}, e_1\&e_0, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n}, s_2, -, -, -)
\end{aligned}$$

If e_1 is the condition of y being a "he" (i.e., being a male human), and e_0 is the eventuality of x being y's, then the conjunction of e_1 and e_0 can be expressed by the determiner "his" that can apply to a partial NP expressing e_2 and referring to x, possibly with associated set s_2.

The lexical axioms for the other possessive pronouns are as follows:

$$\begin{aligned}
&I'(e_1, y, u) \wedge \text{'}s'(e_0, y, x) \\
&\quad \supset Syn(\text{"my"}, e_1\&e_0, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n}, s_2, -, -, -) \\
&we'(e_1, y, u) \wedge \text{'}s'(e_0, y, x)
\end{aligned}$$

$\supset Syn(\text{“our”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{ldan}, x,\mathbf{n}, s_2, -, -, -)$
$you'(e_1, y, u) \wedge \text{'}s'(e_0, y, x)$
$\supset Syn(\text{“your”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{ldan}, x,\mathbf{n}, s_2, -, -, -)$
$she'(e_1, y) \wedge \text{'}s'(e_0, y, x)$
$\supset Syn(\text{“her”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{ldan}, x,\mathbf{n}, s_2, -, -, -)$
$it'(e_1, y) \wedge \text{'}s'(e_0, y, x)$
$\supset Syn(\text{“its”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{ldan}, x,\mathbf{n}, s_2, -, -, -)$
$it'(e_1, y) \wedge \text{'}s'(e_0, y, x)$
$\supset Syn(\text{“its”}, e_1\&e_0,\mathbf{ld.rnc}, e_2,\mathbf{le}, x,\mathbf{n}, s_2, -, -, -)$
$they'(e_1, y) \wedge \text{'}s'(e_0, y, x)$
$\supset Syn(\text{“their”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{ldan}, x,\mathbf{n}, s_2, -, -, -)$

“His” and “its” can occur as headless NPs. The others can’t.

4.10.9 Indefinite Pronouns

Special problems are presented by indefinite pronouns, such as “anything”, “everybody”, and “someone”. By themselves they function as complete NPs. But they can take restrictive complements, as in

anything you can do ()
everybody responsible
someone in this room
something about it

The underlying structure for the last of these is that “some” is a determiner, “thing” is the head noun, and “about it” is a complement added at the $\overline{\mathbf{N}}$ level. It should have the bracketing “[some [thing [about it]]]”.

One possibility would be to treat “something” as a contraction, unpacked by the axiom

$Syn(\text{“some”}, e_1, f_1{:}\mathbf{ld}, e_2, f_2{:}\mathbf{ldan}, x, a{:}\mathbf{n.sing}, -, -, -, -)$
$\wedge\, Syn(\text{“thing”}w, e,\mathbf{ln.rn}, x, a{:}\mathbf{n.sing}, -, -, -, -, -, -)$
$\supset Syn(\text{“something”}w, e,\mathbf{ld}, x, a, -, -, -, -, -, -)$

The string w is the restrictive noun complement adjoined to “something”, and this rule assures that “thing” and w will be treated together as an $\overline{\mathbf{N}}$.

The difficulty with this approach is that

Everybody is here.

and

Every body is here.

have quite different meanings. A similar problem holds with "thing" and "one" pronouns, although the differences are more subtle. But

Everything is ready.

can include the participants' mental preparedness, whereas

Every thing is ready.

is more likely to be restricted to physical objects.

An alternate approach is to treat the indefinite pronouns as complete determiner phrases that can only be applied to headless $\overline{\mathbf{N}}$s, not headed ones. Just as we can have "those in control" we will be able to have "everyone in control". This is the approach we will adopt. The lexical axiom for "something" is therefore the following:

$$\begin{aligned}&\mathit{some}'_1(e_1,x,e_2)\ \wedge\ \mathit{inanimate}'(e_0,x)\\&\quad\supset\ \mathit{Syn}(\text{“something”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{le}, x,\mathbf{n.sing}, -,-,-,-)\end{aligned}$$

If e_1 is the condition of an inanimate x being *some* entity describable by property e_2 and e_0 is the property of x being inanimate, then the conjunction of e_1 and e_0 can be expressed by the determiner "something" which can be applied only to a singular headless $\overline{\mathbf{N}}$ referring to x and conveying property e_2.

The lexical axioms for the other indefinite pronouns are as follows:

$$\begin{aligned}&\mathit{some}'_1(e_1,x,e_2)\ \wedge\ \mathit{person}'(e_0,x)\\&\quad\supset\ \mathit{Syn}(\text{“someone”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{le}, x,\mathbf{n.sing}, -,-,-,-)\\&\mathit{some}'_1(e_1,x,e_2)\ \wedge\ \mathit{person}'(e_0,x)\\&\quad\supset\ \mathit{Syn}(\text{“somebody”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{le}, x,\mathbf{n.sing}, -,-,-,-)\\&\mathit{every}'(e_1,x,e_2)\ \wedge\ \mathit{inanimate}'(e_0,x)\\&\quad\supset\ \mathit{Syn}(\text{“everything”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{le}, x,\mathbf{n.sing}, -,-,-,-)\\&\mathit{every}'(e_1,x,e_2)\ \wedge\ \mathit{person}'(e_0,x)\\&\quad\supset\ \mathit{Syn}(\text{“everyone”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{le}, x,\mathbf{n.sing}, -,-,-,-)\\&\mathit{every}'(e_1,x,e_2)\ \wedge\ \mathit{person}'(e_0,x)\\&\quad\supset\ \mathit{Syn}(\text{“everybody”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{le}, x,\mathbf{n.sing}, -,-,-,-)\\&\mathit{any}'(e_1,x,e_2)\ \wedge\ \mathit{inanimate}'(e_0,x)\\&\quad\supset\ \mathit{Syn}(\text{“anything”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{le}, x,\mathbf{n.sing}, -,-,-,-)\\&\mathit{any}'(e_1,x,e_2)\ \wedge\ \mathit{person}'(e_0,x)\\&\quad\supset\ \mathit{Syn}(\text{“anyone”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{le}, x,\mathbf{n.sing}, -,-,-,-)\\&\mathit{any}'(e_1,x,e_2)\ \wedge\ \mathit{person}'(e_0,x)\\&\quad\supset\ \mathit{Syn}(\text{“anybody”}, e_1\&e_0,\mathbf{ld}, e_2,\mathbf{le}, x,\mathbf{n.sing}, -,-,-,-)\end{aligned}$$

4.10.10 Numbers

Numbers occur as NPs, as in

> Seven is a prime number.

and as determiners, as in

> John bought seven shirts.

We will assume, in our ontologically promiscuous fashion, that numbers are simply entities in the Platonic universe of possible individuals. Suppose we take the numeral representations of numbers to be the names of the constants in our logic that stand for the numbers. Then the natural way to represent a word like "seven" as an NP would be with the *Syn* predication

$$Syn(\text{“seven”}, 7, \mathbf{number.sing}, -, -, -, -, -, -, -, -)$$

where **number** is a subfeature of the *CAT* attribute **n**. The NP is singular since, as in the above sentence, it occurs with the singular form of verbs.

In defining the specialized rules for building up composite numbers, it will be inconvenient to carry around this unwieldy expression, so we introduce an abbreviation:

$$Number(w, n, a) \equiv Syn(w, n, a{:}\mathbf{sing}, -, -, -, -, -, -, -, -)$$

Suppose there is a predicate called *quantity*, where

$$quantity'(e, x, n)$$

says that e is the eventuality of x having a quantity of n. The cardinality of a set s is one example of a quantity.

$$card'(e, s, n) \supset quantity'(e, s, n)$$

However, *quantity* also applies to numbers n that are not integers.

The predicates *sum*, *product*, and *quotient* are also defined, where

$$sum(n_1, n_2, n_3),\ product(n_1, n_2, n_3),\ quotient(n_1, n_2, n_3)$$

mean that n_1 is the sum, product, and quotient, respectively, of n_2 and n_3. These predicates are axiomatized in Chapter 5.

There are four rules that convert a number into a determiner, one for singular and one for plural determiners, and two for headed and two for headless $\overline{\mathbf{N}}$s.

$$Number(w, n, \mathbf{number}) \wedge quantity'(e_1, s, n) \wedge (n > 1 \vee n = 0)$$
$$\supset Syn(w, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.pln}, s, -, -, -)$$
$$Number(w, n, \mathbf{number}) \wedge quantity'(e_1, s, n) \wedge (n > 1 \vee n = 0)$$
$$\supset Syn(w, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.pln}, s, -, -, -)$$
$$Number(w, n, \mathbf{number}) \wedge quantity'(e_1, x, n) \wedge n \leq 1 \wedge n > 0$$
$$\supset Syn(w, e_1, \mathbf{ld}, e_2, \mathbf{ldan}, x, \mathbf{n.sing}, -, -, -, -)$$
$$Number(w, n, \mathbf{number}) \wedge quantity'(e_1, x, n) \wedge n \leq 1 \wedge n > 0$$
$$\supset Syn(w, e_1, \mathbf{ld.rnc}, e_2, \mathbf{le}, x, \mathbf{n.sing}, -, -, -, -)$$

The first axiom says that if w is a word or phrase naming the number n and e_1 is the property of n being the quantity of set s, where n is either zero or greater than one, then e_1 can be conveyed by taking w as a determiner and applying it to a partial plural NP, possibly headless, referring to the set s with typical element x. The other axioms have similar glosses.

All that remains now is to define the axioms that will build up composite numbers. There is a specialized grammar for numbers. In this chapter all that will be presented is the rules for constructing the phrases for integers up through the hundreds, numerals of arbitrary length, and fractions expressed in terms of numerals. Lexical axioms will be presented only for the number words and numerals in the target texts. These will be illustrative of the rest.

Eight subfeatures of the feature **number** are required:

digit:	0, 1, 2, 3, 4, ... , 9
numeral:	1234, ...
digitword:	one, two, three, ... , nine
ty:	twenty, thirty, forty, ... , ninety
n10:	eleven, forty five, ...
hundreds:	one hundred, two hundred, ...
n100:	one hundred forty five, ...
fraction:	1/4, ...

digit is a subfeature of **numeral**. **digitword** and **ty** are subfeatures of **n10**. The feature **hundreds** and **n10** are subfeatures of **n100**. The features **numeral**, **fraction** and **n100** are subfeatures of **number**.

This feature set will be called *NUMBR*. It is illustrated in Figure 4.12.

The axioms for the digits that we need are as follows:

$$Number(\text{"0"}, 0, \mathbf{digit})$$
$$Number(\text{"1"}, 1, \mathbf{digit})$$
$$Number(\text{"4"}, 4, \mathbf{digit})$$

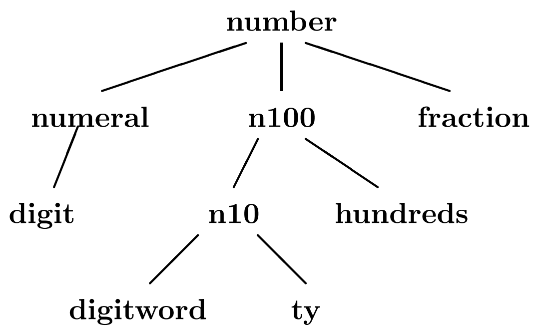

Figure 4.12: Structure of the feature set *NUMBR*.

The axiom that constructs numerals greater than 9 is

$$Number(w_1, n_1,\mathbf{numeral}) \wedge Number(w_2, n_2,\mathbf{digit}) \wedge sum(n, n_3, n_2) \wedge product(n_3, n_1, 10) \supset Number(w_1 w_2, n,\mathbf{numeral})$$

The concatenation of a numeral (n_1) with a digit (n_2) is a numeral (n) naming the sum of 10 times the numeral n_1 plus the digit.

The number words we need for the target texts are defined in the following illustrative axioms:

$Number(\text{“one”}, 1,\mathbf{digitword})$
$Number(\text{“three”}, 3,\mathbf{digitword})$
$Number(\text{“five”}, 5,\mathbf{digitword})$
$Number(\text{“eleven”}, 11,\mathbf{n10})$
$Number(\text{“twelve”}, 12,\mathbf{n10})$
$Number(\text{“fifteen”}, 15,\mathbf{n10})$
$Number(\text{“thirty”}, 30,\mathbf{ty})$
$Number(\text{“forty”}, 40,\mathbf{ty})$

Composite numbers can be formed by concatenating a **ty** word with a **digitword** to form an **n10** word.

$$Number(w_1, n_1,\mathbf{ty}) \wedge Number(w_2, n_2,\mathbf{digitword}) \wedge sum(n, n_1, n_2) \supset Number(w_1 w_2, n,\mathbf{n10})$$

Or by concatenating a **hundreds** phrase with an **n10** phrase.

$$Number(w_1, n_1,\mathbf{hundreds}) \wedge Number(w_2, n_2,\mathbf{n10}) \wedge sum(n, n_1, n_2) \supset Number(w_1 w_2, n,\mathbf{n100})$$

A **hundreds** word is formed by concatenating a **digitword** with the word "hundred".

$$Number(w_1, n_1, \textbf{digitword}) \wedge product(n, n_1, 100) \\ \supset Number(w_1\text{"hundred"}, n, \textbf{hundreds})$$

A fraction can be formed by concatenating two numerals with a "/" between them, as in "1/4".

$$Number(w_1, n_1, \textbf{numeral}) \wedge Number(w_2, n_2, \textbf{numeral}) \\ \wedge quotient(n, n_1, n_2) \\ \supset Number(w_1\text{"/"}w_2, n, \textbf{fraction})$$

These are all composition axioms, but we should not be concerned that they do not reduce to more general composition axioms. The grammar of numbers is a specialized and recent addition to grammar, probably specialized from the grammar of determiners and conjunctions.

4.10.11 Case, Gender, Person, and Number

The traditional grammatical notions of case, gender, person and number are relevant to nouns and pronouns. This section describes our approach to each of these phenomena in turn.

Case: Case in any language is clearly a syntactic phenomenon. That is, case categories such as nominative and accusative are properties of word instances, not of the entities referred to. Case is expressed in English only in pronouns, and it was dealt with in the lexical axioms for pronouns and in the subcategorization constaints in lexical axioms for verbs.

Gender: The central question with respect to gender is whether it is a syntactic property or a semantic property. Should it be represented by features in the *Syn* predication, or should it be represented by predicates like $female$ in logical form? Equivalently, is it a property of the word or of the entity?

Gender in languages such as German and French is clearly a syntactic phenomenon. Gender categories are, at least, properties of word instances, although the category of the prototypical description of an entity might also be viewed as a property of the entity.

In English, however, I would argue that gender is not a syntactic phenomenon. There are predicates *male*, $female$, and *neuter* that are properties of entities; there are no agreement features **masculine**, **feminine**, and **neuter** that are properties of word instances.

Syntactic accounts of gender stipulate that pronouns (or perhaps only "bound" pronouns) agree with their antecedents in gender. (A "bound" pronoun is a pronoun whose antecedent happens to be in the same clause.) Animateness is sometimes subsumed under gender, and in these accounts relative pronouns must agree with their heads in gender, where "who" is masculine or feminine and "which" is neuter.

Pollard and Sag (1994, p. 70) reject the syntactic account for relative pronouns. In the sentences

* The soldiers which died are deeply mourned.
* The soldiers who were made of lead were thrown away.

the problems, they argue, are not syntactic problems, but inconsistencies between what is conveyed by the relative pronouns and by the rest of the sentences. I agree with this analysis.

However, they do not treat gender agreement in pronouns as a semantic phenomenon. Instead, they introduce something called the referential index, which is intermediate between the word instance and the entity referred to. It is referential indices that carry the agreement features of gender, person, and number. Agreement between a pronoun and its antecedent is ensured by requiring that their referential indices be identical.

The key examples for gender involve entities—dogs and ships—that can have more than one gender. Pollard and Sag point out that we can switch gender intersententially.

(4.27) The dog is so stupid, everytime I see it I want to kick it. He's a damned good hunter though.

But we cannot switch gender in simplex clauses, between a bound pronoun and its antecedent.

* That dog is so ferocious, it tried to bite himself.
* The ship lurched, and then she righted itself.

But there is another explanation for these facts. Changing the gender of an entity involves a shift of perspective. In fact, in example (4.27) the shift in perspective almost seems like a correction. When the bad quality is described, the neuter form seems appropriate. When the good quality is described, the speaker remembers to use the more affectionate masculine form.

A simplex clause is just too short for such a change of perspective to occur. Even where seemingly semantically motivated, the gender shift seems inappropriate in discourse of a moderately planned character.

* That dog of mine! Although I hate it, my wife likes him.
* That dog of mine! I hate it, but my wife likes him.
? That dog of mine! I hate it. ... Of course, my wife really dotes on him.

Pollard and Sag give no other argument for the nonsemantic treatment of gender. This argument is not compelling. I will take gender in English to be a semantic property.

The feminine gender for ships, by the way, can be captured by a characterization of "she" involving two axioms:

$$human(x) \wedge female(x) \supset she(x)$$
$$ship(x) \supset she(x)$$

This treatment accords with the fact that the use of "she" for ships is an explicitly learned convention. It also explains why

* the ship who is arriving tonight

is bad. The ship lacks the property *human* that "who" requires.

In brief, our approach to gender and animateness is strictly semantic.

Person: Person is not a big deal in English. In this chapter I have subsumed the notion of person under the agreement feature of number (*NUM*). I am not especially wedded to this approach, but when one sees a table like the following, one suspects false distinctions are being made.

		Present:		**Past:**	
Number:		Singular	Plural	Singular	Plural
	1:	swim	swim	swam	swam
Person:	2:	swim	swim	swam	swam
	3:	swims	swim	swam	swam

The approach presented in Section 4.10.4 is to treat "you" as a plural NP (*NUM* feature **pln**) and to treat "I" as having the *NUM* feature **ego**, which along with **pln** is a subfeature of **pl**. The verb "to be" requires an **ego** subject for "am", and a **pln** subject for "are". Other verbs require a **pl** subject for their plural forms.

An argument in favor of treating **ego** as a subfeature of **pl** involves the use of Aux-inverted copulas with "I":

Aren't I smart?
* Isn't I smart?

Suppose the contraction "amn't" is disallowed on phonological grounds. Then the problem is to discover the nearest alternative. If "I" were classified as having a *NUM* feature of **sing** and a *PERSON* feature of **1st**, then "isn't" would seem to be the better choice, since it agrees in number if not in person. Suppose, on the contrary, that we take "I" to have the feature **ego**, a subfeature of **pl**. The auxilliary "aren't" requires its subject w to have the feature **pln**, or equivalently. **pln**(w) must be true. That doesn't hold for "I", but since **ego**(w) holds, then at least **pl**(w) is true. The choice of auxilliary that involves the least backing off from the strict requirements on the subject is, under this analysis, "aren't", which is correct. (This is a favorite example of optimality theorists, and their account is similar to mine.)

There are a few—very few—examples where number and person must be treated separately. One, discussed by Pollard and Sag (1994, p. 149), is

. . . till there was you.

This usage can be explained if we assume "there" can be of singular or plural number but is 3rd person, "you" in this case is of singular number and is 2nd person, "there" and its predicate complement must agree in number but need not agree in in person, so "there" and "you" are compatible. But "there" must agree with its verb in number and person, so we must use "was". There are no constraints operating between "was" and "you".

In any case, person is not salient enough in what we need to develop here for us to give it a serious treatment, one way or another. Hence, I have simply subsumed it under number.

Number: As with gender, the key issue for number is whether it should be treated as a syntactic or a semantic phenomenon. In the ontology used in this book, plural nouns introduce both a set and a typical member of the set, and the relation between them is expressed by the predication $plural'(e, x, s)$. This predication must be introduced in morphological axioms for plurals or in lexical axioms for irregular plural nouns. This much is necessary for semantics, regardless of one's treatment of agreement.

Tensed verbs and their subjects agree in number. A purely syntactic approach to this constraint is implemented with lexical axioms like the following:

$$man'(e,x) \wedge plural'(e_0,x,s)$$
$$\supset Syn(\text{“men”}, e\&e_0, f, x, a{:}\mathbf{n.pln}, -, -, s, -, -, -)$$
$$Present'(e_1,e_2) \supset VMorph(w,w,e_1,\mathbf{v.tnsd}, e_2,\mathbf{n.pl.nom})$$

The first axiom introduces the semantic *plural* predication and also classifies the word as having the syntactic property **pln**. The second axiom constrains the subject of the verb to have the syntactic property **pl**, a superfeature of **pln**, but no predication of plurality is introduced.

A purely semantic alternative would have no syntactic properties **pl** and **pln**, but the tensed verb would also convey the semantic *plural* property, that is, the fact that x is the typical element of some set s. In this approach, $VMorph$ needs an extra argument for x, which can be inserted just before the a argument. The axioms would be

$$man'(e,x) \wedge plural'(e_0,x,s)$$
$$\supset Syn(\text{“men”}, e\&e_0, f, x, a{:}\mathbf{n}, -, -, s, -, -, -)$$
$$Present'(e_1,e_2) \wedge plural'(e_0,x,s)$$
$$\supset VMorph(w,w,e_1,\mathbf{v.tnsd}, e_2, x,\mathbf{n.nom})$$

Note that the defferences in this form from the purely syntactic approach are the lack of **pl** and **pln** features and the *plural* predications in the antecedent of the $VMorph$ axiom.

In addition, there would be a predication, $individual'(e_0,x)$, associated with the singular form of nouns and verbs, and an axiom encoding the inconsistency between this and *plural*.

$$man'(e,x) \wedge individual'(e_0,x)$$
$$\supset Syn(\text{“man”}, e\&e_0, f, x, a{:}\mathbf{n}, -, -, s, -, -, -)$$
$$Present'(e_1,e_2) \wedge individual'(e_0,x)$$
$$\supset VMorph(w\text{“s”}, w, e_1,\mathbf{v.tnsd}, e_2, x,\mathbf{n.nom})$$
$$individual(x) \wedge plural(x,s) \supset F$$

In this approach, a failure of number agreement would not be a syntactic violation. It would simply be an inconsistency in what is known about x.

A third approach is a hybrid one. In this, the *plural* and *individual* predications would be introduced both by the verb and by the noun as in the purely semantic approach, and the words would be classified as **sing**, **pl** and **pln** as in the syntactic approach. The axioms would be

$$man'(e,x) \wedge plural'(e_0,x,s)$$
$$\supset Syn(\text{“men”}, e\&e_0, f, x, a{:}\mathbf{n.pln}, -, -, s, -, -, -)$$

$$Present'(e_1, e_2) \wedge plural'(e_0, x, s)$$
$$\supset VMorph(w, w, e_1, \mathbf{v.tnsd}, e_2, x, \mathbf{n.pl.nom})$$

In the semantic and hybrid approaches it would be necessary to give an independent treatment of person, so that *plural* is not true of the referents of “I” and the singular “you”.

The compelling arguments for and against the semantic approach all involve entities that can be viewed either as individuals or as sets. Often the required or most natural syntactic form of the subject conveys one perspective, whereas the other perspective is desired. In these cases, the tensed verb can be used to convey the latter. The following is a headline from the San Francisco Chronicle (May 20, 1996) over a story on the crushing defeat of the Orlando Magic basketball team by the Chicago Bulls.

> Magic Seem to Disappear

Most basketball team names are headed by plural count nouns, as in “the Chicago Bulls”. The recent trend to give teams mass noun names, like “Magic”, has placed newspapers in a syntactic dilemma, which they solve as above. A more standard example of a collective noun used with a plural verb is

> The faculty are all agreed on this point.

At the same time, plural count noun names can be used with singular verbs.

> The Chicago Bulls is my favorite team.

Two more examples of what Pollard and Sag (1994, Section 2.3) refer to as “singular plurals” are

> Hash browns is my favorite breakfast.
>
> Of all the problems with hiking in Alaska, grizzly bears worries me the most.

To re-express the subjects in these sentences to accord with the desired perspective and permit number agreement with the verb would involve circum-locution—“the players for Magic”, “the members of the faculty”, “the Chicago Bulls team”, “a serving of hash browns”, and “the problem of grizzly bears”.

The solution that speakers arrive at in these cases is to give the subject its most natural expression and to cancel its number implications with the form of the verb. There is an inconsistency between the *individual* and *plural* predications. But the number feature associated with the verb is more in accord with what the sentence says about the subject, so the number feature associated with the subject is suppressed.

In brief, in the semantic approach the contradictory number information from the subject and the verb force a coercion to the implicit perspective.

Polland and Sag's argument against the purely semantic treatment is that although an intersentential shift in number is acceptable, as in

> The Senate just voted itself another raise. Most of them were overpaid to begin with.

an intrasentential shift in number is questionable or not acceptable:

> ? The faculty is voting themselves a raise.
> * The faculty are voting itself a raise.

This is the same as their argument against a semantic treatment of gender and it is just as uncompelling. A simplex clause is too small to justify such a shift of perspective.

I believe the arguments for a semantic approach to number are fairly strong and the counterarguments quite weak. Nevertheless, I have adopted the syntactic approach in this development. In fact, the differences between them are not great. The addition of two axioms to the either the syntactic or the semantic approach yields a theory equivalent to the hybrid approach. Let Syn_0 be the Syn predicate without the agreement feature arguments— $Syn_0(w, e, x, y, z, v)$. Then the required axioms are

$$(\forall\, w, x)[Syn_0(w, x, -, -, -, -) \supset (\exists\, e_0, s)[\mathbf{pln}(w) \equiv plural'(e_0, x, s)]]$$
$$(\forall\, w, x)[Syn_0(w, x, -, -, -, -) \supset (\exists\, e_0)[\mathbf{sing}(w) \equiv individual'(e_0, x)]]$$

4.10.12 A Word on $\overline{\mathbf{X}}$ Theory

$\overline{\mathbf{X}}$ Theory, as proposed by Chomsky (1970) and explicated in Haegeman (1991), recognizes the similarity of behavior among verbs, adjectives, and prepositions in the attachment of their complements, adjuncts, and subjects. This generalization is captured in HPSG in Schemas 1 and 2. I am completely in accord with it in the current development, although, since I am primarily interested in making explicit the construction of logical form, I have had to split the "$\overline{\mathbf{X}} \rightarrow$ X YP" rule, or Schema 2, into four rules, the Object, Subject Control, Object Control, and Tough Movement Rules.

However, I believe that when we extend $\overline{\mathbf{X}}$ Theory to NPs, it loses all of its appeal. The logical forms that need to be produced are entirely different from the logical forms associated with clauses, and $\overline{\mathbf{X}}$ Theory has nothing significant to say about the complex internal structure of NPs; these have been our two principal concerns here.

There is a superficial similarity between

The barbarians destroyed Rome.

and

the barbarians' destruction of Rome.

But the possessive can indicate many relations besides subjecthood and the preposition "of" can indicate many relations besides objecthood. The most general way to handle the possessive and "of" is thus to view them as introducing relations, *'s* and *of*, between the head noun and the subordinate noun. There will be many axioms of the form

$$p'(e,y,x) \supset {}'s'(e,y,x)$$
$$p'(e,x,y) \supset of'(e,x,y)$$

Among them it is natural to include the axioms

$$Subject'(e,x,y) \supset {}'s'(e,y,x)$$
$$Object'(e,x,y) \supset of'(e,x,y)$$

That is the approach that will be taken in this book.

4.11 Reflexive Pronouns

Binding Theory in GB is an excellent example of a theory in baroque decline.

***** UNDER CONSTRUCTION *****

refl is a subfeature of **acc**;

4.12 Intensive Reflexives

***** UNDER CONSTRUCTION *****

Irene Heim's view: "John called himself" is a displaced right modifier for "John himself called". This appositive is always given contrastive stress. What is stressed contrastively is the identity relation. It is in contrast to other possible actors.

4.13 Relative Clauses and Other Long-Distance Dependencies

4.13.1 Overview

In this section I will discuss three varieties of long-distance dependencies:

- Relative Clauses: "a man whose sister John knows ()"
- Wh-Questions: "After which talk did John leave?"
- Sentential Wh-Nominals: "I don't know what car to buy ()."

These phenomena are called long-distance dependencies, because descriptions of arguments can in principle be located arbitrarily far from their predicates, and yet the association is reliably recoverable via composition rules.

> This is the man whom John said Bill believes Mary told Sam that I thought I had met ().

First we need some terminology. In the NP

> a man the sister of whom I met ()

the noun "man" is the *head* of the NP. The phrase "the sister of whom I met ()" is a *relative clause.* The phrase "the sister of whom" will be called the *filler.* The word "whom" will be called a *wh-word.* If the filler has a wh-word in it, as this one does, it can be called a *wh-phrase* or *relativizer.* The clause

"I met ()" will be called the *matrix clause*. The missing argument "()" will be called the *gap*. The filler *fills* the gap.

At the level of logical form, there is a man x and his sister y. "A man" and "whom" refer to x and "the sister of whom" and the gap "()" refer to y. We will call x the *wh-ed entity* and y the *gapped entity*. In the simplest cases, these are the same.

A treatment of the phenomenon of long-distance dependencies in English can be divided into four problems, each of which must be handled by rules of syntax.

1. There must be rules that introduce gaps into matrix clauses.
2. The rules must provide a means for transmitting information about a deeply embedded gap to the point in the sentence that provides its filler.
3. The filler—in all of the cases considered here, a relativizer—can have internal structure, as in "whose book", "the sister of whom", and "after which". The relativizer will contain a wh-word that refers to a wh-ed entity. Information about that wh-ed entity must be available after the relativizer has been composed with its matrix clause.
4. The relativizer and its matrix clause must be concatenated in a way that associates the filler with the gap and makes the wh-ed entity available for the role it plays in the composite construction. Each of the three long-distance constructions that we consider here are distinctive in this regard.

We have already seen the solution to Problem 2. The v and g arguments of the *Syn* predication transmit the required information between the gap and the filler. Virtually every one of the composition rules that has been presented has specified how gap variables and gap features in constituent phrases are identified with those in the composite phrase.

In the remainder of this section, approaches to the other three problems are presented.

4.13.2 Introducing Gaps

The simplest way to introduce gaps in a matrix clause (Problem 1) is by means of axioms that define the empty string as a gap.

$$(4.28) \qquad \supset Syn(\text{“ ”}, x, a, -, -, -, -, -, -, x, a)$$

That is, the empty string is a constituent with a gap in it, where the referent x of the constituent is identical to the entity that will fill the gap. Normally the constituent will be an NP, but we will also need clauses to be gaps in this fashion for the analysis of the "you know" construction in Section 4.13.6 below.

An alternative approach is followed by Pollard and Sag (1994). They accomplish gap introduction by means of alternation axioms that rearrange the arguments within the *Syn* predication. In our notation, one such rule would be

$$\begin{aligned} &Syn(w, e, f{:}\mathbf{v/p}, x, a{:}\mathbf{n}, y, b, -, -, -, -) \\ &\quad \supset Syn(w, e, f, x, a, -, -, -, -, y, b) \end{aligned}$$

This rule would move the variable for an NP first complement and its agreement feature to the gap position in the *Syn* predication. This means that the corresponding NP will no longer be required or able to appear explicitly in the direct object position of the clause. Rather, whatever is matched with the gap will fill that role in logical form. Similar rules would have to be written for subjects and second complements. This approach strikes me as more complex than it needs to be; hence we will use Rule (4.28) instead.

In a sense, our approach treats a gap as a kind of a lexical item, and Rule (4.28) is thus a kind of a lexical axiom, whereas Pollard and Sag treat the phenomenon at the level of alternation axioms.

Adjuncts can also be gapped in the matrix clause, as in

the man with whom John works.

Suppose we used the following rule to label the empty string as a possible adjunct.

$$(4.29) \qquad \supset Syn(\text{``''}, e_1, f_1{:}\mathbf{adjunct1}, e_2, f_2, -, -, -, -, e_1, f_1)$$

That is, the empty string is an adjunct with a gap in it, where the eventuality e_1 referred to by the empty string is identical to the eventuality conveyed by the relativizer that will fill the gap, and the logical subject of that adjunct is eventuality e_2 described by the clause that the adjunct is adjoined to.

This has the difficulty, however, that the information about the subject of the adjunct is lost if the modified clause is embedded in another clause. In

(4.30) the man with whom George believes John works,

the empty string adjunct would be attached to "John works", with the working e_2 being its logical subject. But when this is embedded in "George believes ...", e_2 survives only as the object of the believing, and when "with whom" is concatenated with "George believes John works", John's working is no longer available to be the logical subject of *with*.

There are at least three possible ways of getting around this difficulty.

The first would be to expand the *Syn* predicate once again to carry not only the v and g arguments pointing to the gap, but another pair of variables to point to the gap's subject, if it has one. This would have the advantage of doing the job strictly within the syntactic part of the framework, but it would entail complications in every other part of the grammar, as we have developed it. (This difficulty would not arise in the standard feature structure approach; it is an artifact of our attempt to use a *Syn* predicate with a fixed number of arguments, rather than labelled arguments.)

An alternative is to appeal to pragmatic processes. One way would be to specify in the syntactic rule that the logical subject of the filler is the top-level eventuality in the matrix clause. The logical subject of *with* would be George's believing, not John's working. Then, as with the phenomena discussed in Section 4.17, this argument would be coerced into the eventuality associated with an embedded clause. We would coerce from George's believing to John's working which is the content of George's believing. In the logical form for the above NP,

$$the'(e_1, x, e_2\&e_3) \wedge man'(e_2, x) \wedge with'(e_3, e_4, x) \wedge believe'(e_4, G, e_5) \\ \wedge work'(e_5, J)$$

the e_4 argument of $with'$ will be coerced into e_5 by the coercion relation $believe'(e_4, G, e_5)$. We coerce George's believing being with x into *the situation that is the content of* George's believing being with x. In addition, we must use $with'(e_3, e_4, x)$ as the coercion relation to coerce the e_5 argument of $believe'$ into e_3, since it is the with-ness rather than the working that is the primary content of George's belief. The resulting logical form would be

$$the'(e_1, x, e_2\&e_3) \wedge man'(e_2, x) \wedge with'(e_3, e_5, x) \wedge believe'(e_4, G, e_3) \\ \wedge work'(e_5, J)$$

A third, and much simpler, approach, however, is made possible by appealing to the pragmatics process of factoring, and it has the added advantage of working for gapped predicate complements as well. Since every phrase type that can be a gapped adjunct can also be a predicate complement, it will be sufficient to specify one rule in which an empty string can act as a **pred**. The rule is a small modification of Rule (4.29), and thus is quite analogous to Rule (4.28).

$$(4.31) \quad Subject(e_2, e_1) \supset Syn(\text{``''}, e_1, f_1{:}\mathbf{pred}, e_2, f_2, -, -, -, -, e_1, f_1)$$

That is, if the eventuality or entity e_2 is the subject of an eventuality e_1, then the empty string can be used as a predicate complement (or adjunct) to describe e_1 as long as it has a gap that will be filled by a relativizer also describing e_1. When an adjunct, this empty predicate complement will be adjoined to a clause describing e_2. When a predicate complement, it will take its place in the VP of a clause having e_2 as its subject.

In example (4.30) the phrase "with whom" will generate a logical form fragment of

$$with'(e_1, z, x)$$

where e_1 is the "with" eventuality, x is the wh-ed entity referred to by "whom" (and "man"), and z is so far unknown. When the empty string is added as an adjunct to the clause "John works", the logical form fragment

$$Subject(e_2, e_1)$$

is generated. As discussed in Chapter 2, there need to be axioms that relate predicates to their arguments of the form

$$with'(e_1, z, x) \supset Subject(z, e_1)$$

The pragmatics process of factoring then uses this axiom to subsume the problem of proving $Subject(e_2, e_1)$ into the problem of proving $with'(e_1, z, x)$, at the same time identifying z with e_2.

A simpler version of this example is illustrated below in Figure 4.15.

An example of the analysis of a gapped predicate complement is illustrated in Figure 4.16 at the end of Section 4.13.4.

4.13.3 The Structure of Relativizers

The next problem (Problem 3) is to specify the structure of possible relativizers. A relativizer that begins a relative clause, wh-question, or sentential wh-nominal can have a moderately complex structure, as seen in "pied-piping" examples:

I saw the man *whose car* you ran into ().
I saw the man *the sister of whom* () is looking for you.

In the first, the man has to be identified with the owner of the car and the car has to be identified as the thing you ran into. In the second, the man has a sister and the sister is looking for you.

To handle these cases we will overload the v and g arguments of Syn. Relativizers cannot have gaps in them, so those argument positions are available. We will use the v and g argument positions to carry the variable representing the wh-ed entity. We will use the second and third argument positions of Syn to carry the variable corresponding to the relativizer as a whole. This structure can be seen most clearly in the lexical axiom for the relative determiner "whose":

$$'s'(e_1, x, y)$$
$$\supset Syn(\text{“whose”}, e_1, \mathbf{ld}, e_2, \mathbf{ldane}, y, \mathbf{n}, s_2, -, x, \mathbf{nrel})$$

This says that if e_1 is the condition of y being x's (e.g., y belongs to x), then e_1 can be expressed by the determiner "whose" applying to a partial NP referring to y and having x as its wh-ed entity. The feature **nrel** indicates that "whose" can appear as part of a relativizer, as explained below. This axiom has the structure of lexical axioms for determiners (Section 4.10), so it specifies the property e_2 conveyed by the partial NP, the partial NP's state of construction **ldane**, and the possible associated set s_2.

Both relative clauses and wh-questions are headed by wh-phrases. Relative clauses headed by "that" require special treatment and are dealt with below. Otherwise, every wh-phrase that can head a relative clause can also head a wh-question, but some wh-phrases that can head wh-questions cannot head relative clauses. Thus, "what" can head a wh-question but not a relative clause, whereas "who" can head both.

What arrived late?
* the shipment what arrived late
Who arrived late?
the man who arrived late

Words and phrases that can head wh-questions will be given the feature **whqhd** in the feature set CAT. Words and phrases that can head relative clauses are given the feature **nrel** in the feature set CAT. The feature **nrel** is a subfeature of **whqhd**.

A second distinction among wh-words is that some can function as or participate in the objects of prepositions and in other NP positions, whereas other others cannot.

Because of what did you leave early?
Because of whom did you leave early?
* Because of why did you leave early?

Those that can occur with prepositions are pronouns; those that cannot are not. The pronouns are a subcategory of nouns, feature **n**. We will thus have a feature **nwhqhd**, which is a subfeature of both **n** and **whqhd**. All wh-words that can occur in the heads of relative clauses can also appear in objects of prepositions and other NP positions. Hence, **nrel** is a subfeature of **nwhqhd**. This feature set is illustrated in Figure 4.13.

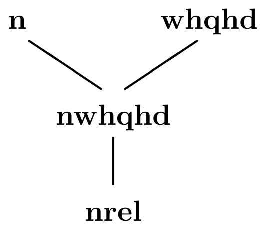

Figure 4.13: Agreement features for long-distance dependencies.

To summarize, the relevant features are as follows:

n:	Nouns.
whqhd:	Words and phrases that can head wh-questions.
nwhqhd:	Words and phrases that head wh-questions and can occur in NP positions.
nrel:	Words and phrases that head relative clauses and can occur in NP positions.

The relevant words in our target texts are classified as follows:

n:	Ordinary nouns
whqhd:	"why", "how"
nwhqhd:	"which" (as a determiner), "what"
nrel:	"who", "whom", "whose", "which" (as a pronoun), "where", "when"

Problems concerning the classification of "where" and "when" are discussed below.

We are now in a position to give the lexical axioms for all the words.

