

VARIABILITY IN ONTOLOGICAL KNOWLEDGE  
AND ITS RELATIONSHIP TO INTELLIGENCE

by  
Kacey Chandler

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A Dissertation Submitted to the  
DIVISION OF EDUCATIONAL FOUNDATIONS AND ADMINISTRATION  
In Partial Fulfillment of the Requirements  
For the Degree of  
DOCTOR OF PHILOSOPHY  
WITH A MAJOR IN EDUCATIONAL PSYCHOLOGY  
In the Graduate College  
THE UNIVERSITY OF ARIZONA

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intelligence**

**Chandler, Kacey, Ph.D.**

**The University of Arizona, 1989**

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As members of the Final Examination Committee, we certify that we have read  
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entitled Variability in Ontological Knowledge

and its Relationship to Intelligence

and recommend that it be accepted as fulfilling the dissertation requirement  
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A handwritten signature in cursive script, reading "Kaye Chanell", is written over a horizontal line.

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## ABSTRACT

This study examined children's performance on a decontextualization task requiring the ability to deduce the meaning of unknown words from verbal context and their ontological knowledge structure as indicated by their judgments about both anomalous and sensible statements containing the unknown words. A comparison was made between performance on the decontextualization task and verbal and nonverbal ability and between the subjects' ontological knowledge structures and verbal and nonverbal ability. It was hypothesized that performance on the decontextualization tasks would be positively correlated with both ability measures, but ontological knowledge structure would remain constant across ability levels. First, third and fifth grade subjects' participated in the study. Performance on the decontextualization task correlated positively with verbal ability for all three grade level and with nonverbal ability for grade one. Presence of the M-constraint (Keil, 1979) was evident across ability levels as well as grade levels. Greater differentiation in ontological knowledge was indicated across grade levels but not across ability levels within a grade level. Results supported previous research of Keil (1979, 1983a, 1983b).

## CHAPTER ONE

The study of intelligence is one that is persuaded by the zeitgeist, as is the case with most psychological phenomena being studied. A noticeable shift in emphasis, for example, has been away from explaining intelligent behavior solely by way of factors that emerge from a statistical analysis of psychometric data toward including an examination of the processes involved as well. Even though there may be elements included in descriptions of intelligence that typify historical time periods, definitions of intelligence given by experts have been known to vary greatly within generations; some emphasizing learning and others innate ability; some attributing all intelligent behavior to one general factor and others to several factors; some including such constructs as motivation as integral parts of intelligence, and others suggesting that those constructs are separate and should not be confounded with intelligence (Sternberg & Detterman, 1986).

In an editorial Keil (1982) discussed the constructs of intelligence and cognition and current theoretical influences on the ways in which these constructs are conceptualized. He suggested that the predominant influence on the study of intelligence is currently that of cognitive psychology. In this article, Keil presented a position on the conceptualization of intelligence that he

referred to as the "constraints approach". Addressed in this approach was the relationship between intelligence and cognition and whether they are constructs explaining the same phenomena.

Cognition, cognitive ability, cognitive capacity are all terms frequently found in the literature to be used synonymously with intelligence (Keil, 1982; Sternberg & Detterman, 1986). It is not clear, however, whether cognition and intelligence are synonymous. In fact, evidence actually suggests that there are components of human cognition that conflict with the criteria included in descriptions of intelligence (Keil, 1982). Regardless of the theoretical approach one takes, or the statistical analysis one uses to gain support for a theory, variability in performance is one criterion that seems to emerge when intelligence is being explained. A consideration with the constraints approach to understanding cognition is that not all cognitive abilities manifest variability (Keil, 1981, 1982).

Keil refers to areas of cognition that do not manifest individual variation as domain-specific abilities. The concept of domain specificity is an important aspect of Keil's (1981) general theory of cognitive development. The constraints approach to explaining cognitive development proposes an alternative to explanations of cognition and intelligence suggesting that these constructs are equivalent.

## CONSTRAINTS ON COGNITION

Recognition of constraints on human cognition is necessary for the understanding of cognitive development according to Keil (1982, 1986a). Keil (1982) states: "The constraints approach is not necessarily at odds with current cognitive psychology, but at the least, it places a different emphasis on what issues are important and how they should be studied." (p. 4) The emphasis in this approach that differs from the emphases of information processing and psychometric approaches to the study of cognition is the issue of invariance, and those areas of cognition that remain constant across human performance. The structure of knowledge becomes the focus with this approach. Therefore, without an understanding of the types of knowledge or content areas that are constrained, and the nature of the constraints on those domains of knowledge, the relationship between intelligence and cognition cannot be realized:

...one cannot really know how difficult a type of knowledge is (and consequently, how intelligent a professor of that knowledge is) if one merely tries to simulate it with unconstrained learning procedures. For what may be a horrendously complex induction in an unconstrained system may be relatively trivial in a constrained one." (Keil, 1982, p. 16)

With the awareness that there may actually be structural constraints that are universal to humans which govern specific aspects of cognitive development, the study of

intellectual performance may be different than if the constraints approach to cognition had not been adopted.

These structural constraints that determine the framework of human knowledge acquisition are referred to as domain specific constraints (Keil, 1981, 1982, 1986a).

Characteristics of domain specific constraints and the type of knowledge acquisition that these constraints govern are described by Keil (1982) as the following: domain specific constraints are considered to be a priori; domain specific constraints govern specific content areas and do not cross content areas; content areas are few in number and cover broad ranges of competence; competence within content areas is invariant across humans; and knowledge acquisition within a domain is tacit. The emphasis in this theory is placed on domain specific constraints; they are the "backbone" of knowledge acquisition.

Two other types of constraints that Keil (1986a) refers to in his theory of cognitive development are domain general and expertise specific. Domain general constraints are also considered to be a priori. These constraints, however, apply across content areas, and rather than determining the "structure" of knowledge that is being acquired, they govern the "process" of knowledge acquisition (Keil 1982, 1986). Unlike domain specific constraints, domain general constraints are not

hypothesized to be invariant across humans.

Expertise specific constraints on knowledge acquisition proposed by Keil (1986a), are considered to be post priori. These are constraints on knowledge acquisition that are determined by previously acquired knowledge. Therefore, what one knows determines what one will know. These are environmentally determined constraints on knowledge acquisition. Thus, because experience varies across individuals, there is variability in the types of knowledge that are governed by expertise specific constraints.

In sum, all knowledge acquisition is constrained in three ways (Keil, 1986a). First, and most fundamental, it is structurally constrained and specific to the natural domain within which it lies. Second, it is constrained by the ability to process information and third, it is constrained by past experience.

When this theoretical approach to cognitive development is taken into consideration, it becomes necessary to revise previous explanations for the constituents of intellectual performance and the individual differences in such performance. Regardless of the philosophical flavor of the argument used to explain individual differences in intelligence, the notion of universal constraints on cognition introduces the possibility that there are elements of what is generally considered intelligence that

do not vary among humans.

#### ONTOLOGICAL KNOWLEDGE

When intelligence is the topic of discussion, either as a theoretical construct or as a predictor of some other variable, psychometric tests are generally considered as vehicles for establishing validity for the purpose at hand. Tests of intelligence often comprise several subtests, and usually include some type of vocabulary subtest (e. g. McCarthy Scale of Children's Abilities, Stanford-Binet Intelligence Scale: Fourth Edition, Wechsler Intelligence Scale for Children -Revised). Though vocabulary is considered a good predictor of overall intelligence, it is possible that there is an important component involved in the acquisition of word meaning that is governed by a domain specific constraint, and thus, does not vary among humans. This component, according to Keil, would be ontological knowledge (1982, 1983a). He suggests that ontological knowledge, or one's internal representation of the way in which the environment is organized, is structurally constrained, and plays a major role in the acquisition of vocabulary.

In Keil's book, Semantic and Conceptual Development, (1979) the research questions being investigated were: Is human knowledge acquisition constrained? If so, what are the constraints on knowledge acquisition? The content area he used in pursuit of the answers to these questions was

ontological knowledge, which was defined as "one's conception of the basic categories of existence". (Keil, 1979; p. 1) The relationship of the structure of ontological knowledge to the acquisition of word meaning should not be underestimated when vocabulary acquisition and intelligence are being investigated. Keil (1979) suggests that one's ontological knowledge structure constrains the nature of semantic and conceptual knowledge." Results of a series of studies investigating ontological knowledge acquisition (Keil, 1979) have not only indicated that there is a constraint on the ontological knowledge structure of adults, but that this constraint also governs the development of such knowledge.

Prior to the publication of Keil's book (1979) on ontological knowledge acquisition, constraints on ontological knowledge had been discussed by Fred Sommers (1959; 1963; 1971) in his articles on natural language and predicability (1959, 1963, 1971). Sommers theory of predicability specified which terms in a language can be logically combined with which predicates. Sommers (1963) referred to ontology as the "bare skeleton" of ordinary language. An example of a sensible combination of a predicate and term is the statement, the child was delighted. This statement is imaginable and makes sense, regardless of its truth value; whereas, the statement, the child happened yesterday, is not even imaginable. Because

of the ontological properties of the term child and predicate happened yesterday, the combination of this term and predicate is logically awkward. If a statement can be assigned a truth value (i.e. Is the statement true or false?), then it is an ontologically sensible statement. The first of the two statements given above fits this criteria because the child is either delighted or not delighted. The second statement cannot be assigned a truth value; neither is it possible for the child to have happened yesterday, nor is it possible for the child to have happened today or any other time. This is a conceptually impossible phenomenon.

Thus, both Sommers and Keil have proposed a constraint on ontological knowledge that governs the ontological knowledge structure in humans. Sommers (1971) refers to this constraint as the M-configuration; Keil (1979) refers to it as the M-constraint. They are speaking of the same phenomenon, however, and this phenomenon is what determines that the statement the child is delighted is ontologically feasible, and that the statement the child happened yesterday is not.