The lexical axiom for "which", as a pronoun, is simpler than that for "whose", since the wh-ed entity is the same as the gapped entity referred to by the whole relativizer.

$$nonperson'(e,x) \supset Syn(\text{“which”}, x, a, -, -, -, -, x, a{:}\mathbf{nrel})$$

That is, “which” is a relative pronoun referring to some x whose wh-ed entity is also x.

The lexical axioms for “who” and “whom” are similar, although restricted to persons:

$$person'(e,x) \supset Syn(\text{“who”}, x, a, -, -, -, -, x, a{:}\mathbf{nrel})$$
$$person'(e,x) \supset Syn(\text{“whom”}, x, a{:}\mathbf{n.acc}, -, -, -, -, x, a : a_{CASE})$$

I have not classified “who” as nominative since it can occur so freely in colloquial English in object position.

For “whom”, the gap must be in an accusative position, but the head of the NP need not be, so the two a variables may differ in their *CASE* feature.

In cases of pied-piping, such as “the sister of whom”, a pointer to the wh-ed entity is carried up to the NP as a whole by NP Composition Rule 2 (4.22)

$$\begin{array}{l} Syn(w_1, e_1, f_1{:}\mathbf{ldan}, x, a{:}\mathbf{n}, y, b, s, -, v_1, g_1) \\ \quad \wedge\, Syn(w_2, e_2, f_2{:}\mathbf{pred/rels/than}, x, a, -, -, -, -, v_2, g_2) \\ \quad \wedge\, gap(v, g, v_1, g_1, v_2, g_2) \\ \supset\, Syn(w_1 w_2, e_1 \& e_2, f_1{:}\mathbf{rc}, x, a, y, b, s, -, v, g) \end{array}$$

The other relevant lexical axioms with their glosses and some justifications are as follows:

$$\begin{array}{l} entity'(e_0, x) \\ \quad \supset\, Syn(\text{“which”}, -, \mathbf{ld}, e_0, \mathbf{ldane}, x, a, s, -, x, a{:}\mathbf{nwhqhd}) \end{array}$$

“Which”, as a determiner, carries no semantic content. Since the NP composition rules require a property, the empty property e_0 of x's being an entity is used. The examples

  After which party did John get angry?
* the party after which event John got angry
  Which party did John go to last night?
* the party which event John went to () last night

show that it can be part of an object of a preposition, and can head wh-questions but not relative clauses. Hence, it is **nwhqhd**.

“What”:

$$nonperson'(e,x) \supset Syn(\text{“what”}, x, a, -, -, -, -, x, a{:}\mathbf{nwhqhd})$$

"What", as a pronoun, can indicate something that is not a person. The examples

After what did John get angry?
* the party after what John got angry
What did John see ()?
* the car what John saw ()

show that it can be the object of a preposition, and can head "wh" questions but not relative clauses. Hence, it is also **nwhqhd**.

"What", as a determiner, is like the determiner "which":

$$entity'(e_0, x) \supset Syn(\text{"what"}, e_0, \mathbf{ld}, e, \mathbf{ldane}, x, a, s, -, x, a{:}\mathbf{nwhqhd})$$

"Where" involves some difficulties. It can head both wh-questions and relative clauses.

Where did John go?
the place where John went

It is probable that "where" should be considered a noun, depending on how one feels about the examples

Where do you come from ()?
the city where I came from ()
From where do you come?
the city from where I came

For me, these sentences are in order of decreasing acceptability, but I'm not sure I would rule any of them out. If all are acceptable, then "where" is simply **nrel**. If we wished to block the last two, we could give "where" a treatment similar to that of "that", presented below.

Accepting all four examples, the lexical axiom for "where" is

$$at'(e, y, x) \supset Syn(\text{"where"}, e, \mathbf{adjunct1}, y, b, -, -, -, -, x, \mathbf{nrel})$$

If e is the condition of y being at x, then e can be indicated by the word "where", where x is the wh-ed element. "Where" can head a wh-question and a relative clause, and can occur as the object of a preposition.

"When" differs from 'where" in interesting ways. It can head a wh-question.

When did John announce his resignation?

It may seem that it can also head relative clauses in certain restricted contexts.

> the day when John announced his resignation
> the party when John left for college

But another analysis is possible for these cases. "When" is also a subordinate conjunction, and subordinate conjunctions can modify event nouns. The above examples have parallels with "before" and "after".

> the day before John announced his resignation
> the party after John left for college

If we interpret the "when" examples as examples of the subordinate conjunction, then there is no need to allow "when" to head a relative clause.

The acceptability of "when" used as an object of a preposition is unclear.

> When have you worked here from ()?
> From when have you worked here?
> ? the day when you have worked here from ()
> * the day from when you have worked here

For me, the first is good, the second not quite as good, the third marginal, and the fourth bad. If we accept the first two and reject the last two and adopt the subordinate conjunction analysis above, then the straightforward description of "when" is that it is **nwhqhd** but not **nrel**.

The lexical axiom is

$$at\text{-}time'(e, y, x) \supset Syn(\text{“when”}, e, \textbf{adjunct1}, y, b, -, -, -, -, x, \textbf{nwhqhd})$$

"Why" can head a wh-question.

> Why did John leave?

In some dialects it can head a relative clause in very semantically, or perhaps even lexically, restricted contexts.

> ? the reason why he left early
> * the situation why he left early

If we disallow such examples, "why" is **whqhd** but cannot head a relative clasue.

Uses of "why" with prepositions border on barbarism:

? Because of why did John leave early?
* Why did John leave early because of ()?

Thus, "why" is **whqhd** but not **nwhqhd**.

The lexical axiom for "why" is

$$because'(e_1, e_2, e_3) \supset Syn(\text{"why"}, e_1, \textbf{adjunct1}, e_2, f_2, -, -, -, -, e_3, \textbf{whqhd})$$

If e_1 is the condition of e_3 being the cause of e_2, then e_1 can be indicated by the word "why", where e_3 is the wh-ed element. "Why" can head a wh-question, but not a relative clause, and does not function as a noun.

The manner sense of "how", as in

How did you do it?

is similar to "why". It also cannot head relative clauses or function as a noun.

* the way how I did it
* By how did you do it?
* How did you do it by ()?

The lexical axiom for this sense of "how" is

$$manner'(e_1, e_3, e_2) \supset Syn(\text{"how"}, e_1, \textbf{adjunct1}, e_2, f_2, -, -, -, -, e_3, \textbf{whqhd})$$

If e_1 is the condition of e_3 being the manner in which e_2 was done, then e_1 can be indicated by the word "how", where e_3 is the wh-ed element. "How" can head a wh-question, but not a relative clause, and does not function as a noun.

The lexical axiom for the measure sense of "how", as in

How strong is John?

is

$$measure'(e_1, y, x, e_2) \supset Syn(\text{"how"}, e_1, \textbf{adjunct1}, y, b, e_2, \textbf{adj/adv}, -, -, -, -, e_3, \textbf{whqhd})$$

If e_1 is the condition of y having measure x on a scale defined by eventuality e_2, then e_1 can be indicated by the word "how", where y is the subject of the resulting adjunct, e_2 is the property conveyed by an adjective or adverb in the first complement position, and e_3 is the wh-ed element. Again, this sense of "how" can head a wh-question, but not a relative clause, and cannot function as a noun.

This example is illustrated below in Figure 4.16.

4.13.4 Composing Relativizers and Matrix Clauses

The final problem (Problem 4) is to specify the rules that link up the relativizer with the matrix clause, filling the gap correctly and generating the required resulting structure. For this, three composition axioms are needed, one each for relative clauses, wh-questions, and sentential wh-nominals. They differ in the role played by the wh-ed entity and in their further compositional possibilities.

Relative clauses will be treated first. The Relative Clause Composition Rule is

$$(4.32)\quad \begin{aligned} & Syn(w_1, v_2, g_2{:}\mathbf{n/adjunct}, y, b, -, -, -, -, v_1, g_1{:}\mathbf{nrel}) \\ & \quad \wedge Syn(w_2, e_2, \mathbf{v.tnsd/inf}, -, -, -, -, -, -, v_2, g_2) \\ & \supset Syn(w_1 w_2, e_2, \mathbf{rels}, v_1, g_1{:}\mathbf{n/v}, -, -, -, -, -, -) \end{aligned}$$

This rule concatenates a relativizer w_1 with a matrix clause w_2 that has a gap. The clause describes the eventuality e_2. The referent of the relativizer is v_2 and it fills the gap in the clause. The wh-ed entity in the relativizer is v_1. The result of the concatenation is a relative clause (**rels**) describing the eventuality e_2. It is a noun complement and can be adjoined to a head noun referring to v_1. It can also function as an adjunct on a clause describing an eventuality v_1. The subject arguments y and b are empty when w_1 is a relative NP and when it is a relative PP they indicate the logical subject of that PP.

The two types of phrases that can function as noun complements are relative clauses and predicate complements. Note that they have the same argument structure, in that both have an unsaturated subject argument.

The two instances of g_1 in this rule place different constraints on the *CAT* feature—**nrel** versus **n/v**. The feature **nrel** in the first conjunct of the antecedent constrains the rule to apply only to phrases containing the right category of wh-word. The feature **n/v** in the consequent allows the relative clause to occur as noun complements and as sentence adjuncts. By our abbreviation conventions of Section 4.2.3, they do not need to unify.

Figure 4.14 illustrates the parse of the $\overline{\mathbf{N}}$ "man whose sister John met ()".

Figure 4.15 illustrates the parse of the $\overline{\mathbf{N}}$ "man with whom John works".

Although most relative clauses occur in NPs, both restrictively and non-restrictively, some occur as adjuncts on clauses, where they can modify either the clause as a whole or its subject.

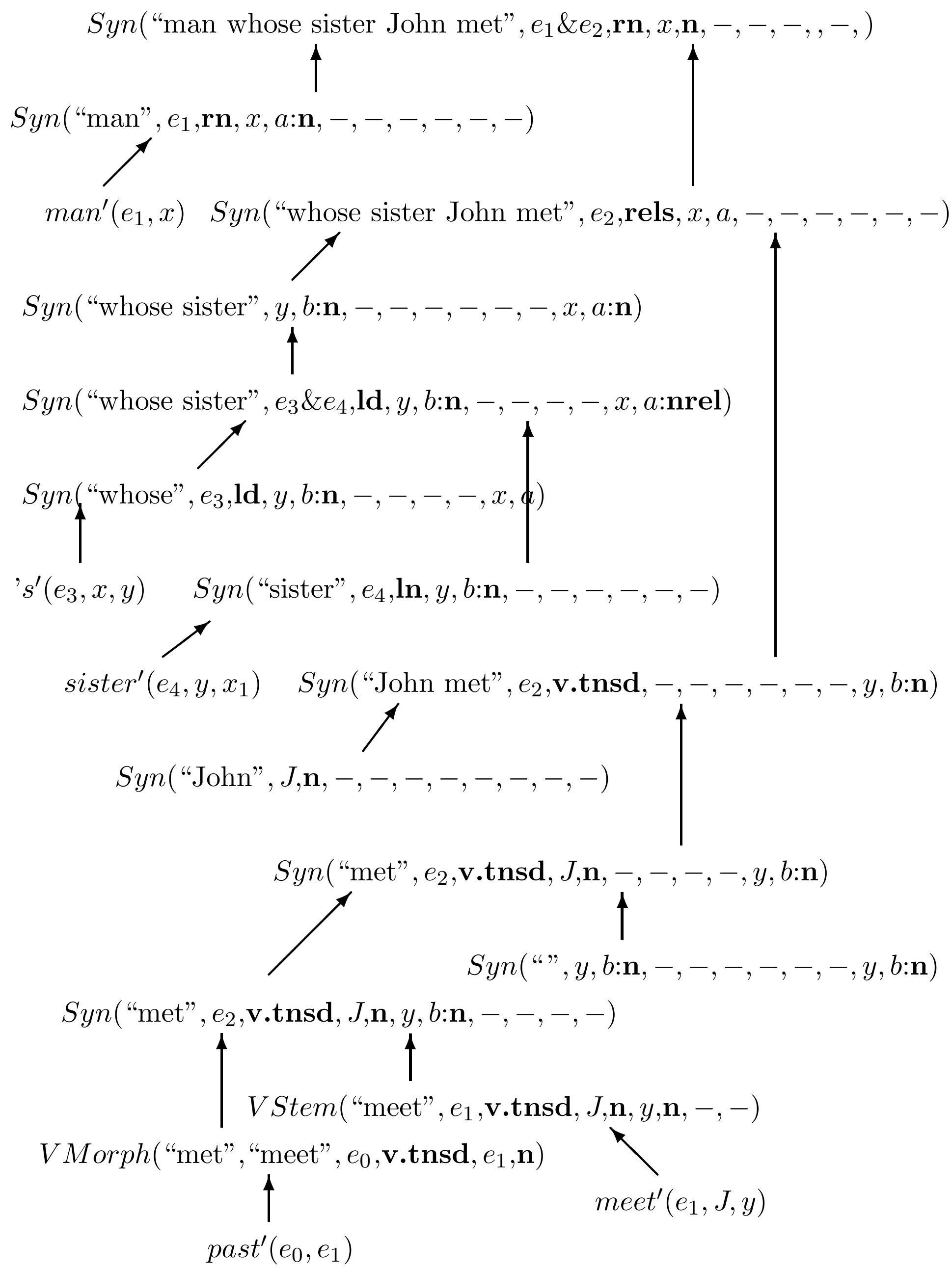

Figure 4.14: Parse of "man whose sister John met"

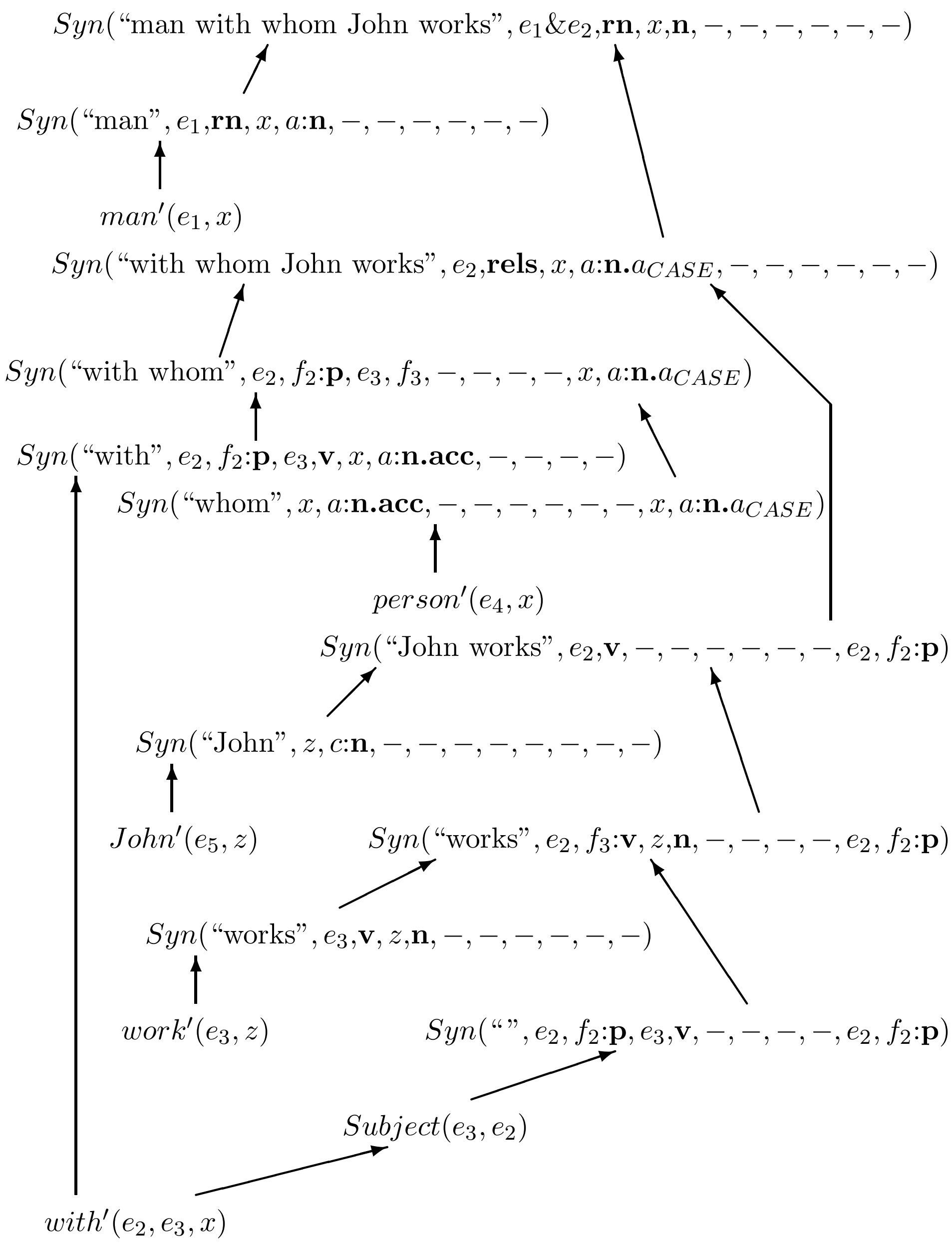

Figure 4.15: Parse of "man with whom John works"

Antibodies appear in blood serum, after which it becomes difficult to isolate the virus.

John spoke, which I found inappropriate.
The person is here who knows how to solve your problem.

Since relative clauses have as their subject argument the wh-ed entity and this will be the eventuality described by the modified clause, the treatment presented here works for the first two examples. Extraposed noun complements, as in the third example, will be interpreted as modifying the clause as a whole and then a metonymy axiom will be used to coerce this argument of the adjunct into the subject of the clause, as described in Section 4.17.2.

The rules presented work as well when the gap is in an adjunct PP or an embedded clause.

the man whom George believes John met ()
the man whom John works with ()

The rules that concatenate adjuncts with the clauses they modify and verbs with their sentential arguments pass the gaps up correctly from the adjuncts and embedded arguments. Similarly, it works when it is the subject that is the gap in the matrix clause, as in

the man who () arrived

The subject NP can be an empty string, introducing a gap which is carried up to the clause level and then discharged when the clause is concatenated with the relativizer.

A kind of noun complement closely related to relative clauses is the infinitive with a gap in it, as in "a job to do ()". The head noun fills the gap. This alternation axiom turns an infinitive with a gap into a relative clause:

$$Syn(w, e, \mathbf{v.inf}, x, a, -, -, -, -, v, g)$$
$$\supset Syn(w, e, \mathbf{rels}, v, g, -, -, -, -, -, -)$$

If there is no subject, as in "a job to do ()", x and a, representing the unsaturated subject, will be lost in this alternation. It will not be possible to determine syntactically who is to do the job. In

George has a job to do.

that George will do the job has to be recovered pragmatically. If there is a subject, as in "a job for John to do ()", then x and a will be the empty constant "$-$", having already been saturated.

Wh-questions can be given a treatment very similar to that for relative clauses. We need a Wh-Question Composition Rule corresponding to the Relative Clause Composition Rule.

(4.33) $Syn(w_1, v_2, g_2{:}\mathbf{n/p}, y, b, -, -, -, -, v_1, g_1{:}\mathbf{whqhd})$
$\wedge\, Syn(w_2, e_2, \mathbf{ynq}, -, -, -, -, -, -, v_2, g_2) \wedge wh'(e_1, v_1)$
$\supset\ Syn(w_1 w_2, e_1, \mathbf{whq}, -, -, -, -, -, -, -, -)$

This rule concatenates a wh-NP or wh-PP with a yes-no question that has a gap. The yes-no question describes the eventuality e_2. The wh-phrase must have a wh-word of type **whqhd**. The gapped entity is v_2 and it fills the gap in the yes-no question. The wh-ed entity is v_1. The result of the concatenation is a wh-question (**whq**) requesting a contextually dependent essential property e_1 of v_1. (The predicate wh, indicating this property, is described in Chapter 2, Section 2.6.4)

If w_1 is a wh-NP, y and b are the empty constant. If w_2 is a wh-PP, y and b stand for the logical subject of the PP, and, as described above for relative clauses, these will get unified with the eventuality associated with the clause that the PP modifies.

As it stands, this rule does not handle wh-questions where the wh-phrase plays the role of subject, as in

Who arrived first?

This can be taken care of by the alternation axiom

$Syn(w, e, \mathbf{v.tnsd}, x, a{:}\mathbf{n.sb}, -, -, -, -, -, -)$
$\supset\ Syn(w, e, \mathbf{ynq}, -, -, -, -, -, -, x, a)$

That is, a verb phrase can be converted into a "yes-no question" by moving the unsaturated subject to the gap position of Syn. It will then be accepted as the w_2 in the Wh-Question Composition Rule. There is no danger of this phrase being interpreted by itself as a yes-no question, since there is a gap in it, and x and a are thus the empty constant.

Figure 4.16 shows the parse for the sentence "How strong is John?"

The final long-distance dependency considered here is the sentential wh-nominal, exemplified in

I don't understand what John did.
I don't know where John went.
I don't know what to do.

The composition rule for sentential wh-nominals is almost identical to the composition rule for wh-questions:

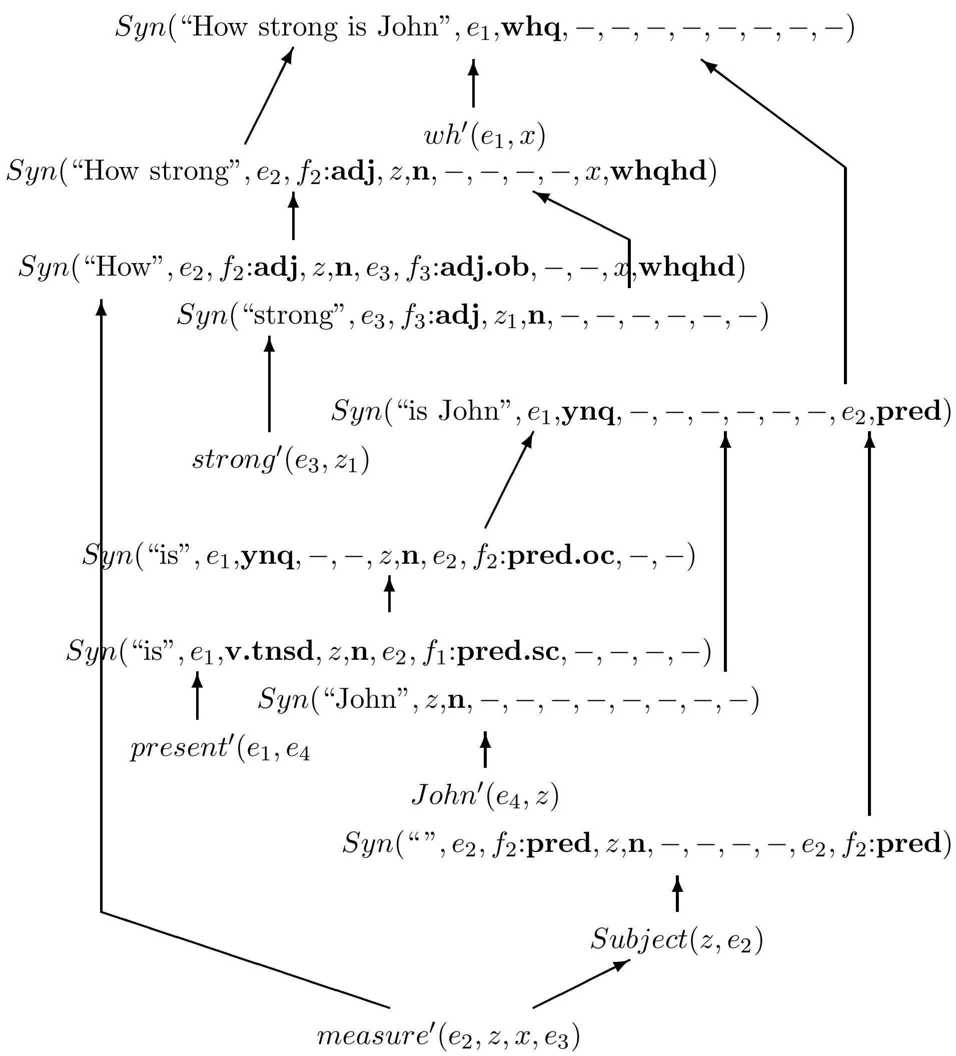

Figure 4.16: Parse of "How strong is John?"

(4.34) $Syn(w_1, v_2, g_2{:}\mathbf{n/p}, y, b, -, -, -, -, v_1, g_1{:}\mathbf{whqhd})$
$\wedge\, Syn(w_2, e_2, \mathbf{v.tnsd/inf}, -, -, -, -, -, -, v_2, g_2)$
$\wedge\, wh'(e_1, v_1)$
$\supset\ Syn(w_1 w_2, e_1, \mathbf{nominal}, -, -, -, -, -, -, -, -)$

The wh-phrases that can head sentential wh-nominals are the same as those that can head wh-questions. In both cases, the dominant eventuality e_1

for the composite phrase is that corresponding to the essential property of the wh-ed entity v_1. The only differences between them are that in this construction the second phrase must be of category **v.tnsd/inf** rather than **ynq**, and the resulting phrase is of category **nominal** rather than **whq**.

This suggests that this composition rule could be eliminated by viewing **ynq** as a composite category combining **v.tnsd** and another feature, say, **inv**, where the category **whq** is a composite of **wh-nominal** and **inv**. This analysis will not be pursued here.

Two other types of long-distance dependency constructions are not dealt with here. The first is noun-like wh-nominals, as in

I didn't do what he did.

Whereas sentential wh-nominals must appear in an epistemic or communicative matrix clause, noun-like wh-nominals may appear anywhere an NP can occur. The second construction is the topicalized sentence, exemplified in

Peanuts I like.

These constructions would require their own composition rules.

To summarize, we have dealt with the four parts of the long-distance dependency problem by utilizing the following:

1. Introducing gaps: Two gap introduction rules, treating the empty string as a lexical item.
2. Linking the gap with its filler: Use of the *gap* predication in composition rules.
3. Subcategorizing wh-phrases for specific long-distance dependency constructions: Lexical axioms based on a lattice of four features.
4. The structure and semantics of the specific long-distance dependency constructions: Two to five new composition axioms.

4.13.5 "That"

The word "that" requires a somewhat different treatment. Unlike wh-words, it can head a relative clause—

the man that left early

—but not a wh-question—

* That left early?

It can head a relative clause where the gap is the object of a preposition—

the man that John works with ()

—but it cannot itself be the object of a preposition—

* the man with that I work

Thus, we cannot classify it as a noun, **n**.

The easiest way to encode its properties is to treat it as an operator. Its complement is a tensed clause. The composite phrase will be of category **rels** so that it can only appear where relative clauses can appear. It will take the referent of the head noun of the NP as its "subject". This "subject" will be identified with the gap in the complement by requiring the *COMPRULE* feature of the complement to be **tf**, dictating the Tough Movement Rule. The lexical axiom for "that" is thus

$$\supset \; Syn(\text{"that"}, e, \mathbf{rels}, x, \mathbf{n}, e, \mathbf{v.tnsd.tf}, -, -, -, -)$$

It has no semantic content, so there is nothing on the left-hand side of the implication. The eventuality conveyed by the composite is the eventuality conveyed by the tensed clause.

The relativizer "that" is frequently omitted.

the man that John met ()
the man John met ()

However, "that" cannot be omitted when it is the subject that is the gapped element.

the man that () arrived
* the man () arrived

Two ways that might suggest themselves of accommodating these facts won't work.

The first would be to restrict the Subject Composition Rule (4.6) to nonempty NPs and to posit another Relative Clause Composition Rule that composed relativizers with gapless VPs. The relativizer could then be omitted only when the matrix clause had a gap. This would give us separate treatments of relative clauses when the gapped element is the subject and when it is something else.

Unfortunately, these solutions don't cover phrases in which the gap is in the subject position of an embedded clause.

a man that John believes () will win
a man John believes () will win
a project that it had not occurred to me () could be done
a project it had not occurred to me () could be done

The gap needs to be generated in subject position somehow, and "that" can be omitted.

A further constraint on "that" omission is that the clause cannot begin with an adverbial. This is true regardless of whether the gap is in the subject or a complement position.

a man that rudely () addressed the queen
* a man rudely () addressed the queen
a man that generally John saw () on Tuesdays
* a man generally John saw () on Tuesdays

We can summarize all this by saying that "that" can be omitted when it is immediately followed by an explicit subject in the matrix clause.

The axiom expressing this is a bit more complex than we might like, but it has the advantage of corresponding to our intuitions. The "that"-less relative clause has the feel of a contraction that is constrained to occur only when the subject in a matrix clause is explicitly expressed. The rule is as follows:

$$\begin{aligned} & Syn(\text{"that"}w_1w_2, e, f{:}\mathbf{rels}, x, a{:}\mathbf{n}, -, -, -, -, -, -) \\ & \qquad \wedge Syn(w_1, y, b{:}\mathbf{n}, -, -, -, -, -, -, -, -) \wedge Subject(y, e_1) \\ & \quad \supset Syn(w_1w_2, e, f, x, a, -, -, -, -, -, -) \end{aligned}$$

This says that if a string consisting of the word "that" followed by a clause w_1w_2 with an explicit subject w_1 is a relative clause, then so is the same string with the "that" omitted. This approach will entail that that the proposition $Syn(w_1, y, b{:}\mathbf{n}, -, -, -, -, -, -, -, -)$ will be generated twice while constructing the proof graph by backchaining, once in the verification of the context of the "that"-less relative clause and once in the analysis of the matrix. But factoring will occur so that the expression in fact only need be proved once. Similarly, this axioms also requires that $Subject(y, e_1)$ be proved, but this will follow immediately from the logical form of e_1. The string w_1 is necessarily nonempty because its *Syn* predication has no gap.

Note that y need not be the subject of the same eventuality as is conveyed by the whole relative clause (e_1 versus e). This is because the whole relative clause can be conjoined clauses, and y needs only to be the subject of the first of these.[7]

[7] I am indebted to Ivan Sag for pointing this out to me.

a man that John met () and Mary didn't meet () a man John met () and Mary didn't meet ()

4.13.6 Some Other Long-Distance Dependency Constructions

It-clefts, such as

It was John who left the party early.

can be accommodated by two lexical rules, one for "it" and one for "be". The rule for "be" is

$$\supset\ VStem(\text{“be”}, e, \mathbf{be}, x, \mathbf{itcleft}, e, \mathbf{nppred}, e_1, \mathbf{rels.sc})$$

In this construction, "be" takes two complements, a predicate complement NP and a relative clause. The main predication of the sentence is the predication e introduced by the predicate complement NP. The subject of that predication and the "subject" of the relative clause, i.e., the entity that fills the gap, must be the same. This is achieved by forcing both to be identical to x, an entity introduced by the subject "it". The subject is always identical to the logical subject of the predicate complement, and by setting the *COMPRULE* feature of the relative clause to **sc**, we ensure that x will also fill the gap there. No further semantic content is introduced by the it-cleft construction, so the left side of the rule is empty.

The second required rule is for "it":

$$\supset\ Syn(\text{“it”}, x, \mathbf{itcleft}, -, -, -, -, -, -, -, -)$$

The problem with the expletive "it" is that it has no referent. The second argument of *Syn* is the empty constant, $-$. But for it-clefts we require a variable that will link the subject of the predicate complement NP and the gap in the relative clause. The word "it" places no semantic constraints on x; it need not be a nonperson, for example.

This treatment achieves the same effect as the old generative semantics analysis of it-clefts as a transformation from underlying clauses like "It who left the party early was John."

Several other constructions involving gaps can occur as adjuncts, where the modified clause fills the gap in the adjunct:

As I tried to tell () you, John is here.
John, you know (), is here.

The meanings of the adjuncts are that I tried to tell you *that John is here* and that you know *that John is here*. The first of these usages is accommodated by the following lexical axiom for "as":

$$\supset Syn(\text{"as"}, e_1, \mathbf{adjunct1}, e_2, \mathbf{v}, e_1, \mathbf{v.tf}, -, -, -, -)$$

The word "as" has no semantic content. The eventuality conveyed by the phrase is the same as that conveyed by the complement of "as", e_1. The eventuality e_2 of the modified clause will fill the gap in the complement, since the complement is subcategorized for the Tough Movement Composition Rule, with the feature **tf**.

The "you know" type of construction can be accommodated by the following alternation axiom:

$$Syn(w, e, f{:}\mathbf{v}, -, -, -, -, -, -, v, g{:}\mathbf{v})$$
$$\supset Syn(w, e, f{:}\mathbf{adjunct1}, v, g, -, -, -, -, -, -)$$

A tensed clause with a gap becomes an adjunct whose logical subject will fill that gap. The logical subject is a clause. The restriction in g that v be described by a constituent headed by a verb (**v**) constrains this rule to verbs that subcategorize for clause complements, that is, primarily to epistemic and communicative verbs.

4.14 Conjunction

4.14.1 Conjunction of Like Constituents

Conjunction is a very complex area of grammar, for which there is probably no adequate account in the literature. Computer grammars that are strong in every other area are generally weak in this.

Statistically, by far most examples of conjunction involve conjoined phrases of the same category. In the target texts, we see the following:

- **Tensed clauses:** Virus is typically found in the blood (viremia), and high levels of virus replication can be observed.

- **VPs:** UNIT HAS EXCESSIVE WEAR ON INLET IMPELLOR ASSEMBLY AND SHOWS HIGH USAGE OF OIL.

- **Predicate complements:** It seems as natural to man as walking, and only less so than breathing.

- **Subordinate clauses:** If I go first and if we get squeezed, I'll eat the time that we lose.

- **Prepositional phrases:** This incubation period is characterized by low viral replication and by slowly decreasing numbers of $CD4^+$ cells.

- **Noun phrases:** The tenants come in for a day of talk and trade.

- **Head nouns:** I don't have to know anything about his current goals and plans.

- **Prenominal nouns:** The Greyhound and White Bus Lines use the Forks Falls Road.

- **Prenominal adjectives:** For a short but variable period, virus is typically found in the blood.

If this were the only case that occurred, the following rule would be sufficient:

$$
\begin{aligned}
(4.35)\quad & Syn(w_1, e_1, f_1{:}f_{CAT}, x, a, y, b, z, c, v, g) \\
& \quad \wedge Syn(w, e, \textbf{conj}.f_{NUM}, e_1, f_1, e_2, f_2, -, -, -, -) \\
& \quad \wedge Syn(w_2, e_2, f_2{:}f_{CAT}, x, a, y, b, z, c, v, g) \\
& \supset Syn(w_1 w w_2, e, f_{CAT}.f_{NUM}, x, a, y, b, z, c, v, g)
\end{aligned}
$$

Two phrases w_1 and 1_2 of the same category f_{CAT} describing eventualities e_1 and e_2 can be conjoined by a conjunction w, and the result is a phrase of the same category describing the conjunction e of e_1 and e_2. The number feature is inherited from the conjunction, if it has one; this allows conjoined singular NPs to result in a plural NP. Note that the corresponding arguments for the conjoined phrases must either be empty, and hence $-$, or identical. This means that any arguments not yet saturated will be the same in the two conjoined predications.

The corresponding v arguments, the gaps, must also be identical. This enforces the subjacency constraint. That is,

* This is the man John fired () and hired George.

is disallowed by this rule because the v arguments differ in the two conjuncts.

The rule allows for prenominal nouns and noun-like adjectives to be conjoined, as in

the asymptomatic or incubation period.

Prenominal nouns yield phrases of type **ln**, noun-like adjectives yield phrases of type **lan**, and their f_{CAT} arguments thus unify.

The lexical axioms for the conjunctions are as follows:

$$\begin{aligned}
&and'(e, e_1, e_2) \wedge eventuality(e_1) \wedge eventuality(e_2) \\
&\quad \supset Syn(\text{“and”}, e, \mathbf{conj}, e_1, f_1, e_2, f_2, -, -, -, -) \\
&or'(e, e_1, e_2) \wedge eventuality(e_1) \wedge eventuality(e_2) \\
&\quad \supset Syn(\text{“or”}, e, \mathbf{conj}, e_1, f_1, e_2, f_2, -, -, -, -) \\
&but'(e, e_1, e_2) \wedge eventuality(e_1) \wedge eventuality(e_2) \\
&\quad \supset Syn(\text{“but”}, e, \mathbf{conj}, e_1, f_1, e_2, f_2, -, -, -, -) \\
&so'(e, e_1, e_2) \wedge eventuality(e_1) \wedge eventuality(e_2) \\
&\quad \supset Syn(\text{“so”}, e, \mathbf{conj}, e_1, f_1, e_2, f_2, -, -, -, -)
\end{aligned}$$

All these senses of the conjunctions are constrained to conjoin eventualites, as would be required in the logical operator senses.

NP conjunction with “and” generally has a different interpretation from the conjunction of other categories. It is a set constructor rather than a logical operator. Thus, “John and Mary” has as its interpretation the set of two people, John and Mary. We introduce a predicate *andn* to capture this notion. The predicate *andn* takes three arguments, the typical element of the set of two elements, and the two elements. The proposition conveyed by the phrase “John and Mary” is $andn(x, J, M)$. This says that x is the typical element of the set consisting of John and Mary.

The lexical axiom for this sense of “and” is

$$andn'(e, x, x_1, x_2) \supset Syn(\text{“and”}, x, \mathbf{conj.pl}, x_1, \mathbf{n}, x_2, \mathbf{n}, -, -, -, -)$$

That is, if e is the condition of x being the typical element of the set consisting of x_1 and x_2, then x can be referred to by linking two NPs referring to x_1 and x_2, respectively, with the conjunction “and”.

NPs conjoined with “or” will be dealt with below.

The word “to” is also sometimes used an an NP conjunction, as in

a short but variable period—a few weeks to a few months

This will be treated as a special sense of “to” and its meaning will be explicated in Chapter 5. Briefly, when it is used to conjoin two NPs, the NPs must be locatable along some scale and the result of the conjunction is another entity on that scale, between the two conjuncts. For now we will simply use the predicate to_2 to encode all of this. It has the same structure as *andn*.

$$to_2'(e, x, x_1, x_2) \supset Syn(\text{“to”}, x, \mathbf{conj}, x_1, \mathbf{n}, x_2, \mathbf{n}, -, -, -, -)$$

Conjoined phrases can be iterated, separated by commas in written discourse. When the last two items in such a sequence are separated by “or”, the interpretation of the commas is *or*. When the last two items are separated by “and” or, as occurs several times in the target texts, simply a comma, the interpretation is *and* or *andn*. The following axiom handles iteration with “or”:

$$or'(e, e_1, e_2) \wedge or'(e_2, e_3, e_4) \supset Syn(\text{“,”}, e, \mathbf{conj}, e_1, f_1, e_2, f_2, -, -, -, -)$$

The second conjunct in the antecedent is a kind of selectional constraint that forces the second conjoined phrase to be interpreted as *or*. This can only happen if eventually the word “or” appears in the sentence. This rule also forces right recursion in this case.

The following lexical axioms allow commas to be interpreted as *and* and *andn*.

$$and'(e, e_1, e_2) \supset Syn(\text{“,”}, e, \mathbf{conj}, e_1, f_1, e_2, f_2, -, -, -, -)$$
$$andn'(e, x, x_1, x_2) \supset Syn(\text{“,”}, e, \mathbf{conj}, x_1, \mathbf{n}, x_2, \mathbf{n}, -, -, -, -)$$

These three “lexical” axioms for comma do not rule out the possibility of mixing *and*s, *andn*s and *or*s rather arbitrarily, but no further constraints will be developed here.

4.14.2 Ellipsis

***** UNDER CONSTRUCTION *****

There are a number of examples that cannot be handled by conjunction of phrases of the same category, including the following examples.

John cooked and Mary ate dinner.
John cooked and Mary pretended to try to eat dinner.
John trusted and Mary relied on George.
John distrusted but tried to rely on George.

Among such examples are conjunctions of pairs of complements of verbs, as in

John gave Mary a book and George a magazine.

Four examples of this occur in Shakespeare's sonnet.

Increasing store with loss and loss with store;

sometime lofty towers I see down-rased
And brass eternal slave to mortal rage;

I have seen the hungry ocean gain
Advantage on the kingdom of the shore,
And the firm soil win of the wat'ry main.

I have seen such interchange of state,
Or state itself confounded to decay,

4.14.3 Gapping

***** UNDER CONSTRUCTION *****

The phenomenon known as gapping occurs in the target texts, and consequently we will want to handle it.

Viremia can be reduced, and $CD4^{+}$ cell counts raised.
The winters here are short and raw, the summers white with glare and fiery hot.

In both of these examples the copula of the second clause is omitted. But much more complex and problematic examples of gapping can occur:

John likes Mary, and Susan George.
John tried hard to meet Mary at the party, and Susan George.
Yesterday John flew to Chicago on business, and Mary Houston.
John bought three books and Mary four.

I once ran across the sentence

> Sudan is an underdeveloped country, the northern half of which is desert and the southern jungle.

Here the material that has been gapped out of the second clause, "half of which is", spans the tail end of a pied-piping relative NP and the beginning of a VP.

I recently wrote

> What is to prevent the first copy of "flying planes" to be interpreted as "airplanes which are flying" and the second as "the activity of flying airplanes"?

Here the gapped material, "copy of 'flying planes' to be interpreted", is the end of an NP and the beginning of a VP.

The following sentence exhibits the full complexity of the phenomenon:

> I saw a large crowd of people, approximately 100 of whom were in and 200 next to the river.

The desired expanded version of the sentence is

(4.36) I saw a large crowd of people, approximately 100 of whom were in [the river] and [approximately] 200 [of whom were] next to the river.

4.14.4 Other Conjunction Phenomena

***** UNDER CONSTRUCTION *****

Conjunctions of two words or two phrases can be signaled with the word "both". Thus, "both" can be viewed as an operator that applies to a phrase describing a conjunction, provided it is a conjunction of two things, and results in a phrase of the same type describing the same eventuality. For the logical operator *and* sense of "and", the lexical axiom for "both" is

$$two(e) \wedge and'(e, e_1, e_2) \supset Syn(\text{“both”}, e, f, -, -, e, f{:}\mathbf{ob}, -, -, -, -)$$

This says that if e is a conjunction of two eventualities, then the word "both" can be prefixed to a phrase describing e, yielding a phrase of the same type and describing the same eventuality.

"Either ... or ..." and "neither ... nor ..." can be given similar treatments.

The "both ... and ..." construction cannot be used to link two Ss.

* Both John flunked and Mary passed.

This constraint is not captured in this axiom.

The lexical axiom for the set constructor *andn* sense of "and" is

$$two(s) \wedge plural(x,s) \wedge andn(x,x_1,x_2)$$
$$\supset Syn(\text{"both"}, x, a, -, -, x, a{:}\mathbf{n.ob}, -, -, -, -)$$

This says that if s is a set of two elements, having the typical element x, then the word "both" can be prefixed to a phrase referring to x, yielding a phrase of the same type and also referring to x.

This lexical axiom covers the target text construction

LUBE OIL SATURATED WITH BOTH METALLIC AND NON-METALLIC PARTICLES.

Rule (4.**??**) will distribute the head noun "PARTICLES" across the two adjectives. Rule (4.35) will conjoin the resulting NPs, and finally "BOTH" will be prefixed to the conjoined NP, leaving its reference and agreement features unchanged.

"Both" is of course also a determiner, so

both red and blue cars

could refer to any number of cars that are either red or blue (the conjunction use), or it could refer to exactly two cars that are red and blue (the determiner use).

Conjunctions often occur sentence initially. In the target texts, there are the following examples:

And, so we can do that, y'know probably use that for discussion time, and maybe even keep it to a half an hour.

Or is that too...

But we've got to take into account that they're typically late on these things So, um.

So let's say we block out the twelve to um, twelve thirty for working lunch.

So, um, if I went first, let's say with for um, see I, as I said, I need about an hour and fifteen minutes I could do the, my reporting on the ongoing project, ah, for that first hour.

So it's almost exactly ...

So we're gonna get squeezed someplace.

So in other words, I'll eat out of the hour, that I originally scheduled.

There are two ways these could be handled. We could either appeal to the abduction mechanism or define new lexical axioms. In the abduction approach, Rule (4.35) would be invoked, but we would not be able to prove the existence of the first conjunct. Hence, we would assume it for the sake of getting an interpretation. The variable e_1 for the eventuality described by the first clause would be unconstrained except by the conjunction itself. Its reference would be resolved when the discourse structure was being interpreted, as described in Chapter 6.

The fact that all of the examples in the sample texts occur in the one spoken conversation and not in the written texts suggests that this is the approach to take. As we will see in Section 4.19.4, abduction will be used to interpret discourse rife with the disfluencies of speech.

The other approach is to posit lexical axioms very similar to the ones we have seen already for the conjunctions. I will illustrate this approach with the conjunction "so" since it is so frequent as a sentence-initial conjunction.

$$\begin{aligned}&so'(e, e_1, e_2) \wedge eventuality(e_1) \wedge eventuality(e_2)\\&\quad \supset Syn(\text{“so”}, e_2, f_2, -, -, e_2, f_2{:}\mathbf{v.ob}, -, -, -, -)\end{aligned}$$

If e is the eventuality of a (causal) "so" relation holding between eventualities e_1 and e_2, then the word "so" can be prefixed to a clause describing e_2, yielding a clause of the same type describing the same eventuality.

4.15 Comparatives

4.15.1 Overview

The general pattern for comparatives is as follows:

$P[\ldots A \ldots]$ more *scale* than B.

Two entities (or eventualities), an explicit P and an implicit Q, are being compared on the scale *scale*. There are two explicit entities A and B that play similar roles in P and Q, respectively. It is the job of interpretation to identify P, Q, and *scale*, generally by identifying A and B.

When there is a "than" phrase, it is clear from the syntax of the sentence what B is; it is just the complement of "than". It is also often clear from syntax what *scale* is—for example, in comparative adjectives. Interpretation must (1) discover the A that corresponds to B, and (2) use this information to discover the corresponding P and Q that embed A and B. (3) The scale *scale* must be determined when it is not explicit. Finally, (4) it must be determined what it means to compare P and Q on that scale. In this section, we will look only at the first two of these interpretation problems:

- How to determine A.
- How to determine P and Q.

The other two problems are addressed in Chapters 5 and 6.

I will give several examples of increasing complexity to illustrate this characterization of the comparative construction.

In

John is taller than George.

A and P are both John, B and Q are both George, and the scale is tall-ness. John and George are being compared on the scale of tall-ness.

In

John likes Mary more than George hates Bill.

P and A are both John's liking Mary, and Q and B are both George's hating Bill. The scale has to be determined by pragmatics, but is something like the intensity of feeling.

In

John likes Mary more than George.

there is an ambiguity. In one reading, P is John's liking Mary, A is John, B is George, and Q is George's liking Mary. In the other reading, P is John's liking Mary, A is Mary, B is George, and Q is John's liking George. In both readings, the scale has to be determined by pragmatics.

In

John likes Mary more than George does.

the ambiguity is resolved. P is John's liking Mary, and Q is George's liking Mary. B is George's being the subject of some present action or state, and therefore A is John's being the subject of some present action or state (which we know to be his liking of Mary). The scale is the intensity of the likings, as must be determined by pragmatics.

In

> John climbed a mountain faster than George.

there is again an ambiguity. In both (reasonable) readings, P is John's climbing of some mountain M, A is John, B is George, and the scale is speed. In one reading, Q is George's climbing the same mountain M. In the other reading, Q is George's climbing some unspecified, not necessarily identical mountain. (We won't mention the reading in which John climbs George.)

In

> John wants to buy more books than George.

there is an ambiguity. In both readings, P is the set of books John wants to buy, A is John, B is George, and the scale is quantity. In one reading, Q is the set of books George wants to buy. In the other reading, Q is the set of books George bought.

In

> Salaries are higher in New York than in San Francisco.

P is salaries in New York, A is being in New York, B is being in San Francisco, Q is salaries in San Francisco, and the scale is height, metaphorically understood. The "heights" of the salaries are being compared.

In

> Salaries are increasing two times faster in New York than in San Francisco.

P is the increasing of salaries in New York, A is again being in New York and B being in San Francisco, Q is the increasing of salaries in San Francisco, and the scale is speed. The speeds of the increases are being compared. The phrase "two times" provides a measure for this comparison.

In

> John is fonder of Mary than George of Bill.

P is John's fondness for Mary, Q is George's fondness for Bill, and the scale is intensity of fondness. B is a relation between George and the property of some unspecified entity or eventuality being "of" Bill. A is therefore the same relation (which we know to be fondness) between John and the property of the fondness being "of" Mary.

In

There are more smokers in Hungary than was believed.

P is the set of smokers that there are in Hungary and Q is the set of smokers that people believed there to be in Hungary. The comparison is between the sizes of these two sets. A is the predication of existence, and B is the predication of people's belief.

We see, therefore, that our characterization covers a very broad range of often problematic examples of comparison. In this section, this characterization is formalized. We have three tasks. We need to specify several lexical axioms for "more"; we need to specify two lexical axioms for "than"; and we need to explicate and axiomatize the notion of "playing the same role". At the end of this section, illustrations will be presented of the interpretations of several of the above examples in terms of these axioms.

For convenience in this development, P will be called the first matrix, Q the second matrix, A the first anchor, and B the second anchor.

4.15.2 "More"

The word "more" can be used as a determiner,

John has more information than George.
John has more computers than George.
John has more than George.

as a comparative operator on an adjective or adverb,

John is more careful than George.
John is a more careful person than George.
John proceeded more carefully than George.

and as an independent adverbial,

John likes apples more than oranges.

The four lexical axioms for the determiner senses were given in Section 4.10.

$$much'(e_0, z) \wedge more'(e_1, x, y, e_0)$$
$$\supset Syn(\text{“more”}, e_1, f_1{:}\mathbf{ld}, e_2, f_2{:}\mathbf{ldan}, x, a{:}\mathbf{n.sing}, -, -, -, -)$$
$$much'(e_0, z) \wedge more'(e_1, x, y, e_0)$$
$$\supset Syn(\text{“more”}, e_1, f_1{:}\mathbf{ld.rnc}, e_2, f_2{:}\mathbf{le}, x, a{:}\mathbf{n.sing}, -, -, -, -)$$
$$many'(e_0, s) \wedge more'(e_1, x, y, e_0)$$
$$\supset Syn(\text{“more”}, e_1, f_1{:}\mathbf{ld}, e_2, f_2{:}\mathbf{ldan}, x, a{:}\mathbf{n.pln}, s, -, -, -)$$
$$many'(e_0, s) \wedge more'(e_1, x, y, e_0)$$
$$\supset Syn(\text{“more”}, e_1, f_1{:}\mathbf{ld.rnc}, e_2, f_2{:}\mathbf{le}, x, a{:}\mathbf{n.pln}, s, -, -, -)$$

The axiom given for its use with adjectives in Section 4.10 was

$$more'(e_1, x, y, e_2) \supset Syn(\text{“more”}, e, \mathbf{adj}, x, \mathbf{n.sb}, e_2, \mathbf{adj.ob}, -, -, -, -)$$

This axiom can be generalized somewhat to handle uses of “more” with adverbs as well.

$$more'(e_1, x, y, e_2)$$
$$\supset Syn(\text{“more”}, e_1, f_{CAT}, x, \mathbf{sb}, e_2, f_{CAT}.\mathbf{ob}, -, -, -, -)$$

If e_1 is the condition of x being more than y on a scale defined by e_2, then e_1 can be described by the word “more”, which can have any kind of phrase describing x as its subject, and can have any kind of phrase as its complement. It produces a phrase of the same type as its complement.

The uses of “more” as an independent adverbial are enabled by the axiom

$$more'(e_1, x, y, e_2) \supset Syn(\text{“more”}, e_1, \mathbf{adv}, x, \mathbf{sb}, -, -, -, -, -, -)$$

If e_1 is the condition of x being more than y on a scale defined by e_2, then e_1 can be described by the adverb “more”, which can have any kind of phrase describing x as its subject. It has no complement; the scale must be determined contextually.

4.15.3 “Than”

The word “than” can take a word or phrase of almost any category as its complement:

John is more arrogant than he is intelligent.
John is more arrogant than intelligent.
Salaries are higher in New York than in San Francisco.
Salaries are higher in New York than San Francisco.
Salaries are higher in New York than outside.

In addition, it can be followed by two phrases, with an elided relation between them.

John saw more museums in London than George in Paris.

On the other hand, the constraints on the complement of "than" are varied and complex:

John likes Mary more than George likes Mary.
* John likes Mary more than George likes.
John likes Mary more than George does.
? John likes Mary more than George does Mary.
John likes Mary more than George does Susan.
* John likes Mary more than George Mary.
? John likes Mary more than George Susan.

One suspects that the questionable or unacceptable character of some of these examples is not so much a matter of simple syntactic ill-formedness, but rather a complex mix of interpretability, the existence of better ways of conveying the content, and other such factors.

In any case, in this section I will not address the problem of constraints. I will assume the complement of "than" can be anything, and trust that pragmatic factors in interpretation and generation will rule out the bad examples. The only constraint on the complement of "than" that we will consider here is the one given in our general characterization of comparison. It should be a B for which there can be found an explicit A and P and an implicit Q such that A plays the same role in P that B plays in Q.

The word "than" is always associated semantically with a comparative, but it is not always adjacent to the comparative.

Bill was a *more* serious presidential candidate in the last campaign *than George*.
People are *more* friendly in San Francisco during the winter *than in New York*.

In general, a "than" phrase can occur wherever a noun complement or a sentence adjunct can appear, with the exception that it must appear after the comparative.

* Than George, John is taller, but than Bill, John is shorter.

This last constraint is probably pragmatic in nature and I will not attempt to capture it in the lexical axioms for "than".

All of these considerations can be accommodated by two essentially trivial lexical axioms for the word "than" and one axiom explicating the predicate *than*. The first lexical axiom covers the case where there is no elided material.

$$\begin{aligned}&than'(e, e_0, y_2)\\&\quad\supset Syn(\text{“than”}, e, \mathbf{than}, e_0, a, y_2, b, -, -, -, -)\end{aligned}$$

If e is a "than" relation between a comparison e_0 and something else y_2, then e can be described by a **than** phrase headed by the word "than", attached to a phrase describing the comparison e_0, and taking a phrase of any category b describing y_2 as its complement. The feature **than** is a subfeature of **adjunct**; The adjunct composition rules and NP Composition Rule 2 (4.24) have already been written to allow "than" complements.

The second lexical axiom for "than" handles the case of elided material. Our approach is to treat the two phrases that occur explicitly as a first and second complement, and to recover the relation between them pragmatically.

$$\begin{aligned}&than'(e, e_0, y_2) \wedge rel'(y_2, z_1, z_2)\\&\quad\supset Syn(\text{“than”}, e, \mathbf{than}, e_0, a, z_1, b, z_2, c, -, -)\end{aligned}$$

If e is a "than" relation between a comparison e_0 and a relation y_2 between z_1 and z_2, then e can be described by a **than** phrase headed by the word "than", attached to a phrase describing the comparison e_0, and taking two phrases of any categories b and c describing z_1 and z_2 as its two complements.

So far, *than* is just an empty relation. The following axiom gives it the meaning it needs.

$$(4.37) \qquad more'(e_0, x_1, x_2, e_s) \wedge SR(y_1, x_1, y_2, x_2) \supset than'(e, e_0, y_2)$$

If e_0 is a comparison relation between x_1 and x_2 on a scale defined by e_s and y_1 plays the same role in x_1 that y_2 plays in x_2, then there is a "than" relation e between e_0 and y_2.

This strong constraint on the first argument of "than"—that it be a *more* relation—allows a considerable amount of metonymy, or displacement from its proper attachment site.

For completeness, one other use of "than" can be mentioned, i.e., its use to signal the second argument of "other" in predicate complement position, as in

We need a teacher other than Mr. Smith.

The lexical axioms that capture this usage are

$$other'(e,x,y) \supset Syn(\text{“other”}, e, \mathbf{adj}, x, a, y, \mathbf{than}, -, -, -, -)$$
$$\supset Syn(\text{“than”}, y, \mathbf{than}, y, a, -, -, -, -, -, -)$$

The adjective "other" subcategorizes for a constituent signalled by "than" for its complement. The second axiom parallels the treatment of PP arguments in Section 4.6.3.

4.15.4 Playing the Same Role

Finally, we need to explicate the "same role" relation SR. A good start is the $Subst$ relation, introduced in Chapter 2. In fact, there it was glossed as "plays the same role". To review, the $Subst$ relation is a first-order axiomatization of substitution.

$Subst(x, e_1, y, e_2)$ says that if y is substituted for x in e_1, then the result is e_2. The axioms and axiom schemas explicating $Subst$ were as follows:

$$\text{(4.38)} \quad (\forall\, a, b, e_1, e_2, \ldots, u_i, \ldots)[Subst(a, e_1, b, e_2) \wedge p'(e_1, \ldots, u_i, \ldots) \supset (\exists\, \ldots, v_i, \ldots)[p'(e_2, \ldots, v_i, \ldots) \wedge \ldots \wedge Subst(a, u_i, b, v_i) \wedge \ldots]]$$

$$\text{(4.39)} \quad (\forall\, a, b, e_1, \ldots, u_i, v_i, \ldots)[\ldots \wedge Subst(a, u_i, b, v_i) \wedge \ldots \wedge p'(e_1, \ldots, u_i, \ldots) \supset (\exists\, e_2)[p'(e_2, \ldots, v_i, \ldots) \wedge Subst(a, e_1, b, e_2)]]$$

$$\text{(4.40)} \quad (\forall\, a, b, e_1, e_2, \ldots, u_i, v_i, \ldots)[Subst(a, e_1, b, e_2) \wedge p'(e_1, \ldots, u_i, \ldots) \supset [p'(e_2, \ldots, v_i, \ldots) \equiv \ldots \wedge Subst(a, u_i, b, v_i) \wedge \ldots]]$$

$$\text{(4.41)} \quad (\forall\, a, b, e_1, e_2, \ldots, u_i, v_i, \ldots)[\ldots \wedge Subst(a, u_i, b, v_i) \wedge \ldots \wedge p'(e_1, \ldots, u_i, \ldots) \supset [p'(e_2, \ldots, v_i, \ldots) \equiv Subst(a, e_1, b, e_2)]]$$

The first axiom schema allows us to proceed from substitution into predications to substitution into their arguments. The second allows the reverse. The first two axiom schemas guarantee a "substitution" eventuality of the right structure. The second two axiom schemas say that an eventuality is of the right structure if and only if it is a substitution eventuality.

Two more axioms enable substitution to bottom out.

(4.42) $(\forall\, a, b)Subst(a, a, b, b)$
(4.43) $(\forall\, a, b, c)\neg eventuality(c) \,\wedge\, c \neq a \,\supset\, Subst(a, c, b, c)$

The predicate *Subst* takes care of the case where only one element is being substituted for another in a predication. That is, if $p'(e_1, x_1, y_1)$ and $p'(e, x_2, y_1)$, then $Subst(x_1, e_1, x_2, e)$. It is also useful to allow the substitution of pairs of arguments. Continuing the example, if $p'(e_2, x_2, y_2)$, then $Subst(y_1, e, y_2, e_2)$. We can define $Subst_2$ as expressing the composite of these two simple substitutions.

$$Subst(x_1, e_1, x_2, e) \wedge Subst(y_1, e, y_2, e_2) \;\equiv\; Subst_2(x_1, y_1, e_1, x_2, y_2, e_2)$$

In this book, we will not need *Subst* relations for more than pairs of entities.

We would like the predicate *SR* to do more work for us than is done by the *Subst* relations alone. Essentiallly, the axiomatization of *SR* should be the explication of a theory of parallelism.

It is useful to distinguish between eventualities, which can be viewed as properties of their arguments, and noneventuality entities, which can be arguments of eventualities. It will be convenient in this section to refer to the former as properties and the latter as arguments.

There are then dual cases to consider in axiomatizing *SR*:

- A property with a number of arguments.
- An argument with a number of properties.

The first is illustrated by

$$p'(e, a, b, c, \ldots)$$

The second is illustrated by

a such that $p'(e_1, a, b), q'(e_2, a, c), \ldots$

To axiomatize *SR* we need to consider four cases:

1. **AP:** Argument-1 plays the same role with respect to property-1 that argument-2 plays with respect to argument-2—$SR(x_1, e_1, x_2, e_2)$. Here we would like to maximize the similarity of the other arguments of property-1 and property-2 to each other.

2. **PA:** Property-1 plays the same role with respect to argument-1 that property-2 plays with respect to argument-2—$SR(e_1, x_1, e_2, x_2)$. Here we

would like to maximize the similarity of the other properties of argument-1 and argument-2 to each other.

3. **AA:** Argument-1 plays the same role with respect to argument-3 that argument-2 plays with respect to argument-4—$SR(x_1, x_3, x_2, x_4)$. Here we need to find a common pair of properties to mediate between the arguments.

4. **PP:** Property-1 plays the same role with respect to property-3 that property-2 plays with respect to property-4—$SR(e_1, e_3, e_2, e_4)$. Here we need to find a common pair of arguments to mediate between the properties.

The first case, **AP**, is the best place to begin. When the property has only one argument (other than the self argument), the SR relation reduces to a $Subst$ relation. If $man'(e_1, x_1)$ and $man'(e_2, x_2)$ hold, then so does $SR(x_1, e_1, x_2, e_2)$. Similarly, if $like'(e_1, x_1, M)$ and $like'(e_2, x_2, M)$ hold, then so does $SR(x_1, e_1, x_2, e_2)$. Hence the axiom

$$(4.44) \qquad Subst(x_1, e_1, x_2, e_2) \wedge nev(x_1) \wedge nev(x_2) \supset SR(x_1, e_1, x_2, e_2)$$

If a noneventuality x_2 is substituted for another noneventuality x_1 in e_1 with the result e_2, then x_1 plays the same role in e_1 that x_2 plays in e_2.

We will postpone dealing with the general **AP** case until we handle the **PA** case.

The **PA** case is complicated to motivate and state. We want to handle the case of an eventuality e_1 playing a role with respect to an entity x_1 by virtue of its being one property of x_1 among many. Suppose we have two entities x_1 and x_2 with characterizing properties as follows:

x_1 such that $man'(e_1, x_1)$ and $tall'(e_3, x_1)$
x_2 such that $man'(e_2, x_2)$ and $tall'(e_4, x_2)$

We would like to specify the conditions under which the property e_1 plays the same role with respect to the entity x_1 that the property e_2 plays with respect to the entity x_2. There are two conditions. The first is that they are the same property, i.e., that x_1 plays the same role with respect to e_1 that x_2 plays with respect to e_2. The second is that the other properties of x_1 and x_2 reinforce this relation. That is, we want to find as many other properties e_3 and e_4 as possible for which e_3 plays the same role with respect to the entity x_1 that the property e_4 plays with respect to the entity x_2.

The problem is that whereas properties have a fixed number of arguments, arguments do not have a fixed number of properties. We need as many other properties e_3 and e_4 as possible. That is, the more properties we find, the better the SR relation should be.

As described in Chapter 3, the abductive framework provides us with a mechanism for realizing this kind of constraint. In general, we may have an axiom of the form

$$Q \wedge P \supset P$$

We can never prove P with this axiom. But the weights can be set up in such a way (e.g., .6 on both conjuncts in the antecedent) that every time we backchain across this axiom and prove an instance of Q, then it becomes cheaper to assume P. This rule has the effect of saying, "To establish P, prove as much partial evidence Q as possible."

We can exploit this device for maximizing the number of corresponding other properties of the corresponding entities. The axiom can be stated as follows:

(4.45) $$SR(x_1, e_1, x_2, e_2) \wedge SR(e_3, x_1, e_4, x_2) \wedge ngen(e_1, e_3) \wedge ngen(e_2, e_4) \supset SR(e_1, x_1, e_2, x_2)$$

That is, if the argument x_1 plays the same role in the property e_1 that x_2 plays in e_2 and furthermore there is another property e_3 of x_1 and another property e_4 of x_2 where e_3 plays the same role with respect to x_1 that e_4 plays with respect to x_2, then e_1 plays the same role with respect to x_1 that e_2 plays with respect to x_2. The *ngen* antecedents insure that the new properties e_3 and e_4 will be independent of e_1 and e_2.

We seek to prove a property-argument relation (**PA**). We backchain across this axiom, and then have to prove an argument-property relation, (**AP**). In addition, we have to prove a property-argument relation for another property. If such properties can be found, we recurse. If not, we assume the second conjunct of the antecedent, having maximized the number of other properties of x_1 and x_2 that we have found.

We are now in a position to return to the **AP** case. We would like SR to be true when x_1 and x_2 are a pair of corresponding arguments in a set of pairs of corresponding arguments. For example, if $married'(e_1, x_1, y_1)$ and $married'(e_2, x_2, y_2)$ hold, then it seems that $SR(x_1, e_1, x_2, e_2)$ should hold as well. If John is married to Mary and George is married to Susan, then we would like to say that John plays the same role with respect to his marriage relation that George plays to his. However, some constraints are needed. We want SR to capture a similarity of structure. If John has a car and George has trouble, we don't want to say that John plays the same role with respect to his "having" relation that George plays to his. Cars and trouble are insufficiently similar. We can enforce this constraint by insisting that there be other eventualities in which the other pair of corresponding arguments plays the same role. If John is married to Mary and George is married to Susan, then one of the reasons John and George play the same role is that Mary and Susan play the same role in some other eventuality, e.g., their being women. We could capture the constraint that y_1 and y_2 have at least one other property in common by including in the antecedent of the axiom for SR the literal $SR(y_1, e_3, y_2, e_4)$ for some e_3 and e_4. But we would like the axiom to force the greatest similarity possible between the two sides of a comparison. A very simple change will accomplish this—switching the y's and e's around in the SR predication in the antecedent. Adopting this device gives us the axiom

$$(4.46) \quad Subst_2(x_1, y_1, e_1, x_2, y_2, e_2) \wedge SR(e_3, y_1, e_4, y_2) \wedge nev(x_1) \wedge nev(x_2) \supset SR(x_1, e_1, x_2, e_2)$$

If a noneventuality x_2 and a y_2 are substituted for another noneventuality x_1 and a y_1, respectively, in e_1, resulting in e_2, and there are other eventualities e_3 and e_4 such that e_3 plays the same role with respect to y_1 that e_4 plays with respect to y_2, then x_1 plays the same role in e_1 that x_2 plays in e_2. To establish the SR predication in the antecedent, we must now use Axiom (4.45), and this will force us to maximize the number of properties we find that y_1 and y_2 have in common.

Next a useful "corollary": Suppose we apply Axiom (4.46) to $SR(x_1, e_1, x_2, e_2)$, then apply Axiom (4.45) to $SR(e_3, y_1, e_4, y_2)$, yielding $SR(y_1, e_3, y_2, e_4)$ and $SR(e_5, y_1, e_6, y_2)$, and then assume the latter. We will in effect have proven $SR(x_1, e_1, x_2, e_2)$ by proving $Subst_2(x_1, y_1, e_1, x_2, y_2, e_2)$ and $SR(y_1, e_3, y_2, e_4)$. We can write this as a corollary of (4.46), applicable when we know only one other pair of properties, e_3 and e_4, of y_1 and y_2.

$$(4.47) \quad Subst_2(x_1, y_1, e_1, x_2, y_2, e_2) \wedge SR(y_1, e_3, y_2, e_4) \wedge nev(x_1) \wedge nev(x_2) \supset SR(x_1, e_1, x_2, e_2)$$

If a noneventuality x_2 and a y_2 are substituted for another noneventuality x_1 and a y_1, respectively, in e_1, resulting in e_2, and there are other eventualities e_3 and e_4 such that y_1 plays the same role in e_3 that y_2 plays in e_4, then x_1

plays the same role in e_1 that x_2 plays in e_2. This is illustrated in Figure 4.17, where a box is drawn around the assumed predication.

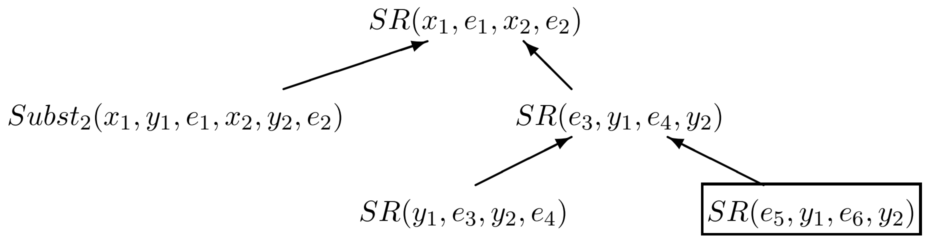

Figure 4.17: "Proof" of "Corollary".

It will be convenient to use this corollary instead of (4.46) in some of the examples in the next section.

We could write the corresponding axioms for three-argument predications in terms of a $Subst_3$ predicate, but we will not need them in the examples.

Axioms (4.44) and (4.46) give us an argument-property relation provided the other arguments are in the right relation as well, Axiom (4.45) gives us a property-argument relation provided the other properties are in the right relation as well.

The next case, **AA**, relates arguments to other arguments. If John is married to Mary, and George to Susan, then we would like to say that John plays the same role with respect to Mary that George plays with respect to Susan, by virtue of the "married" relation. But, again, if there are further relations between the pairs of people, that would strengthen the SR relation, and we would like to find them as well. We can accomplish this by reducing the **AA** case to two instances of the **PA** case.

(4.48) $$SR(e_1, x_1, e_2, x_2) \wedge SR(e_1, y_1, e_2, y_2) \supset SR(x_1, y_1, x_2, y_2)$$

If the eventuality e_1 plays the same role with respect to x_1 that the eventuality e_2 plays with respect to x_2 and e_1 also plays the same role with respect to y_1 that e_2 plays with respect to y_2, then x_1 plays the same role with respect to y_1 that x_2 plays with respect to y_2. In our example, since John and Mary's "married" relation plays the same role with respect to John that George and Susan's "married" relation plays with respect to George, and since John and Mary's "married" relation plays the same role with respect to Mary that George and Susan's "married" relation plays with respect to

Susan, we can say that John plays the same role with respect to Mary that George plays with respect to Susan.

A "corollary" is useful here as well. If we apply Axiom (4.48) to $SR(x_1, y_1, x_2, y_2)$, apply Axiom (4.45) to the two literals generated, assume the two e_3-e_4 literals generated thereby, apply corollary (4.47) to the remaining literals, and unify the two instances of $Subst_2$ generated thereby, we arrive at the corollary

$$(4.49) \quad Subst_2(x_1, y_1, e_1, x_2, y_2, e_2) \wedge ev(e_1) \wedge ev(e_2) \supset SR(x_1, y_1, x_2, y_2)$$

If x_2 and y_2 are substituted for x_1 and y_1, respectively, in an eventuality e_1, resulting in the eventuality e_2, then x_1 plays the same role with respect to y_1 that x_2 plays with respect to y_2. This corollary is useful in the examples in the next section where there is only one property available to establish the SR relation.

Axiom (4.48) handles the case of arguments playing a role with respect to other arguments. We also need to handle properties playing a role with respect to other properties (Case **PP**). Just as when we have

$married'(e_1, J, M)$,
$married'(e_2, G, S)$

we would like to conclude that J plays the same role with respect to M that G plays with respect to S,

$SR(J, M, G, S)$,

when we have

x_1 such that $man'(e_1, x_1)$ and $tall'(e_3, x_1)$
x_2 such that $man'(e_2, x_2)$ and $tall'(e_4, x_2)$

we would like to conclude the e_1 plays the same role with respect to e_3 that e_2 plays with respect to e_4. That is, we need the dual of Axiom (4.48). The rule is

$$(4.50) \quad SR(e_1, x_1, e_2, x_2) \wedge SR(e_3, x_1, e_4, x_2) \supset SR(e_1, e_3, e_2, e_4)$$

That is, to show that a property e_1 plays the same role with respect to another property e_3 that a property e_2 plays with respect to a property e_4, we need to show that there are arguments x_1 and x_2 such that e_1 plays the same role with respect to x_1 that e_2 plays to x_2, and that e_3 plays the same role with respect to x_1 that e_4 plays to x_2,

Just as Axiom (4.48) relates two arguments of the same property, Axiom (4.50) relates two properties of the same argument.

A very common speccial case of **PP** in the analysis of comparatives has $e_1 = e_3$ and $e_2 = e_4$. A property plays the same role with respect to itself as another property plays with respect to itself. We cannot prove this from Axiom (4.44) because of the constraint in that axiom that x_1 not be an eventuality. The reason for this is that if $SR(e_1, e_1, e_2, e_2)$ is to hold, we would like the structure of e_1 and e_2 to be the same. If $man'(e_1, x_1)$ and $man'(e_2, x_2)$ hold, then so does $SR(e_1, e_1, e_2, e_2)$. Similarly, if $married'(e_1, x_1, y_1)$ and $married'(e_2, x_2, y_2)$ hold, then so does $SR(e_1, e_1, e_2, e_2)$. However, if $sleep'(e_1, x_1)$ and $work'(e_2, x_2)$ hold, then we do not want it to follow that $SR(e_1, e_1, e_2, e_2)$. We can think of SR in this case as specifying that the two properties have the same predicate. Axiom (4.50) in this case reduces to

$$SR(e_1, x_1, e_2, x_2) \supset SR(e_1, e_1, e_2, e_2)$$

which by Axiom (4.45) reduces to

$$SR(x_1, e_1, x_2, e_2) \wedge SR(e_3, x_1, e_4, x_2) \supset SR(e_1, e_1, e_2, e_2)$$

We will assume the second conjunct in the antecedent (or ignore it as perversely strong) and take the rule for this case to be simply

$$SR(x_1, e_1, x_2, e_2) \supset SR(e_1, e_1, e_2, e_2)$$

By Axioms (4.44) and (4.46), this reduces to two axioms, one for one-argument predicates and one for two-argument predicates.

(4.51) $$Subst(x_1, e_1, x_2, e_2) \wedge nev(x_1) \wedge nev(x_2) \supset SR(e_1, e_1, e_2, e_2)$$

If a noneventuality x_2 is substituted for another noneventuality x_1 in e_1 with the result e_2, then e_1 plays the same role in e_1 that e_2 plays in e_2. That is, they have the same structure.

(4.52) $$Subst_2(x_1, y_1, e_1, x_2, y_2, e_2) \wedge nev(x_1) \wedge nev(x_2) \wedge nev(y_1) \wedge nev(y_2) \supset SR(e_1, e_1, e_2, e_2)$$

If a noneventuality x_2 and a noneventuality y_2 are substituted for another pair of noneventualities x_1 and y_1, respectively, in e_1, resulting in e_2, then e_1 plays the same role in e_1 that e_2 plays in e_2. That is, they have the same structure.

Corollaries (4.51) and (4.52) handle the common special case of Axiom (4.50) in which eventualities play a role with respect to themselves.

The following table summarizes the axioms and "corollaries" for SR:

Axioms (4.44), (4.46), (4.47):	Argument – Property
Axiom (4.45):	Property – Argument
Axiom (4.48), (4.49):	Argument – Argument
Axioms (4.50), (4.51), (4.52):	Property – Property

As illustrated in Figure 4.18, the **AA** and **PP** cases reduce to the **PA** case, the **PA** case reduces to one or more **AP** cases and an assumption, and the **AP** case ultimately bottoms out in a *Subst* relation.

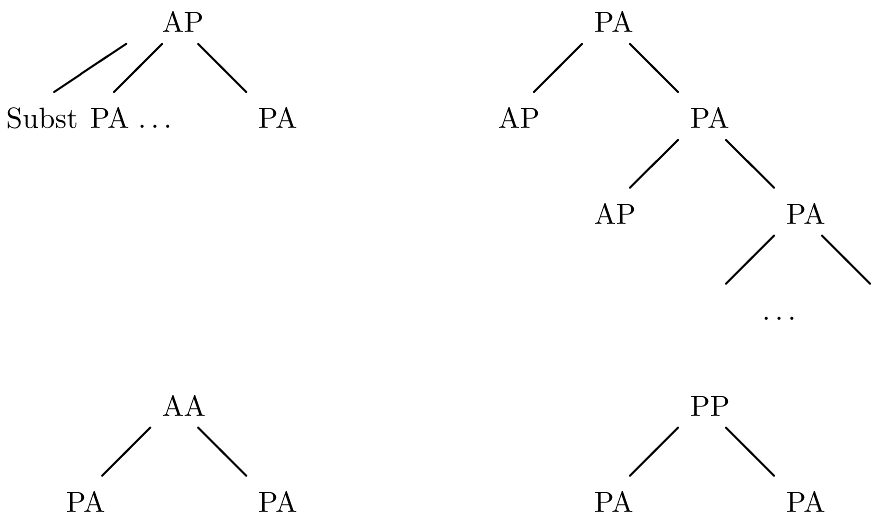

Figure 4.18: Structure of axioms for SR.

4.15.5 Some Examples Analyzed

The first example to be analyzed is

John is taller than George.

The relevant part of the logical form is

$$tall'(e_s, z) \wedge more'(e_0, J, x_2, e_s) \wedge than'(e, e_0, G)$$

That is, there is a relation e_0 of John J being more than some x_2 on a scale e_s defined by some abstract entity z being tall, and there is a than relation e between this more-ness and George G. This is what must be proved abductively to interpret the sentence. We know the first matrix is J and the second anchor is G. We need to find the first anchor and the second matrix.

Figure 4.19 illustrates the interpretation. Of the parse of the sentence, I have only shown the terminal notes, and in these I have only indicated the relevant arguments of *Syn*. I have left out the eventuality and noneventuality preconditions, as I also do in the discussion.

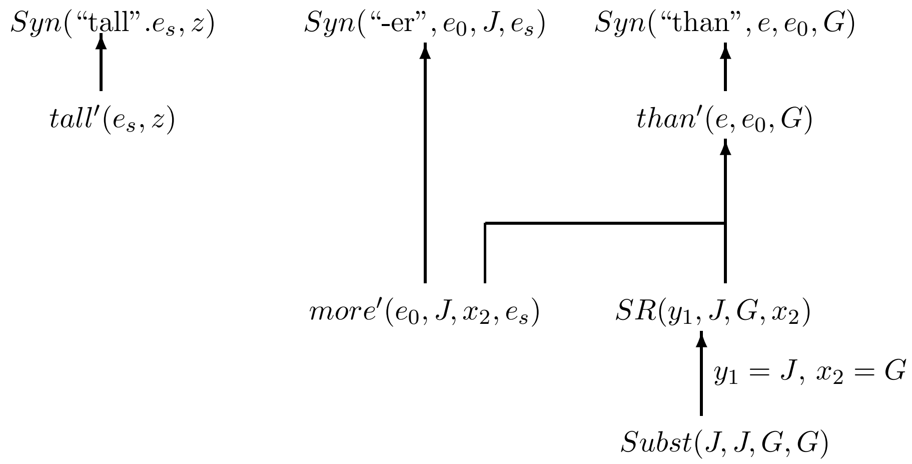

Figure 4.19: Interpretation of "John is taller than George."