The M-constraint imposes a hierarchical organization on conceptual knowledge acquisition. An example of this is illustrated in Figure 1. This is referred to as an ontological tree (Keil, 1979). Figure 2, a predicability tree, represents this same organization with the use of

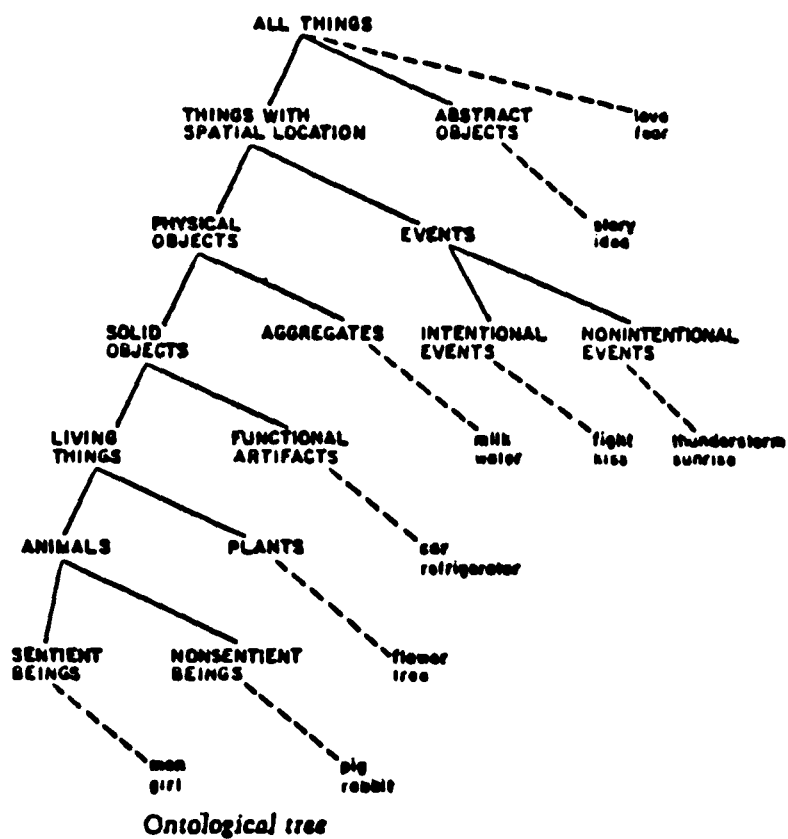


Figure 1. Reprinted, with permission, from Keil (1979).

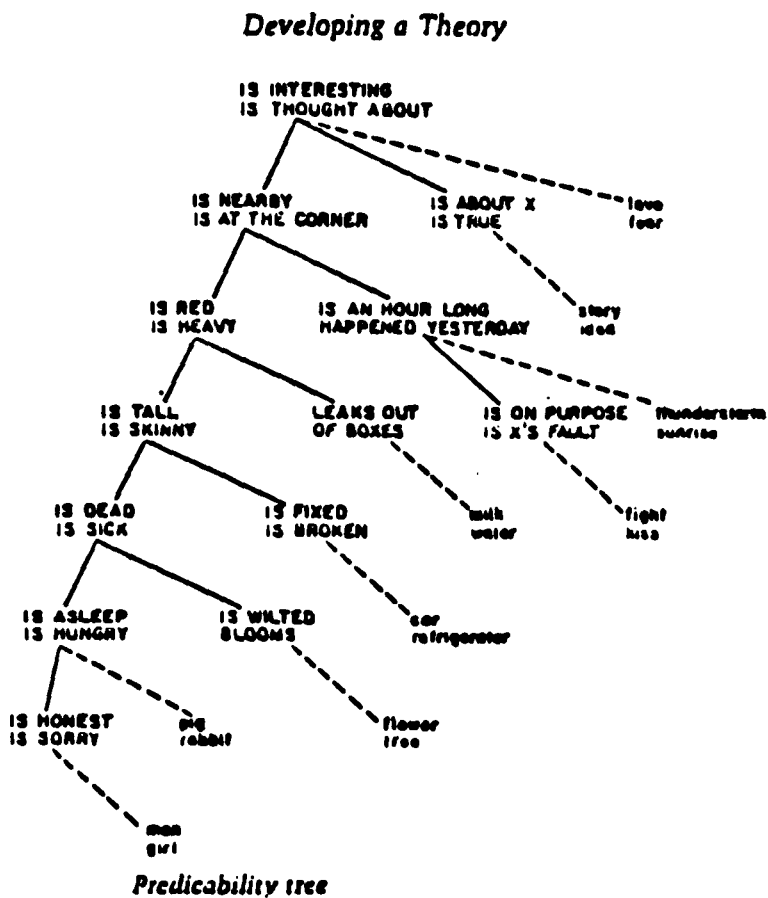


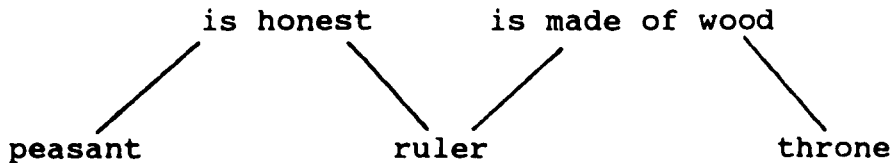
Figure 2. Reprinted, with permission, from Keil (1979).

predicates and terms in language. The predicability tree is equivalent to the ontological tree; however, the terms and predicates used in this illustration are examples of members of the ontological categories given in Figure 1. The constraint governing this hierarchical organization in the ontological tree, and therefore, in the corresponding predicability tree, determines the criterion for the organization of predicates and terms. Compliance with this criterion is described by Keil (1979): "The general rule to use in interpreting a tree structure is that a predicate spans all those terms that every predicate below it spans." (p. 14) Some examples of the above criterion illustrated in Figure 2 are listed below:

- (1) Is interesting spans every term that every other predicate in the tree spans because it is the highest predicate in the hierarchy.
- (2) Is asleep also spans all terms that is honest and is sorry span because it is higher in the hierarchy than both is honest and is sorry.
- (3) Milk and water share all of the same predicates; they are in the same location on the tree.
- (4) Flower shares a subset of predicates with milk and water; its location is below milk and water on the tree.

The M-constraint allows no downwardly convergent nodes that create M's or W's on the predicability tree.

Predicates may not have terms in common, and, at the same time, terms unique to each; however, a predicate can span either a subset or a superset of terms spanned by another predicate. Consider the illustration given below:



This combination of predicates and terms is a violation of the M-constraint. The term ruler is common to both predicates is honest and is made of wood; whereas, the term peasant is unique to the predicate is honest in this example, and the term throne is unique to is made of wood. Keil and Sommers both contend that violations of the M-constraint result from ambiguities in word meanings. In this example, the term ruler can be ambiguous out of context, but most likely, this ambiguity would be eliminated when placed in context. Empirical evidence involving the intuitions of children and adults, in fact, does indicate that the M-constraint is rarely violated (Keil, 1979).

When a new concept is acquired, the ontological properties of that concept are part of its conceptual representation. Thus, it can be assumed that ontological properties are included in the acquisition of a word meaning. Even though vocabulary is a positive correlate of intelligence, if ontological knowledge is universally

constrained and is also included in the conceptual representation of the meaning of words, then there must be a component of vocabulary acquisition that does not vary among humans, and therefore, is not what is generally considered intellectual functioning. When the constraints approach to the understanding of cognition is adopted, the possibility arises that cognition and intelligence are not identical constructs. As Keil (1982) stated: "For the most part, cognitive psychologists have failed to disambiguate carefully intelligence from the rest of cognition." (p. 18)

#### VOCABULARY IN CONTEXT

Vocabulary subtests are included in intelligence tests because they are good predictors of intelligence. In fact, expressive vocabulary subtest scores are often more highly correlated than other subtest scores with over all intelligence quotients (Jensen, 1980). Considered by some experts to be an even better predictor of over all intelligence than expressive vocabulary is the ability to acquire vocabulary from context (Jensen, 1980; Sternberg, 1984a). Jensen explains the relationship between vocabulary and intelligence in the following way:

Vocabulary tests are among the best measures of intelligence, because the acquisition of word meanings is highly dependent on the "eduction" of meaning from the contexts in which the words are encountered.

Vocabulary for the most part is not acquired by rote memorization or through formal instruction. The meaning of the word is most usually acquired by encountering the word in some context that permits at least some partial inference to its meaning. (p. 146)

Thus, it is suggested that one acquires the meaning of an unknown word from the context in which it lies by drawing an inference about its conceptual properties from the relationships between the remaining words. Jensen goes on to state that

the acquisition of vocabulary is not as much a matter of learning and memory as it is of generalization, discrimination, education, and inference. Children of high intelligence acquire vocabulary at a faster rate than children of low intelligence, and as adults, they have a much larger than average vocabulary, not primarily because they have spent more time in study or have been more exposed to words, but because they are capable of educing more meaning from single encounters with words and are capable of discriminating subtle differences in meanings between similar words. (p. 146)

Hence, it is suggested that the relationship between vocabulary and intelligence and perhaps the factor which contributes to individual differences in intelligence is some type of verbal problem solving ability. The questions

that are being asked, however, are (1) Is there an element of the acquisition of vocabulary from verbal context that is not necessarily representative of verbal reasoning?, and (2) If so, is this element constant among humans such that those who are more proficient at acquiring vocabulary from context still have the same knowledge structures with regard to this element. As stated above, Keil (1983a) suggests that ontological knowledge does govern, in part, the acquisition of word meaning, and that this type of knowledge is constrained by a domain specific constraint. It is suggested, therefore, that if intellectual ability must display individual variation then there is an additional aspect of cognition involved in vocabulary acquisition that is separate from intelligence.

It is proposed that Keil's research on ontological knowledge acquisition does introduce an additional element to the ability to infer word meanings from context that Sternberg and others have not yet mentioned. This element is the domain specific ability to make assumptions about ontological properties of one's environment. If the process of acquiring word meanings from context actually does involve a constrained component to cognition that is specific to the domain of ontological knowledge then evidence of the M-constraint consistent across ages and levels of intelligence should emerge in a task measuring this process. This would lend support to Keil's (1982)

argument that intelligence and cognition are not synonymous.

#### STATEMENT OF THE PROBLEM

This study was designed to investigate the relationship between intelligence and constraints on cognition. If intelligence and cognition are not analogous constructs, what is the relationship between the two? Is there a part of cognition generally considered intelligent behavior that is incompatible with certain aspects of intelligence? If there is, is this indicated by the presence of a constraint in the performance on a task that is correlated with performance on tests of intelligence? And finally, if such a constraint should manifest itself in performance on tasks that are considered to be good measures of intelligence, is this constraint consistent across intellectual and developmental levels.

## CHAPTER TWO

## REVIEW OF THE LITERATURE

"By faculty psychology I mean, roughly, the view that many fundamentally different kinds of psychological mechanisms must be postulated in order to explain the facts of mental life." (Fodor, 1983, p. 1) In Fodor's treatise on the modularity of human cognition (1983) he discusses "domain specific, information encapsulated" modules as input systems that enable efficient processing of incoming information. A single module processes a specific type of information and only that type of information. These information encapsulated psychological mechanisms are, according to Fodor, one of two identifiable orders of mental systems. They are referred to as vertical faculties. The second set of systems, horizontal faculties, have been described as central processes. The central processes are not information encapsulated, nor are they domain specific. They are operations that cross content domains. Thus, incoming information is initially processed through the module that is specific to its type. No inferences are made on the information up to this point. Finally, all information is processed by the central processes and at this point an inference is made. The function of the information encapsulated vertical faculties in cognitive processing is analysis of input; the function of the horizontal faculties, or central processes, is the

development of thought, or described by Fodor as the fixation of belief.