Backchaining on Axiom (4.37) gives us $more'(e_0, x_1, x_{21}, e_t)$ and $SR(y_1, x_1, G, x_{21})$. The first predication unifies with the literal $more'(e_0, J, y_1, e_s)$ in the logical form, identifying x_1 with J, x_{21} with x_2, and e_t with e_s, and converting the second predication into $SR(y_1, J, G, x_2)$. This last is then established by means of Axioms (4.44) and (4.42), taking y_1 to be J and x_2 to be G; thus we find the first anchor to be J and the second matrix to be G.

The literals $tall'(e_s, z)$ and $more'(e_0, J, G, e_s)$ are assumed, $Subst(J, J, G, G)$ is proved from Axiom (4.42), and $than'(e, e_0, G)$ is proved as described above.

In general, the anchor is only a part of the matrix. This example is simple because it is the whole thing.

The next example is

John likes Bill more than George.

The relevant part of the logical form is

$$Present'(e_{10}, e_{11}) \wedge like'(e_{11}, J, B) \wedge more'(e_0, e_{10}, e_{20}, e_s) \\ \wedge than'(e, e_0, G)$$

That is, there is the eventuality e_{10} of the eventuality e_{11} being in the present, where e_{11} is the eventuality of John J liking Bill B, there is a relation e_0 of e_{10} being more than some e_{20} on some scale e_s (to be determined contextually by pragmatics), and there is a "than" relation e between this more-ness e_0 and George G. The first matrix is e_{10}, the present-ness of John's liking for Bill. The second anchor is George. We need to find the first anchor and the second matrix.

This example again involves the argument-eventuality rule for SR, but it is a little more complicated because we have to go through two substitutions.

Figure 4.20 illustrates one interpretation.

We again first backchain on Axiom (4.37), yielding $more'(e_0, e_{30}, e_{20}, e_t)$ and $SR(y_1, e_{30}, G, e_{40})$. The first predication unifies with the literal $more'(e_0, e_{10}, e_{20}, e_s)$ in the logical form, identifying e_{30} with e_{10}, e_{40} with e_{20}, and e_t with e_s, and converting the second predication into $SR(y_1, e_{10}, G, e_{20})$. This last is expanded by means of Axiom (4.44) to $Subst(y_1, e_{10}, G, e_{20})$. From $Present'(e_{10}, e_{11})$ in the logical form and from $Subst(y_1, e_{11}, G, e_{21})$, we could infer, by Axiom (4.39), $Subst(y_1, e_{10}, G, e_{20})$ and $Present'(e_{20}, e_{21})$. The eventuality e_{20} is the second matrix.

It remains to prove $Subst(y_1, e_{11}, G, e_{21})$. There are two ways this could be done. The first is to take y_1 to be identical to B. Then we can infer it, by Axiom (4.39), from $like'(e_{11}, J, B)$, $Subst(J, B, J, G)$, and $Subst(B, B, G, G)$. The last two follow from Axioms (4.43) and (4.42), respectively. Axiom (4.39) also allows us to conclude $like'(e_{21}, J, G)$. This interpretation corresponds to the reading in which John likes Bill more than John likes George. The first anchor is Bill.

The second way to prove $Subst(y_1, e_{11}, G, e_{21})$ is by taking y_1 to be identical to J. Then the substitutions bottom out in $Subst(J, J, G, G)$, and $Subst(J, B, G, B)$, and we can conclude $like'(e_{21}, G, B)$. This interpretation corresponds to the reading in which John likes Bill more than George likes Bill. The first anchor is John.

In both interpretations the literals $Present'(e_{10}, e_{11})$, $like'(e_{11}, J, B)$, and $more'(e_0, e_{10}, e_{20}, e_s)$ are assumed.

It is the first interpretation that is illustrated in Figure 4.20.

The pattern illustrated in this example by the axioms

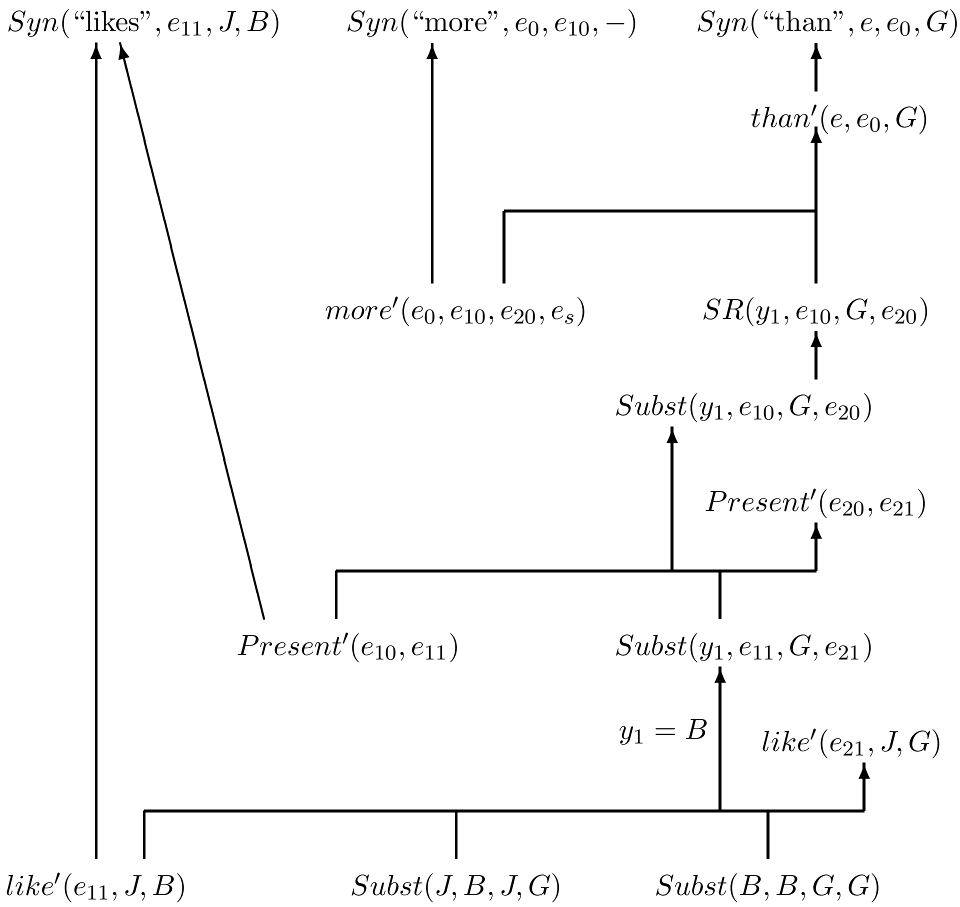

Figure 4.20: Interpretation of "John likes Bill more than George."

$$
\begin{aligned}
&Subst(y_1, e_{10}, G, e_{20}) \supset SR(y_1, e_{10}, G, e_{20}) \\
&Present'(e_{10}, e_{11}) \wedge Subst(y_1, e_{11}, G, e_{21}) \\
&\qquad \supset Subst(y_1, e_{10}, G, e_{20}) \wedge Present'(e_{20}, e_{21}) \\
&like'(e_{11}, J, B) \wedge Subst(J, B, J, G) \wedge Subst(B, B, G, G) \\
&\qquad \supset Subst(y_1, e_{11}, G, e_{21}) \wedge like'(e_{21}, J, G)
\end{aligned}
$$

is very common in these examples, so in the remaining examples and figures, it will be abbreviated as in

$$
\begin{aligned}
&Present'(e_{10}, e_{11}) \wedge like'(e_{11}, J, B) \\
&\qquad \Rightarrow SR(y_1, e_{10}, G, e_{20}) \wedge Present'(e_{20}, e_{21}) \wedge like'(e_{21}, J, G)
\end{aligned}
$$

A seemingly related example has a rather different analysis.

John likes Bill more than George does.

The ambiguity of the previous example is resolved here; it can only mean that John likes Bill more than George likes Bill. The information conveyed by the phrase "than George does" is that the complement of "than", the second anchor, is an event in the present that George is the logical subject of. The relevant part of the logical form of this sentence is

$$\begin{aligned}&Present'(e_{10}, e_{11}) \wedge like'(e_{11}, J, B) \wedge more'(e_0, e_{10}, e_{20}, e_s)\\&\quad \wedge than'(e, e_0, e_{40}) \wedge Present'(e_{40}, e_{41}) \wedge Subject(G, e_{41})\end{aligned}$$

That is, there is the eventuality e_{10} of the eventuality e_{11} being in the present, where e_{11} is the eventuality of John J liking Bill B, there is a relation e_0 of e_{10} being more than some e_{20} on some scale e_s (to be determined contextually by pragmatics), and there is a "than" relation e between this more-ness e_0 and an eventuality e_{40} of some eventuality e_{41} being in the present where George G is the logical subject of e_{41}. The eventuality e_{10} is the first matrix, e_{40} is the second anchor.

This example requires the eventuality-eventuality rule (4.51) for SR, and like the previous example requires two substitutions. The two substitutions will be compressed as in the above schema. Figure 4.21 illustrates the interpretation.

We again first backchain on Axiom (4.37) and unify the *more* predication with that in the logical form, yielding $SR(y_1, e_{10}, e_{40}, e_{20})$.

Next we backchain from $SR(y_1, e_{10}, e_{40}, e_{20})$ using Axiom (4.51), the eventuality-eventuality rule for SR, identifying y_1 with e_{10} and e_{40} with e_{20}, and requiring us find a z_1 and a z_2 such that $Subst(z_1, e_{10}, z_2, e_{20})$. That is, we take the matrices and anchors to be the same, but we have not worked out their details yet.

The proof of $Subst(z_1, e_{10}, z_2, e_{20})$ is as in the last example. We can infer it from $Present'(e_{10}, e_{11})$ and $like'(e_{11}, J, B)$, identifying z_1 with J and z_2 with G and inferring $Present'(e_{20}, e_{21})$ and $like'(e_{21}, G, B)$ in addition. This gives us the missing details in the second matrix. From this last literal, we can conclude $Subject(G, e_{41})$ provided we identify e_{41} with e_{21}.

The interpretation of the sentence

John likes Bill more than George likes Bill.

would be similar, but without requiring the inference from $like'(e_{21}, G, B)$ to $Subject(G, e_{21})$.

The interpretation of the sentence

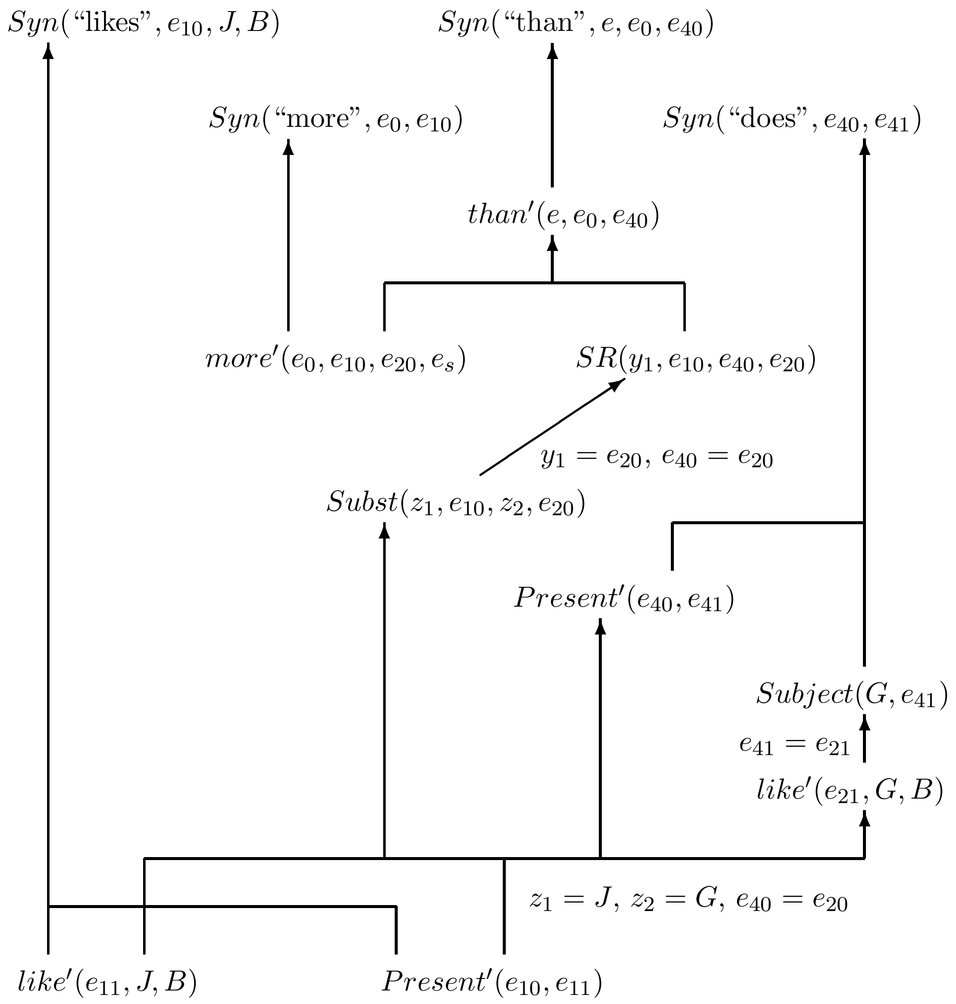

Figure 4.21: Interpretation of "John is likes Bill more than George does."

John likes Bill more than George likes Max.

would be similar, but would make use of the $Subst_2$ version (4.52) of the eventuality-eventuality rule for SR.

The sentence

(4.53) John likes Bill more than George hates Max.

is an interesting case, since our rules require that the eventualities being compared have the same predicate. But it is not the case that any two eventualities can be compared.

* John likes Bill more than George sleeps.

To interpret sentences like (4.53), we need to reduce them to a common predicate, such as, say, *feel-toward*. We could use axioms like

$$feel\text{-}toward(e,x,y) \wedge etc \supset like'(e,x,y)$$
$$feel\text{-}toward(e,x,y) \wedge etc \supset hate'(e,x,y)$$

to backchain on to get a common predicate, and then make that the basis of the substitution.

The next example contains a "scope" ambiguity.

John read a book faster than George.

The existential could outscope the comparative, in which case they read the same book. Or it could be outscoped by the comparative, in which case they may have read different books.

Ignoring tense, the relevant part of the logical form is

$$read'(e_{11}, J, b_1) \wedge a'(e_{12}, b_1, e_{13}) \wedge book'(e_{13}, b_1) \wedge fast(e_s, e_1)$$
$$\wedge\, more'(e_0, e_{11}, e_{21}, e_s) \wedge than'(e, e_0, G)$$

That is, there is a reading eventuality e_{11} by John J of b_1, where b_1 is a book and is not uniquely identifiable by the property e_{13} of its being a book, and the reading event is more than some other event e_{21} on a scale defined by the property e_s of some abstract entity e_1 being fast, and there is a "than" relation e between e_0 and George G. The first matrix is e_{11} and the second anchor is George. We need to determine the first anchor and the second matrix.

One interpretation is illustrated in Figure 4.22.

The literal $than'(e, e_0, G)$ expands, via Axiom (4.37), into a *more* relation, which unifies with $more'(e_0, b_1, b_2, e_s)$, and the relation $SR(y_1, b_1, G, b_2)$.

If we use Axiom (4.47), the latter expands into $Subst_2(y_1, b_1, e_{11}, G, b_2, e_{21})$ and $SR(b_1, e_{32}, b_2, e_{22})$.

The literal $Subst_2(y_1, b_1, e_{11}, G, b_2, e_{21})$ is established by assuming the literal $read'(e_{11}, J, b_1)$ in the logical form, identifying y_1 with J and inferring $read'(e_{21}, G, b_2)$. We have thereby determined the first anchor to be John and the second matrix to be e_{21}, George's reading, but we still need to determine the properties of b_2.

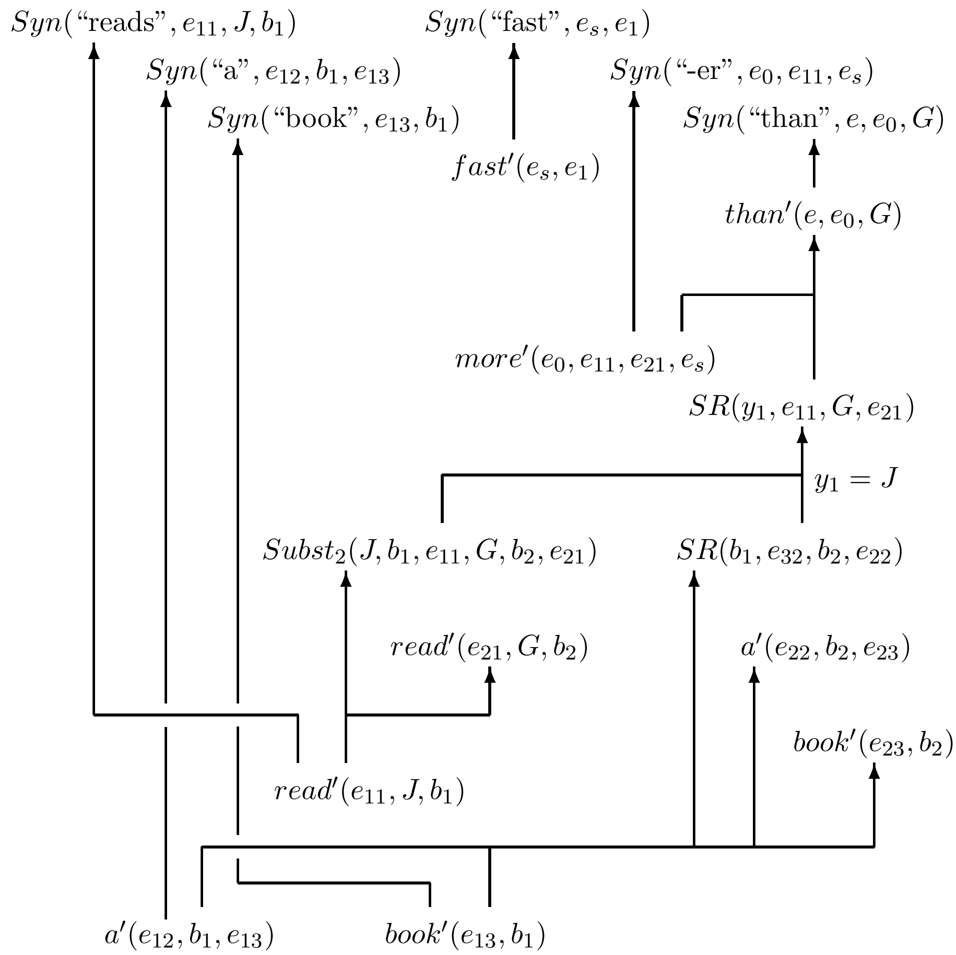

Figure 4.22: Interpretation of "John reads a book faster than George."

The relation $SR(b_1, e_{32}, b_2, e_{22})$ can be established from $a'(e_{12}, b_1, e_{13})$ and $book'(e_{13}, b_1)$ by Axiom (4.44), identifying e_{32} with e_{12}, and inferring $a'(e_{22}, b_2, e_{23})$ and $book'(e_{23}, b_2)$. This is the narrow scope reading; b_2 like b_1 is a book that is not uniquely mutually identifiable in context.

The wide scope reading is obtained from $SR(b_1, e_{32}, b_2, e_{22})$ by identifying b_2 with b_1 and e_{32} and e_{22} with e_{12}, yielding $SR(b_1, e_{12}, b_1, e_{12})$, which holds by Axiom (4.44).

It is the narrow scope interpretation that is illustrated in Figure 4.22.

In a way, I cheated in this example by selecting e_{12}, the indefiniteness of b_1, as e_{32}, the property by which to establish the similarity of b_1 and b_2.

The choice forced the use of e_{13}, the book-ness of b_1, as well, since e_{13} is an argument of e_{12}. But I could just as easily have selected to instantiate e_{32} as e_{13} instead. This choice would not have forced the use of e_{12}, and I would have inferred that b_2 is a book, but not that it is indefinite.

More generally, Axiom (4.47) will let me get away with finding only one property the new pair of arguments has in common. In

John read a long difficult book faster than George.

Axiom (4.47) would allow me to expand this as any of

John read a long difficult book faster than George read book.
John read a long difficult book faster than George something difficult.
John read a long difficult book faster than George something long.

This is the reason Axiom (4.47) was refined into Axiom (4.46). In this example, this axiom would have forced us to maximize the number of properties that b_1 and b_2 have in common. The interpretations would be essentially the same; the only difference is that they would have involved an assumed SR relation when we had run out of properties of b_1.

The distinction between strict and sloppy identity (??, 19??) is handled in a similar fashion. Consider

John gave his brother a more expensive present than George.

The "he" in "his" could refer to someone external to the sentence or to John. The second matrix could be the present George gave to the external person's brother or to Johne's brother (strict identity) or to George's brother (sloppy identity). The relevant parts of the logical form are

The next example involves the argument-argument rule (4.49) for SR.

John earns more than George.

Ignoring tense in this example, the relevant part of the logical form for the sentence is

$$earn'(e_{11}, J, m_1) \wedge much'(e_s, m) \wedge more'(e_0, m_1, m_2, e_s) \\ \wedge than'(e, e_0, G)$$

That is, there is an eventuality e_{11} of John J earning m_1 where m_1 is more than some m_2 on a scale defined by the property e_s of some abstract entity

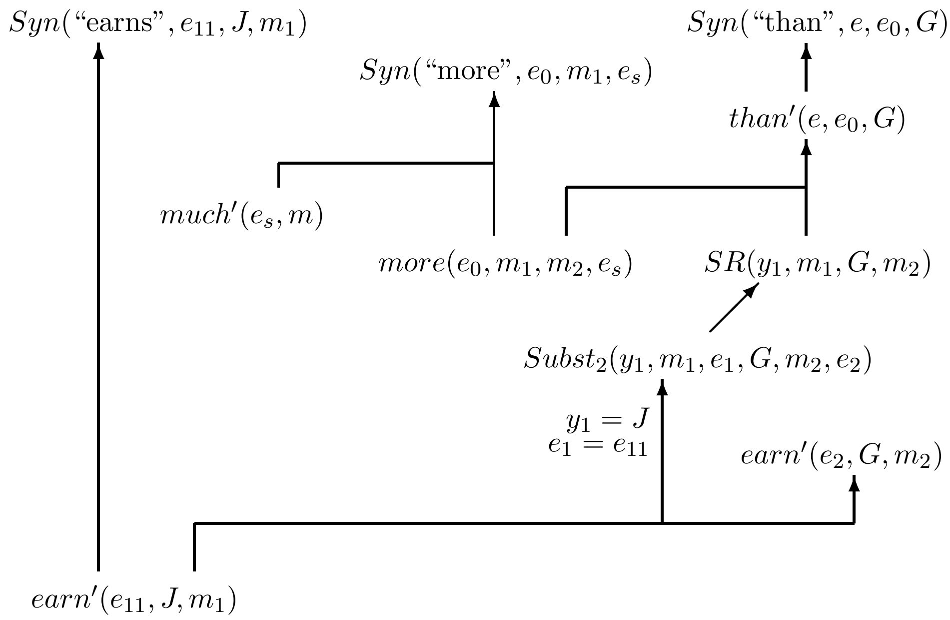

Figure 4.23: Interpretation of "John earns more than George."

m being much, and there is a "than" relation e between e_0 and George G. The entity m_1 is the first matrix; George is the second anchor.

Figure 4.23 illustrates the analysis.

As before, $than'(e, e_0, G)$ expands into a *more* relation, which unifies with $more'(e_0, m_1, m_2, e_s)$, and the relation $SR(y_1, m_1, G, m_2)$. We need to find some y_1 that bears the same relation to m_1 that G bears to some m_2, and we need to find a characterization of m_2.

Here we use the argument-argument rule (4.49) to backchain to

$$Subst_2(y_1, m_1, e_1, G, m_2, e_2)$$

The literal $earn'(e_{11}, J, m_1)$ provides the required eventuality e_1 by virtue of which J plays a role with respect to m_1, leading us to identify e_1 with e_{11} and y_1 with J. We also conclude $earn'(e_2, G, m_2)$, giving us the desired characterization of m_2. The amount of money John earns is more than the amount of money George earns.

The next example involves the eventuality-argument rule (4.45) for SR.

Salaries are higher in New York than in San Francisco.

The phrase "in New York" has the place of an adverbial on "higher" but in fact qualifies the subject "salaries". This is an example of a kind of metonymy described below in Section 4.17.2, where the relation $more'(e_0, s_1, s_2, e_s)$ is the coercion relation linking the explicit logical subject e_0 of *in* with the actual logical subject s_1. Assuming this coercion has already happened by the time the lexical nodes in the parse tree are reached, the logical form will be

$$salary'(e_{11}, s_1) \wedge plural'(e_{12}, s_1, t_1) \wedge high'(e_s, s) \wedge more'(e_0, s_1, s_2, e_s) \\ \wedge in'(e_{13}, s_1, NY) \ \wedge \ than'(e, e_0, e_{23}) \ \wedge \ in'(e_{23}, z, SF)$$

That is, there is an eventuality e_{11} of s_1 being a salary, where s_1 is the typical element of a set t_1, s_1 is more than s_2 on a scale defined by the property e_s of some abstract entity s being high, there is an eventuality e_{13} of s_1 being in New York NY, there is a "than" relation e between the more-ness e_0 and an eventuality e_{23} of something z being in San Francisco SF. The entity s_1 is the first matrix, and the eventuality e_{23} is the second anchor.

The interpretation of this example is shown in Figure 4.24.

As always, we backchain on Rule (4.37) from $than'(e, e_0, e_{23})$ and unify with $more'(e_0, s_1, s_2, e_s)$ to get $SR(e_{33}, s_1, e_{23}, s_2)$. We apply Axiom (4.45) to this to generate the subgoals $SR(s_1, e_{33}, s_2, e_{23})$ and $SR(e_{31}, s_1, e_{21}, s_2)$.

To prove $SR(s_1, e_{33}, s_2, e_{23})$, and as a by-product also $in'(e_{23}, z, SF)$, we use Axiom (4.47) together with $in'(e_{13}, s_1, NY)$, in the process identifying e_{33} with e_{13} and z with s_2 (i.e., now we know that the thing in San Francisco is what is being compared with salaries in New York), and generating as a new subgoal the literal $SR(NY, e_{14}, SF, e_{24})$. To establish this, we need to apply Axiom (4.44) along with a property we know about New York, say, $city'(e_{14}, NY)$, allowing us to conclude as well what we already knew, $city'(e_{24}, SF)$. The last two steps have been compressed in Figure 4.24.

To prove $SR(e_{31}, s_1, e_{21}, s_2)$, we apply Axiom (4.45) again to generate the subgoals $SR(s_1, e_{31}, s_2, e_{21})$ and $SR(e_{32}, s_1, e_{22}, s_2)$.

The literal $SR(s_1, e_{31}, s_2, e_{21})$ follows by Axiom (4.44) from $salary'(e_{11}, s_1)$, identifying e_{31} with e_{11}, and allowing us to infer $salary'(e_{21}, s_2)$. That is, s_2 is a salary.

To prove $SR(e_{32}, s_1, e_{22}, s_2)$, we again apply Axiom (4.45) to generate the subgoals $SR(s_1, e_{32}, s_2, e_{22})$ and $SR(e_{15}, s_1, e_{25}, s_2)$.

We next apply Axiom (4.47) to the literal $SR(s_1, e_{32}, s_2, e_{22})$, using $plural'(e_{12}, s_1, t_1)$, identifying e_{32} with e_{12}, inferring $plural'(e_{22}, s_2, t_2)$ (i.e., now we know that s_2 is the typical element of a set), and generating the new subgoal $SR(t_1, e_{16}, t_2, e_{26})$. To establish the last of these, we need to apply Axiom (4.44) along with a property we know about t_1, say, $set'(e_{16}, t_1)$, allowing us to conclude as well $set'(e_{26}, t_2)$.

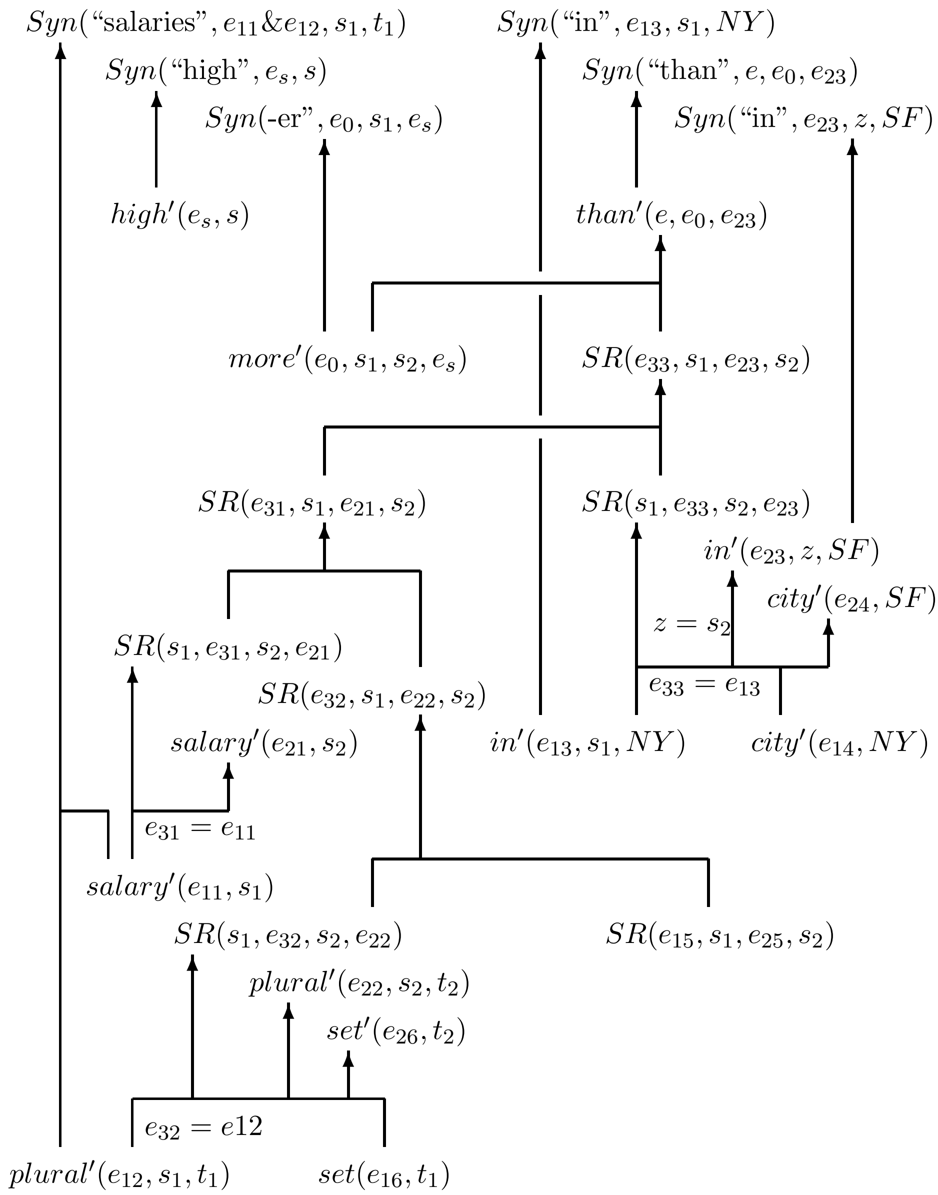

Figure 4.24: Parse of "Salaries are higher in New York than in San Francisco."

Finally, we need to prove $SR(e_{15}, s_1, e_{25}, s_2)$. But we have run out of properties of s_1 to use. So we simply assume it. It is the price we pay for not being able to establish a stronger similarity between s_1 and s_2.

The final example

> Salaries increased two times faster in New York than in San Francisco.

Two points need to be made about this sentence. First, the phrase "two times" is a measure phrase, measuring the comparison; it is parsed as described for measure phrases in Section 4.9 above; we postpone discussing its interpretation until Chapter 5.

Second, there is a benign ambiguity. The phrase "in New York", by the same metonymic process as in the last example, could be taken to qualify the increasing or the subject "salaries". As far as the meaning goes, it does not matter which element we attach the PP to. If it is attached to the increasing, then the analysis of this example is the same as the last. If it is attached to "salaries", a new wrinkle is introduced. So we will assume the latter.

The logical form after this resolution of the metonymy, ignoring tense, is

$$\begin{aligned}&salary'(e_{11}, s_1) \wedge plural'(e_{12}, s_1, t_1) \wedge increase'(e_1, s_1) \wedge fast'(e_s, s)\\&\quad \wedge measure'(e_{13}, e_0, t) \wedge time'(e_{14}, t) \wedge plural'(e_{15}, t, ts)\\&\quad \wedge two'(e_{16}, ts) \wedge more'(e_0, e_1, e_2, e_s) \wedge in'(e_{17}, s_1, NY)\\&\quad \wedge than'(e, e_0, e_{27}) \wedge in'(e_{23}, z, SF)\end{aligned}$$

The top-level SR relation that needs to be proved is

$$SR(y_1, e_1, e_{27}, e_2)$$

This requires the eventuality-eventuality rule for SR, Axiom (4.50), taking y_1 to be e_{17}. Applying that yields

$$SR(e_{13}, z_1, e_{23}, z_2) \wedge SR(e_{17}, z_1, e_{27}, z_2)$$

for some z_1 and z_2. That is, we have to find corresponding entities that the increasing and the in-ness eventualities are both properties of. Now backchaining on Axiom (4.45) from the first conjunct yields

$$SR(z_1, e_{13}, z_2, e_{23}) \wedge SR(e_{11}, z_1, e_{21}, z_2)$$

Backchaining from the second conjunct and unifying the two eventuality-argument conjuncts yields

$$SR(z_1, e_{17}, z_2, e_{27}) \wedge SR(e_{11}, z_1, e_{21}, z_2)$$

The literal $SR(z_1, e_{13}, z_2, e_{23})$ is established by using $increase'(e_{13}, s_1)$ to infer $increase'(e_{23}, s_2)$ and identify z_1 with s_1 and z_2 with s_2.

The literal $SR(s_1, e_{17}, s_2, e_{27})$ is established by using $in'(e_{17}, s_1, NY)$ to prove $in'(e_{27}, s_2, SF)$.

The literal $SR(e_{11}, s_1, e_{21}, s_2)$ is supported by using $salary'(e_{11}, s_1)$ and $plural'(e_{12}, s_1, t_1)$ to infer $salary'(e_{21}, s_2)$ and $plural'(e_{22}, s_2, t_2)$.

The relevant parts of the interpretation are shown in Figure 4.25.

In this chapter I have been driven by the syntactic phenomena that occur in the target texts. In this section on comparatives I have been driven in no small measure by one sentence in the target texts:

> As AIDS develops, viral isolation becomes easier; the proportion of infected cells in peripheral blood is 100 to 1000 times higher in AIDS patients than in asymptomatic individuals (12).

We are now able to handle it.

4.15.6 Comparatives and Superlatives

I have not considered superlatives in this section, because I believe they are much more of a pragmatic phenomenon, less directed by syntax than comparatives are by the "than" clause. Gawron (1995) argues for treating the two alike, urging that the sentence

> Jean gave Betty the most expensive present.

is ambiguous between readings in which the comparison sets are the presents Jean gave and the presents Betty was given. But it seems to me that these are just two of potentially many contextually available sets. A more likely one, independent of intonation, is the presents anyone gave anyone.

4.16 Summary of Grammar

4.16.1 Overview

We have characterized a large portion of English syntax using three kinds of axioms—composition, alternation, and lexical.

Uttering a word provides information, and in the present framework information is represented by a predicate applied to one or more arguments. The relation between words and the information they convey is captured in lexical axioms.

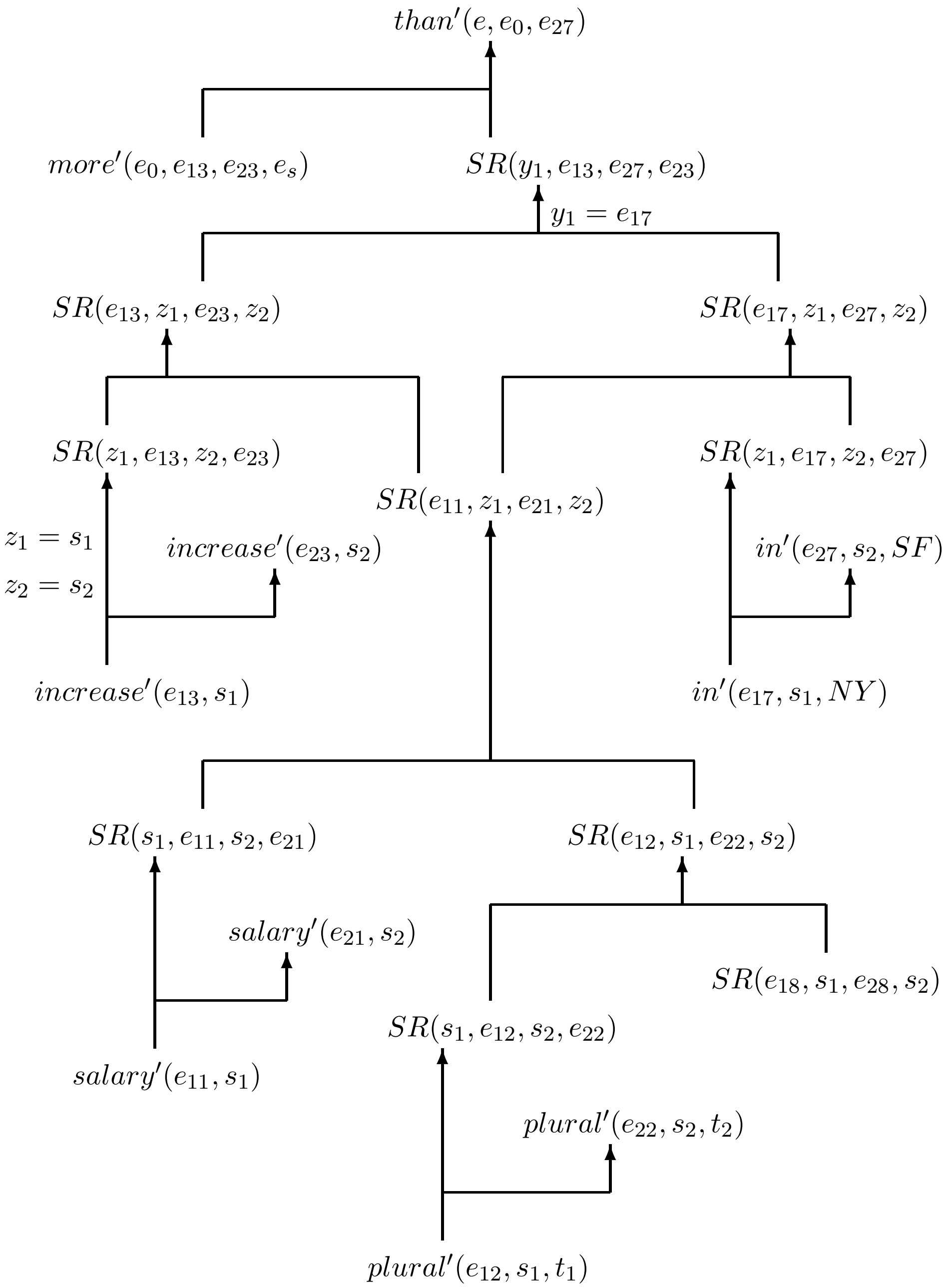

Figure 4.25: Interpretation of "Salaries increased faster in New York than in San Francisco."

When single words or larger stretches of text are concatenated, the adjacency that results conveys information, and within the scope of the sentence, this information is generally information about predicate-argument relations. The composite information conveyed by the segment that results from the concatenation must be characterized. All of this is captured by the composition axioms.

Lexical axioms specify the canonical mapping between the arguments of the predicate and the constituents of the sentence. However, English and every other language provide noncanonical ways for constituents to be mapped into arguments. Alternation axioms mediate between lexical axioms and composition axioms, in a sense, by permuting the mapping between constituents and arguments, and in some cases adding new information.

4.16.2 Composition Rules

It has been the fashion in recent linguistics research to attempt to minimize the number of composition rules, generally by packing more information into lexical rules. The extent to which this is possible depends on the amount of information that is conveyed in the representations of the structures being composed. When no more than the positions of the constituents are being represented and all other information is implicit in the feature structures of the constituents, then it is possible to get by with only two rules—one in which the predicate is on the left and the argument on the right, and one in which the opposite is true. This is very nearly the situation that obtains in $\overline{\mathbf{X}}$ Theory and in HPSG.

In the approach developed here, I have wanted to represent the predicate-argument structure explicitly in the *Syn* predicate. In addition, I have wanted to capture the rather strict constraints that hold for the internal structure of the NP, the relative freedom of placement of adjuncts, and the full range of possibilities (though not the full range of constraints) for conjunction. This has led to five types of composition axiom:

1. Five primary rules for clause-level composition: Subject, Object, Subject Control, Object Control, and "Tough Movement";
2. One primary rule for adjunct placement and interpretation;
3. Two primary rules for the internal structure of NPs, one for left adjuncts and one for right adjuncts;
4. Two primary rules for long-distance dependencies, one for relative clauses and one for wh-questions (and perhaps sentential wh-nominals);

5. Three primary rules for conjunction: Same-Category Conjunction, Ellipsis, and Gapping.

The Subject Composition Rule is as follows:

$$(4.6) \quad \begin{aligned} & Syn(w_1, x, a, -, -, -, -, -, -, v_1, g_1) \\ & \quad \wedge Syn(w_2, e, f, x, a{:}\mathbf{sb}, -, -, -, -, v_2, g_2) \\ & \quad \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ & \supset Syn(w_1 w_2, e, f, -, -, -, -, -, -, v, g) \end{aligned}$$

If a phrase of type a, referring to x, is concatenated with a phrase of type f, describing the eventuality e and having a subject argument subcategorized for feature structure a and rule **sb**, the result is a phrase of type f describing e. The composite phrase has a gap v with agreement features g if and only if exactly one of its constituents does too. Rule (4.6) covers the application of a subject to ordinary verb phrases, predicate complement constructions, and several other kinds of complements.

The Object Composition Rule is as follows:

$$(4.7) \quad \begin{aligned} & Syn(w_1, e, f, x, a, y, b{:}\mathbf{ob}, z, c, v_1, g_1) \\ & \quad \wedge Syn(w_2, y, b, -, -, -, -, -, -, v_2, g_2) \\ & \quad \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ & \supset Syn(w_1 w_2, e, f, x, a, z, c, -, -, v, g) \end{aligned}$$

If a head word or phrase w_1 describing eventuality e with agreement feature structure f and having arguments x, y and z with agreement feature structures a, b and c, respectively, is concatenated with a phrase w_2 referring to y and having agreement feature structure b, then the result $w_1 w_2$ is a phrase of type f describing eventuality e, and having as its unsaturated arguments the subject x and a possible remaining complement z, which have agreement feature structures a and c respectively.

The Subject Control Rule is stated as follows:

$$(4.8) \quad \begin{aligned} & Syn(w_1, e_1, f_1, x, a, e_2, f_2{:}\mathbf{sc}, z, c, v_1, g_1) \\ & \quad \wedge Syn(w_2, e_2, f_2, x, a, -, -, -, -, v_2, g_2) \\ & \quad \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ & \supset Syn(w_1 w_2, e_1, f_1, x, a, z, c, -, -, v, g) \end{aligned}$$

This is the same as rule (4.7) except that the subject of the first complement is the same as the subject of the head.

The Object Control Rule is as follows:

$$(4.9)\quad \begin{aligned} & Syn(w_1, e_1, f_1, x, a, y, b, e_3, f_3{:}\mathbf{oc}, -, -) \\ & \quad \wedge Syn(w_2, y, b, -, -, -, -, -, -, v_2, g_2) \\ & \quad \wedge Syn(w_3, e_3, f_3, y, b, -, -, -, -, v_3, g_3) \\ & \quad \wedge gap(v, g, v_2, g_2, v_3, g_3) \\ & \supset Syn(w_1w_2w_3, e_1, f_1, x, a, -, -, -, -, v, g) \end{aligned}$$

If w_1 is a word or phrase of type f_1 describing e_1 and having x, y, and e_3 as its arguments with agreement feature structures a, b, and f_3, respectively, w_2 is a word or phrase of type b referring to y, and w_3 is a phrase of type f_3 describing e_3, then the concatenation of the three is a phrase of type f_1 describing e_1 and having subject x with agreement feature a. The subject of the second complement is identical to the first complement.

The Tough Movement Rule is as follows:

$$(4.17)\quad \begin{aligned} & Syn(w_1, e_1, f_1, x, a, e_2, f_2{:}\mathbf{tf}, z, c, v, g) \\ & \quad \wedge Syn(w_2, e_2, f_2, x_2, a_2, -, -, -, -, x, a) \\ & \supset Syn(w_1w_2, e_1, f_1, x, a, z, c, -, -, v, g) \end{aligned}$$

A word or phrase w_1 of type f_1 describing eventuality e_1 and having arguments x, e_2, and z with agreement features a, f_2, and c, respectively, can be concatenated with a phrase w_2 of type f_2 describing eventuality e_2, having a gap, and possibly having an unsaturated subject x_2 with agreement feature a_2, to produce a phrase of type f_1 describing e_1, with unsaturated arguments x and z. The gap in w_2 is filled by x. The resulting phrase inherits its gap from w_1.

The last three rules each involve a sentential complement's sharing an argument with its matrix clause.

The most important rule for adjuncts is Adjunct Composition Rule 1, which is as follows:

$$(4.18)\quad \begin{aligned} & Syn(w_1w_3, e_1, f_1, x, a, y, b, z, c, v_1, g_1) \\ & \quad \wedge Syn(w_2, e_2, f_2{:}\mathbf{adjunct1}, e_1, f_1, -, -, -, -, v_2, g_2) \\ & \quad \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ & \supset Syn(w_1w_2w_3, e_2, f_1, x, a, y, b, z, c, v, g) \end{aligned}$$

If w_1w_3 is a phrase of type f_1 describing e_1, and w_2 is an adjunct taking a phrase of type f_1 describing e_1 as its logical subject, then $w_1w_2w_3$ is a phrase of type f_1 describing e_2.

The first of the two important rules for NP construction allows us to add prenominal nouns, adjectives, and determiners to the left of a head noun. It is NP Composition Rule 1.

$$(4.22)\quad \begin{aligned} & Syn(w_1, e_1, f_1, e_2, f_2, x, a{:}\mathbf{n}, s, -, v_1, g_1) \\ & \quad \wedge Syn(w_2, e_2, f_2, x, a, y, b, s, -, v_2, g_2) \\ & \quad \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ & \quad \supset Syn(w_1w_2, e_1\&e_2, f_1, x, a, y, b, s, -, v, g) \end{aligned}$$

A word w_1, such as an adjective, conveying the property e_1 can be concatenated with a word or phrase w_2 of category **n** conveying the property e_2 and referring to x. The property conveyed by the composite phrase is the conjunction of e_1 and e_2. The applicability of the rule will be conditioned on the *LEFT* feature of feature structure f_2 of w_2, and the *LEFT* feature of f_1 of the composite will be determined by w_1.

NP Composition Rule 2 attaches noun complements to the right of the head noun.

$$(4.24)\quad \begin{aligned} & Syn(w_1, e_1, f_1{:}\mathbf{ldan}, x, a{:}\mathbf{n}, y, b, s, -, v_1, g_1) \\ & \quad \wedge Syn(w_2, e_2, f_2{:}\mathbf{pred/rels/than}, x, a, -, -, -, -, v_2, g_2) \\ & \quad \wedge gap(v, g, v_1, g_1, v_2, g_2) \\ & \quad \supset Syn(w_1w_2, e_1\&e_2, f_1{:}\mathbf{rc}, x, a, y, b, s, -, v, g) \end{aligned}$$

A partial $\overline{\mathbf{N}}$ w_1 referring to x with agreement features a and conveying the property e_1 can be concatenated with a predicate complement, relative clause, or "than" phrase. The logical subject of the predicate complement or relative clause is x. The composite phrase has the *RIGHT* feature of **rc** indicating that a complement has been added.

The Relative Clause Composition Rule is

$$(4.32)\quad \begin{aligned} & Syn(w_1, v_2, g_2{:}\mathbf{n/adjunct}, y, b, -, -, -, -, v_1, g_1{:}\mathbf{rel}) \\ & \quad \wedge Syn(w_2, e_2, \mathbf{v.tnsd/inf}, -, -, -, -, -, -, v_2, g_2) \\ & \quad \supset Syn(w_1w_2, e_2, \mathbf{rels}, v_1, g_1{:}\mathbf{n}, -, -, -, -, -, -) \end{aligned}$$

This rule concatenates a relativizer w_1 with a matrix clause w_2 that has a gap. The clause describes the eventuality e_2. The referent of the relativizer is v_2 and it fills the gap in the clause. The wh-ed entity in the relativizer is v_1. The result of the concatenation is a relative clause (**rels**) describing the eventuality e_2. It is a noun complement and can be applied to a head noun referring to v_1.

The Wh-Question Composition Rule is as follows:

(4.33) $$\begin{aligned} & Syn(w_1, v_2, g_2{:}\mathbf{n/p}, y, b, -, -, -, -, v_1, g_1{:}\mathbf{whqhd}) \\ & \quad \wedge Syn(w_2, e_2, \mathbf{ynq}, -, -, -, -, -, -, v_2, g_2) \wedge wh'(e_1, v_1) \\ & \supset Syn(w_1 w_2, e_1, \mathbf{whq}, -, -, -, -, -, -, -, -) \end{aligned}$$

This rule concatenates a wh-NP or wh-PP with a yes-no question that has a gap. The yes-no question describes the eventuality e_2. The wh-phrase must have a wh-word of type **whqhd**. The gapped entity is v_2 and it fills the gap in the yes-no question. The wh-ed entity is v_1. The result of the concatenation is a wh-question requesting a contextually dependent essential property e_1 of v_1.

The Same-Category Conjunction Rule is as follows:

(4.35) $$\begin{aligned} & Syn(w_1, e_1, f_1{:}f_{CAT}, x, a, y, b, z, c, v, g) \\ & \quad \wedge Syn(w, e, \mathbf{conj}.f_{NUM}, e_1, f_1, e_2, f_2, -, -, -, -) \\ & \quad \wedge Syn(w_2, e_2, f_2{:}f_{CAT}, x, a, y, b, z, c, v, g) \\ & \supset Syn(w_1 w w_2, e, f_{CAT}.f_{NUM}, x, a, y, b, z, c, v, g) \end{aligned}$$

Two phrases of the same category f_{CAT} describing eventualities e_1 and e_2 can be conjoined by a conjunction w, and the result is a phrase of the same category describing the conjunction e of e_1 and e_2. The number feature is inherited from the conjunction, if it has one; this allows conjoined singular NPs to result in a plural NP. The corresponding arguments and gaps for the conjoined phrases must either be empty or identical.

***** UNDER CONSTRUCTION *****

The Ellipsis Rule is as follows:

(4.**??**) $$\begin{aligned} & Syn(w_1 w_2 w_4 w w_1 w_3 w_4, e, f, x, a, y, b, z, c, v, g) \\ & \quad \wedge Syn(w, e, \mathbf{conj}, e_1, f_1, e_2, f_2, -, -, -, -) \\ & \supset Syn(w_1 w_2 w w_3 w_4, e, f, x, a, y, b, z, c, v, g) \end{aligned}$$

In the phrase $w_1 w_2 w_4 w w_1 w_3 w_4$, where w is a conjunction, w_1 may be elided from the second conjunct and w_4 from the first.

The Gapping Rule is as follows:

(4.??) $Syn(w_1w_2w_3ww_4w_3w_5, e, f, x, a, y, b, z, c, v, g)$
$\wedge\, Syn(w, e, \mathbf{conj}, e_1, f_1, e_2, f_2, -, -, -, -)$
$\wedge\, Parallel(e, e_1, e_2)$
$\supset\, Syn(w_1w_2w_3ww_4w_5, e, f, x, a, y, b, z, c, v, g)$

In the phrase $w_1w_2w_3ww_4w_3w_5$, conveying e, where w is a conjunction and e is a parallel relation between the eventualitiess described by the two conjuncts, w_3 can be elided from the second conjunct.

4.16.3 Alternation Axioms

Alternation axioms rearrange or modify the arguments of the *Syn* predication, allowing words to associate with their arguments in noncanonical manners. They also sometimes introduce new predications that are conveyed by the position of a constituent in a sentence, rather than by an explict morpheme.

It is the fashion these days to restrict these alternation rules to the lexical level, and not allow them to apply to composite phrases. Indeed, sometimes they are viewed as alternations on lexical entries, yielding further lexical entries. While most of the alternation axioms I have used apply at the lexical level, I do not see any point in following this practice as a principle.

The passive alternation axiom is illustrative:

$$Syn(w, e, \mathbf{v.en}, x, a, y, b{:}\mathbf{n.acc.ob}, -, -, v, g)$$
$$\supset\, Syn(w, e, \mathbf{adj}, y, b{:}b_{CASE}\mathbf{.sb}, -, -, -, -, v, g)$$

If w is the past participle of a verb which takes a subject x and an object y, with agreement feature structures a and b, respectively, then w can function as an adjective, taking an NP subject referring to y. In making this alternation, the b feature structure associated with y has the composition rule **ob** replaced by **sb**, and the accusative feature **acc** replaced by the indeterminate variable b_{CASE}. This alternation axiom identifies the subject of the passivized sentence with the logical object of the underlying active predicate, thereby mediating between the lexical axiom that provides the predicate-argument structure and the composition axioms that find the arguments.

Aux-Inversion is accomplished by an alternation axiom:

$$Syn(w, e, \mathbf{v.aux.tnsd}, x, a{:}\mathbf{n.sb}, e_1, f_1{:}\mathbf{v.tnsless.sc}, -, -, v, g)$$
$$\supset\, Syn(w, e, \mathbf{ynq}, -, -, x, a, e_1, f_1{:}\mathbf{v.oc}, v, g)$$

So is the separability of the particle in verb-particle constructions:

$$VStem(w, e, \mathbf{v}, x, \mathbf{n.sb}, -, \mathbf{p.ob}, y, \mathbf{n.acc.ob}) \\ \supset VStem(w, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, \mathbf{p.ob})$$

So is the optional order of prepositional arguments:

$$Syn(w, e, f, x, a, y, \mathbf{n.pcase}, z, c, v, g) \\ \supset Syn(w, e, f, x, a, z, c, y, \mathbf{n.pcase}, v, g) \\ Syn(w, e, f, x, a, y, b, z, \mathbf{n.pcase}, v, g) \\ \supset Syn(w, e, f, x, a, z, \mathbf{n.pcase}, y, b, v, g)$$

So is the optionality of the complements of adjectives:

$$Syn(w, e, f{:}\mathbf{adj}, x, a, y, b, -, -, -, -) \\ \supset Syn(w, e, f, x, a, -, -, -, -, -, -)$$

Dative Movement could be handled in a similar fashion if it were felt that both variants carried the same information and the pattern were viewed as sufficiently productive. As we will see in Section 4.17.1, Metonymy is also handled by an alternation axiom that modifies arguments.

Several alternation axioms introduce new predications. These are predications that are conveyed not by specific morphemes but by the position of the constituent in the structure of the sentence. Examples of this include purpose infinitives:

$$Syn(w, e_2, \mathbf{v.inf}, x, a, -, -, -, -, v, g) \wedge \textit{in-order-to}'(e, e_1, e_2) \\ \supset Syn(w, e, \mathbf{adjunct2}, x, a, e_1, f_1, -, -, v, g)$$

time NPs:

$$Syn(w, x, \mathbf{ntime}, -, -, -, -, -, -, v, g) \wedge \textit{at-time}'(e, e_1, x) \\ \supset Syn(w, e, \mathbf{adjunct1}, e_1, \mathbf{v}, -, -, -, -, v, g)$$

measure NPs:

$$Syn(w, x, \mathbf{nmeasure}, -, -, -, -, -, -, v, g) \wedge measure'(e, e_1, x, s) \\ \supset Syn(w, e, \mathbf{adjunct1}, e_1, \mathbf{v}, -, -, -, -, v, g)$$

compound nominals:

$$Syn(w, e_1, f_1{:}\mathbf{lan}, y, b{:}\mathbf{n}, z, c, s_1, -, -, -) \wedge nn'(e, y, x) \\ \supset Syn(w, e_1\&e, f_1{:}\mathbf{nn}, e_2, f_2{:}\mathbf{nn}, x, a, s_2, -, -, -)$$

and NP predicate complements:

$$Syn(w, y, \mathbf{nominal}, -, -, -, -, -, -, -, -) \wedge be'(e, x, y) \\ \supset Syn(w, e, \mathbf{nppred}, x, \mathbf{nominal.sb}, -, -, -, -, -, -)$$

In each of these alternations, information is added about how further constituents are to be related to newly interpreted phrase.

Finally, there are a number of alternation axioms that merely alter the agreement features in the *Syn* predication, allowing the word to function in environments that are not directly enabled by the word's lexical axioms. Among these are the axioms that convert a predicate complement adjective into a prenominal adjective:

$$Syn(w, e_1, f_1{:}\mathbf{adj/prog}, x, a, y, b, z, c, -, -)$$
$$\quad \supset\ Syn(w, e_1, f_1{:}\mathbf{la}, e_2, f_2{:}\mathbf{lan}, x, a{:}\mathbf{n}, s, -, -, -)$$

the internal characterization of an NP into the external version:

$$Syn(w, e, f{:}\mathbf{ldan}, x, a{:}\mathbf{n}, -, -, s, -, v, g)$$
$$\quad \supset\ Syn(w, x, a, -, -, -, -, -, -, v, g)$$

and a tensed or tenseless clause into a nominal:

$$Syn(w, e, \mathbf{v.tnsd/tnsless}, -, -, -, -, -, -, -, -)$$
$$\quad \supset\ Syn(w, e, \mathbf{thats.ob}, -, -, -, -, -, -, -, -)$$

Many, if not all, of the alternation axioms could be eliminated in favor of a multiplication of lexical axioms, but there would be no point in doing this.

4.16.4 Lexical Axioms

I will use the lexical axiom for the subordinate conjunction "because" as an illustration, since (as I have modified it here) it contains all the features of lexical axioms.

$$because'(e, x, y) \wedge event(x) \wedge event(y)$$
$$\quad \supset\ Syn(\text{"because"}, e, \mathbf{p}, x, a, y, \mathbf{v.tnsd.ob}, -, -, -, -)$$

This says that if e is the eventuality of an event x causing an event y, then e can be conveyed by the word "because", which is of category **p**, taking a phrase describing x as its logical subject and taking a phrase headed by a tensed verb as its first complement. The Object Composition Rule is used to attach its first complement.

The first conjunct in the antecedent of the axiom specifies the logical form associated with the word "because"; it represents the information conveyed by that word. The second and third conjuncts specify the selectional constraints on the arguments of *because*; these are properties x and y must have before $because(x, y)$ can make sense, and they often force coercions by the metonymy mechanism of Section 4.17.1. The first argument of the *Syn* predication in the consequent specifies the spelling (or pronunciation) of the word. The e, x, and y arguments are used in the construction of the logical form for this word and for the rest of the sentence. The feature **p** associated with e constrains the use of phrases headed with "because" in other constructions. The feature structure **v.tnsd.ob** associated with y constrains the set of phrases that can be used to convey y. The feature structure a associated with x places no such constraints on the set of phrases that can be used to convey x.

Similar to this lexical axiom are the axioms for prepositions—

$$about'(e, x, y) \supset Syn(\text{“about”}, e, \mathbf{p}, x, a, y, \mathbf{n.acc.ob}, -, -, -, -)$$

—and adjectives—

$$correct'(e, x) \supset Syn(\text{“correct”}, e, \mathbf{adj}, x, \mathbf{n.sb}, -, -, -, -, -, -)$$
$$able'(e, x, e_1) \supset Syn(\text{“able”}, e, \mathbf{adj}, x, \mathbf{n.sb}, e_1, \mathbf{v.inf.sc}, -, -, -, -)$$

John is able to leave early.

—and adverbs—

$$actual'(e, e_1) \supset Syn(\text{“actually”}, e, \mathbf{adv1}, e_1, \mathbf{v}, -, -, -, -, -, -)$$

Verbs are decomposed into their tense and stem by the following rule:

$$VMorph(w_1, w, e_1, f{:}\mathbf{v}, e_2, a) \wedge VStem(w, e_2, f, x, a, y, b, z, c)$$
$$\supset Syn(w_1, e_1, f, x, a, y, b, z, c, -, -)$$

w_1 is the word and w is its stem. *VStem* has the same structure as *Syn*. Tense and aspect information is hung off of the *VMorph* predicate, as illustrated by the axiom

$$present'(e_1, e_2) \supset VMorph(\text{“goes”}, \text{“go”}, e_1, \mathbf{v.tnsd}, e_2, \mathbf{n.sing.nom})$$

The lexical axioms for verbs then involve the predicate *VStem* instead of *Syn*. Some illustrative axioms follow:

Intransitive:

$$pause'(e, x) \supset VStem(\text{“pause”}, e, \mathbf{v}, x, \mathbf{n.sb}, -, -, -, -)$$

Transitive:

$$define'(e, x, y) \supset VStem(\text{“define”}, e, \mathbf{v}, x, \mathbf{n.sb}, y, \mathbf{n.acc.ob}, -, -)$$

Ditransitive:

$$give'(e, x, y, z) \supset VStem(\text{"give"}, e,\mathbf{v}, x,\mathbf{n.sb}, z,\mathbf{n.acc.ob}, y,\mathbf{n.acc.ob})$$

A verb taking a "that" complement:

$$believe'(e, x, e_1) \supset VStem(\text{"believe"}, e,\mathbf{v}, x,\mathbf{n.sb}, e_1,\mathbf{thats.ob}, -, -)$$

Two Equi verbs:

$$try'(e, x, e_1) \supset VStem(\text{"try"}, e,\mathbf{v}, x,\mathbf{n.sb}, e_1,\mathbf{v.inf.sc}, -, -, -, -)$$
$$promise'(e, x, y, e_1) \supset VStem(\text{"promise"}, e,\mathbf{v}, x,\mathbf{n.sb}, y,\mathbf{n.acc.ob}, e_1,\mathbf{v.inf.sc})$$

A Raising verb:

$$seem'(e, e_1) \supset VStem(\text{"seem"}, e,\mathbf{v}, x,\mathbf{n.sb}, e_1,\mathbf{v.inf.sc}, -, -)$$

An Object Control verb:

$$persuade'(e, x, y, e_1) \supset VStem(\text{"persuade"}, e,\mathbf{v}, x,\mathbf{n.sb}, y,\mathbf{n.acc}, e_1,\mathbf{v.inf.oc})$$

The infinitive particle "to" is treated as a subject control verb having no content.

$$\supset Syn(\text{"to"}, e,\mathbf{v.inf}, x,\mathbf{n.sb}, e,\mathbf{v.tnsless.sc}, -, -, -, -)$$

Existential "there" clauses are treated as arising from a special sense of the verb "to be", explicated in the lexical axiom

$$exist'(e, y) \supset VStem(\text{"be"}, e,\mathbf{be}, -,\mathbf{there.}a_{NUM}, y,\mathbf{n.}a_{NUM}, -, -, -, -)$$

If e is the eventuality of y existing, then e can be described by a form of the auxilliary verb "be" taking "there" as subject and an NP referring to y as its complement. By assuming that the expletive "there" has an unexpressed number agreement feature that must agree with the number feature on the y argument, we can enforce the latter's number agreement constraint with the verb.

This axiom works in conjunction with the following axiom for the expletive "there":

$$\supset Syn(\text{"there"}, -,\mathbf{there}, -, -, -, -, -, -, -, -)$$

Lexical axioms for nouns carry information about the entity referred to, the property conveyed, and the set referred to in cases of plurals. The following are illustrative:

$$man'(e,x) \supset Syn(\text{“man”}, e, \mathbf{ln.rn}, x, \mathbf{n.sing}, -, -, -, -, -, -)$$
$$man'(e,x) \wedge plural'(e_0, x, s)$$
$$\supset Syn(\text{“men”}, e\&e_0, \mathbf{ln.rn}, x, \mathbf{n.pln}, -, -, s, -, -, -)$$

If e is the condition of x being a man, then x can be described by the singular noun “man”, so far unadorned by modifiers (the *LEFT* feature is **ln** and the *RIGHT* feature is **rn**). If e is the condition of x being a man and e_0 is the condition of x being the typical element of the set s, then s can be described by the plural noun “men”, again so far unadorned by modifiers. For plurals, the property conveyed by the word is the conjunction of e and e_0, and the set referred to is s.

Various particles and other hard-to-classify operators are given lexical axioms that characterize their idiosyncratic constraints.

4.16.5 Agreement Features

The agreement features function to restrict which pairs of constituents can be construed as conveying predicate-argument relations and hence composed into larger structures. They come in hierarchically related feature sets.

The richest feature set is *CAT*, the set of categories. Its features are as follows, where indenting indicates subfeature relations:

- **whq**: a wh-question;
- **ynq**: a yes-no question;
- **v/n**: a phrase headed by a verb or a noun;
  - **v**: a phrase headed by a verb;
    - **got**: a phrase headed by the verb “got”;
    - **aux**: a phrase headed by an invertible auxilliary verb;
      - **be**: a phrase headed by a form of the verb “to be”;
      - **have**: a phrase headed by a form of the verb “to have”;
      - **do**: a phrase headed by a form of the verb “to do”;
      - **modal**: a phrase headed by a modal verb;
  - **n**: a phrase headed by a noun;
    - **ntime**: a phrase headed by a time noun;
    - **nmeasure**: a phrase headed by a measure noun;
    - **nwhqhd**: a wh-word that can both function as a noun and be the head of a wh-question;

nominal: a noun or weak nominalization;
- **thatsubjunct**: a subjunctive "that" clause;
- **n/thats**: a phrase headed by a noun or a tensed "that" clause;
  - **thats**: a tensed "that" clause;
  - **n**: as above;

nx: a noun or an expletive "it" or "there";
- **n**: as above;
- **it**: the expletive "it";
- **there**: the expletive "there";

adjunct: an adjunct;
- **adjunct2**: an adjunct that shares its subject with its matrix clause;
  - **adv2**: an adverb that shares its subject with its matrix clause;
- **adjunct1**: an adjunct that does not share its subject with its matrix clause;
  - **rels**: a relative clause;
  - **than**: a "than" clause;
  - **adv1**: an adverb that does not share its subject with its matrix clause;
  - **pred**: a predicate complement;
    - **adj/prog**: and adjective phrase or the progressive form of a verb.
      - **adj**: an adjective phrase;
      - **prog**: the progressive form of a verb;
    - **nppred/p**: an NP predicate complement or a phrase headed by a preposition;
      - **nppred**: an NP predicate complement;
      - **p**: a phrase headed by a preposition;
        - **as**: a phrase headed by the word "as";

rel/whqhd: a phrase that can head a relative clause or a wh-question;
- **whqhd**: a phrase that can head a wh-question;
  - **nwhq**: as above;
    - **nrel**: a word that can head a relative clause or a wh-question and can head an NP;
- **rel**: a phrase that can head a relative clause;
  - **nrel**: as above;

Verbs have one other feature set—*TNS*:

tnsd: tensed, including present plural tense;
tnsless: tenseless, the infinitive form;
inf: infinitive, having the word "to";
ing: present participle form;
en: past participle form;

Nouns have four other associated feature sets, the first two of which they share with pronouns and expletive pronouns. The first is *NUM*:

sing: a singular noun;
pl: a plural noun or the word "I";
  ego: the word "I";
  pln: a plural noun;

The second is *CASE*:

nom: a (partial) NP in the nominative case;
acc: a (partial) NP in the accusative case;
pcase: an NP preceded by a preposition indicating the NP's role as an argument;
  from: an NP preceded by the preposition "from";
  for/to: an NP preceded by the preposition "for" or "to";
    for: an NP preceded by the preposition "for";
    to: an NP preceded by the preposition "to";
  in/of: an NP preceded by the preposition "in" or "of";
    in: an NP preceded by the preposition "in";
    of: an NP preceded by the preposition "of";
  on: an NP preceded by the preposition "on";
  with: an NP preceded by the preposition "with";

The third and fourth feature sets are associated only with nouns—*LEFT* and *RIGHT*. They used in constraining the internal structure of NPs and partially built NPs. *LEFT* is

ldane: a (partial) NP in any stage of construction;
  le: a (partial) NP whose leftmost element is an empty head;
  ldan: a (partial) NP whose leftmost element is a determiner, an adjective, or a noun;
    ld: a (partial) NP whose leftmost element is a determiner;
    lan: a (partial) NP whose leftmost element is an adjective or a noun;

la: a (partial) NP whose leftmost element is an adjective;
ln: a (partial) NP whose leftmost element is a noun.

The feature set *RIGHT* has the following features:

- **rnce**: a (partial) NP whose rightmost element is a noun a noun complement, or an empty head;
  - **re**: a (partial) NP whose rightmost element is an empty head;
  - **rnc**: a (partial) NP whose rightmost element is a noun or a noun complement;
    - **rn**: a (partial) NP whose rightmost element is a noun;
    - **rc**: a (partial) NP whose rightmost element is a noun complement.

Prepositions have one associated feature set, *PART*, which enables them to function as separable particles for certain verbs:

off: the particle "off';
out: the particle "out";
up: the particle "up";

All categories can have features from the feature set *COMPRULE*, which specifies the clause-level composition rule the phrase can function as a constituent in:

sb: the Subject Composition Rule;
ob: the Object Composition Rule;
sc: the Subject Control Rule;
oc: the Object Control Rule;
tf: the Tough Movement Rule;

Finally, those numbers dealt with here have features from the feature set *NUMBR*:

- **number**: 1/4, 1, 145, one, one hundred forty, ...;
  - **fraction**: 1/4, ...;
  - **numeral**: 1234, ...;
    - **digit**: 1, 2, 3, 4, ...;
  - **n100**: one hundred forty-five, ...;
    - **hundreds**: one hundred, two hundred, ...;
    - **n10**: eleven, forty-five, ...;
      - **digitword**: one, two, three, ...;
      - **ty**: twenty, thirty, forty, ...;

4.17 Some Problems Analyzed as Metonymy

4.17.1 The Basic Axioms of Metonymy

Metonymy is the linguistic device by which an entity is referred to by referring to a functionally related entity. For example, when we say "John reads Proust." we really mean "John reads the novels by Proust." "Proust" has been coerced into "the novels by Proust", or "read" has been coerced into "read the novels by".

In Chapter 3, there was a brief mention of how metonymy could be accommodated in the abduction framework, and in the examples, where relevant, the possibility of a coercion was slipped in, along with a selectional constraint to force its use. We are now in a position to handle metonymy in a coherent fashion. Within the framework developed in this chapter, metonymy can be handled by simple alternation axioms that substitute one variable for another in an argument position and introduce a *rel* predication.

There are two ways to characterize the relation of metonymy. Metonymy occurs when an explicit predication $p(x)$ is conveyed by a fragment of text and the intended interpretation is $p(f(x))$ for some function f. This can be viewed as x being coerced into $f(x)$; this corresponds to the usual characterization of metonymy as an entity being coerced into something functionally related to it. Or it can be viewed as the predicate p being coerced into the predicate $p \circ f$, or p composed with f. Nunberg (1995) refers to the first case as *deferred ostension* and to the second case as *predicate transfer*. He argues that the former occurs only in actual cases of ostension, as when a parking attendent holds up a key and says "This is parked out back." In non-ostensive cases, including the vast majority of examples that occur in discourse, he argues that the metonymies should be thought of as instances of predicate transfer. His arguments rest primarily on the availability of entities for subsequent pronominal reference and occurrence within elliptical constructions. In the following examples, the first two illustrate deferred ostension, the second two predicate transfer:

  This [holding up key] is parked out back and may not start.
* This [holding up key] is parked out back and fits only the left front door.
  John is parked out back and has been waiting fifteen minutes.
* John is parked out back and may not start.

In the first two examples the key x is coerced into the car $f(x)$ and the latter becomes the only possible subject for the second clause. In the last two examples, John x remains the same and is the only possible subject for the second clause; the predicate

λx[x is parked out back]

is coerced into something like

λx[the car belonging to x is parked out back]

Both varieties of metonymic transfer can be easily captured in the present framework by means of alternation axioms. The coercion from x to $f(x)$ is a matter of substituting for the leading argument (or eventuality) variable in the *Syn* predication another variable representing a functionally related entity.

(4.54) $$Syn(w, e_0, f, x, a, y, b, z, c, v, g) \wedge rel(e_0, e) \\ \supset Syn(w, e, f, x, a, y, b, z, c, v, g)$$

Viewed from the perspective of interpretation, this says that the phrase w is being used in the embedding context as though it referred to or described one entity or eventuality e (e.g., the novels of Proust), but in fact w, by itself, refers to or describes a related entity or eventuality e_0 (Proust). From the perspective of generation, it says that if you want to refer to or describe an entity or eventuality e you can do so by referring to or describing a related entity or eventuality e_0.

The coercion from p to $p \circ f$ is a matter of substituting for one of the x, y or z arguments in the *Syn* predication another variable representing a functionally related entity. Three axioms are required, one for each argument position. The first is

(4.55) $$Syn(w, e, f, x_0, a, y, b, z, c, v, g) \wedge rel(x_0, x) \\ \supset Syn(w, e, f, x, a, y, b, z, c, v, g)$$

The effect of this axiom in interpretation is as follows: In backchaining, the axiom is applied to the predicate or head word w in the proof graph below the point at which it links up with its argument x. Above the application of this axiom, the argument is the variable x and refers to the explicit, uncoerced argument. The axiom introduces the coercion $rel(x_0, x)$. Below the application of the axiom, the argument is x_0, the implicit, coerced argument.

It is this that becomes the argument of the predication associated with w and to which the selectional constraints are applied.

The other two "predicate transfer" axioms are as follows:

$$(4.56) \quad Syn(w,e,f,x,a,y_0,b,z,c,v,g) \wedge rel(y_0,y) \supset Syn(w,e,f,x,a,y,b,z,c,v,g)$$

$$(4.57) \quad Syn(w,e,f,x,a,y,b,z_0,c,v,g) \wedge rel(z_0,z) \supset Syn(w,e,f,x,a,y,b,z,c,v,g)$$

Figure 4.26 illustrates the use of Axiom (4.56) for the sentence

John read Proust.

in conjunction with axioms that say that Proust wrote novels, which are texts, and that the writing relation is a possible coercion.

The coercion occurs on the word "read", changing its second argument from Proust to the novels of Proust. This in effect "transfers" the predicate "read" into the predicate "read the novels of". Note that the phrase "Proust" is still and only an NP referring to the man Proust and not his works. This is what restricts the possibilities for subsequent pronominal reference.

By contrast, if this example were to be handled with Axiom (4.54), as a coercion from Proust to the novels of Proust, the interpretation would be as illustrated in Figure 4.27. Here the *rel* coercion relation is part of the interpretation, not of the word "read", but of the word "Proust".

In this chapter, Nunberg's lead will be followed, and cases of metonymy will be treated as instances of predicate transfer.

Any attempt to determine constraints on metonymic coercions will be postponed until Chapter 6. Here the coercion relation *rel* will be axiomatized in the loosest possible way. It is symmetric and transitive:

$$(\forall x,y)rel(x,y) \supset rel(y,x)$$
$$(\forall x,y,z)rel(x,y) \wedge rel(y,z) \supset rel(x,z)$$

For the purposes of this chapter any relation will be taken to be a possible coercion relation. This is captured by the axiom schema

$$(\forall \ldots,x,\ldots,y,\ldots)p'(\ldots,x,\ldots,y,\ldots) \supset rel(x,y)$$

That is, any two arguments of the same predication are related to each other. Any predication can function as a coercion relation between any two of its arguments, including its eventuality arguments.

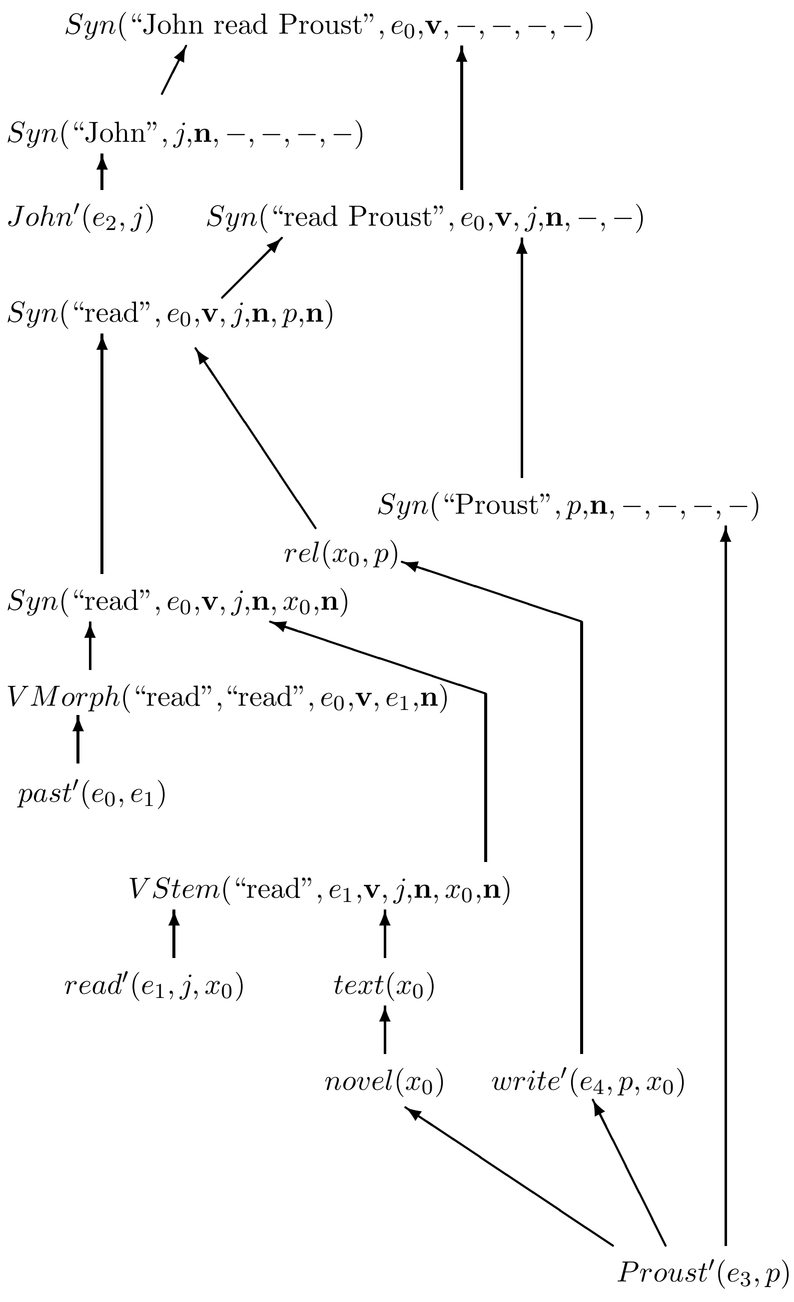

Figure 4.26: Parse of "John read Proust" using predicate transfer.