Fodor does not stand alone with his theory of how the human cognitive system operates. Views that are similar to his proposal are held by Chomsky (1980, 1988) and Keil (1981), to name a few. Although Chomsky is a linguist, as reflected in the majority of his publications relating specifically to language, his theory extends well beyond the details of language acquisition. "I would like to think of linguistics as that part of psychology that focuses its attention on one specific cognitive domain and one faculty of mind, the language faculty". (p. 1, 1980)

The theories of Fodor and Chomsky share two fundamental premises: (1) innate cognitive structure, and (2) modularity. Even though Chomsky proposes that the initial mental state of the infant is homogeneous and undifferentiated, the prewired structure of the mind, rather than the environment, determines language. A biological predisposition to generate some hypotheses rather than others enables efficient acquisition of knowledge. The environment is not without a role in the development of cognition, however, according to Chomsky. It creates a "triggering" effect, otherwise described as those external conditions that "facilitate the unfolding of an internally controlled process." (Chomsky, 1980, p. 3)

In a later publication discussing the same phenomenon

Chomsky (1988) states: "The language faculty selects relevant data from the events taking place in the environment; making use of these data in a manner determined by its internal structure." (p. 35) Thus, even minimal environmental interaction leads to greater differentiation of the cognitive system.

Chomsky (1980) claims that innate structure is possible without modularity, but to conceptualize a modular cognitive structure without the provision of biological prewiring is improbable. He states that "the belief that various systems of mind are organized along quite different principles leads to the natural conclusion that these systems are intrinsically determined, not simply the result of common mechanisms of learning and growth." (1980, p. 3) He suggests that those principles that determine development within a cognitive domain are specific to that domain and do not generalize to other domains.

Therefore, when domain specific principles or constraints are postulated, the hypothesis space is greatly reduced. This helps explain the exceptional amount of competence children exhibit in different domains at very young ages. For example, even with minimal exposure to language, it becomes a rare exception that a child does not acquire language complete with syntax within the first few years of life. Chomsky (1988) explains: "It seems that the child approaches the task of acquiring a language with a rich

conceptual framework already in place and also with a rich system of assumptions about sound structure and the structure of more complex utterances." (p. 34)

Keil (1981), who has also embraced an approach to the explanation of cognitive development comparable to Chomsky's approach, states:

when one examines what sorts of constraints are present, one discovers that they are highly elaborated and domain-specific, and that such specificity is necessary to explain the ease and rapidity with which so much of human knowledge is acquired. The solution to the mystery of how children acquire so much so fast lies not in the formulation of ever more powerful and sophisticated induction procedures but rather in the specification of how relatively simple induction procedures are limited in particular domains.

(p. 200)

Although both Chomsky (1980, 1988) and Keil (1981) have proposed a modular structure to cognitive development with constraints attached to specific domains, their inquiries used as support for these theories are generally limited to a single content area. Chomsky examines the structure of language and its acquisition which is highly constrained. He also refers to a "number faculty", although not in detail, as a specific domain that is innately constrained. Keil studies ontological knowledge; however, he uses the

research of Gelman and Gallistel (1978), among others, as support for his theory of constraints on cognition.

A preamble to Keil's research on ontological knowledge acquisition is a series of articles written by philosopher Fred Sommers (1959, 1963, 1971). Sommers has proposed a formal constraint on ontology that dictates the structure of natural language by determining those relationships between all predicates and terms that are logically permitted and those that are prohibited. This is manifested in a strict hierarchical organization. The constraint is referred to by Sommers (1971) as the M-configuration because of the pattern that results on a language tree when an ontologically unnatural association is made. (See Chapter One.) Sommers (1971) states: "The tree structure is a universal constraint on significant category correct predication in every natural language." (p. 40) Thus, the constraint is universal and determines the ontological knowledge structure of humans.

Keil (1979) extended Sommers' theory by investigating the development of conceptual knowledge and whether a constraint on ontology governs this development. He began by examining the ontological structure of adults in order to ascertain any patterns that might emerge, in particular, the M-constraint. Keil's adult studies were followed by investigations of the ontological knowledge structure of school age children and an analysis of the similarities

between the structures of adults and children.

#### Research on Adult Ontological Knowledge Structure

Predicability can be regarded as the surface structure of ontology. Therefore, any discernable relationship between predicates and terms in a language can legitimately be viewed as a reflection of underlying ontological knowledge. There are four psychological phenomena that Keil (1979) uses to study predicability: anomalous sentences, natural classes, similar classes, and natural copredications. The first phenomenon, anomalous sentences, are those sentences to which a truth value cannot be assigned. Thus, the moon is purple is merely false, but, the moon is disappointed is anomalous. The next phenomenon, natural classes, indicates that some classes of things seem to be more natural than others. For example, the class of humans, plants, and animals seems to be more natural than the class of plants, solids, and events. The phenomenon of similar classes suggests that a given class will be more like some classes than others. Animals might be more similar to plants than to nonliving solid objects, but also more similar to nonliving solid objects than to liquids. The final phenomenon discussed by Keil, natural copredication, infers that some combinations of predicates are natural and sensible, and others are not. For example, the combination of predicates is honest and is loyal appears to be sensible, whereas the combination of predicates is honest

and is a week long does not.

Prior to investigating ontological knowledge development, it would be useful, according to Keil (1979), to have some understanding of adult ontological knowledge structure. He takes this very approach by studying adults' intuitions of the four psychological phenomena. The study of anomaly is a study of the M-constraint. A simplified predicability tree was constructed in order to draw comparisons from those trees constructed from subjects' intuitions. In his first study subjects were given a series of sentences and asked to determine whether each sentence was anomalous or not. They were cautioned against using metaphor in making their judgments. Results indicated that predicability trees from the intuitions of thirteen out of sixteen subjects did not violate the M-constraint. Ten of these trees were identical to the experimental tree constructed prior to the analysis of the results. Out of the numerous possible M-constraint violations, only six occurred. The probabilities for both of these events were very low. ( $p < .001$ ).

The study of natural classes did not investigate the M-constraint, but investigated the hierarchical structure of the predicability tree. The same experimental tree used in the anomaly study was used in this study. Results indicated that thirteen out of sixteen subjects ordered classes compatible with the experimental tree, ( $p < .001$ ).

Although there was great variety in the responses of these thirteen subjects, agreement with the final tree was still demonstrated. Keil (1979) suggests that this lends greater support for the theory than if all response patterns were identical. The theory does allow for several different orders of natural classes that ultimately conform to the final structure. If only one particular course were chosen by all subjects, then the phenomena is only partially accounted for. Analysis of responses in the study of similar classes indicated comparable results to the study of natural classes.

The study of copredication was designed to investigate the M-constraint. None of the subjects responses led to duplication of the experimental tree, however. Keil (1979) interpreted this to be a result of ambiguities in some of the predicates. For example, the predicate is broken was intended to mean is defective as an artifact could be broken. However, some subjects interpreted this to mean is fractured as a limb of a human being or an animal could be broken. The dual meaning of this predicate led to violations of the M-constraint which probably would not have occurred if the ambiguity had been eliminated. [Violations of the M-constraint, according to Sommers (1963, 1971), are caused by ambiguities.] Ambiguities occurred involving other terms and predicates, as well. Keil suggested that this type of study, more than the other

three, must lend itself to the use of ambiguities. He came to this conclusion even though several subjects on several occasions judged some predicates to be copredicable which the experimental tree did not predict. Regardless, this conclusion was drawn because of all the copredicates that the tree predicted were copredicable, no response from any subject indicated otherwise.

Keil (1979) summarized the results of these four investigations by pointing out that the intuitions of adults regarding these four phenomena are remarkably alike. Moreover, the subjects consistently conform to the M-constraint. These results support the proposition that the ontological knowledge structure of adults is constrained, and that the constraint on this structure is the M-constraint. (For a detailed description of these four studies see Keil, 1979.)

#### Research on Ontological Knowledge Development

As part of the same progression of studies, and after some conception of the pattern of adult ontology was obtained, Keil (1979) continued with a series of child studies. The purpose of these studies was to determine the ontological knowledge structure of children, whether it is constrained by the M-constraint or some other constraint, whether developmental changes occur in ontological knowledge, and if so, whether these changes result in qualitatively different knowledge structures than those

which existed prior to the change.

Keil pursued answers to these questions by investigating children's intuitions of anomaly. He developed a technique different than that which he used with his adult subjects in an attempt to avoid the chance of mistaking a true-false distinction for a decision about anomaly. His first child study included students from kindergarten, second, fourth and sixth grades. Subjects were read a set of randomly ordered set of predicates with one of two sets of terms arranged in sentences such as "An x is x", followed by "Is that silly or is that okay?". A series of questions would follow the initial question that would vary depending on the subject's response to the first question.

Results indicated that violations of the M-constraint were rare, only six out of a possible 100,000 occasions. Keil (1979) stated: "The conclusion is that, at least for the predicates and terms used in the study, the M-constraint is honored scrupulously by children as young as five years." (p. 71) A developmental pattern emerged from the results, as well. Although children violated the M-constraint just as infrequently as did adults, predicability trees constructed from children's intuitions about anomaly were not identical to those of adults, nor were they identical to those trees from children of a different age group. Predicability trees were constructed for all subjects. Kindergarten subjects, in general,

collapsed all ontological categories into two basic categories: living and nonliving. Thus, terms that fell under both categories shared some common predicates including think of, is heavy, is tall, and even is an hour long. However, only plant, animal and human terms (tree, rabbit, and girl) could be alive, hungry and sorry. Trees constructed from second graders' responses demonstrated greater differentiation of ontological categories as compared to the kindergarten subjects. Plants and animals emerged from the living category, and a physical and nonphysical distinction emerged from the nonliving category. Intuitions of fourth graders represented those same distinctions made by most adults with the exception of a lack of differentiation between humans and other animals, and between abstract objects and events. These distinctions were representative of a majority of Keil's subjects. Responses indicated no significant differences between the two groups of terms.

The above series of studies, as discussed by Keil (1979), produced some significant findings. First, and foremost, the M-constraint not only appears to govern adult ontological knowledge structure, but it also appears to govern the ontological knowledge structure of children at different developmental levels. He proposed that the development of ontological knowledge occurs in a systematic manner resulting in greater differentiation of ontological

categories, which, according to Keil, seems to be highly constrained.

Obviously, the results of any investigation creates some unanswered questions. Some of the unanswered questions, according to Keil (1979), that arose from his original child studies were: (1) Do these results generalize to a different set of terms and predicates? That is, would the same developmental effects be seen when predicates and terms reflecting different positions on the predicability tree were used; (2) Are the less differentiated tree structures of younger children a result of a different conceptual framework, or are they a result of some word meanings being different for them than for adults and older children? (3) How does the transition from lesser to greater differentiation of ontological categories occur? (4) Do children even younger than age five honor the M-constraint? and (5) Are these developmental patterns only representative of English speaking individuals, or are they independent of particular languages?

As part of the second series of child studies, one study was conducted for the purpose of answering the first three questions listed above (Keil, 1979). A different and larger set of predicates were used. Several predicates reflecting each category were included. Predicates reflecting additional nodes were also included. For example, artifacts such as cars, and a differentiation

between intentional events like birthday parties and natural events like hurricanes were added. These additions to the first group of child studies provided a test of the M-constraint that involved more nodes on the predicability tree, thus, a greater chance of M-constraint violations. It provided a test of the developmental pattern that led to greater differentiation in ontological categories indicated by the first child studies due to a greater number of possible collapses in this study. In general, it was designed to determine whether the results of the first study would generalize with the use of more predicates and terms at each node and at additional nodes.

The M-constraint was violated as infrequently in this study as it was in the original child studies. Seven children out of fifty-eight violated the M-constraint, and of over 100,000 possible violations, eight (one subject violated it twice) violations occurred. Results indicated greater differentiation of ontological categories with age, as did the first child studies. The developmental patterns were similar to those found in the first studies. In addition, evidence for a transitional stage appeared. That is, terms would represent ontological categories before predicates specific to those categories would be associated with those terms. The example Keil (1979) gave for this phenomenon was event terms would represent a separate category while the predicate is an hour long would still be

located at a higher node. Hence, this study provided support for results of the first child studies.

To test the generalizability of the results to younger ages and other languages a preschool study and a study of Spanish speaking children from Puerto Rico was conducted (1979). Results of the preschool study indicated that preschoolers do honor the M-constraint. In addition, the basic distinction that was made, as was made with the kindergarten subjects, was a living-nonliving differentiation. This single distinction resulted in, of course, several collapses. (A plant term was not used in this study, so it was not determined where preschoolers would locate plants on the predicability tree.) Even though the ontological knowledge structure of preschoolers appears to be very simplistic as compared to the adult structure, evidence does suggest that there is a common constraint governing the structure at both extremes of the developmental continuum. The results of the preschool study, therefore, did generalize beyond the age groups included in the original investigations to include children even younger than age five.

The Puerto Rican study conducted by Keil (1979) produced generalizable results. Spanish speaking children also honored the M-constraint. The developmental pattern that signifies greater differentiation of ontological categories with age was also manifested in responses given by the

Puerto Rican children. This study supported Keil's original findings suggesting that the results generalize across languages, or at least across Indo-European languages.

To summarize the results of Keil's 1979 investigation, the ontological knowledge structure of children, even as young as preschool age, appears to be constrained. And not only does it appear to be constrained, the constraint appears to be equivalent to that which constrains adult ontological knowledge structure. The constraints result in a rigid developmental pattern for the acquisition of ontological knowledge. This pattern is hierarchical and one that seems to endure semantic and syntactic fluctuations both within and across languages. Keil explained that neither the tree structures nor the individual nodes on any tree configuration should be interpreted as accounting for the M-constraint or the developmental patterns that are manifested in subjects' responses. More appropriately, the entire structure represented by the trees should be attributed the underlying development of ontological knowledge, according to Keil. Keil states: "the trees appear to represent growth of an underlying conceptual knowledge of ontological categories, a knowledge that is intricately linked to language use via predicability but which seems to be the original source of predicability phenomena." (1979, p. 118)

## CRITICISMS OF KEIL'S RESEARCH

To date, the most vocal adversary of Keil regarding his research on ontological knowledge has been Susan Carey (1983, 1985, 1986). Carey has objected to the essence of Keil's theory by rejecting the following propositions: (1) a rigid hierarchical relationship is formed by ontological categories, and (2) predicates in natural language do not logically cut across ontological categories in natural language.

Carey (1983) has declared that the M-constraint does not constrain ontological knowledge. In her first counterexample of the above hypotheses she cited Davis' 1979 master thesis. He investigated the likelihood of the M-constraint constraining the relationship between spatial predicates such as is long, and is tall with various terms. Davis duplicated Keil's procedure but his results were not consistent with those obtained by Keil. The M-constraint did not appear to dictate the judgments of his subjects. In reflection on Davis' results, Carey stated: "I take this difference to show that Keil chose examples where the basic ontological types actually were hierarchically related, but that there is no constraint on human conceptualization to construe the world thus." (1983, p. 132) Therefore, according to Carey, predicates can and do logically apply to members of different ontological categories without indicating a hierarchical relationship.

Carey (1983, 1985) provided additional counterexamples in her attempt to illustrate the flaws in Keil's theory. She suggested that the statement the man is pregnant is a category mistake, and therefore, an obvious violation of the M-constraint. She also reacted to Keil's (1982, 1983a) proposal that the M-constraint actually governs hypothesis generation in the process of acquiring word meanings. Carey argued that if this is actually occurring, then languages should naturally guard against the production of terms that violate the M-constraint. Words like book and Russia are given as examples of common terms that violate the M-constraint with dual meanings.

In sum, the theory of ontological knowledge constructed by Keil is not plausible according to Carey. She disagreed with the conclusion that ontological knowledge acquisition is constrained by the M-constraint, and with the conclusion that ontological knowledge in humans is hierarchically organized. She hypothesized that ontological knowledge is determined by scientific theory. Carey states:

If there is an ontological level of concepts, the set of core concepts in our theories is the best candidate. In this view, the clearest cases of category mistakes will be when predicates from one theoretical domain are applied to terms from another. (1983, p. 139)

Gerard and Mandler (1983) in a study investigating the replicability of Keil's (1979) results used a procedure

with undergraduate college students similar to that described by Keil. Three factors were included in their design: four sets of predicates and terms; a condition including syntactically normal filler sentences and one including syntactically bizarre filler sentences; and conditions either including or excluding instructions not to use metaphors when judging anomaly. The statistic used was the percentage of violations from the M-constraint out of total possible violations (total possible violations varied across conditions depending on the set of predicates and terms subjects were assigned to). Results indicated that the M-constraint was violated frequently across all conditions (an average of 24% for normal fillers, no metaphor instructions, and an average of 63.6% for bizarre fillers, metaphor instructions included.) Subjects in the normal filler conditions, those in the no metaphor condition, and those in predicates and terms adopted from Keil had significantly lower average M-constraint violations than subjects in all other conditions. Based on these results, Gerard and Mandler suggested that judgments regarding anomaly are context dependent. They also contended that Keil's set of predicates and terms were conducive to fewer M-constraint violations and that they were not necessarily representative of language in general. Thus, according to Gerard and Mandler, Keil's theory on ontological knowledge was not supported. They stated:

The data presented here suggest that Keil's task is far more sensitive to pragmatic factors than he suspected. The subjects in this study did not respond in a manner consistent with Keil's formulation of the relationship between language and ontological knowledge, nor did they show a capacity to make absolute judgments about the acceptability of sentences. The flexibility of language provides a range of sentence interpretation that escapes the boundaries of a rigid hierarchy.

(Gerard & Mandler, 1983, p. 119-120)

#### ADDITIONAL SUPPORT FOR THE M-CONSTRAINT

The message that Carey (1983, 1985, 1986) delivered in her responses to Keil's research is that his entire theory is not viable because the M-constraint in fact does not govern the ontological knowledge structure in humans. If the M-constraint is actually a meaningless construct then Keil's theory of ontological knowledge does become worthless; the theory revolves around this structural constraint. Keil apparently took the criticisms of Carey, and of Gerard and Mandler (1983) under advisement when he considered future projects. This section will review Keil's research after the publication of his book in 1979.

In 1983 Keil (1983a) investigated the relationship between inferences children make on word meanings and their ontological knowledge, and whether ontological knowledge assisted the acquisition of word knowledge. Specifically,

what was being asked was (1) whether the hierarchical relationship between ontological categories demonstrated in previous studies with children would be instrumental in guiding word knowledge acquisition, (2) whether category differentiation would occur systematically and (3) whether differentiation would indicate downward predicate movement. Children were first asked to give the definition of an unknown word embedded in verbal context, and second, to answer a series of questions about the ontological properties of that word. Results supported Keil's hypothesis that concept acquisition would be influenced by ontological knowledge. The ontological knowledge structure that emerged in children's inferences was hierarchically organized, ontological knowledge of younger children was less differentiated than that of older children, and the change over age in ontological knowledge corresponded to those levels of development indicated in previous child studies (Keil, 1979). Moreover, even children who reported to have no knowledge of a word's meaning could still answer questions about the ontological properties of that word with responses representative of their developmental level. For example, kindergarten children who responded with "I don't know" when asked to define a target word could still tell the examiner whether the word represented something alive or not. Keil stated: "inferences from ontological knowledge only provide a framework within which much finer

differentiation about meaning must occur. Put differently, ontological knowledge provides both a core meaning and the boundary conditions in which further refinements of the meaning can develop." (1983a, p. 123)

Keil (1983b) extended his investigation of ontological knowledge by examining differentiation of ontological categories more carefully. When collapsed categories begin to separate into those distinctions that more closely represent adult knowledge structures, does this occur term by term and predicate by predicate until a category is formed, or by the simultaneous branching of all terms and predicates to form a new category? In the first study the differentiation of event predicates from predicates requiring terms with physical dimension was investigated because of Gerard and Mandler's (1983) finding that more M-constraint violations occur when event predicates are involved than with any other predicate group. Twenty-four children and sixteen adults participated in this study. Results supported Keil's previous findings which demonstrated that both children and adults rarely violate the M-constraint, and that the resemblance of children's tree structures to that of adults increases with age. Also indicated by these results was that incorrect associations of physical object predicates with event terms and event predicates with physical object terms occurred significantly more often when applied to all four

predicates or not at all than when applied incorrectly to only one, two or three of the predicates ( $p < .001$ ). This result implies that the differentiation process occurs as a conceptual separation rather than as an individual distinction between a single predicate and a set of terms that eventually spreads to other predicates in the same conceptual category. When associations between both event and physical object terms with predicates were examined, incorrect associations for all four terms in a category, or no incorrect associations at all still occurred far more frequently than when the incorrect association was occurring for only one, two or three terms in a category ( $p < .01$ ); however, this separation was not as clear cut as that indicated for the predicate differentiation.

Further examination of these data (Keil, 1983b) suggested asymmetry in the differentiation of the two basic categories, events and physical objects. Event terms were more readily broken up, being paired with some of the physical object predicates and not others, whereas either all physical object terms were paired with event predicates or none were. (No fourth grade subject agreed that it was logical to pair a physical object term with an event predicate.) In addition, of the few M-constraint violations that were observed, each one involved an event taking a physical object predicate, like the storm is black, rather than vice versa.