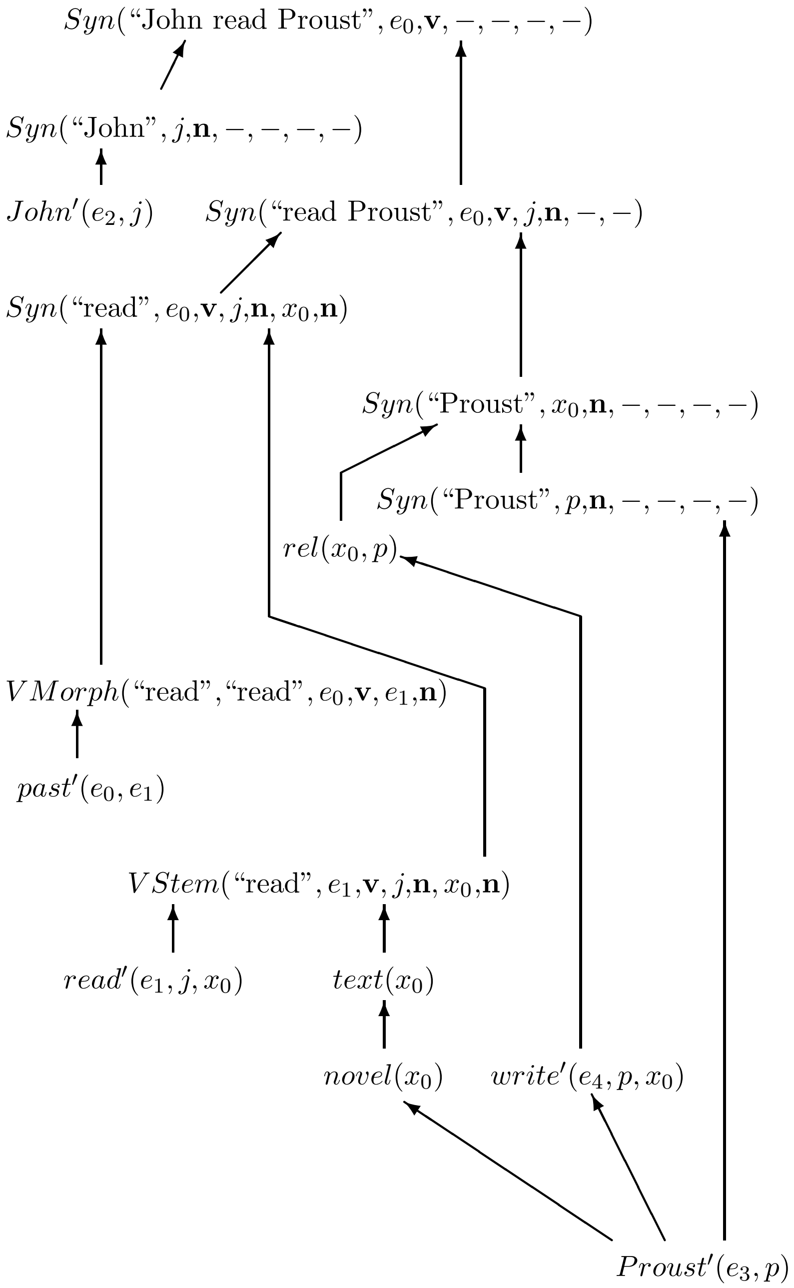

Figure 4.27: Parse of "John read Proust" using entity coercion.

Of the possible coercion relations, the most salient will be selected by the abductive interpretation process. Among the most salient relations between entities are those conveyed explicitly in the text itself. A number of seemingly disparate phenomena that are normally thought of as syntactic can be analyzed as examples of metonymy, where the coercion relation is provided by the explicit content of the sentence itself. Five such cases will be examined here—extraposed modifiers of the subject, ataxis, distributive readings, the assertion of grammatically subordinated information, and the interpretation of monotone decreasing quantifiers.

4.17.2 Extraposed Modifiers

Consider the sentences

> Mary saw Denver flying to Chicago.
> A jolly old man arrived with an armload of presents.
> The man arrived whom John had invited to dinner.

Neither the seeing nor Denver was flying to Chicago, but Mary. It was the old man who had an armload of presents, not the arriving. John had invited the man and not the arriving to dinner. In each of these cases what seems as though it should be a right modifier to the subject NP is extraposed to the end of the sentence.

It is possible to interpret these cases as examples of metonymy, where the coercion relation is provided by the predication associated with the head verb. That is, normal syntactic processing would attach the postmodifier to the verb, and then that would be coerced to the subject, using the predication of the verb as the coercion relation. Thus, by normal syntactic processing, the seeing is flying to Chicago, the arriving is with an armload of presents, and John had invited the arriving to dinner. These interpretations will not satisfy the selectional constraints associated with "fly", "with", and "invite", respectively. The application of Axiom (4.55) coerces each of these arguments to the subject of the sentence. In the first sentence

> $see'(e, M, D)$ coerces from the seeing e to Mary M,

and in the second sentence

> $arrive'(e, m)$ coerces from the arriving e to the man m.

Figure 4.28 illustrates this with the sentence "Mary saw Denver flying to Chicago." The flying event e_2 takes the seeing event e_1 as its logical subject.

However, seeing events don't fly, a fact encoded here by the selectional constraint that the predicate *mobile* be true of the logical subject of fly. So e_1 is coerced to M. The coercion relation is simply $see'(e_1, M, D)$, introduced by the word "saw".

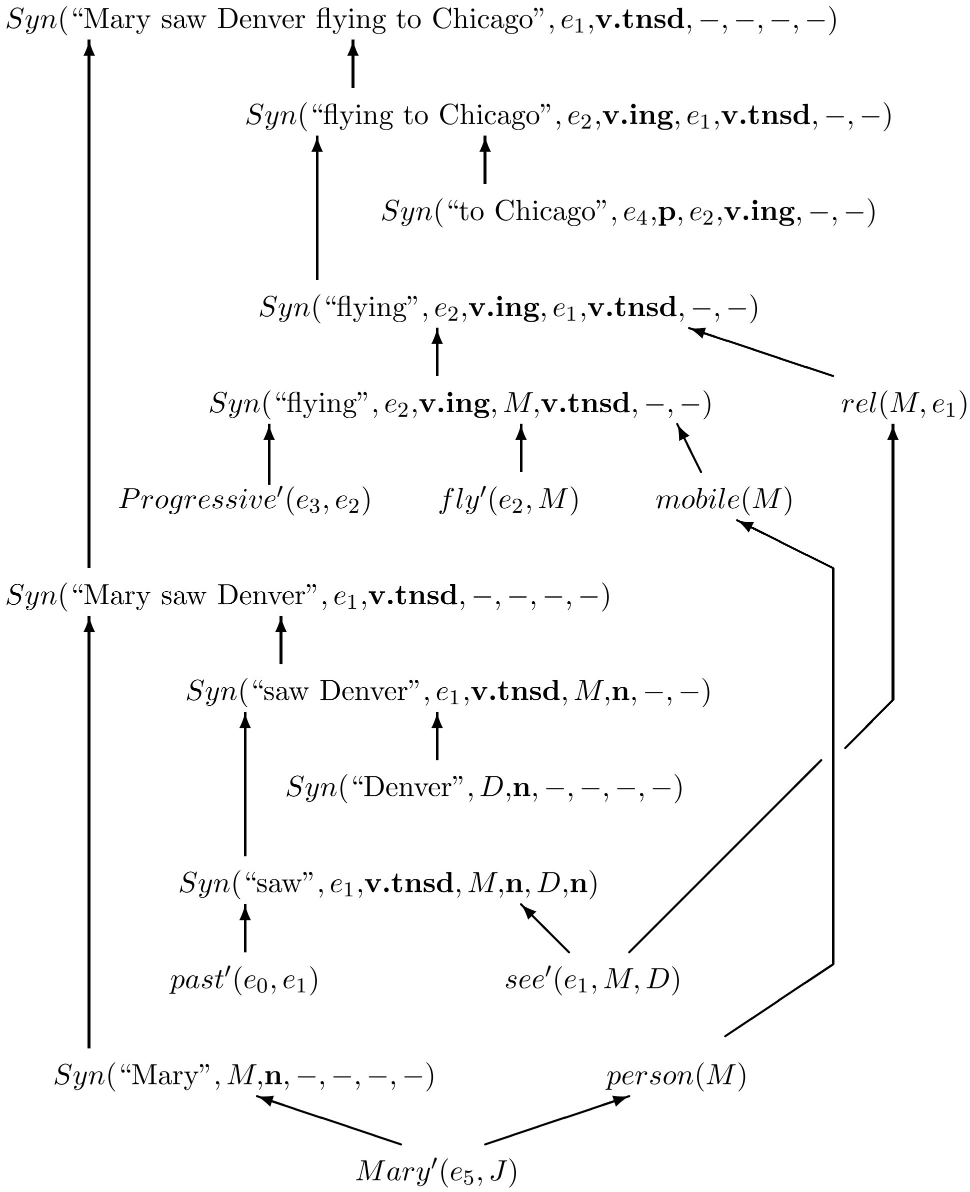

Figure 4.28: Parse of "Mary saw Denver flying to Chicago."

A similar analysis can be used to correct for incorrect prepositional phrase attachments. In

I saw the man in the park with the telescope.

if the park is incorrectly identified as the logical subject of "with", the *in* and *see* relation can be used to coerce it to the seeing event. Instead of the park being with the telescope, it is the seeing event of a man in the park.

Sometimes the complement of an adjective used prenominally appears as the noun complement, as in

a similar boat to that.

This kind of example can also be viewed as an instance of metonymy, as illustrated in Figure 4.29. The complement "to that" is taken first as a property of the boat b.

$$Syn(\text{"to that"}, e_3, \mathbf{p}, b, \mathbf{n}, y_1, \mathbf{n}, \ldots)$$

This is then unpacked by the metonymy axiom (4.55) into

$$Syn(\text{"to that"}, e, \mathbf{p}, e_1, \mathbf{n}, y_1, \mathbf{n}, \ldots) \wedge rel(e_1, b)$$

The first conjunct eventually bottoms out in the predication $to'(e_3, e_1, y_1)$, among others. The second conjunct, the coercion relation, is established using $similar'(e_1, b, y_2)$, the logical form fragment associated with the word "similar". Finally y_1 and y_2 are identified using the axiom

$$(\forall\, e, x, y) similar'(e, x, y) \supset (\exists\, e_1) to'(e_1, e, y)$$

relating *similar* to the preposition used to signal its second argument.

This is .

Split relatives (Kamp and Wittenburg, 19??) can be handled in a similar way. In

John introduced some men to some women who had never met before.

the rules of syntax result in a reading in which some women had never met before. This is then coerced into the pair consisting of the set of men and the set of women by the coercion relation $andn'(x, m, w)$, where m is the typical element of the set denoted by "some men", w is the typical element of "some women", and x is the typical element of the pair consisting of m and w.

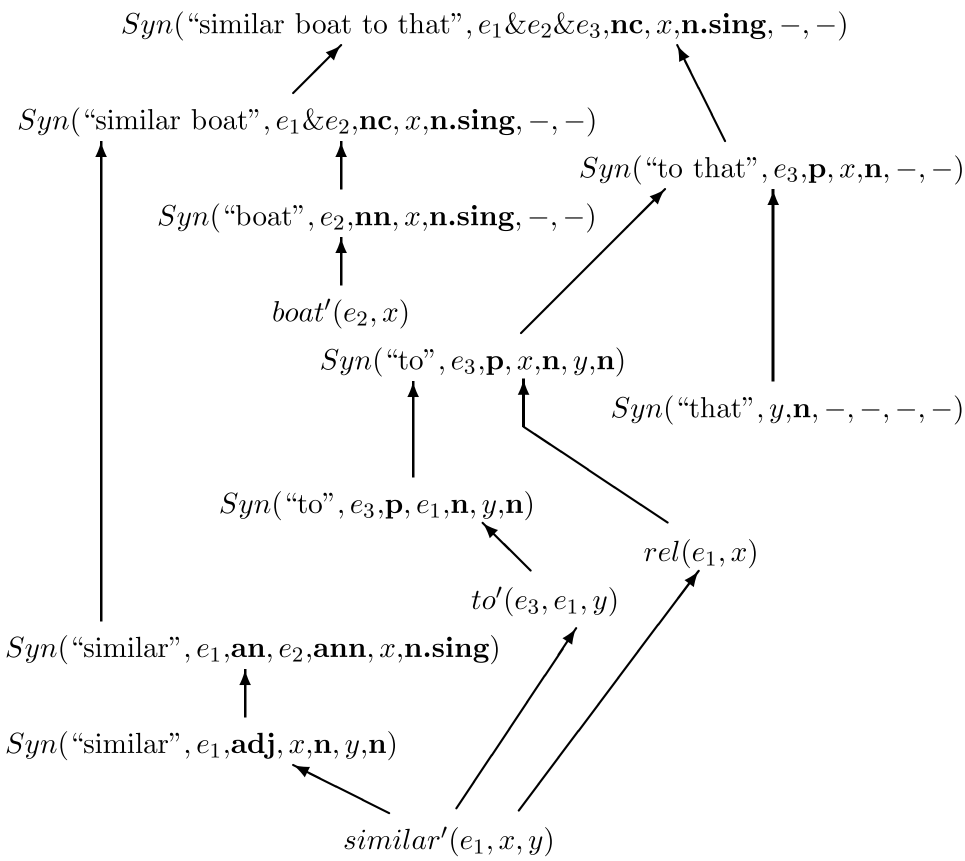

Figure 4.29: Parse of "similar boat to that"

In languages that have a freer word order than English has, many of the displaced elements can be treated similarly. For example, a noun complement occurring before its head noun can be treated in a manner analogous to extraposed noun complements in English, by having syntactic analysis attach them at the sentence level and then applying the Metonymy Axiom to attach it to its head noun.

4.17.3 Ataxis

A similar approach will handle sentences (cf. Bolinger, 19??) such as

John smokes an occasional cigarette.

The adjective "occasional" requires an event for its argument, but its explicit argument is a cigarette, which is not an event. The reference to the cigarette must be coerced into a reference to an associated event. The main verb of the sentence provides that event—the smoking of the cigarette.

Figure 4.30 illustrates this interpretation. Explicitly, the adjective "occasional" takes the cigarette y as its argument. This is coerced into the smoking event e_1, using the smoking predication, $smoke'(e_1, J, y)$, itself as the instantiation of the coercion relation $rel(e_1, y)$. The selectional constraint $event(e_1)$ is also inferred from $smoke'(e_1, J, y)$.

Of course, the most salient event associated with cigarettes is smoking them, regardless of the rest of the sentence, so in

> An occasional cigarette can't be harmful.

the coercion will again be to the smoking. However, this salient event is overridden in such sentences as

> John buys an occasional cigarette.
> John eats an occasional cigarette.

where the coerced events are the buying and the eating, respectively.

4.17.4 Distributive and Collective Readings

There are two entities associated with plural NPs—the set of entities referred to by the NP and the typical element of that set. In

> The men ran.

each individual man must run by himself, so the predicate *run* applies to the typical element. This is the distributive reading. In

> The men gathered.
> The men were numerous.

the predicates *gather* and *numerous* apply to the set of men. This is the collective reading of the NP. The sentence

> The men lifted the piano.

is ambiguous between the two readings. They each could have lifted it individually—the distributive reading—in which case the logical subject of *lift* would be the typical element of the set, or they could have lifted it together, the collective reading, in which case it would be the set, or the corresponding aggregate.

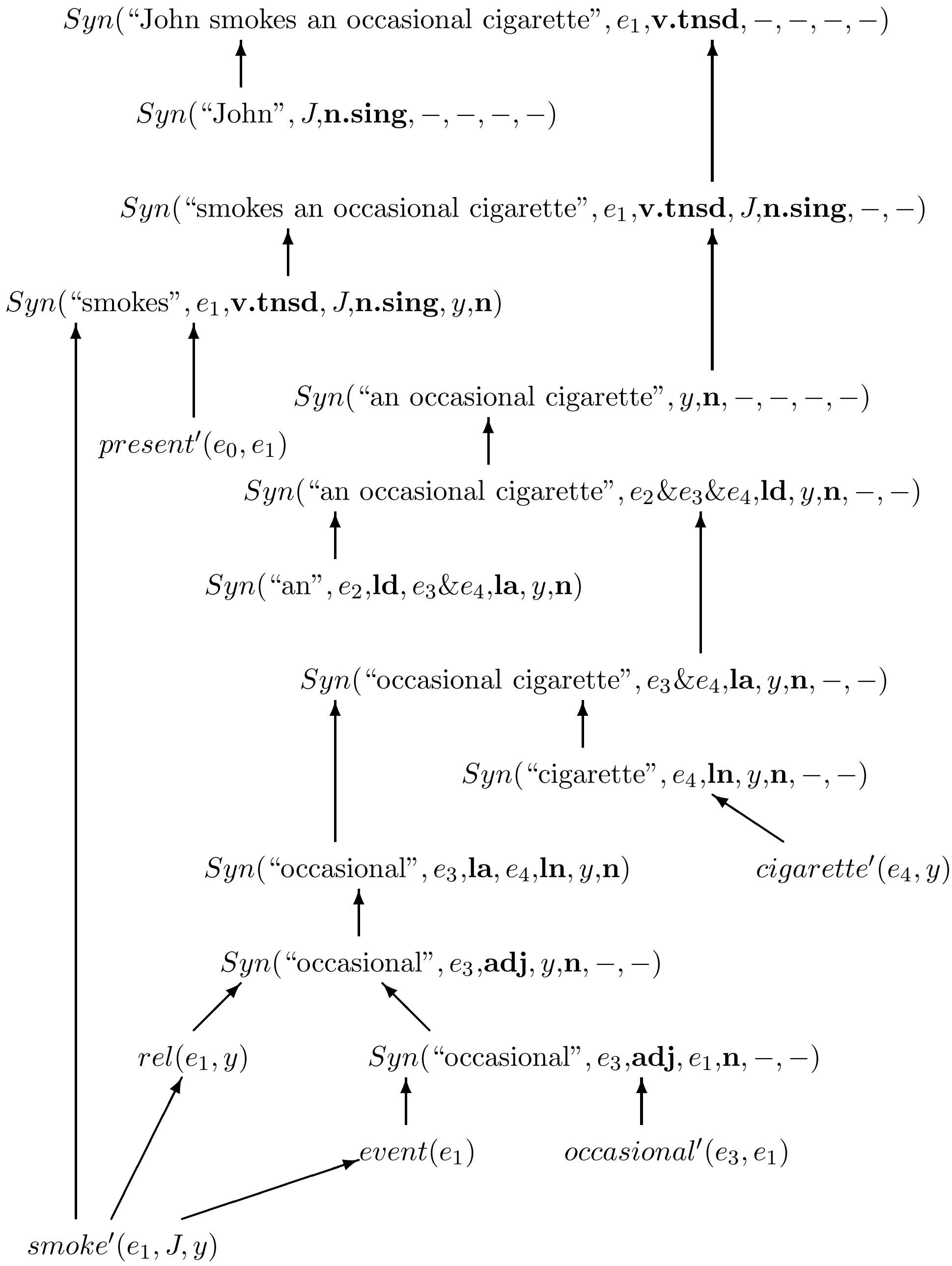

Figure 4.30: Parse of "John smokes an occasional cigarette."

The *Syn* predication associated with NPs, however, only carries information about one of these entities, the typical element. In cases where the collective reading is the correct one, there must be a coercion into the set. This can be effected by the relation between the typical element and its set that we expressed as $plural(x, s)$. That is, distributive readings are taken as basic, and collective readings are taken as examples of metonymy.

Figure 4.31 illustrates the (collective) interpretation of "Men gathered." The predicate *gather* requires a set for its argument. The explicit subject x of the verb phrase "gathered" is the typical element of the set of men, rather than the set itself. Thus, there is a coercion, in which the predication $plural'(e_2, x, s)$, relating x to s, is used as the instantiation of the coercion relation $rel(s, x)$.

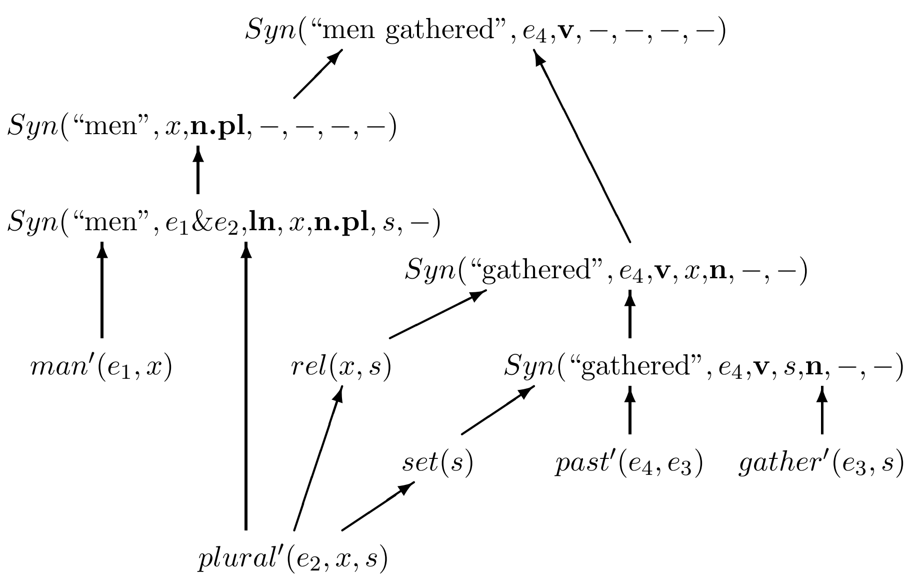

Figure 4.31: Parse of "Men gather."

The opposite approach could have been followed, taking the basic referent of the NP to be the set and coercing it into the typical element when the distributive reading is required. This approach is perhaps more intuitively appealing since a plural NP by itself seems to describe a set. However, in the majority of cases the distributive reading is the correct one, so the approach taken here minimizes appeals to metonymy.

4.17.5 Asserting Grammatically Subordinated Information

Grammatically subordinated material in sentences, such as adjectives modifying nouns, often carries the primary information of a sentence, and is thus its assertion. For example, in

I have a sore throat.

it is not the possession of a throat that is being asserted, but the soreness of the throat the hearer already knows the speaker has. This can be viewed as an example of metonymy as well. The explicit assertion of the sentence, the possession, is coerced into the soreness of what is possessed. The possession is related to the throat and the throat is related to the soreness, both by properties that are explicit in the logical form of the sentence and are thus emminently accessible.

The logical form of the sentence, associated with the lexical level of the proof graph, contains the predications

$$have'(e_1, i, t) \wedge sore'(e_2, t) \wedge throat'(e_3, t)$$

The entire sentence would normally be described by the predication

$$Syn(\text{"I have a sore throat."}, e_1, \mathbf{v.tnsd}, -, -, -, -, -, -, -, -)$$

Axiom (4.10)

$$\begin{aligned} &Syn(w, e, \mathbf{v.tnsd}, -, -, -, -, -, -, -, -) \wedge goal(i, e_1) \wedge know'(e_1, u, e) \\ &\quad \supset utter'(e_2, i, u, w) \end{aligned}$$

that relates sentences to the superficial speech act of assertion introduces, as part of an explanation of the utterance, the predications

$$goal(i, e_3) \wedge believe'(e_3, u, e_1)$$

That is, the speaker i (superficially) intends the hearer u to believe the possession e_1 of the throat occurred. But what we actually want is

$$goal(i, e_4) \wedge believe'(e_4, u, e_2)$$

The speaker intends the hearer to believe the soreness holds.

This can be achieved by applying the metonymy axiom to the top-level *Syn* predication. The top-level *Syn* predication is thus

$$Syn(\text{"I have a sore throat."}, e_2, \mathbf{v.tnsd}, -, -, -, -, -, -, -, -)$$

indicating that the soreness is what the sentence asserts. The metonymy axiom (4.54) will immediately decompose this into

$$Syn(\text{"I have a sore throat."}, e_1, \mathbf{v.tnsd}, -, -, -, -, -, -, -, -)$$
$$\wedge\, rel(e_1, e_2)$$

The first conjunct is proved as it is normally. The transitivity of *rel* decomposes the second conjunct into

$$rel(e_1, m) \wedge rel(m, e_2)$$

This example requires that both possession and soreness be possible coercion relations:

$$have'(e_1, z, x) \supset rel(x, e_1)$$
$$sore'(e_2, x) \supset rel(e_2, x)$$

The composite of the having and the soreness constitute the coercion relation.

I have not said what constraint forces this coercion, but it could be the constraint that what is said should be informative.

Figure 4.32 illustrates this interpretation schematically.

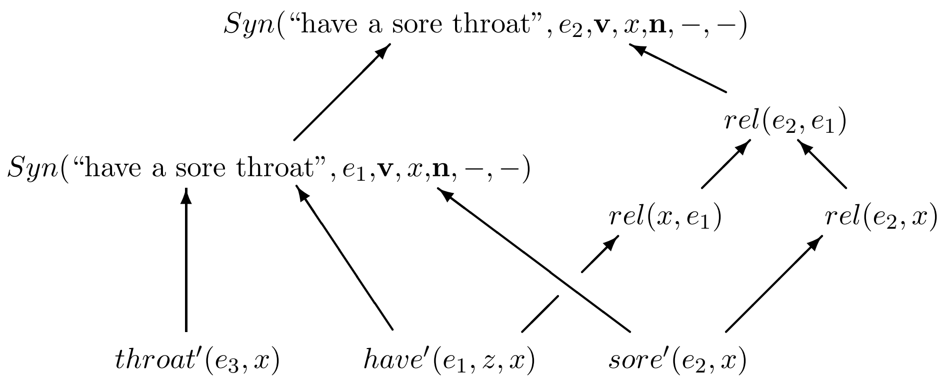

Figure 4.32: Interpretation of "... have a sore throat."

The assertion of grammatically subordinated material is often accompanied by high stress on the word conveying the predication to be asserted—here, "sore". High stress indicates that the corresponding predication is new information. The coercion is one way to bring the intonation and the rest of the interpretation into correspondence with one another.

A similar story can be told about examples in which high stress changes the arguments to higher-level predications in sentences. For example, in

John didn't introduce Bill to MARY.
John only introduced Bill to MARY.

the high stress forces a coercion of the argument of *not* and *only* from the e such that $introduce'(e, j, b, m)$ to the e_0 such that $Mary'(e_0, m)$, using the conjunction of these two properties as the coercion relation.

4.17.6 Monotone Decreasing Quantifiers

Coercion of the assertion of a sentence plays a key role in the treatment of monotone decreasing quantifiers in the present framework, as described in greater detail in Hobbs (1996). Consider the sentence

Few men work.

In Chapter 2 I proposed that the syntactic component of the interpretation process generate as a logical form for this sentence the expression

$$few'(e_1, s_2, s_1) \wedge dset(s_1, x, e_2) \wedge man'(e_2, x) \wedge plural'(e_3, y, s_2) \\ \wedge work'(e_4, y)$$

That is, there is a set s_1 defined by the property e_2 of its typical element x being a man, there is a set s_2 which is few of s_1 where this few-ness is property e_1, and s_2 has y as its typical element (property e_3), and the eventuality e_4 of y's working exists in the real world. Note that all of this is true, as far as it goes; there *is* a set consisting of few men, and the members of this set work. It just doesn't go far enough, because it does not rule out a much larger set.

This stronger interpretation is achieved in two steps. First, the predication $plural'(e_3, y, s_2)$ is specialized or strengthened to the more specific $dset'(e_3, s_2, y, e_2\&e_4)$. That is, the set s_2 is not just some subset of s_1 that has few elements, but the subset defined by the conjunction of conditions e_2 and e_4, where

$$man'(e_2, y) \wedge work'(e_4, y)$$

This is the set of men who work.

Finally, in a manner similar to the "sore throat" example, the property e_1 where $few'(e_1, s_2, s_1)$ is taken to be the assertion of the sentence, rather than the property e_4 where $work'(e_4, y)$. That is, the sentence would be interpreted as saying

The men who work are few.

The coercion relation $rel(e_4, e_1)$, used in this example to coerce from the working to the few-ness, comes from the explicit content of the sentence, namely,

$$few'(e_1, s_2, s_1) \wedge plural'(e_3, y, s_2) \wedge work'(e_4, y)$$

These three predications provide the link from e_4 to y to s_2 to e_1.

Increasing the plausibility of this analysis is the fact that it is hard to unstress the word "few" when it is functioning as a monotone decreasing quantifier, and high stress, as noted above, is an indication that the information conveyed by the morpheme is new.

4.18 Performing with Competence: A Sentence Processed

4.18.1 The Data and the Analysis

I ran a small informal experiment, with twenty-one subjects. They were given the successive initial segments of the opening sentence of Sapir's *Language*,

> Speech is so familiar a feature of daily life that we rarely pause to define it.

and they were asked to complete it at each point. Eleven subjects were told that it was the first sentence of Sapir's *Language*, something a reader of the original sentence would know; the other ten were not. This variable seemed to have no effect on the responses. The subjects were almost all employees of SRI, mostly of the Artificial Intelligence Center. Eight were linguists or computational linguists, the sort of people who would be most likely to read the book; this variable had no effect with respect to the use made of the data here.

The aim of the experiment was twofold. How they completed the sentence is good evidence for how they had parsed the sentence so far. It also gives some indication of how what they had seen so far influenced their expectations for the rest of the sentence.

In this section I analyze in detail the completions provided by one of the subjects and discuss what that says about how the initial segments must have been processed. I will also use the completions as admittedly weaker evidence of the subject's expectations for the rest of the sentence; where there is a high degree of agreement among the subjects, I will take the completions to be reasonably strong evidence of the subjects' expectations. I will then show how the "grammar" developed in this chapter could be deployed in interpreting this sentence, word-by-word, in a way that is consistent with the experimental data.

The grammar has been presented as a competence grammar, but this section shows how it can be deployed in a plausible way in performance.

The responses for one typical subject were the following, where the prompt is in roman type and the response in italic:

Speech *is the way people communicate.*

Speech is *the way people communicate.*

Speech is so *important to human communication that it deserves study.*

Speech is so familiar *that we don't think about it.*

Speech is so familiar a *mode of communication that we don't think about it.* (after a long pause)

Speech is so familiar a feature *of human life that we don't think about it.*

Speech is so familiar a feature of *human life that we don't think about it.*

Speech is so familiar a feature of daily *life that we don't think about it.*

Speech is so familiar a feature of daily life *that we don't think about it.*

Speech is so familiar a feature of daily life that *we don't think about it.*

Speech is so familiar a feature of daily life that we rarely *think about it.*

Speech is so familiar a feature of daily life that we rarely pause *to think about it.*

Speech is so familiar a feature of daily life that we rarely pause to *think about it.*

Speech is so familiar a feature of daily life that we rarely pause to define *what it is.*

> Speech is so familiar a feature of daily life that we rarely pause to define it.

This was from someone I will call Subject A, not a linguist, who was told where the sentence came from.

We cannot take data such as this as a direct printout from the subject's mental state as he or she is reading the sentence in real time. But we may expect that the subject completes the sentence in a way that is consistent with his or her interpretation of the initial segment, insofar as it is interpreted at all. Thus, it may be that Subject A, reading in real time, would not have decided upon anything about the word "speech" after hearing just that, but, given his responses, if he had made any decisions, they would likely be a subset of the following properties:

1. "Speech" is a noun.

2. "Speech" is the head noun of a noun phrase.

3. "Speech" is the complete noun phrase.

4. "Speech" is the subject of the sentence.

5. "Speech" and the word "Language" of the title refer to the same concept.

6. The sentence will state a significant, global property of speech or language.

7. The sentence is copular and the word "is" is likely to be next.

8. The sentence is copular, the word "is" is next, and the predicate complement is a noun phrase describing a significant, global property of speech.

In any case, this experiment gives us an idea about what information is available to the reader at any point in the processing.

Let us look at the possible processing one word at a time. I will suggest what the state of Subject A's processing might be and back it up with a summary of the other subjects' responses. At every point in the hearing of the sentence, the subject will have developed a partial interpretation of the string of words, as though it were the beginning of a sentence. This partial interpretation will include both the analysis of what has already been heard and some expectations about what is to come. A proof graph will be presented at key points that corresponds to the partial interpretation, according to the grammar developed in this chapter. As we proceed through the sentence, new branches will grow and occasionally an old branch will be modified. It is likely that people forget the syntactic structure of the parts of the sentence that have already been completely interpreted, so this will be dropped from one proof graph to the next. It is not clear for how many previous words the syntactic analysis should be retained, but only so much of the proof graph will fit on the page, so I will assume two words. Thus, in the diagrams, the only active parts of the proof graph are the currently open syntactic nodes, the analyses of the last two words, and the semantic content of all of the sentence so far. As previously, only the essential arguments of the *Syn* predications will be shown.

1. "Speech": The subject reads the word "speech" and recognizes it unambiguously as a noun. Because it has no determiner, it does not refer to a specific event, and it is resolved to the general faculty of speech. It is the first word of a book entitled *Language*, so these two words probably resolve to the same concept. Since it is the first word in the sentence, it may well be the subject. Since this is the first sentence in the book, the sentence may be expected to state some important property of speech or language, and the next word may well be "is", followed by an NP complement.

In fact, among the twenty-one subjects, sixteen took "speech" to be the entire subject. The other five took it to be the first word of the compound nominal "speech recognition", "speech technology", or "speech recognition technology"; there is a speech recognition research group downstairs from the Artificial Intelligence Center.

Of the sixteen who took "speech" to be the entire subject, all began the completion with "is". Twelve continued it with an NP complement, four with an adjective phrase. Of the twelve, eight had some variation on "the way people communicate". Four used the word "way"; the others used "means", "method", "form", and "media". Seven used some form of the word "communicate", while the eighth used "expressing ourselves".

Let us assume that after hearing the word "speech", Subject A has analyzed it as the entire subject of the sentence and expects the word "is" next. This partial interpretation is represented in Figure 4.33. Even though only "speech" has occurred, the word "is" is hypothesized and interpreted.

2. "is": The word "is" could be an auxilliary for a present progressive construction, possibly passive, or it could be a copula for a predicate complement. But since the sentence is the first sentence of a technical book and since speech is not an animate being, the progressive is less likely. A predicate complement is therefore likely to be next. At this point, one can be sure

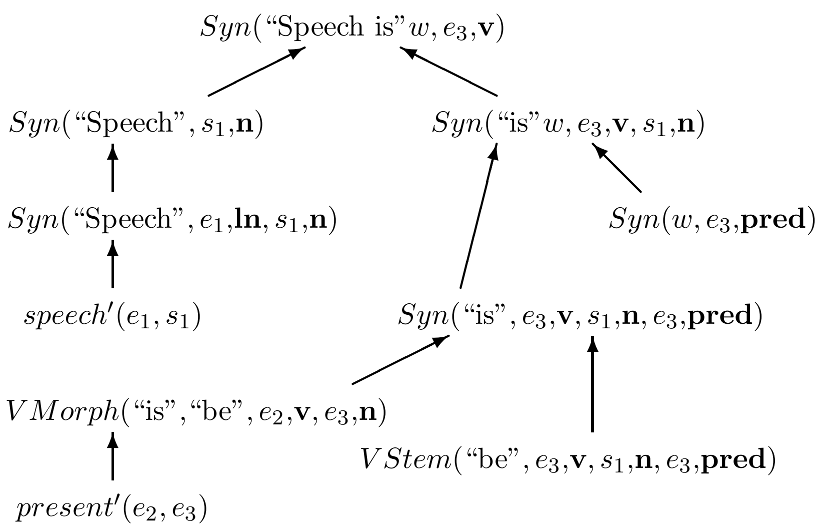

Figure 4.33: Parse of "Speech . . ."

that "speech" is a complete noun phrase and the subject of the sentence.

For Subject A, this had all already been predicted; the prediction is confirmed.

Of the five subjects who did not guess the word "is" to be second, three now completed the sentence with an NP complement, two with an adjective phrase.

3. "so": At this point the most likely syntactic possibility becomes an adjective phrase of the form "so Adj that . . .". The adjective can be expected to represent some scalar property that speech can have to some degree. This construction is used to indicate that an entity has the scalar property to such a degree that a related consequence follows, although one is not likely yet to have a clear idea of what that consequence is.

Of the twenty-one subjects, twenty continued the sentence with an adjective; the other hypothesized the adverbial phrase "so far". There was a wide range of adjectives used, but "important", with four instances, was the most common. Of the twenty, seven used a "that" clause (possibly "that"-less) in the remainder of the sentence, five used some other complement on the adjective, and eight had no complement on the adjective. One subject at this point completed the sentence in a way that is close to the meaning of the actual sentence—"Speech is so pervasive that we take it for granted."

It is reasonable to hypothesize that at this point Subject A was expecting an adjective followed by a "that" clause, but had no realistic expectations beyond this.

4. "familiar": This is probably not the adjective a reader would be expecting. But once it is read, one can arrive at something very close to the final meaning of the entire sentence. Familiar things do not generally command attention, so it is quite possible that the entire sentence will be something like "Speech is so familiar that we never think about it." We expect next to see the word "that".

Of the twenty-one, thirteen completed the sentence with a "that" clause. Four of these responses involved not thinking about speech, including Subject A's response and another that was identical to it. Two more responses conveyed the same meaning—"that we take it for granted" and "that it seems trivial". Two more responses addressed the unexpected difficulty of processing speech. Six subjects completed the sentence with a "to" prepositional phrase, and the remaining two with an adverbial clause.

The word "so" expresses a causal relation:

$$cause'(e_3, e_4, e_{12}) \supset so'(e_3, s_1, e_4, e_{12})$$

If a property e_4 of an entity s_1 causes e_{12}, then s_1 is so e_4 that e_{12}. Frequently, what causes one not to attend to something is familiarity with it:

$$cause'(e_3, e_4, e_{12}) \wedge not'(e_{12}, e_{15}) \wedge attend'(e_{15}, w_{11}, s_1) \\ \supset familiar'(e_4, w_{11}, s_1)$$

If something e_4 causes the absence e_{12} of the attending e_{15} by w_{11} to something s_1, then e_4 may be w_{11}'s familiarity with s_1.

Using these axioms to encode Subject A's sense of the semantics of the sentence, the current state of the partial interpretation is as illustrated in Figure 4.34. The syntactic analysis of "Speech" has been "forgotten", since it is more than two words back; only the semantic content remains.

5. "A": It was frequent for subjects to pause a long time after this word. There were then two continuations. Fifteen subjects, including Subject A, completed the sentence with the rare "so Adj a $\overline{N}$ that" construction. Six completed it with a "that"-less "that" clause, as in "so familiar a child could understand it". Of the fifteen, all picked a very abstract $\overline{N}$. Two other subjects besides Subject A said "mode of communication".

There are two possible processing stories we could tell here. The most likely is that on hearing the word "a" the hearer simply suspends processing until more of the sentence is heard. Nodes are built for

$$Syn(\text{"a"}, e_5, \mathbf{ld}, e_6, \mathbf{ldan}, x, \mathbf{n.sing}, -, -, -, -)$$

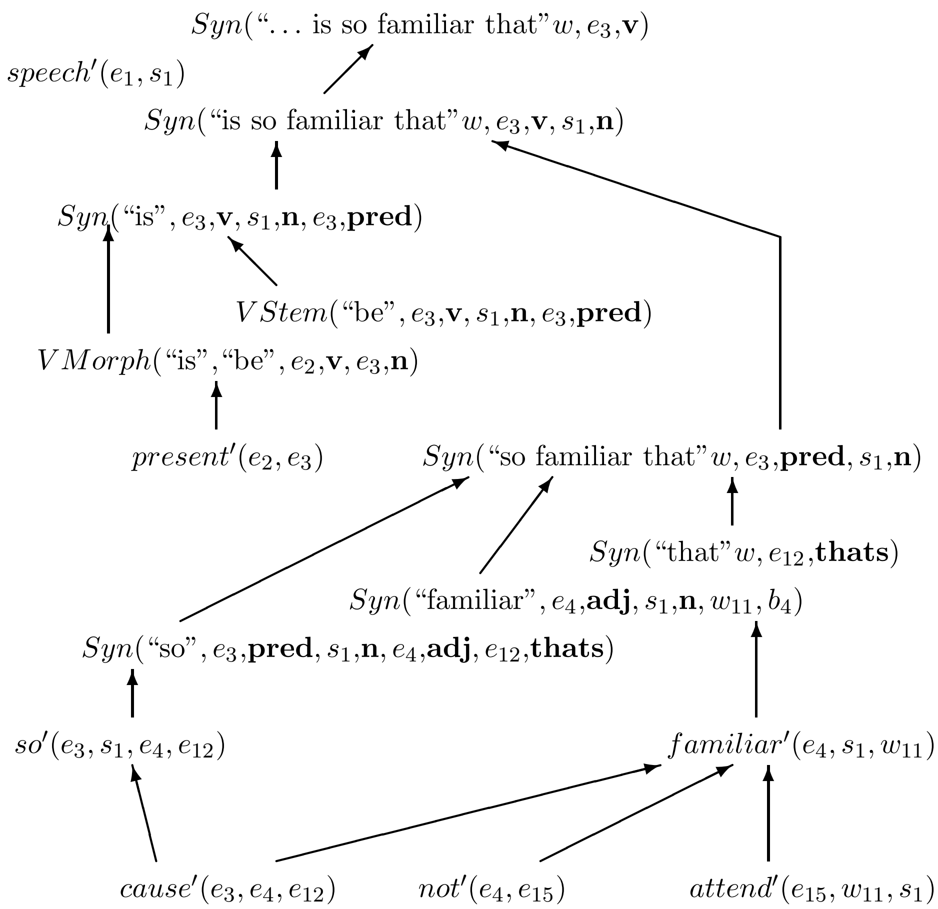

Figure 4.34: Parse of "... is so familiar ..."

and for

$$a'(e_5, x, e_6)$$

but no attempt is made to link these to the rest of the sentence by, for example, resolving x.

The second possibility is that the initial part of the sentence is immediately reanalyzed. The more likely lexical axiom for "so" is rejected in favor of the less likely one that accounts for the word "a". Figure 4.35 illustrates this analysis.

6. "feature": This noun should now be enough to enable us to recognize the "so Adj a $\overline{N}$ that" construction. In fact, all twenty-one subjects came

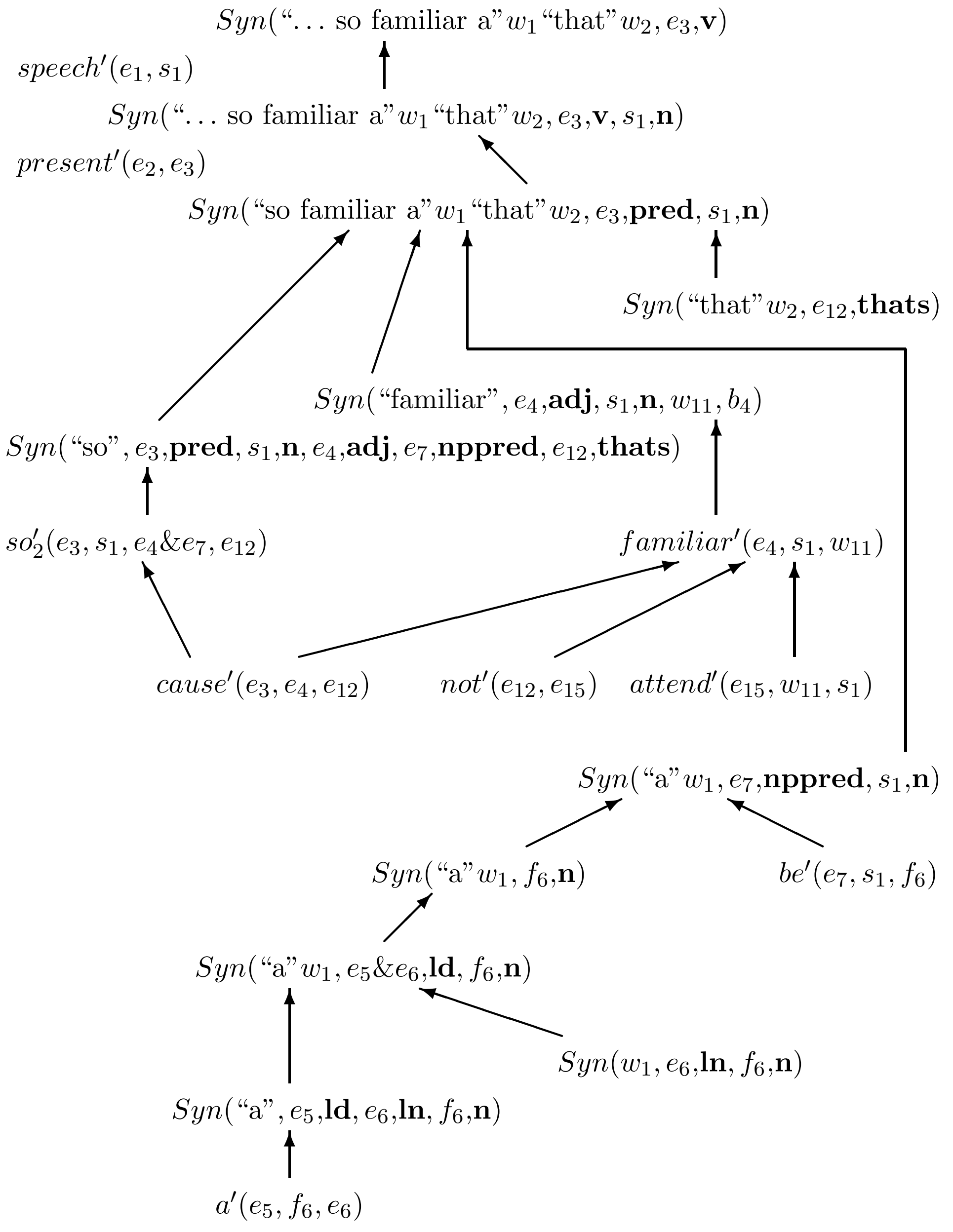

Figure 4.35: Parse of "… so familiar a …"

up with this interpretation, rather than one that continued the "that"-less "that" clause interpretation, such as

> Speech is so familiar a feature movie could not be made about it.

"Feature" requires two arguments, so one might ask what speech can be a feature of. In fact, thirteen of the subjects had the word "of" next. Two more had the word "in", as in "a feature in everyday life". Two others had the word "to", presumably picking up on the subcategorization of the adjective "familiar" for the preposition "to".

Seven of the seventeen subjects giving "feature" a prepositional complement used a complement involving the word "life" or "lives", and three more used close synonyms. The phrases "everyday life" occurred twice, and "everyday lives", "daily life", and "daily lives" once each. Four more used words related to communication.

Fifteen subjects now hypothesized a "that" clause later in the sentence. Nine of these involved some statement related to not attending to the phenomenon of speech.

We can assume that Subject A at this point has analyzed the sentence correctly so far, expects the next word to be "of" followed by an NP whose head is "life" and that after this will come a "that" clause related to not attending to the notion of speech.

7. "of": Subject A's expectations are confirmed.

Of the eight subjects who had not previously guessed "of", four now completed it with an NP relating to communication, two with an NP relating to language, and two with the phrase "everyday life".

Of the six subjects who had not previously had a "that" clause, only one now added one.

8. "daily": This is an adjective. One may not have expected exactly this word, but since activities can be daily it is easy to incorporate into our expectations. There is a concurrence between "daily" and "familiar"; things that happen daily are certainly familiar.

One expects a noun next. Of the twenty-one subjects, nineteen continued the sentence with the noun "life", one with "living", and one with "discourse".

We may assume Subject A has parsed the sentence correctly so far. He expects the word "life" next, he expects that to be the end of the NP, and he expects after that a "that" clause relating to not attending to the phenomenon of speech.

The state of processing is illustrated in Figure 4.36.

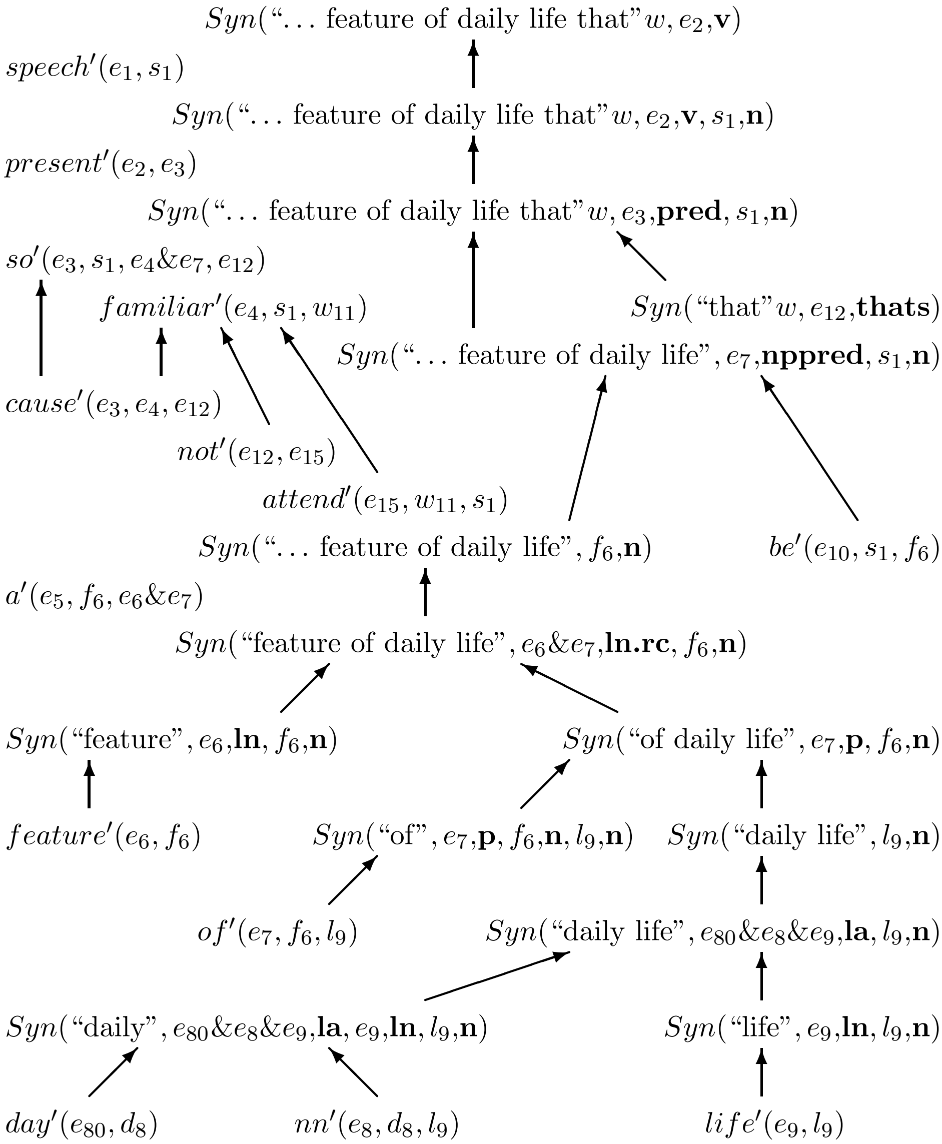

Figure 4.36: Parse of "... feature of daily ..."

9. “life”: Expectations are confirmed.

Because of the experimental setup, subjects knew this was not the end of the sentence, and they had to continue somehow. Eleven subjects continued with the words “that we” followed by a clause that involved not attending to the phenomenon of speech. In addition, one subject used “most people” instead of “we”, and one used a comma instead of “that”. Five of these thirteen responses involved not thinking about speech and four more involved taking it for granted.

One more subject continued with “that we” but not a clause involving not attending. Four additional subjects took the next word to be “that”. Two others completed the sentence by conjoining something to “life”, and one completed it with a prepositional phrase.

We may assume that Subject A now expects the words “that we” followed by a clause about not attending to the phenomenon of speech.

10. “that”: Expectations are confirmed.

One of the three who had not predicted “that” now continued it with “we”. Altogether, fourteen of the twenty-one expect the word “we” next. All have parsed the sentence correctly so far.

11. “we”: Expectations are confirmed.

Every subject took this word to be the subject of the embedded sentence.

Of the eight subjects who had not previously predicted not attending, only two now do, saying “that we take it for granted”. Fifteen out of twenty-one subjects now have the sense of the sentence.

Four subjects expect the word “don’t” next, and four more predict another word with negative import. None predicts “rarely”.

We may assume that the pronoun “we” is resolved to a group that includes possibly all people, but certainly the writer and the readers.

Subject A is now expecting a verb phrase about not attending to the phenomenon of speech, probably beginning with a negative, possibly with “don’t”.

The state of Subject A’s interpretation is illustrated in Figure 4.37.

12. “rarely”: This is the negative that was expected, although not the negative that was expected.

All twenty-one subjects parsed it as an adverb modifying the main verb of the clause. Twenty continued with a verb; the other with the words “if ever”. Twelve of the twenty completed the sentence with a verb phrase involving not attending to the phenomenon of speech. Five of these completed it with the phrase “think about it.”

We will assume that Subject A has parsed the sentence correctly so far and now expects a verb phrase like “think about it”. This partial interpre-

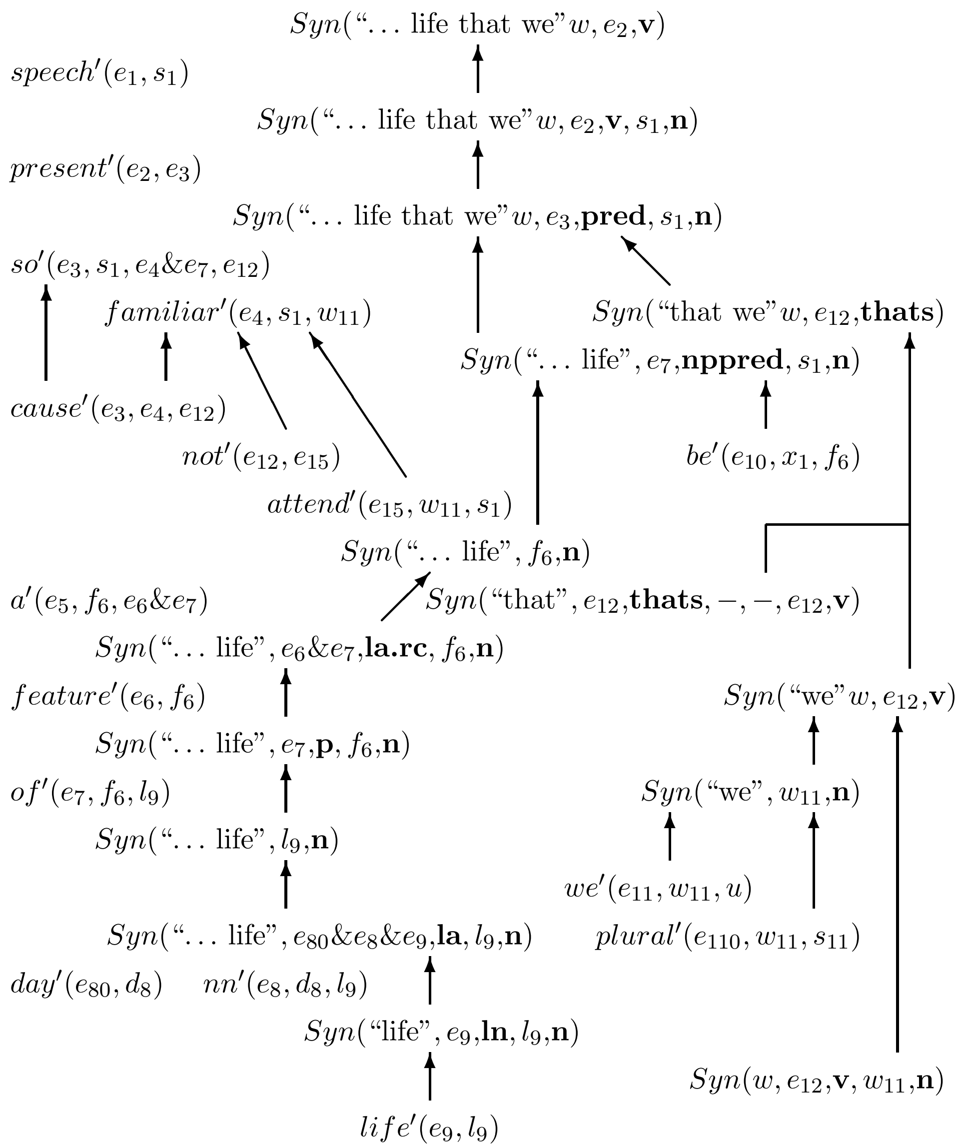

Figure 4.37: Parse of "... life that we ..."

tation is illustrated in Figure 4.38.

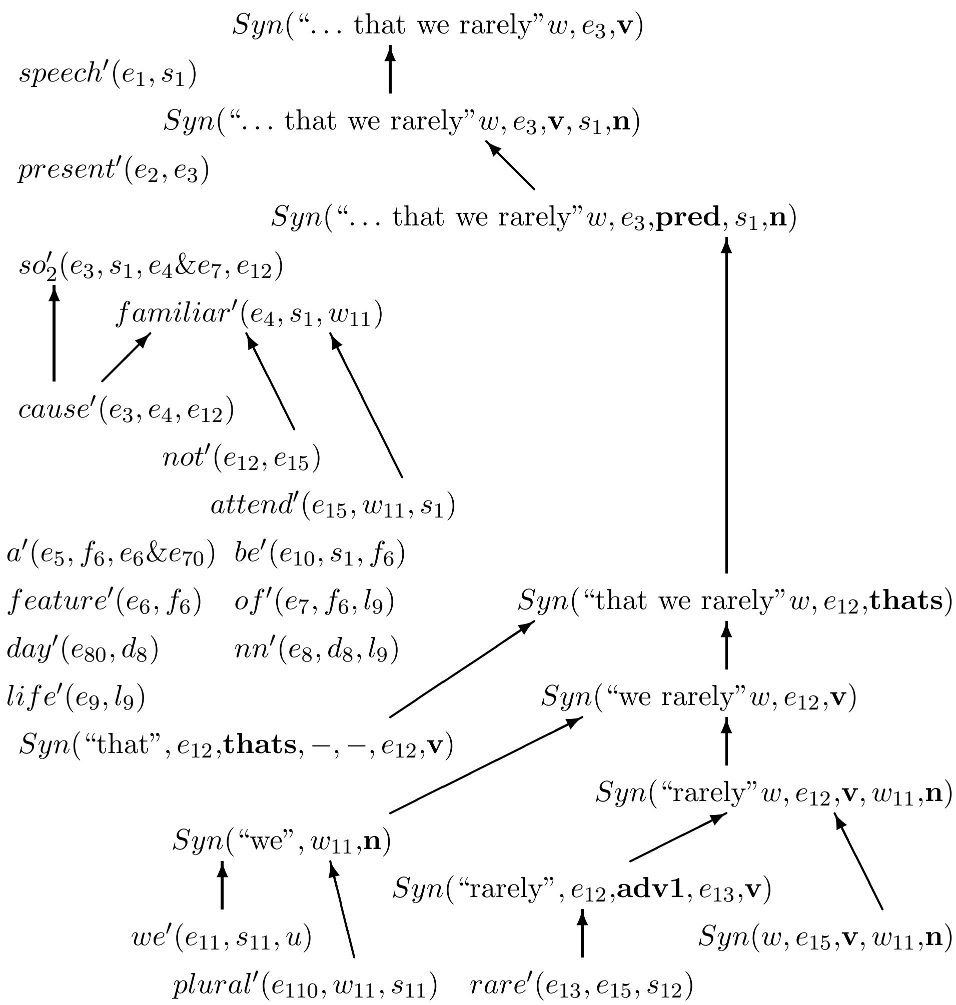

Figure 4.38: Parse of "... that we rarely..."

13. "pause": This is clearly a verb rather than a noun, because of its position in the sentence, but semantically it throws one off. It does not mean "attend to". But it is empty enough of content that it can be accommodated, by putting the expected verb phrase into a purpose infinitive. Whatever action was expected can be done while pausing. The word "to" is expected next.

Twenty of the twenty-one subjects continued with an infinitive verb phrase. Sixteen of these used a verb phrase involving not attending to the phenomenon of speech.

In the formal representation of this account, previous to this word, Subject A had identified the attending to speech e_{12} whose negation is associated with familiarity, with the eventuality conveyed by the verb phrase following "rarely". This has to be revised somewhat. The eventuality e_{12} now must be embedded in the pausing.

14. "to": Expectations are confirmed.

The state of Subject A's interpretation is illustrated in Figure 4.39.

15. "define": This is probably not the verb that would be expected—no one guessed it—but it is not inconsistent with expectations. Defining is certainly one mode of thinking, and we rarely pause to define familiar features of daily life.

A noun phrase is expected next, since "define" is a transitive verb, and it is very likely that that noun phrase will refer to speech or some important property of speech. Eight of the twenty-one subjects completed the sentence with a definite noun phrase, eight with a sentential "wh" nominal ("what it is"), and only three with the word "it". It is probably an artifact of the experimental situation that most of the completions are so complex. The subjects are still in a sentence completion task, and to complete it with simply the word "it" seems too simple.

We will assume that Subject A has linked up "define" with the attending eventuality e_{12} whose negation he had associated with familiarity.

16. "it": The reference of the pronoun is resolved to speech and comprehension of the sentence is complete.

Ten of the tweny-one subjects used the word "it" referring to speech in their completions after "define". All eleven other users used "it" to refer to speech in at least one of their completions prior to "define". In all the data there was only one instance of "it" referring to something other than speech.

The state of Subject A's interpretation is illustrated in Figure 4.40.

There are several things to note about this account. Syntactic, semantic, and pragmatic decisions are all required and are very much intermixed. Decisions are made on the basis of likelihood given the information so far available, but they can be retracted as more information becomes available. Expectations play a very important role.

Any formal model one devises for language processing must support the kind of account I have given here. The formal account of the syntax and compositional semantics of English given in this chapter does just that.

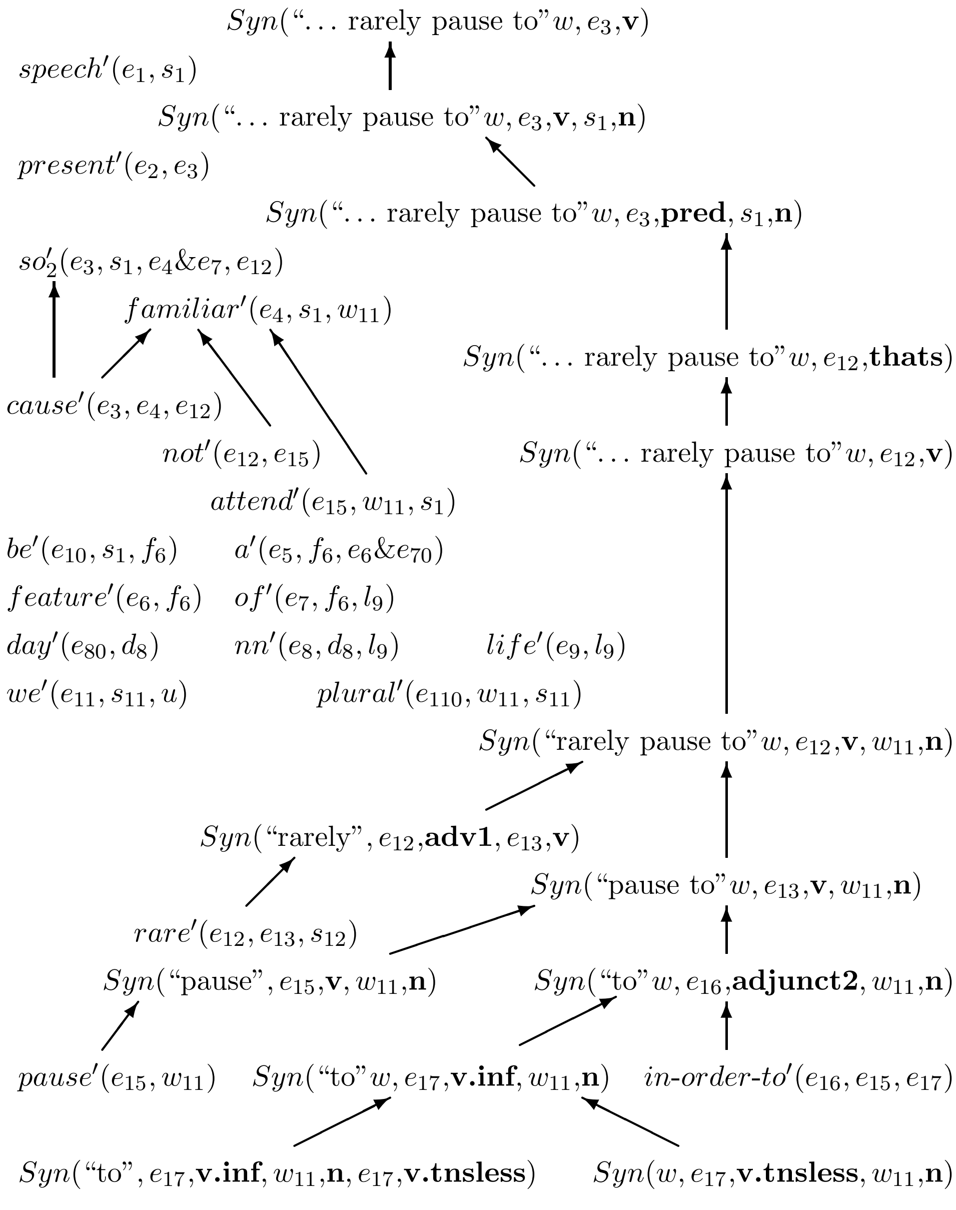

Figure 4.39: Parse of "... rarely pause to ..."

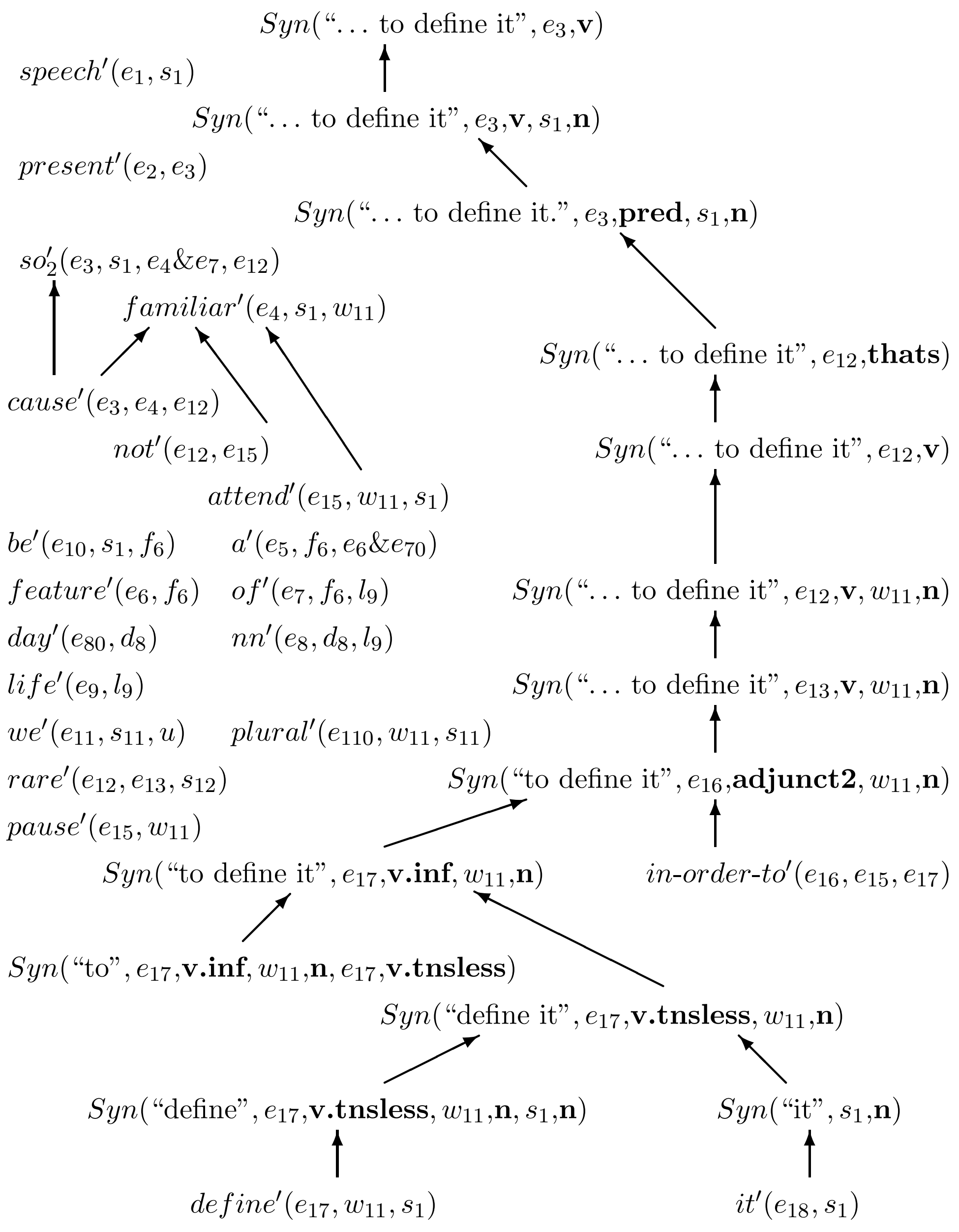

Figure 4.40: Parse of "... to define it."

4.18.2 Elementary Operations

4.19 The Edges of Syntax

4.19.1 Language and Protolanguage

In his book *Language and Species*, Derek Bickerton introduces the notion of "protolanguage". He does not define it precisely, but he gives several examples, namely, the language of apes, the language of children between two and two and a half, the language of wolf children, and pidgens. It is of course controversial whether all of these phenomena can properly be lumped into a single category. But the notion is nevertheless a useful one.

It is possible to define the notion in a more precise manner, and when this is done, it will be found that protolanguage pervades everyday discourse. The key distinguishing feature of Bickerton's examples of protolanguage is that fragments of language are uttered independent of any syntactic constraints, and the interpretation of the composite segments is, in a sense, up for grabs. Adjacency does not necessarily convey predicate-argument relations or modification relations, as it does in syntactic sentences. Instead, adjacency can convey virtually any relation. Thus, the child's utterance, "Mommy sock," might mean that this sock belongs to Mommy, or that Mommy should put my sock on, or any number of other possible relations between Mommy and the sock.

When viewed in this way, we can see many examples of protolanguage in ordinary discourse. One is the language of panic. Suppose someone runs down the hall shouting, "Help! Heart attack! John! My office! CPR! Someone! On the floor!" The hearers will be able to construct a scenario from the utterances, but it will not be because the relevant predicate-argument relations were conveyed. The hearers will have had to abduce the situation from the fragments uttered and from the fact that those fragments were adjacent.

A more staid example, in written discourse, is tables. Suppose we see the table

George Washington	VA	Federalist	1789	1797
John Adams	MA	Federalist	1797	1801
Thomas Jefferson	VA	Democratic Republican	1801	1809

and so on, and we are not told the relations among George Washington, Virginia, and Federalist. We only know from their adjacency in the table that they are related somehow, and we have to abduce the most plausible relation from the rest of what we know.

Ellipsis in conversation is another example. In the target text from the decision-making meeting, there is the exchange

A: Get some information from him, maybe, maybe take at least fifteen minutes for that purpose.
C: When he first gets here, of course.

It is implausible to suppose that the speakers have fully formed sentences in their heads that they then pare down. They probably have fully formed *thoughts* in their heads, or in the terms of our formalization, fully saturated predications, of which they then express the essential pieces. Their hearers interpret the fragments and then relate these fragments as best they can to each other and to the available context.

English compound nominals can be seen as another example of protolanguage. When we see phrases like "coin laundry" or "money laundering", no rule of syntax tells us the relation between the two nouns. We have to figure that out for ourselves, knowing only that there must be *some* relation.

Finally, discourse itself, once one is beyond the scope of individual sentences, is an example of protolanguage, in our sense. Two segments of discourse are adjacent, and we must figure out the relation between them as best we can, given the context.

Protolanguage can be characterized by a single axiom. We will take the predicate *Segment* to have two arguments, a string of words w and an entity or eventuality e, and to mean that the string w describes the entity or eventuality e.

The predicate *Segment* is not true of *any* string of words, only those that carry a coherent package of information. For example, if we construct a string of ten words by taking every fifth word in the first paragraph of this section, we get

And the does but namely the two half children of.

Although substrings of this yield interesting interpretations, knowing how it was constructed, we could not call the entirity a phrase with a coherent package of information. *Segment* would not be true of this string.

We will take the predicate *comprel* to apply to three arguments e, e_1, and e_2, which are entities or eventualities, and to mean that there is a relation between e_1 and e_2 and that the composite formed by this relation is e.

The single "composition" axiom for *Segment* is then

(4.58) $Segment(w_1, e_1) \wedge Segment(w_2, e_2) \wedge comprel(e, e_1, e_2)$
$\supset Segment(w_1 w_2, e)$

That is, if string w_1 describes e_1, string w_2 describes e_2, and there is a relation between e_1 and e_2 yielding the composite structure e, then the concatenation of w_1 and w_2 can be used to describe e. I will refer to this as the Protosyntax Rule.

The Protosyntax Rule is a specific instance of the more general rule that whenever two entities or eventualities are spatially or temporally adjacent, there may be a relation between them that explains their adjacency.

The composition rules of syntax are specializations of the Protosyntax Rule, in that both the antecedent and consequent of the composition rules are specializations of the corresponding parts of the Protosyntax Rule. In particular, they restrict the interpretation of *comprel* to be a predicate-argument relation. One axiom and one axiom schema will entail this relationship. The axiom is

(4.59) $Syn(w, e, f, x, a, y, b, z, c, v, g) \supset Segment(w, e)$

That is, if w is a grammatical string, possibly with arguments unsaturated, describing the situation e, then w is a coherent fragment of language describing the situation e.

The axiom schema is

$$p'(e, \ldots, x, \ldots) \supset comprel(e, e, x)$$

That is, if e is the eventuality of p being true of some arguments, including x, then there is a relation between e and x where the composite formed by the relation is e itself.

In the Subject Composition Rule, the *Syn* predication for the subject, $Syn(w_1, x, \ldots)$, implies $Segment(w_1, x)$; the *Syn* predication for the VP, $Syn(w_2, e, \ldots)$, implies $Segment(w_2, e)$; the latter *Syn* predication's being true requires that a predication of the form $p'(e, x, \ldots)$ be introduced at the lexical level; and this in turn implies the relation $comprel(e, e, x)$ required in the antecedent of the Protosyntax Rule. Similarly, the *Syn* predication for the entire clause, $Syn(w_1 w_2, e, \ldots)$ implies $Segment(w_1 w_2, e)$. Thus, the Subject Composition rule specializes the Protosyntax Rule. The same is true for the other syntactic composition rules.

It is certainly the case that we are quicker to take a complete grammatical sentence as a meaningful segment of discourse, to be related to the rest of the discourse pragmatically, than we are to take a random constituent. We could enforce this by associating an *etc* predication with the general "*Syn* to *Segment*" rule, imposing a cost for using it, and having a special rule interpreting a fully formed clause as a meaningful segment, without the cost.

$$Syn(w,e,f,x,a,y,b,z,c,v,g) \wedge etc(w,e) \supset Segment(w,e)$$
$$Syn(w,e,\mathbf{ynq/whnq/v.tnsd},-,-,-,-,-,-,-,-)$$
$$\supset Segment(w,e)$$

The coherence relations presented in Chapters 3 and 6 are also specializations of the Protosyntax Rule. There the relation is specialized to one involving a causal, change-of-state, figure-ground, or similarity relation.

Bickerton may or may not agree with this formalization of his notion of protolanguage, and linguists in general will find controversial the claim that it represents a prior stage in the evolution of language. But it is certainly possible to tell a plausible story in which the essential features of full-blown syntax develops by incremental steps from a protolanguage as it is characterized here, where the incremental steps are all reasonable specializations of the Protosyntax Rule. This account is given in Section 4.20.

Before doing this, however, we will examine some of the target texts that contain ungrammaticalities, and show how the use of the Protosyntax Rule along with a small number of other interpretive moves can be used with the grammar to provide interpretations. Four phenomena in particular will be examined: sentence fragments in telegraphic messages, scrambling in poetry, and disfluencies and co-construction in conversation. In every case, we will pose the interpretation problem in the following way. We must prove that the segment of discourse is an interpretable segment of discourse, that is, that *Segment* is true of it and some entity or eventuality. In the course of this proof, all of the right propositional content must be abduced.

4.19.2 Fragments: A Telegraphic Message

The telegraphic messages contain two kinds of ungrammaticalities—sentence fragments and count nouns without determiners.

The fragments are

[There was] LOSS OF LUBE OIL PRESSURE DURING OPERATION.
[I] REQUEST REPLACEMENT OF SAC.

Computational linguists (Sager, 19??; Hirschman et al., 19??; Hobbs et al., 19??) have typically handled fragments by augmenting their grammars with rules for the most common fragments. It turns out that a very small number of rules will do the job, such as

- A noun phrase can function as a sentence, most often asserting the existence of the entity referred to by the noun phrase.
- A verb phrase can function as a sentence, where the subject must be recovered from context.
- The copula can be omitted from a copular sentence.

It would of course be possible for us to take the same approach and write axioms for these constructions. However, there is a reason these fragments can function as interpretable sentences. Hearers have means for interpreting them in the absence of such rules. It is thus a good exercise for us to examine what these mechanisms would be in our formal account.

The first two of these cases, covering the only sentence fragments in the target texts, are easy to handle. For a fragment w consisting of only a noun phrase, we have the predication

$$Syn(w, x, \mathbf{n}, -, -, -, -, -, -, -, -)$$

This implies

$$Segment(w, x)$$

which is what we need to prove. The content of the noun phrase will be abduced in the course of proving the *Syn* predication, as with grammatical sentences. For a nominalization like "loss of lube oil pressure", the entity x described by the segment will already be an event, the losing, so there is no need to infer another event involving x. In the case of NPs describing objects, such as "chips in propellor blades", we do need to infer an event or condition in which x participates. This will be determined by context, however. As Wittgenstein (19??) shows, the simple noun phrase "Brick." can be used to convey a wide variety of propositions in different contexts.

Fragments consisting of only VPs can be handled similarly. The fragment is described by the *Syn* predication

$$Syn(w, e, \mathbf{v.tnsd}, x, \mathbf{n}, -, -, -, -, -, -)$$

This implies

$Segment(w, e)$

which is what we need to prove. The proof of the *Syn* predication will involve, at the lexical level, a predication of the form $p'(e, x, \ldots)$. Because we do not have a subject, we can only find out the identity of x by relating this to the surrounding context. This is similar to the situation that obtains when x is described by a pronoun.