Keil (1983b), in an attempt to replicate the results of the first part of this study examining the differentiation of event predicates from predicates requiring terms with physical dimension, conducted a similar investigation with a different sample with the same characteristics as in the initial study. In this study, the category of physical objects also included the categories of plant, animal and human besides inanimate object. No adults violated the M-constraint in this investigation and, again, children very infrequently violated the constraint. However, the results of the first study suggesting simultaneous differentiation of entire categories was not replicated. Predicates misapplied to terms were frequently split within a category, but terms were rarely misclassified. Of those terms that were incorrectly misclassified, however, none resulted in M-constraint violations. Thus, they were misclassified with all predicates of a category. For example, a rock that was reported to be able to be hungry could also be sleepy and excited. Keil drew no firm conclusions from the results of these two studies, especially in light of the small sample sizes, and decided to investigate further.

In the third study (Keil, 1983b) Keil used first grade subjects and the same stimuli as were used in the first two studies described above. The M-constraint was violated by two of the eight subjects, and a total of only three times.

Few or no M-constraint violations were expected. Results were similar to those found in the first study. When misapplications occurred they generally occurred with all predicates being misapplied to terms. The terms clustered more in this study than in the first two, however they still clustered less dependably than the predicates did. One unexpected result was that ontological knowledge structures of these six-year-old children was less mature than expected. They misapplied predicates to terms about as frequently as the kindergarten subjects did. In this study, as in the second study, the living things predicates almost never dominated animals and not plants. On the other hand, when animal predicates were misapplied, they frequently dominated both plant and animal terms. Keil suggested that these results provide counterevidence to the proposal that there is a transitional period in grade one.

Keil (1983b) appeared unsure of exactly what conclusions to draw from the results of these three studies and the differences between them. He suggested that conceptual distinctions as manifested in predicate application emerge as a "single conceptual insight". Following this development is the gradual application of terms to the predicates of a particular category. Thus, new distinctions surface and old ones become more refined. But the most noticeable phenomenon that emerged from all of these data is the constraint that seems to govern the

ontological development at all ages regardless of the differences in conceptual insights across age groups.

One of Carey's (1986) arguments opposing the M-constraint as the structural constraint on ontological knowledge related to the frequent violations she suggested occurred when spatial terms were applied to objects like shadow or hole that had spatial properties but no physical substance. Keil and Kelly (1986) agreed with Carey's objection that M-constraint violations did tend to occur with spatial predicates. Therefore, they suggested that the task at hand was to determine whether violations were actually common when spatial predicates were involved. They selected terms at random from a common English dictionary and paired them with the terms heavy, tall, and long. Subjects were asked to judge the sensibility of each sentence, and were encouraged to look up unknown words in the dictionary. Results indicated that 95% of the judgments made adhered to the M-constraint. Because Keil and Kelly found only one subject who would not pair the predicate is long with human beings (this resulted in 83% of his judgments violating the M-constraint), they suggested "that Carey should find more of these cases is most likely a consequence of her subjects confusing the pragmatically odd with the semantically odd." (p. 175) Nineteen out of twenty instances in which subjects used a dictionary resulted in judgments conforming to the M-

constraint, according to Keil and Kelly, even though dictionaries generally do not supply the ontological properties of a word in a definition. They state:

This pattern of results suggests that when individuals attempt to learn the meanings of novel words, an initial bias is to assume that the physical objects, event, and abstract object categories are non-intersecting sets, just as the M-constraint would predict. (p. 177)

Thus, Keil and Kelly examined that part of the ontological tree that seemed to be the most precarious and found comparatively few violations. They concluded that these results actually lend support to the hypothesis that the M-constraint structures conceptual knowledge at an ontological level.

Another argument Carey (1983) had used against the M-constraint is that this constraint, given it actually governs conceptual knowledge, should prevent the production of violations among predicates and terms in language via word meanings. Keil and Kelly (1986) replied that the M-constraint does continue to influence word meanings even with ambiguous terms like Russia and book -which Carey considered obvious violations- by placing the term in a context that removed the ambiguity. In other words, when one refers to Russia, the political system, it is considered to be red only metaphorically speaking. When the geographical region of Russia is referred to as red,

however, it can be assigned a truth value without necessitating a metaphorical interpretation. The claim is that the context will eliminate the ambiguity. Keil and Kelly added that it would be more likely for category confusion to occur with terms in categories close in proximity on the ontological tree than with those far apart. Those terms that Carey has claimed produce M-constraint violations due to a confusion of category membership tended to belong to categories far from each other on the tree. To return to the example Russia, this is either a physical entity or an abstract object, categories that are not adjacent on the ontological tree.

Nonetheless, according to Keil and Kelly (1986), the possibility for conceptual confusion with terms like Russia, that can logically use predicates from different ontological categories, needed to be investigated. Thus, a study was designed to investigate whether statements that combined predicates from different categories like It is mountainous and empirialistic were considered conceptually more awkward than statements that included predicates from the same categories like It is mountainous and cold. Keil and Kelly report that cross-category predications were invariably considered more awkward than within-category predications. They state:

"When elements from two ontologically distinct categories frequently co-occur in the real world,

language users often adopt the convention of using one term to refer to both, especially when one of the two categories is developmentally more basic than the other." (p. 179)

They concluded: "The most important point here, however, is the recognition that the M constraint primarily affects concepts and only secondarily word meanings." (p. 179)

In defense of the M-constraint against one more allegation from Carey (1983, 1985) that the statement The man is pregnant is an ontological error, Keil and Kelly (1986) provided more evidence to support their claim. They proposed that this statement is a contradiction and not an ontological anomaly. The clash within the statement The man is pregnant occurs due to linguistic contradictions between the meanings of the words involved and not because of conceptual contradiction, according to Keil and Kelly. They cited an unpublished doctoral dissertation (Baynes, 1984) as evidence that linguistic contradictions and anomalies can be distinguished from one another. Baynes investigated the capability of Broca's and fluent aphasics of differentiating contradictions from plausible statements versus differentiating anomalies from plausible statements. According to Keil and Kelly, Baynes' results indicated that fluent aphasics had more difficulty than Broca's aphasics in differentiating plausible from anomalous statements, whereas the opposite was true when the subjects were

distinguishing plausible statements from contradictions. These results were reported to be as Baynes predicted, given the nature of the two handicapping conditions. Thus, Keil and Kelly suggested that Baynes' study lends support for the claim that anomalies occur at a conceptual or ontological level and contradictions occur at a lexical or semantic level. They stated:

It seems as if these two types of information are represented in different ways and perhaps in different parts of the brain. Since the M constraint is fundamentally conceptual in nature, the existence of contradictions does not stand as a relevant violation.

(p. 180)

Additional support for Keil's claim that conceptual knowledge is constrained at an ontological level was found in a series of studies that were conducted investigating the features children attend to when learning the meanings of words (Keil, 1986b; Keil, 1989; Keil & Batterman, 1984). Results of the initial study (Keil & Batterman, 1984) investigating children's attention to either characteristic or defining features of a word indicated that, in general, the subjects, regardless of age (participants included kindergarten, second, and fourth grade children) relied on characteristic more often than defining features when making a decision about whether a definition was appropriate for a concept. The data also have suggested,

according to Keil and Batterman, however, that a shift in the focus of characteristic to defining features when developing word meanings did occur over time. Older children appeared to rely on defining features of concepts more than younger children. Moreover, Keil and Batterman declared that for many concepts the shift was distinct in that very few kindergarten subjects observed defining features whereas nearly every fourth grade subject did. The shift also was reported to occur at different times for different concepts such that children's focus on defining features came at a later age for some concepts than for others.

In a continuation of the above line of research Keil (1986b) hypothesized the following: "Here I want to suggest that from an early age we have a natural bias to try to go beyond characteristic features, and believe that there is a deeper causal structure that is the essence of meaning, even when there sometimes may not be." (p. 138) He investigated his claim by comparing children's knowledge of natural kinds and artifact terms and their associations of characteristic and defining features to these two types of categories. The methodology included a story about a "discovery" of natural kind terms, and artifact terms in which the animals or objects appeared to be and act like or function like one thing, but actually had the blood of or were made out of the same materials as something else. A

decision regarding the identity of the animal or object was required. Results indicated a distinct shift across age in judgement as to whether the identity of a natural kind depended on superficial or characteristic features, older children having judged that the identity had remained constant. Almost none of the subjects of any age group made the judgement that the discovery was relevant to the identity of an artifact. The results were replicated using stories involving a transformation of natural kind to natural kind or artifact to artifact. (An example of this would be the transformation of a lion to tiger after shaving and dying its hair.) Keil concluded that as children's knowledge bases increase their judgments also change to include what is essential in determining the identity of an object. Thus, the determination of identity of a natural kind includes some notion of causal structure, whereas with artifacts, function determines identity which is in turn determined by perceptual features.

Keil (1986b, 1989) did not remain content with the conclusion that young children focus on perceptual features alone when determining the identity of a natural kind, however. He proposed that there was some type of conceptual framework that was accurately guiding these children's judgments concerning some of the basic conceptual properties of the terms. The transformation

study was copied using stories about real and toy plants and animals being changed into either an animal, a plant or some kind of artifact like a toy tiger. Results indicated that young children were nearly as willing to accept that the identity of a natural kind has changed after a superficial transformation as they are to accept the change in identity of an artifact, only when the change in natural kind remains within the same category. They did not accept the identity change after the transformation when the change crossed ontological categories. For example, kindergartners accepted that the identity of a lion could change to a tiger after shaving and dying its hair, but did not accept that the identity of a porcupine could change to a cactus, or that a toy tiger could change to a real tiger. Keil (1986b) concluded from this series of studies that children's judgments about objects are determined by more than just perceptual features. He stated:

From the start they seem to have some global underlying principles that distinguish broad categories such as plants, animals, and artifacts, but they need to learn a great deal more to go beyond characteristic features in distinguishing a horse from a zebra. (1986b, p. 151)

More evidence for the existence of a hierarchically organized ontological knowledge structure in humans can be found in a paper published by Kelly and Keil (1985), and in Keil's (1986c) study of the acquisition of metaphor. Kelly

and Keil analyzed mythological transformations found in the Metamorphoses and Grimm's Fairy Tales in terms of ontological categories and have discovered a relationship between the distance from the original category and another category on the ontological tree, and the probability that it would be transformed into a member of that category.

For example, in myth, a conscious being is more likely to be transformed into an animal than a plant, and much more likely to be transformed into an animal than into an abstract object. Kelly and Keil concluded from this finding that ontological knowledge structure is partially responsible for these transformations.

Results of Keil's (1986c) investigation of the acquisition of metaphor in children led to a number of conclusions. First, children do not acquire metaphor as an ability that emerges at a particular point in development, but rather they acquire the understanding of different metaphors at different times depending on the subject matter. Moreover, acquisition of metaphor is dependent on the ontological category from which the subject matter comes. Thus comprehension of a metaphorical relationship generally occurs across an entire category. What is happening, according to Keil, is that the acquisition of metaphor involves an interaction between ontological categories rather than just specific terms within these categories. Additionally, Keil indicated that the order in

which categories are comprehended in metaphorical expression is the same as the order in which conceptual distinctions emerge. Previous research (Keil, 1979) has shown that the first conceptual distinction made by young children is the living/nonliving distinction. Accordingly, children also seem to have comprehended metaphors that portray inanimate objects with characteristics of living things. An example of this type of metaphor would be the expression The car is sick. Even kindergartners can give a nonliteral interpretation of this statement. Keil concluded:

More broadly, these findings indicate that many, if not all, concepts do not develop in isolation. They develop their meanings and nuances largely as a consequence of the relations they come to have with other concepts within the same conceptual domain; and that once one concept in a domain can be manipulated or construed in a novel way, such as through metaphor, that insight is easily shared with other concepts in the same domain.