The case of copular sentences with the omitted copula is a bit more complex. An example is

COMPRESSOR BROKEN.

Here we have two grammatical phrases, an NP and a predicate complement.

$$Syn(w_1, x, \mathbf{n}, -, -, -, -, -, -, -, -)$$
$$\wedge\, Syn(w_2, e, \mathbf{pred}, x_1, \mathbf{n}, -, -, -, -, -, -)$$

where we cannot yet conclude that x and x_1 are identical. From this we can infer

$Segment(w_1, x) \wedge Segment(w_2, e)$

The proof of the predicate complement's *Syn* predication will introduce a predication of the form $p'(e, x_1, \ldots)$, which implies $comprel(e, e, x_1)$. If we assume that x and x_1 are identical, then the antecedent of the Protosyntax Rule is established, and we can conclude

$Segment(w_1 w_2, e)$

which is what we had to prove.

Count nouns without determiners are very common in telegraphic messages. In our target texts we see several examples.

[A] LOSS OF LUBE OIL PRESSURE DURING [the] OPERATION.
[An] INVESTIGATION REVEALED ADEQUATE LUBE OIL SATURATED WITH BOTH METALLIC AND NON-METALLIC PARTICLES.
REQUEST [a] REPLACEMENT OF [the] SAC.
[The] UNIT HAS EXCESSIVE WEAR ON [the] INLET IMPELLOR ASSEMBLY.
[The?] BLADES ARE BENT AND 1 / 4 INCH CHIPS ARE VISIBLE ON [the] LEADING EDGE.

The standard computational linguistic approach is to lift the constraint without penalty.

As our grammar stands right now, count nouns without a determiner present no problem, because we have not written the rules for NPs in a way that would require them. To do this, we would need to change one alternation axiom and introduce another. Rule (4.26) that converts the internal representation of NPs into the external representation can apply to partial NPs of any structure, the *LEFT* feature **ldan**. This can be limited to NPs having a determiner, *LEFT* feature **ld**.

$$\begin{aligned}&Syn(w, e, f{:}\mathbf{ld}, x, a{:}\mathbf{n}, -, -, s, -, v, g)\\ &\quad\supset Syn(w, x, a, -, -, -, -, -, -, v, g)\end{aligned}$$

Then a new alternation axiom can be introduced to convert (partial) $\overline{\mathbf{N}}$s with mass nouns as their heads into $\overline{\mathbf{N}}$s with the *LEFT* feature **ld**. This would require us also to introduce a new feature set for nouns which had **mass** and **count** as its features.

$$\begin{aligned}&Syn(w, e, f{:}\mathbf{lan}, x, a{:}\mathbf{n.mass}, -, -, s, -, v, g)\\ &\quad\supset Syn(w, f{:}\mathbf{ld}, x, a, -, -, s, -, v, g)\end{aligned}$$

Any semantic content that is introduced by the use of a bare NP could be included in the antecedent of this axiom.

One way to deal with count nouns without determiners in telegraphic text would be to simply assume, contrary to fact, that the required word is actually there. This assumption would be made in order to arrive at the best global interpretation of the text. The hearer would not have to actually come to believe it.

The bare NP “OPERATION” would be characterized by the *Syn* predication

$$Syn(\text{“OPERATION”}, e, \mathbf{ln}, x, \mathbf{n.count}, -, -, -, -, -, -)$$

Recall from Section 4.2.1 that when we write the first argument as “OPERATION”, this is really an abbreviation for a string instance w such that “OPERATION”(w). If the word “the” appeared before w, we would say

$$concat(w_0, w_1, w) \wedge \text{“the”}(w_1) \wedge \text{“OPERATION”}(w)$$

If w_1 is the empty string and w_0 is thus the same as w, then the first and third of these conjuncts are true. However, the second conjunct should be “ ”(w_1). But we can arrive at the best global interpretation of the text if we assume, contrary to fact, that “the”(w_1) is true. So we do.

As it happens, this assumption is not always contrary to fact. When Neil Armstrong first stepped onto the surface of the moon, he said, "One small step for a man, one giant leap for mankind." But the word "a" got lost in the transmission. Many listeners (but not Walter Cronkite) simply assumed that that word had occurred there.

A second way to deal with count nouns without determiners is to assume contrary to fact that the partial $\overline{\mathbf{N}}$ does have the required structure for conversion to a complete NP. Consider "OPERATION" again.

$$Syn(\text{“OPERATION”}, e, \mathbf{ln}, x, \mathbf{n.count}, -, -, -, -, -, -)$$

Recall from Section 4.2.3 that when we use the feature **ln** in the *Syn* predication, this is really an abbreviation for a predication $\mathbf{ln}(w)$ about the string. What is required for the conversion to a complete NP is the predication $\mathbf{ld}(w)$. In order to arrive at the best interpretation for the whole text, we simply assume, contrary to fact, that this predication is true.

In the first of these interpretive moves, we have to hypothesize the actual word that is missing. In the second, we only need to assume that the partial $\overline{\mathbf{N}}$ is adequate as a complete NP. In the latter case we are not forced into deciding whether the NP is definite or indefinite, which many times may be an artificial distinction to make.

These same two interpretive moves are available for the sentence fragments as well. In

LOSS OF LUBE OIL PRESSURE DURING OPERATION.

the hearer can assume, contrary to fact, that the words "There was" occurred before this fragment. Alternatively, he could assume, contrary to fact, that the category of the phrase is not **n** but **v.tnsd**.

Another way to deal with all of these fragments is to assume, again contrary to fact, that the empty string is a constituent of the right sort. Consider the fragment "Works," said at the end of an effort to repair something. We would attempt to prove

$$Syn(\text{“works”}, e, \mathbf{v.tnsd}, -, -, -, -, -, -, -, -).$$

This woud decompose into

$$Syn(\text{“ ”}, x, a{:}\mathbf{n}, -, -, -, -, -, -, -, -)$$

and

$$Syn(\text{“works”}, e, \mathbf{v.tnsd}, x, a, -, -, -, -, -, -).$$

The latter is a grammatical VP and presents no problems. The former would simply be assumed. That is, we would assume there is an empty string in front of "works" that is an NP referring to some x.

To summarize, four interpretive moves for interpreting sentence fragments have been introduced:

1. The fragment can be interpreted as is as a segment of coherent discourse, using the "*Syn* to *Segment*" rule.

2. One can assume the occurrence of some words that actually did not occur.

3. One can assume that a string of words has a form that it actually does not have.

4. One can assume, contrary to fact, the occurrence of an empty string that is a constituent of the right structure.

4.19.3 Scrambling: A Sonnet

In Shakespeare's 64th sonnet, the clause

> I have seen by Time's fell hand defaced the rich, proud cost of outworn buried age.

is a scrambled version of

> I have seen the rich, proud cost of outworn buried age defaced by Time's fell hand.

Similarly, the clause

> Sometime lofty towers I see down-rased.

is a scrambled version of

> I see sometime lofty towers rased down.

One possibility would be to analyze the maximal grammatical phrases in terms of the *Syn* predicate, then deduce *Segment* predications from that, and interpret the concatenation of these with the Protosyntax Rule, trusting the predicate-argument relations to work out correctly. In the first example, "by Time's fell hand" composes with "defaced" because of the unconstrained character of our Adjunct Composition Rule. The following are then the *Syn* predications for the four maximal grammatical phrases:

$$Syn(\text{“I”}, x, \mathbf{n.nom}, -, -, -, -, -, -, -, -)$$
$$Syn(\text{“have seen”}, e, \mathbf{v.tnsd}, x_1, \mathbf{n.nom}, y_1, \mathbf{n.acc}, e_2, \mathbf{pred.oc}, -, -)$$
$$Syn(\text{“by … defaced”}, e_1, \mathbf{pred}, h_1, \mathbf{n}, y_2, \mathbf{n.acc}, -, -, -, -, -, -)$$
$$Syn(\text{“the … age”}, y, \mathbf{n}, -, -, -, -, -, -, -, -)$$

Associated with the second of these is the predication $see'(e, x_1, e_2)$, and with the third $hand'(e_5, h)$, $by'(e_4, e_1, h)$ and $deface'(e_1, h, y_1)$. From each of these predications the corresponding *Segment* predication is deduced. The Protosyntax Rule is used to concatenate "by ... defaced" and "the ... age", identifying y with y_1 and using $deface'(e_1, h, y)$ as the *comprel* relation. The composite segment, "by ... age" is composed with "have seen" and then with "I" by two applications of the Protosyntax Rule, identifying e_2 with e_1 and x_1 with x. The variable y_2 never gets identified with y since it does not occur in the logical form associated with "have seen". Figure 4.41 illustrates this interpretation in schematic form.

This solution is somewhat unsatisfactory. When we read the sonnet, it is a much more considered process than interpreting, say, the language of panic. When we achieve an understanding of the passage, we understand very well what the syntax of the unscrambled sentence would be. We are aware of just what scrambling took place. We know, for example, that "the rich, proud cost ..." is not only the logical object of the defacing but also the first complement of "seen"; we resolve y_2 to y. This suggests that the reasoning about composition should take place in the finer-grained *Syn* regions of the proof graph, rather than in the coarser-grained *Segment* regions.

We can accomplish this by unpacking the notation w_1w_2 in the same way that in the last section we unpacked the notation "the" and the notation **ld**. Recall that the expression w_1w_2 is an abbreviation for a string instance w such that $concat(w, w_1, w_2)$ holds. Now it is not the case that

$$concat(\text{“the rich … age defaced”}, \text{“defaced”}, \text{“the rich … age”})$$

But if we assume, contrary to fact, that it is true, then we will have a satisfactorily grammatical interpretation of the clause, and as a result get a better global interpretation for the text. So we do assume it.

Both of these interpretive moves are highly unconstrained, the second because there is no locality constraint on w_1 and w_2; they can be arbitrarily distant. However, there is no reason that both processes could not be operative at the same time, since they lead to the same interpretation. As we are applying the first method, reasoning about the possible relations among successive grammatical fragments on the basis of their semantics, we could notice that by assuming one proposition of the form $concat(w, w_1, w_2)$ we

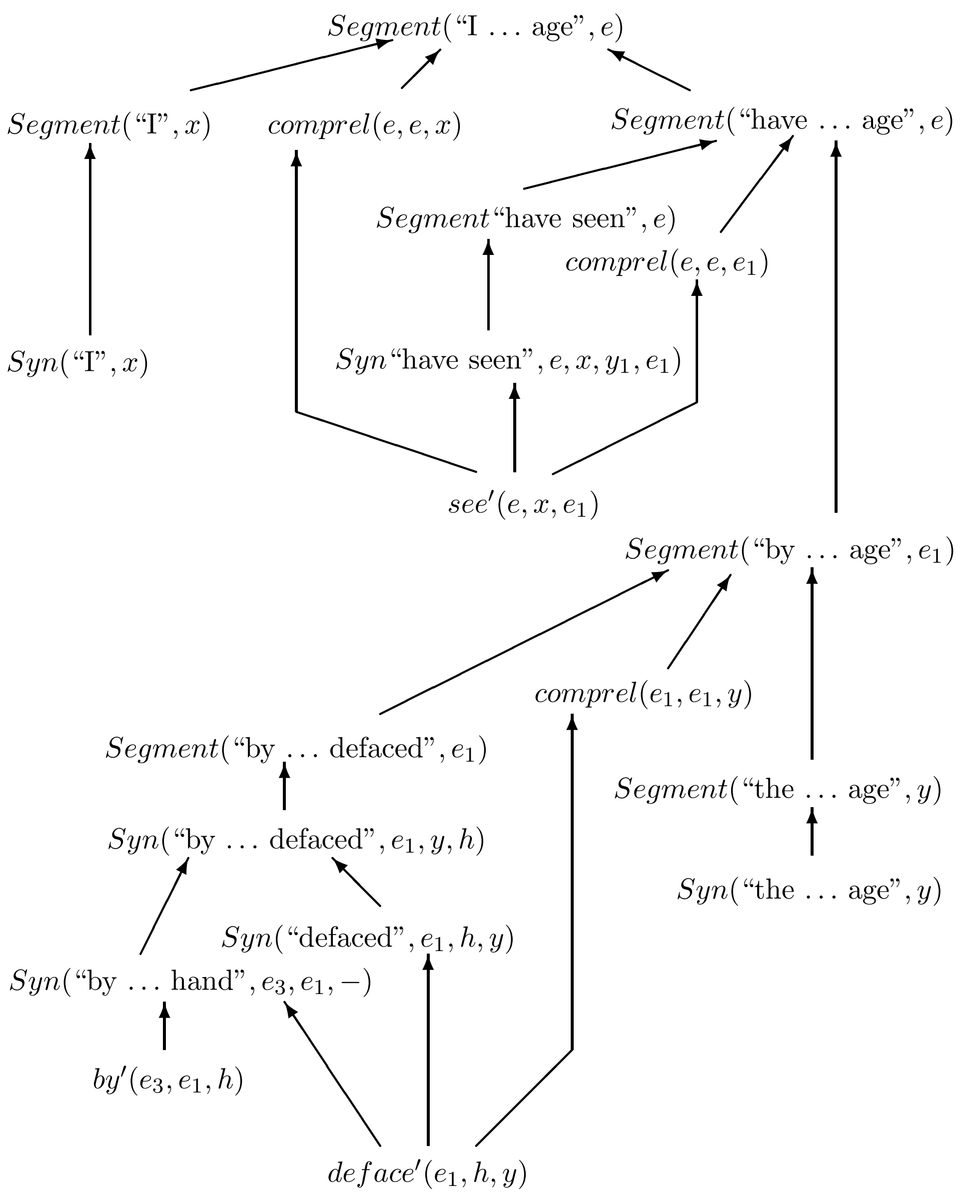

Figure 4.41: Parse of "I have seen by Time's fell hand defaced …"

can arrive at the same interpretation by purely syntactic reasoning. The two processes would reinforce each other. The Protosyntax method would enforce the locality constraints, and the assumption of *concat* would allow the finer-grained syntactic rules to justify the semantically plausible predicate-argument relations. Contending interpretations that are suggested by each process singly but not reinforced by the other would be eliminated.

Another possibility, independently motivated for free word-order languages, is to uncouple *concat* into adjacency and order. Then only order needs to be assumed contrary to fact, and adjacency continues to provide the locality constraint.

The other scrambled line in the sonnet,

> Sometime lofty towers I see down-rased.

is one step more complicated to interpret on the Protosyntax account. We would need a relation between the seeing and the towers, but that must be mediated by the down-rasing.

4.19.4 Disfluencies: A Transcript of a Meeting

Most of the disfluencies in the target text that comes from the transcript of a decision-making meeting fall under a single pattern. In this section, the pattern is described. Terminology is introduced for its parts. For clarity, each part will be referred to by a standard string instance variable. Examples, including most of the disfluencies in the target text, are discussed.

The full complexity of the pattern is not represented in the target text, but is represented by the following made-up fragment:

(4.60) And so John said um so Bill said we should leave.

This consists of the following parts:

Initial Segment:	w_1	"And"
Pre-alignment Cue:	w_{21}	"so"
Mistake:	w_{31}	"John"
Post-alignment Cue:	w_{41}	"said"
Edit Signal:	w_0	"um"
Pre-Alignment Cue:	w_{22}	"so"
Correction:	w_{32}	"Bill"
Post-Alignment Cue:	w_{42}	"said"
Continuation:	w_5	"we should leave"

In general, each one of these parts can be several words, one word, or a part of a word. It can also be the empty string. Note that w_{21} and w_{22} are the same string but not the same string instance; the same is true of w_{41} and w_{42}.

The parts can be characterized as follows:

Initial Segment:	The string that precedes the mistake and correction, is not repeated, and is required in the interpretation of the whole.
Pre-alignment Cue:	The string before the mistake that is repeated to signal where the mistake occurred.
Mistake:	The string that is replaced.
Post-alignment Cue:	The string after the mistake that is repeated to signal where the mistake occurred.
Edit Signal:	The string that signals that a correction is to be made.
Correction:	The string that replaces the mistake.
Continuation:	The string following the mistake and its correction that is not repeated and is required in the interpretation of the whole.

When this pattern is matched against the fragment, the edit signal is excised and the string $w_{21}w_{31}w_{41}$ is replaced by the string $w_{22}w_{32}w_{42}$. Example (4.60) becomes

And so Bill said we should leave.

A complication that arises with this simple replacement picture will be discussed toward the end of this section.

Most of the time one or more of the strings is empty, and any one of the parts can be the empty string. In the following example, only the pre-alignment cue, the mistake, the edit signal, and the correction are present.

the intervening hour, I mean the twelve to one o'clock slot

Pre-alignment Cue:	"the"
Mistake:	"intervening hour"
Edit Signal:	"I mean"
Pre-Alignment Cue:	"the"
Correction:	"twelve to one o'clock slot"

The following example has a pre-alignment cue, the mistake, the edit signal, the correction, and a continuation.

have somebody, ah, have the secretaries just bring us some sandwiches

Pre-alignment Cue:	"have"
Mistake:	"somebody"
Edit Signal:	"ah"
Pre-Alignment Cue:	"have"
Correction:	"the secretaries"
Continuation:	"just bring us some sandwiches"

Sometimes the mistake can be the empty string. That is, the correction adds material rather than correcting existing material.

if we get squeezed, uh if I go first and if we get squeezed

Post-alignment Cue:	"if we get squeezed"
Edit Signal:	"uh"
Correction:	"if I go first and"
Post-Alignment Cue:	"if we get squeezed"

Sometimes the correction can be the empty string. That is, material is excised.

if we get squeezed on the, uh,

Initial Segment:	"if we get squeezed"
Mistake:	"on the"
Edit Signal:	"uh"

Similarly,

So, um.

Mistake:	"So"
Edit Signal:	"um"

Often the edit signal is absent, as in the following examples:

what the what new things he might have available

Pre-alignment Cue:	"what"
Mistake:	"the"
Pre-Alignment Cue:	"what"
Correction:	"new"
Continuation:	"things he might have available"

for lun', til lunch

Mistake:	"for"
Post-alignment Cue:	"lun' "
Correction:	"til"
Post-Alignment Cue:	"lun-"
Continuation:	"-ch"

for some, for your project

Pre-alignment Cue:	"for"
Mistake:	"some"
Pre-Alignment Cue:	"for"
Correction:	"your"
Continuation:	"project"

with for

Mistake:	"with"
Correction:	"for"

Shriberg (19??) has demonstrated that pauses of greater than 200 milliseconds can function as edit signals, and in some but not all of the above examples, that is what is happening. We can accommodate this in our framework by treating the pause as a "morpheme" of the same sort as "um", "uh", and "ah", conveying the same sort of information as explicit edit signals convey.

Also subsumed under this pattern are disfluencies in which there is no mistake or correction at all. Both the mistake and correction are the empty string, but a word or phrase is repeated, with or without an edit signal. In examples like this, the repeated material could be considered either a pre-alignment cue or a post-alignment cue. We will arbitrarily take it to be a pre-alignment cue. The modification on the string is the same as in the general pattern; the edit signal, if any, is excised, and the string instance w_{21} is replaced by the string instance w_{22}, which, incidentally, happens to be the same string.

The following examples contain an edit signal.

I y'know, I

Pre-alignment Cue:	"I"
Edit Signal:	"y'know"
Pre-Alignment Cue:	"I"

the ah the

Pre-alignment Cue: "the"
Edit Signal: "ah"
Pre-Alignment Cue: "the"

The following three examples do not have an edit signal.

what what

Pre-alignment Cue: "what"
Pre-Alignment Cue: "what"

un' unless

Pre-alignment Cue: "un' "
Pre-Alignment Cue: "un-"
Continuation: "-less"

I don't, I don't feel strongly about that.

Pre-alignment Cue: "I don't"
Pre-Alignment Cue: "I don't"
Continuation: "feel strongly about that"

Finally, there are several examples in the target text where there is only an edit signal, with no mistake, correction, or alignment cues. These are filled pauses. In these cases, the effect of matching the pattern and making the "correction" is simply to excise the edit signal.

the ah intervening hour

Initial Segment: "the"
Edit Signal: "ah"
Continuation: "intervening hour"

all the time we need, let's see an hour for Brian ...

Initial Segment: "all the time we need"
Edit Signal: "let's see"
Continuation: "an hour for Brian ..."

This procedure of pattern matching and replacement can work recursively. In

> what the what what new things he might have available

the string "what what" is first recognized and collapsed to "what". Then

> what the what new things he might have available

is corrected to

> what new things he might have available

In

> I don't, I y'know, I don't feel strongly about that

the string "I y'know, I" is first collapsed to "I". Then

> I don't, I don't feel strongly about that

is corrected to

> I don't feel strongly about that

Nearly all the disfluencies in the target text can be accounted for in this fashion. The only other disfluencies are fragments, an "intonational run-on sentence",

> I need about an hour and fifteen minutes I could do the, my reporting on the ongoing project, ah, for that first hour.

and a missing "that" in

> what I'd be willing to do is if we get squeezed I'll eat the time that we lose.

There can be some ambiguity in how the pattern is matched against the string. In a corpus of queries to an air travel information system studied by Bear et al. (19??), the following string occurs.

> Show the delta flights united flights.

The desired interpretation is that "delta" is the mistake, "flights" is a post-alignment cue, and "united" is the correction, so that the string is corrected to "Show the united flights." But it is also possible to take "flights" as a pre-alignment cue, "united" as the mistake, and the empty string as the correction. In this case, the interpretation is "Show the delta flights." The difference is significant.

The edit signal tells the hearer that a error has occurred and a correction is coming. The pre- and post-alignment cues help to locate the mistake and correction. But as the above example shows, these are, in general, not enough. Three other criteria seem to be operating as well.

1. The corrected string $w_1 w_{22} w_{32} w_{42} w_5$ should be grammatical and interpretable. This is a straightforward criterion. The purpose of the correction is to make the string correct.

2. An interpretation is favored if the string $w_1 w_{21} w_{31} w_{41}$ is "on its way to grammaticality and interpretability", perhaps because $w_1 w_{21} w_{31} w_{41} w_5$ is grammatical and interpretable. This is a harder constraint to state precisely. But our intuition about why the second interpretation of the above example is not acceptable is that "Show the delta flights united" is not on its way to a grammatical sentence, whereas "Show the delta flights" is not only on its way, it is already there. Similarly, "have somebody bring sandwiches" is as grammatical as "have the secretaries bring sandwiches". One problem with this criterion, however, is that often the string cannot be completed in a grammatical manner and in fact that is precisely why it was abandoned. For example, "find out what the" could not be followed by "new things he has available". At best, we would require some sort of circumlocution to complete the string, such as "find out what the new things are that he has available". This is probably why the correction occurred.

3. An interpretation is favored if the mistake and the correction are in some sense similar. The phrases "intervening hour" and "twelve to one slot" are both descriptions of an interval of time. The words "for" and "til" are both temporal prepositions. The descriptions "somebody" and "the secretaries" are both descriptions of people. In some cases the similarity is more forced; in "what the, what new things ...", the similarity of "the" and "new" is only that they are words that can appear prenominally.

We now need to show how this pattern, with these criteria, can be embedded within the abductive framework developed in this chapter.

4.19.5 Co-Construction

***** UNDER CONSTRUCTION *****

4.19.6 The FASTIAN Bargain: Skimming, or Language as Protolanguage

***** UNDER CONSTRUCTION *****

4.20 The Evolution of Syntax: A Plausible, Strong AI Account

***** ROUGH DRAFT *****

1. The Two-Word Stage: When agents encounter two objects in the world that are adjacent, they need to explain this adjacency by finding a relation between the objects. Usually, the explanation for why something is where it is is that that is its normal place. It is normal to see a chair at a desk, and we don't ask for further explanation. But if something is out of place, we do. If we walk into a room and see a chair on a table, or we walk into a lecture hall and see a dog in the aisle, we wonder why.

Much of our knowledge is about how things are composed of other things. We know that lettuce with dressing on top is a salad, and that a stack of pieces of paper with ink on them is a book. In general, the problem facing the agent can be characterized by the following pattern:

$$(\forall\, x, y, z) B(y) \wedge C(z) \wedge \mathit{aggregate}(x, y, z) \wedge \mathit{rel}(y, z) \supset A(x) \quad (4.61)$$

If we recognize a thing y as an instance of B, a thing z as an instance of C, and a particular relation between y and z, then we recognize the aggregate x of y and z as an instance of A.

Similarly, when agents hear two adjacent utterances, they need to explain the adjacency by finding a relation between them. A variety of relations are possible. "Mommy sock" might mean "This is Mommy's sock" and it might mean “Mommy, put my sock on”. As before, let $Segment(w, e)$ mean that the string of words w describes the entity or eventuality e. Then the general problem facing the agent is characterized by the following pattern:

$$(4.62) \quad (\forall w_1, w_2, x, y, z) Segment(w_1, y) \wedge Segment(w_2, z) \wedge rel(x, y, z) \supset Segment(w_1 w_2, x)$$

That is, to recognize the concatenation of two adjacent words or strings of words w_1 and w_2 as a coherent segment meaning x, one must recognize w_1 as a segment meaning y, recognize w_2 as a segment meaning z, and find some relation between y and z, where x is determined by the relation that is found.

This rule is a specialization of rule (4.61), where concatenation is the aggregation operation.

Rule (4.62) is the characterization of what Bickerton calls proto-language. One utters meaningful elements sequentially and the interpretation of the combination is determined by context. The utterance “Lion. Tree.” could mean there’s a lion behind the tree or there’s a lion nearby so let’s climb that tree, or numerous other things. Bickerton gives several examples, including the language of children in the two-word phase and the language of apes. I’ll offer another example: the language of panic. If a man runs out of his office shouting, ”Help! Heart attack! John! My office! CPR! Just sitting there! 911! Help! Floor! Heart attack!” we don’t need syntax to tell us that he was just sitting in his office with John when John had a heart attack and is now on the floor, and he wants someone to call 911 and someone to apply CPR.

Most if not all rules of grammar can be seen as specializations and elaborations of pattern (4.62).

The simplest example in English is compound nominals. To understand “turpentine jar” one must understand “turpentine” and “jar” and find the most plausible relation (in context) between turpentine and jars. In fact, compound nominals can be viewed as a relic of protolanguage in full-blown language.

Often with compound nominals the most plausible relation is a predicate-argument relation, where the head noun supplies the predicate and the prenominal noun supplies an argument. In “chemistry teacher”, a teacher is a teacher of something, and the word ”chemistry” tells us what that something is. In “language origin”, something is originating, and the word ”language” tells us what that something is.

The two-word utterance "Men work" can be viewed in the same way. We must find a relation between the two words to explain their adjacency. The relation we find is the predicate-argument relation, where "work" is the predicate and "men" is the argument.

The predicate *Syn* also conveys a relation between a string of words and an entity or eventuality. $Syn(w, e, f)$ says that the string w is a grammatical word, phrase or sentence of type f that describes e. Then *Syn* is a specialization of *Segment*.

$$Syn(w, e, f) \supset Segment(w, e)$$

The phrase structure rule

S → NP VP

can be written in this framework as

$$(4.63) \quad (\forall w_1, w_2, x, e) Syn(w_1, x, \mathbf{n}) \wedge Syn(w_2, e, \mathbf{v}) \wedge Subject(x, e) \supset Syn(w_1 w_2, e, \mathbf{v})$$

That is, if w_1 is string of words headed by a noun describing an entity x and w_2 is a string of words headed by a verb describing the eventuality e and x is the logical subject of e, then the concatenation $w_1 w_2$ of the two strings can be used to describe e, with the resulting string being headed by the verb. This means that to interpret $w_1 w_2$ as describing some eventuality e, segment it into a string w_1 describing the logical subject of e and a string w_2 providing the rest of the information about e.

This rule specializes rule (4.62), because *Syn* specializes *Segment* and *Subject* is an instance of the relation *rel*.

Syntax in general can be viewed as a set of constraints on the interpretation of adjacency, specifically, as predicate-argument relations.

This must be modified somewhat. Metonymy is a pervasive characteristic of discourse. When we say

I've read Shakespeare.

we coerce "Shakespeare" into something that can be read, namely, the writings of Shakespeare. So syntax is a set of constraints on the interpretation of adjacency as predicate-argument relations plus metonymy. This is probably not a recent development in the evolution of language. Rather it is the most natural starting point for syntax. In many protolanguage utterances, the relation found between adjacent elements involves a predicate argument relation plus just such a coercion function.

Rule (4.63) would be stated as follows, allowing for coercions.

$$(\forall\, w_1, w_2, x, e) Syn(w_1, x, \mathbf{n}) \wedge Syn(w_2, e, \mathbf{v}) \wedge Subject(y, e) \\ \wedge\, coercionrel(y, x) \supset Syn(w_1 w_2, e, \mathbf{v})$$

Here the conjunction $Subject(y, e) \wedge coercionrel(y, x)$ provides the relation between x and e that instantiates the relation rel.

In multiword discourse, when a relation is found to link two words or larger segments into a composite unit, it too can be related to adjacent segments in various ways. The tree structure of sentences arises out of this recursion.

The move from protolanguage to true, though elementary, syntax, can thus be seen as resulting from specializations of concepts and rules from ones useful in general cognition.

The selective advantage this development confers is clear. There is less ambiguity in utterances and therefore more precision, and therefore more complex messages can be constructed. Groups of individuals can thereby engage in more complex joint action.

Signalling Predication and Modification: The languages of the world signal predication primarily by means of position and particles (or affixes). They signal modification primarily by means of adjacency and various concord phenomena. We saw above how we can capture positional signals of predication.

Signalling predication by particles as does Japanese with postpositions, can be captured an axiom specializing and elaborating axiom (4.62) as follows:

$$(\forall\, w_1, w_2, w_3, x, r, e) Syn(w_1, x, \mathbf{n}) \wedge Syn(w_2, r, \mathbf{p}) \wedge Syn(w_3, e, \mathbf{v}) \\ \wedge\, r(x, e) \supset Syn(w_1 w_2 w_3, e, \mathbf{v})$$

That is, if w_1 is a noun phrase referring to x, w_2 is a particle denoting the relation r, w_3 is a phrase headed by a verb describing the eventuality e, and r is plausibly a relation between x and e, then $w_1 w_2 w_3$ is a phrase headed by a verb describing e. This rule is like (4.62) except that it has a further conjunct in the antecedent.

The other means of signalling predication and modification can be represented similarly.

Discontinuous Elements: Consider

John is likely to go.

To interpret this, an agent must find a relation between "John" and "is likely". Syntax says that it should be a predicate-argument relation plus metonymy. The predicate "is likely" requires a proposition as its argument, so we must coerce "John" into a proposition. The next phrase "to go" provides the required coercion function. John's *going* is likely.

Formally, this link between the subject and the infinitive can be mediated by increasing the arity of the *vp* predicate to allow a variable to pass information between the subject and the infinitival complement. The VP rule for such "raising" constructions in the framework presented here is

$$Syn(w_1, e, e_1, -) \wedge Syn(w_2, e_1, x, -) \supset Syn(w_1 w_2, e, x, -)$$

That is, if a string w_1 ("is likely") describing a situation e and looking for a logical subject referring to e_2 (John's going) is concatenated with a string w_2 ("to go") describing e_2 and looking for a subject x (John), then the result describes the situation e provided we can find a logical subject describing x.

The approach taken here is thus closer to unification grammar in that information is passed between distant parts of a sentence by means of variables, rather than by a "move α" transformation, as in government and binding approaches.

Long-Distance Dependencies: One of the most "advanced" and probably one ofthe latest universal phenomena of language is long-distance dependencies, as illustrated in relative clauses and wh-questions. They are called *long-distance* dependencies because in principal the head noun can be an argument of a predication that is embedded arbitrarily deeply. In the noun phrase

the man John believes Mary said Bill saw

the man is the logical object of the seeing event, at the third level of embedding.

In accounting for the evolution of long-distance dependencies, we will take our cue from the Japanese. It has been argued that the Japanese relative clause is as free as the English compound nominal in its interpretation. That is, all that is required is that there be *some* relation between situation described by the relative clause and the entity described by the head noun (Akmajian and Kitagawa, 1974; Kameyama, 1994). The cite the following noun phrase as an example.

Hanako ga iede shita Taroo
Hanako Subj run-away-from-home did Taroo
Taroo such that Hanako ran away from home

Here it is up to the interpreter to find some plausible relation between Taroo and Hanako's running away from home.

We may take Japanese as an example of the basic case. Any relation will explain the adjacency of the relative clause and the noun. In English, a further constraint is added, analogous to the constraint between subject and verb. The relation must be the predicate-argument relation, where the head noun is the argument and the predicate is provided, roughly, by the top-level assertion in the relative clause. Thus, in "the man who John saw", the relation between the man and the seeing event is the predicate-argument relation—the man is the logical object of the seeing. It is thus a specialization of pattern (1), and a constraint on the interpretation of the relation.

This can be incorporated into the grammar by increasing the arity of the *Syn* predicate, relating strings of words to their meaning. Before we had arguments for the string, the entity or situation it described, and the missing logical subject and object. We will increase the arity by one, and add an argument for the entity that will fill the gap in relative clause. The rules for relative clauses then becomes

$$Syn(w_1, e_1, x, y, -) \wedge Syn(``", y, -, -, -) \supset Syn(w_1, e_1, x, -, y)$$
$$Syn(w_1, x, -, -, -) \wedge Syn(w_2, e, -, -, x) \supset Syn(w_1w_2, x, -, -, -)$$

The first rule introduces the gap. It says an eventuality e_1 looking for its logical object y can concatenate with the empty string provided the gap is eventually matched with a head describing y. The second rule says that a head noun w_1 describing x can concatenate with a relative clause w_2 describing e but having a gap x to form a string w_1w_2 that describes x.

Sportscaster English, where "which" is used as a subordinate conjunction, can be seen as a relaxation of this constraint back to the protolanguage pattern of composition.

Seeking a relation between adjacent or proximate words or larger segments in an utterance is simply an instance of seeking explanations for the observables in our environment. Syntax can be seen largely as a set of constraints on such interpretations, primarily constraining the relation to predicate-argument relations. The changes leading to this from protolanguage are of three kinds, the first two of which we have discussed.

- Specializing predicates that characterize strings of words, as the predicate *Syn* specializes the predicates in pattern (1).

- Increasing the arity of the *Syn* predicate, i.e., adding arguments, to transmit arguments from one part of a sentence to another, as was done to handle long-distance dependencies.

- Adding predications to antecedents of rules to capture agreement and subcategorization constraints.

The acquisition of syntax, whether in evolution or in development, can be seen as the accumulation of such constraints.

4.21 Modularity

For the past several decades, there has been quite a bit of discussion in linguistics, psycholinguistics, and related fields about the various modules involved in language processing and their interactions. A number of researchers have, in particular, been concerned to show that there was a syntactic module that operated in some sense independently of processes that accessed general world knowledge. Fodor (1983) has been perhaps the most vocal advocate of this position. He argued that human syntactic processing takes place in a special "informationally encapsulated" input module, immune from top-down influences from "central processes" involving background knowledge. This position has been contentious in psycholinguistics. Marslen-Wilson and Tyler (1987), for example, presented evidence that if there is any information encapsulation, it is not in a module that has logical form as its output, but rather one that has a mental model or some other form of discourse representation as its output. Such output requires background knowledge in its construction. At the very least, if linguistic processing is modular, it is not immune from top-down context dependence.

Finally, however, Marslen-Wilson and Tyler argue that the principal question about modularity—"What interaction occurs between modules?"—is ill-posed. They suggest that there may be no neat division of the linguistic labor into modules, and that it therefore does not make sense to talk about interaction between modules. This view is very much in accord with the integrated approach presented here. Knowledge of syntax is just one kind of knowledge of the world. All is given a uniform representation and a uniform biological realization. Any rule used in discourse interpretation can in principle, and often in fact will, involve predications about syntactic phenomena, background knowledge, the discourse situation, or anything else. In such an approach, issues of modularity simply go away.

In one extended defense of modularity, Fodor (n.d.) begins by admitting that the arguments against modularity are powerful. "If you're a modularity theorist, the fundamental problem in psycholinguistics is to talk your way out of the massive effects of context on language comprehension" (p. 15). He proceeds with a valiant attempt to do just that. He begins with an assumption: "Since a structural description is really the union of representations of an utterance in a variety of different theoretical vocabularies, it's natural to assume that the internal structure of the parsers is correspondingly functionally differentiated" (p. 10). But in the present abductive framework, this assumption is incorrect. Facts about syntax and pragmatics are expressed in different theoretical vocabularies only in the sense that facts about doors and airplanes are expressed in different theoretical vocabularies—different predicates are used. But the "internal structure of the parsers" is the same. It is all abduction.

In discussing certain sentences in which readers are "garden-pathed" by applying the syntactic strategy of "minimal attachment", Fodor proposes two alternatives, the first interactionist and the second modular: "Does context bias by penetrating the parser and *suspending* the (putative) preference for minimal attachment? Or does it bias by correcting the *output* of the parser when minimal attachment yields implausible analyses?" (p. 37) In my view, neither of these is true. The problem is to find the interpretation of the utterance that best satisfies a set of syntactic, semantic, and pragmatic constraints. Thus, all the constraints are applied simultaneously and the best interpretation satisfying them all is selected.

Moreover, often the utterance is elliptical, obscure, ill-formed, or unclear in parts. In these cases, various interpretive moves are available to the hearer, among them the local pragmatics moves of assuming metonymy or metaphor, the lexical move of assuming a very low-salience sense of a word, and the syntactic move of inserting a word to repair the syntax. The last of these is required in a sentence in a rough draft that was circulated of Fodor's paper:

> By contrast, on the Interactive model, it's assumed that the same processes have access to linguistic information can also access cognitive background. (p. 57–8)

The best way to interpret this sentence is to assume that a "that" should occur between "processes" and "have". There is no way of knowing *a priori* what interpretive moves will yield the best interpretation for a given utterance. This fact would dictate that syntactic analysis be completed even where purely pragmatic processes could repair the utterance to interpretability.

In Bever's classic example (Bever, 1970),

> The horse raced past the barn fell.

there are at least two possible interpretive moves: insert an "and" between "barn" and "fell", or assume the rather low-frequency, causative sense of "race". People generally make the first of these moves. However, Fodor himself gives examples, such as

> The performer sent the flowers was very pleased.

in which no such low-frequency sense needs to be accessed and the sentence is more easily interpreted as grammatical.

The abductive approach to this problem is in the spirit of Crain and Steedman (1985), who argue that interpretation is a matter of minimizing the number of presuppositions it is necessary to assume are in effect. Such assumptions add to the cost of the interpretation.

There remains, of course, the question of the optimal order of search for a proof for any particular input text. The various proposals of modularizations can be viewed as suggestions for order of search. But in the present framework, there is no particular reason to assume a rigid order of search. It allows what seems the most plausible account—that sometimes syntax drives interpretation and sometimes pragmatics does.

It should be pointed out that if Fodor were to adopt this position, it would only be with the utmost pessimism. According to him, we would have taken a peripheral, modular process that is, for just that reason, perhaps amenable to investigation, and turned it into one of the central processes, the understanding of which, on his view, would be completely intractable. However, nothing can be lost in this move. Insofar as syntax is tractable and the syntactic processing can be traced out, this information can be treated as information about efficient search orders in the central processes.

Finally, the reader may object to this integration because syntax and the other so-called modules constitute coherent domains of inquiry, and breaking down the barriers between them can only result in conceptual confusion. This is not a necessary consequence, however. One can still distinguish, if one wants, between syntactic axioms and background knowledge axioms. It is just that they will both be expressed in the same formal language and used in the same fashion. What the integration has done is to remove such distinctions from the code and put them into the comments.