(p. 95)

Substantial evidence in support of the M-constraint and the hierarchical organization of ontological knowledge has been provided by Keil and his colleagues. Keil's research even supports the hypothesis that ontological knowledge structure influences concept acquisition at the level of acquiring the meaning of words. Keil and Kelly (1986), in

commenting on results of a previous study of Keil's, state that "children seemed to use their ontological knowledge in a surprisingly effective manner to guide their inductions about the meanings of the words." (p. 181) In other words, the M-constraint must be influencing the acquisition of vocabulary in some manner. If one's ability to acquire vocabulary is actually a skill that is highly correlated with intellectual potential, then perhaps this structural constraint on ontological knowledge influences what is generally considered to be intellectual performance. What kind of evidence is there to support the hypothesis that there is a functional relationship between the acquisition of vocabulary in context and intelligence? Even though the data supporting this hypothesis are limited, they do indicate that there is a significant positive relationship between the two variables.

#### INTELLIGENCE AND THE ACQUISITION OF WORD MEANING

Vocabulary is a legitimate representative of intelligence if intelligence is actually an identifiable construct. As discussed in Chapter 1, a vocabulary subtest is included in most tests of intelligence that contain a verbal component, and it is often the highest correlate with overall intelligence quotients. It is argued that vocabulary is as good predictor of intelligence as it is because of the skill required to acquire word meanings (Jensen, 1980; Sternberg, 1984a, Sternberg & Davidson,

1982). The acquisition of the meaning of a new word is a form of verbal problem solving, according to Sternberg and Powell (1983), in which relevant information is identified and made useful. Thus, comprehension of the process by which one acquires the meaning of a word in context becomes important to those investigating intelligence.

In the componential subtheory of Sternberg's (1985) Triarchic Theory of Human Intelligence the process by which word knowledge is acquired was briefly discussed.

Sternberg and Powell (1983) suggested that the three kinds of components, metacomponents, performance components and knowledge acquisition components, interact in vocabulary acquisition. However, they claim that the knowledge acquisition components are most central to this process.

(These are the components involved in all knowledge acquisition, according to Sternberg, not only the acquisition of word knowledge.) These components are referred to as selective encoding, selective combination, and selective comparison. Selective encoding involves the ability to recognize and separate relevant from irrelevant incoming information. Selective combination involves the organized integration of encoded information. Selective comparison involves the retrieval and combination of old information with new information into a coherent whole. Metacomponents regulate the functions of the other two component categories, according to this theory. The

performance components are the processes involved in task performance.

In the process of acquiring word meaning from context, the knowledge acquisition components operate on cues that exist in the contextual setting. These cues either facilitate or inhibit the acquisition of the unknown concept depending on how effectively the knowledge acquisition components are operating. The cues can be internal, information found within the word itself, and also external, information found within the context. The value of these cues as hints to the meaning of the word is determined by what Sternberg and his colleagues (1983) refer to as moderating variables. A variable like frequency of an external cue interacts with the knowledge acquisition components to determine the value of that particular cue.

Thus, the likelihood of making an accurate inference depends on the use as well as the nature of the context in which the word lies. Individual differences in the ability to make accurate inferences about word meanings in context, according to Sternberg and his colleagues (1983), are a result of differences in information processing ability. They suggested that an individual who is proficient at inferring a word's meaning from context, is proficient at encoding relevant information, combining this information in a meaningful sequence, and comparing the new information

with previously stored material. Success is also dependent upon proficiency of the performance components and metacomponents. Hence, an interaction between the three types of component processes determines task proficiency, according to this theory.

Support for Sternberg's theory as it relates to the acquisition of vocabulary in context was provided by a study (Sternberg, et al, 1982) in which (1) prediction of definition quality was correlated with the quality and strength of contextual cues and moderating variables, and (2) definition quality was correlated with scores on standardized tests of vocabulary, reading comprehension, and intelligence. Four different types of passages were used: literary, newspaper, science, and history. Prediction of definition quality was reported to be highly correlated with quality and strength of cues and moderating variables across all passage types. The range of correlations was .92 for literary passages to .74 for newspaper passages. The correlations between definition quality (collapsed across passage types) and test scores was considered high as well: .56 for vocabulary; .65 for reading comprehension; and .62 for intelligence. Thus, according to results of this investigation, the ability to infer word meanings from context is not only significantly correlated with a measure of vocabulary and reading comprehension, but is also significantly correlated with

some measure of intelligence.

Van Daalen-Kapteijs and Mohr (1981) proposed a model for explaining individual differences in acquiring word meanings from context that is similar to that of Sternberg and his colleagues (1982). Results of their investigation indicated that there was a difference between the way in which high and low verbal children use contextual information. High verbal children were reported to formulate hypotheses about unknown words that are adjusted as new information is obtained. Low verbal children, on the other hand, were reported to attempt to fit new information to their initial hypothesis rather than to adjust any hypotheses. Two separate studies were conducted, only one of which indicated significantly higher decontextualization scores for high verbal children. Although no significant differences were indicated between the two groups in one of the two studies, Van Daalen-Kapteijs and Mohr hypothesized that high verbal children are more skilled than low verbal children at inferring unknown words from context due to their ability to separate and meaningfully integrate parts of the context with existing information.

Developmental effects have also been noticed in the ability to infer word meanings from context (Sternberg, 1984b, Werner & Kaplan, 1950). Sternberg reported that younger children appear to be less able than older children

to separate relevant from irrelevant cues. Older children organize cues more efficiently and are more skilled at retrieving stored information. Werner and Kaplan also have observed that older children are better able to organize incoming information and separate relevant from irrelevant components of the verbal context. Thus, it is reported by both groups of researchers that through the process of separation and organization the word meaning is inferred.

Researchers seem to agree that vocabulary development is an important part of intellectual growth. Many of them also seem to agree that it would be beneficial to educate children in the acquisition of vocabulary from verbal context. Sternberg, et al, (1982) suggested that if individuals improve their ability to acquire meaning from context through their awareness of organization of contextual cues, they may not only increase vocabulary, but improve their general problem solving skills as well. Gibe and Arnold (1979) indicated that a contextual method for vocabulary building has been more effective than other methods of teaching vocabulary, including definition memorization, for both good and poor readers. Crist and Petrone (Crist & Petrone, 1977; Crist, 1981) found that college students who learned word meanings from context were better able to transfer their learning to other contexts than were students who memorized word definitions. O'Rourke (1974) argued that no single method of teaching

vocabulary is best and thus, should not be used exclusively. However, he also suggests that instruction in the use of contextual cues should accompany other training methods in vocabulary development. Although O'Rourke did not specify a method for teaching external decontextualization skills, he did propose early and continual instruction in internal decontextualization, as in the teaching of prefixes, suffixes and root words. He predicted that children who experience this kind of training will develop a habit of analyzing and synthesizing internal contextual cues, which will, in turn, facilitate the accurate inference of unknown words' meanings.

In sum, there is some evidence that the ability to acquire vocabulary in context is significantly correlated with intellectual functioning, whether intelligence is measured by some conventional intelligence test or by some form of verbal comprehension. Some evidence suggests that this ability is a form of problem solving in that it appears to be an ability to separate relevant from irrelevant information and to organize this information. There is also evidence that there are developmental effects of the ability to extract meanings of words from verbal context, as there is evidence that intellectual functioning improves with age. And finally, experts recommend that children be instructed in the skills needed to learn word meanings from context.

## SUMMARY

The notion of faculty psychology is currently considered a viable answer for explaining at least some aspects of human cognition, according to some theorists (Chomsky, 1980, 1988; Fodor, 1983; Keil, 1981). It is proposed by these individuals that there are specific domains of cognition that are governed by constraints specific to a single domain of knowledge. Constraints do not cross domains and abilities within a domain are universal and constant across the human population. Ontological knowledge is an example of a content area governed by a domain specific constraint, according to Keil (1979).

Keil (1982) suggested that when a constraints approach to cognition is taken, intelligence could be misunderstood. He proposed that intelligence and cognition are not synonymous, but rather that intelligence is a subset of cognition. He indicated that there are some aspects of cognition (those governed by domain specific constraints) that have characteristics that may be antagonistic to what is generally considered intelligence. One fundamental characteristic is the lack of variability. Variability is an essential element when intelligence among humans is considered, however, those areas of cognition that are governed by domain specific constraints, according to Keil, are constant within the human population.

Ontological knowledge is an area that is governed by a

domain specific constraint and that exhibits little individual variability among humans. The constraint on ontology was originally described by Sommers (1959, 1963, 1971), and is referred to by both Sommers (1971) and Keil (1979) as the M-configuration or the M-constraint. Keil (1983a) argued that this constraint plays a role in the acquisition of word meanings. According to Keil, when inferring a word's meaning from context children naturally make inferences about the ontological properties of that word, and that these inferences are governed by the M-constraint. He provided substantial support for his hypotheses; however, his claims were also refuted by Carey and others. Even though Carey's counterclaims are supported with data, Keil did not retreat from his position. It appears as though, in serious consideration of Carey's objections, more questions were generated, and thus, more research projects conducted.

One reliable predictor of intelligence is vocabulary, or the number of words one knows the meaning of. It has also been suggested that the ability to acquire vocabulary from context is an even better predictor of intelligence. Thus, if (1) ontological knowledge is an area of knowledge that is constrained by a domain specific constraint, and therefore, does not exhibit much variability among humans; (2) the constraint on ontological knowledge contributes to the process of inferring word meanings from context; (3)

the acquisition of vocabulary in context is a valid representative of intelligent behavior; and (4) intelligence is an attribute that varies among humans, then perhaps there are aspects of what is generally considered intellectual behavior that are actually entirely separate aspects of cognition.

### CHAPTER THREE

#### METHODS AND PROCEDURES

There are obvious methodological obstacles an investigator has to overcome to attain validity when a study involves measuring the ability to define unknown words in context. When such an investigation is expanded to include the evaluation of ontological knowledge it becomes even more difficult to design a study with minimal threats to internal validity. Previously, an investigation was conducted in which not only decontextualization skills in children were examined, but ontological knowledge of unknown words in context were examined as well (Keil, 1983a). As was indicated in Keil's 1979 inquiry, when the topic of investigation is ontological knowledge the methodology is trickier when the subjects are children than when they are adults. For example, Keil demonstrated that the contrast between anomaly and falsehood can be conveyed to adults without too much difficulty, and subsequently, they can be asked to remark about their intuitions regarding the ontological awkwardness of a series of statements. Likewise, most adults can be effectively cautioned against the use of metaphors when drawing conclusions about the sensibleness of their intuitions. Thus, it is possible to obtain reliable estimates of the ontological knowledge structure of adults.

It is also possible to capture children's intuitions

about ontology (Keil, 1979), even though it may be a more difficult task than that of capturing adults' intuitions. Keil used a technique that forced a distinction between truth, falsehood and anomaly with a series of questions that vary depending on individual responses. A flow chart illustrating this technique is shown in Figure 3.

This chapter contains the methods and procedures employed in this investigation. A description of the methodology proceeds as follows: the research questions being investigated; development of the materials; the pilot investigations; and finally, the general investigation of vocabulary acquisition in context and its relationship to ontological knowledge.

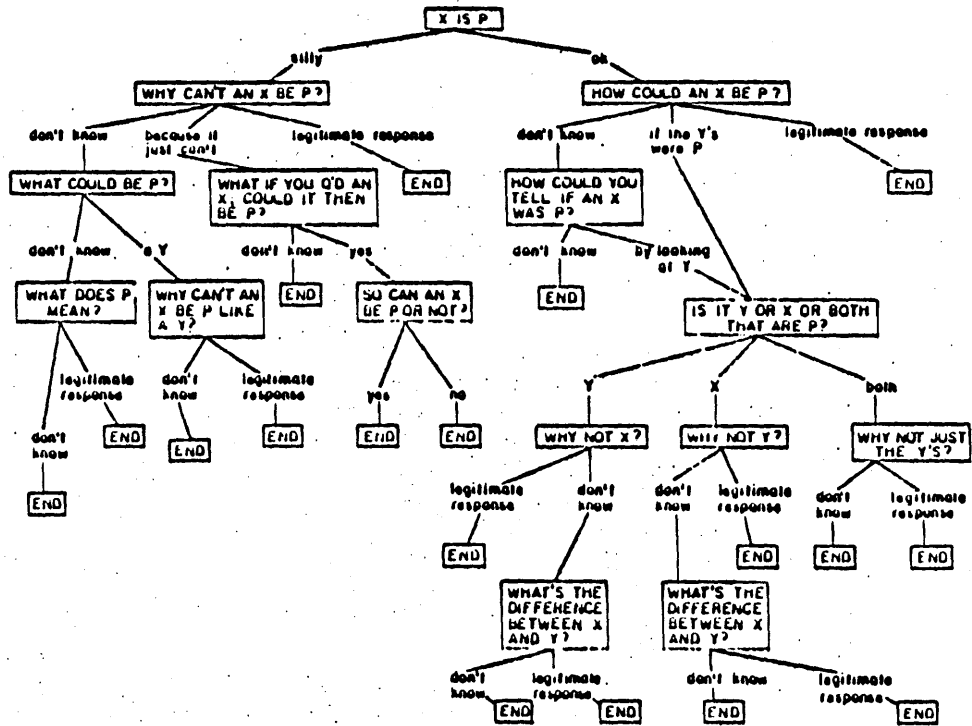
#### RESEARCH QUESTIONS

The following research questions guided this investigation in an attempt to determine the relationship between vocabulary acquisition in context and constraints on cognition.

(1) Is there a relationship between the ability to acquire unknown words in context and intelligence?

(2) Are the subjects' judgments regarding the ontological properties of the target words governed by the M-constraint?

(3) Are these judgments consistent with Keil's (1979, 1983b) findings indicating a developmental trend in the ontological knowledge structure that suggests greater



Flow chart showing probe question procedure

Figure 3. Reprinted, with permission, from Keil (1979).

differentiation of ontological categories with age?

(4) If vocabulary acquisition in context does appear to be constrained by a structural constraint at the ontological level, does this constraint apply across levels of intelligence?

#### DEVELOPMENT OF MATERIALS

##### SELECTION OF TARGET WORDS

Numerous studies have been conducted investigating children's ability to deduce the meanings of unknown words in context (Gibe & Arnold, 1979; Keil, 1983; Sternberg, Powell, & Kay, 1982; Van Daalen-Kapteijns & Mohr, 1981; Werner & Kaplan, 1950). Some have been done with neologisms, or made-up words (Sternberg, et al, 1982), and others with real words whose meanings are unknown to the subjects involved (Keil, 1983a). There are apparent advantages to both approaches (Cook, Heim, & Watts, 1963; Sternberg et al., 1982), however, as long as it can be determined that the target word is unknown to the subject, it is considered more advantageous to use a real word than to use a neologism. Keil (1983) argues that real words should be used in a task measuring decontextualization skills, if for no other reason, to give the subject the opportunity to learn the meaning of a new word.

The target words used in this investigation were the following real words: conferva, dossier, fop ghee, ridotto, and tench. Part of the criteria that determined the

selection of these words was that their exposure in common English discourse be infrequent so that the meanings would be known to few if any subjects who agreed to participate in the study. [Definitions of the target words were obtained from the English section of the Random House Dictionary of English Language (1983).] Additionally, it was necessary that each of the following six ontological categories be represented by a single target word: event, liquid, solid object, plant, nonhuman animal, and human being. These categories were chosen to be represented in order to investigate replicability of Keil's (1979, 1983b) results indicating specific patterns of ontological differentiation with age. Category distinctions being examined were the following: living-nonliving; plant-animal; liquid-solid object; nonhuman animal-human being; and event-physical object. A prototype ontological tree displaying separation of the six categories is illustrated in Figure 4.

#### CONSTRUCTION OF PASSAGES

The original six passages, designed for deriving meaning of words by decontextualization each containing a single target word, were constructed by three college graduates. These individuals were given the definitions of a target word and asked to compose a literary passage two to four sentences in length that contained the target word along with "hints" about the meaning of the word. The passage

authors were instructed to avoid any specific references to the word's definition. They were also told that the passages would be read to elementary age children who would then be asked to guess the target word's meaning. Each author was given a different target word to include in a passage. Two authors composed more than one passage.

#### PILOT STUDY

##### PHASE I

The purpose of the first phase of the pilot study was to ascertain any obvious flaws in the scoring criteria for or content of the original six passages. An initial set of criteria for scoring definitions was developed prior to data collection.

Five subjects aged five years six months, five years eleven months, seven years one months, nine years five months and twelve years participated in the first phase of the pilot study. The age range of these initial participants was intentionally greater than the range displayed in the general study in order to screen passages that were either too easy or too difficult. None of these subjects knew the meaning of any of the six target words prior to hearing these words in context. The passages were read to each of the five children who were then asked to define the target words following the reading of each passage. Based on their responses scoring criteria for three of the passages and the content of two of the

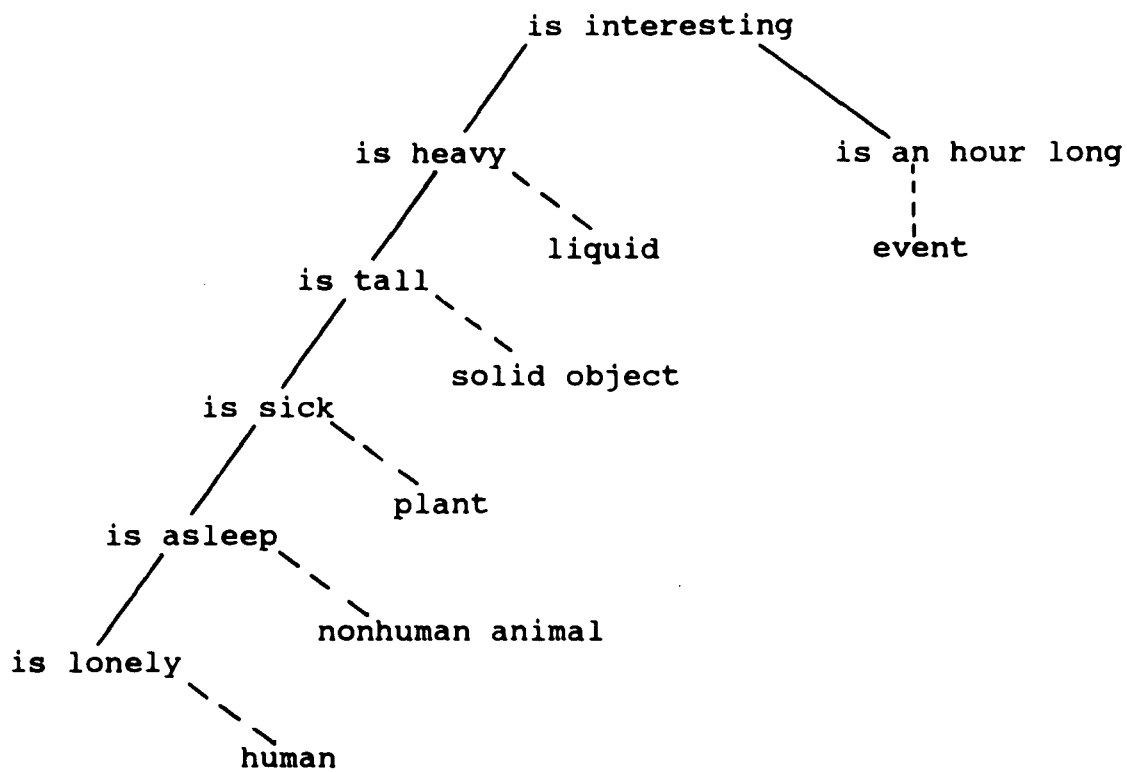


Figure 4. Prototypical ontological tree including the six target word categories and seven predicates.

passages were modified.

## PHASE II

Fifteen children participated in the second phase of the pilot study. Subjects were between the ages of six years five months and ten years six months of age. This age range was representative of the age range of subjects who participated in the general study.

The passages and scoring criteria modified from phase one were used in phase two of the pilot investigation.

(Tables 1 and 2.) Subjects were asked individually to define each target word. Specifically, the subjects were asked, "Do you know what a (target word) is?" Any subject who had obtained a score of one or greater on any of the target words according to the scoring criteria listed in Table 2 prior to hearing the words in context would have been eliminated from the study. However, even though several subjects did guess possible meanings of the target words, no subject was eliminated from the pilot study due to previous knowledge of the words.

The subjects were read the instructions given in Table 3. These instructions were repeated until subjects heard passages containing all six target words. Subjects obtained a score of three if they clearly stated in their definition all concepts in the concept column, Table 2. A score of two was obtained if two concepts were clearly stated, and a score of one was obtained if only one concept

was clearly stated. A score of zero was given for definitions that included a clear statement in which none of the concepts were mentioned.

Means and standard deviations were computed separately for definitions of each target word. Passages with means of greater than two and less than one, and/or passages with standard deviations of less than .60 would have been discarded from the study. These criteria were established to insure significant variability in scores on target word definitions, and the elimination of passages that were either too easy or too difficult. All six passages met the criteria, therefore, they were used in the general study.

#### GENERAL STUDY

##### SUBJECTS

Parental consent forms were sent home with all students from grades one, three, and five who attended two parochial schools in Tucson, Arizona. Students from each of the three grades who returned parental consent participated in the general study. Thirty-four first grade, 27 third grade, and 27 fifth grade subjects participated. Two first grade and two third grade subjects were eliminated from the final analysis due to incomplete interviews. Thus the final sample size included a total of 84 subjects.

The first grade sample consisted of 16 female and 16 male subjects. The mean age was seven years zero months. The age range was six years four months to seven years eight

months. The third grade sample consisted of 15 female and ten male subjects. The mean age was eight years eight months. The age range was eight years two months to nine years six months. The fifth grade sample consisted of 17 female and ten male subjects. The mean age was ten years ten months. The age range was ten years four months to eleven years nine months.

Keil (1979, 1983a, 1983b, 1986b), in nearly all of his investigations of ontological knowledge development, has used kindergarten, second and fourth grade subjects. Therefore, for the purpose of investigating replicability of Keil's results across age groups, first, third and fifth grade levels were chosen. Five years age range was also considered to be large enough to investigate developmental differences in ontological knowledge structure as have resulted in previous investigations (Keil, 1979, 1983a, 1983b).

#### MATERIALS

Six passages used in the pilot investigation (see Table 1) were used to obtain measures of decontextualization ability for the present study.

To gain a measure of ontological knowledge structures, the following predicates were used in sentences with each target word:

is an hour long

is interesting

Table 1

---

Passages

1. He waded through the water for at least a mile sorting through everything he saw below. Finally he found what looked like the right species and pulled it out of the wet ground by its roots. He dried himself off and walked home, wondering as he walked whether the conferva he found would help his injured wife.
  2. The old woman hunched under the weight of the dosser full of clay pots. She walked slowly and purposefully down the dusty road to market, just as she had done every week for the last sixty years.
  3. The silly fop waltzed past us the same time every day after he got off work. He always appeared to be admiring his reflection in the store windows as he would adjust his tie and comb his hair back.
  4. She knew she could not get the ghee she needed until her sister milked the cows. This was always early in the morning so she wasn't worried. When she finally got it, she had to boil it for several minutes and let it cool before pouring it into the batter. Within an hour the bread was done and everyone could have breakfast.
  5. A few centuries ago groups of people would gather for a ridotto. Colorful but unusual outfits were worn. It was most exciting, however, because even though everybody usually knew each other nobody ever really knew with whom they were dancing.
  6. The tench rarely swam to those parts where the warm sun was felt or daylight was seen. Those were the dangerous parts of the lake and those parts where food was not available.
-

Table 2

## Criteria for Scoring Target Word Definitions

---

<u>Target Word</u>	<u>Concepts</u>	<u>Dictionary Definition</u>
<u>conferva</u>	(1) plant (2) lives in the water (3) has healing power	Any simple filamentous green alga. A certain water plant supposed to heal wounds.
<u>dosser</u>	(1) something for carrying objects in (2) medium to large in size (3) worn on one's back	A basket for carrying objects on the back, pannier.
<u>fop</u>	(1) a person (2) male (3) vain, concerned about appearance	A man who is excessively vain and concerned about his manners and
<u>ghee</u>	(1) a product generally found in bread (2) a milk product (3) a liquid milk product or milk that needs to be boiled for purification	A kind of liquid butter made from the milk of cows or buffaloes and clarified by
<u>ridotto</u>	(1) social event (party) (2) music (3) masquerade or costumes	A public ball or dance with music and often in masquerade, popular in the 18th century.
<u>tench</u>	(1) fish (2) eats or lives off bottom (3) lives in fresh water	A fresh water cyprinoid fish.

---

Table 3

## Passage Instructions for target word definition.

---

Listen to me while I read something to you.\*  
(Passage will be read to subject.)  
Remember when you were asked what a (target word)  
meant. Did you hear the word (target word) in those  
sentences I read to you?  
(If the subject responds "yes" the examiner replies:  
"The word (target word) was in those sentences, wasn't  
it?".)  
(If the subject responds "no", the examiner replies:  
"Well, the word (target word) was in those sentences.")  
Now I'm going to read the same thing to you again.  
Listen carefully, and when I'm through I want you to  
tell me everything you can about a (target word).  
(Passage will be read to the subject a second time.)  
What is a (target word)?  
(Subject's response)  
Can you tell me anything else about a (target word).  
(If the subject responds with "I don't know.", the  
examiner will ask the subject to guess the word  
meaning. Any requests to read passages more than twice  
will be granted.)

---

\*Following the reading of the first passage this sentence  
was eliminated.

is heavy  
is tall  
is sick  
is asleep  
is lonely.

Following the statements including the target words and predicates first and third grade subjects were asked: "Is that silly or is that okay?". Fifth grade subjects were asked: "Is it possible for a (target word) to be (predicate)?" The order of presentation of predicates paired with each target word was random. Table 4 lists the six groups of sentences according to target word in the order in which they were presented to each subject.

The Peabody Picture Vocabulary Test -Revised (PPVT-R) (1981) was used as a measure of verbal aptitude. The normative sample consisted of children ages three to 18 years of age. A measure of internal consistency indicated reliability coefficients greater than .77 for all three age groups. Test-retest reliability coefficients were .78, .73 and .90 for grades one, three and five respectively. The correlation between the PPVT-R and the Stanford-Binet Intelligence Scale was .62, as stated in the examiners manual. The correlation between the PPVT-R and the

Table 4

## Sentences with target words and predicates

Conferva

The conferva is heavy.  
 The conferva is tall.  
 The conferva is lonely.  
 The conferva is interesting.  
 The conferva is asleep.  
 The conferva is an hour long.

The conferva is sick.  
 long.

Fop

The fop is heavy.  
 The fop is sick.  
 The fop is lonely.  
 The fop is an hour long.  
 The fop is asleep.  
 The fop is interesting.  
 The fop is tall.

Ridotto

The ridotto is asleep.  
 The ridotto is an hour long.  
 The ridotto is tall.  
 The ridotto is sick.  
 The ridotto is interesting.  
 The ridotto is heavy.  
 The ridotto is lonely.

Dosser

The dosser is tall.  
 The dosser is asleep.  
 The dosser is heavy.  
 The dosser is sick.  
 The dosser is lonely.  
 The dosser is interesting.

The dosser is an hour

Ghee

The ghee is interesting.  
 The ghee is sick.  
 The ghee is an hour long.  
 The ghee is heavy.  
 The ghee is lonely.  
 The ghee is asleep.  
 The ghee is tall

Tench

The tench is heavy.  
 The tench is an hour long.  
 The tench is sick.  
 The tench is asleep.  
 The tench is tall.  
 The tench is interesting.  
 The tench is lonely.

Wechsler Intelligence Scale for Children -Revised Full Scale Intelligence Quotient and Verbal Scaled score was .66 and .64 respectively, also as stated in the examiners manual. The Matrix Analogies Test -Short Form (MAT) (1985) was used as a measure of nonverbal aptitude. A measure of internal consistency indicated reliability coefficients greater than .80 for all three age groups involved in this study. Test-retest reliability coefficients were .79, .86, and .78 for grades one, three and five respectively. Content, construct and criterion-related validity were established for the MAT as stated in the examiners manual. Statistical support for the claim that this test is a measure of "general nonverbal ability" was provided.

#### Procedure

All subjects were administered the MAT and the PPVT-R in that order. To control for prior knowledge of the words, subjects were also asked whether they knew the meaning of each target word. Criteria for elimination of subjects based on previous knowledge of the target words was as stated in the pilot study. (Any subject who had obtained a score of one or greater on any of the target words according to the scoring criteria listed in Table 2 prior to hearing the words in context would have been eliminated from the study.) No subjects were eliminated from the general study for this reason.

Subjects met individually with an interviewer and

received the instructions stated in Table 3. The subjects were then asked a series of questions about the ontological properties of each target word immediately after being asked to define that target word. The initial statements read to each subject are given in Table 4. The sequence of questioning was comparable to that illustrated in the flow chart shown in Figure 3. Subjects were asked these questions regardless of their performance on the word definition portion of the task. The entire inquiry, including administration of the ability tests, lasted between thirty to sixty minutes for each subject.

#### INTERVIEWERS

Two females and two males trained in the interview technique illustrated in Figure 1 presented the passages, asked for target word definitions and completed the enquiry on the ontological properties of the target words. Training of the interviewers consisted of (1) an observation by each trainee of two interviews conducted by a trained interviewer, (2) a discussion of the procedure and outcome of the observed interviews, and (3) observations by the trained interviewer of two interviews conducted by the trainees.

Intelligence tests were administered and scored by the investigator.

#### SCORING

Two individuals who reached interrater agreement of .92

on definitions given in the pilot study scored target word definitions in the general study. Definitions with discrepant scores were scored again and a consensus was reached. Criteria for scoring definitions were identical to those stated in the pilot study. (See Table 2).

## CHAPTER FOUR

## RESULTS

Research question one, the relationship between ability to acquire unknown words in context and intelligence, was investigated using a Spearman rank difference correlation. This correlation coefficient was used because scores for target word definitions were considered to be ordinal level data. The correlation between the verbal ability measure and score on the decontextual task was .59 for first grade subjects, .40 for third grade subjects and .31 for fifth grade subjects. These values are statistically significant at the .01 level for grade one and the .05 level for grades three and five. The mean verbal IQ's were 114.7, 114.5 and 117.4 for grades one, three and five respectively. These values are approximately one standard deviation above the mean value obtained with the normative sample. The median decontextualization scores were five for grade one, eight for grade three and 10.5 for grade five. The maximum possible score on this task was 18. (Table 5)

The correlations between scores on the nonverbal ability measure and the decontextualization task were .31, .03 and -.03 for first, third and fifth grade subjects respectively. The correlation of .31 for first grade

Table 5

Means and correlations of definition quality with verbal and non verbal intelligence.

	Mean Verbal*	Median Nonverbal*	Median Definition Quality	Correlation with Definition Quality	
				Verbal	Nonverbal
<u>Grade</u>					
First	114.7	62.5	5.0	.59***	.31**
Third	114.5	61.0	8.0	.40*	.03
Fifth	117.4	32.0	10.5	.31**	-.03

\* The mean for the verbal ability measure is a standard score. The median for the nonverbal ability measure is a percentile rank.

The maximum value for the decontextualization score was 18.

\*\*p<.05

\*\*\*p<.01

respectively. The correlation of .31 for first grade subjects is statistically significant at the .05 level. Median percentile ranks for the nonverbal measure were 62.5, 61, and 32 for grades one, three and five.

Research question two, the relationship between children's ontological knowledge structure and the M-constraint was investigated by comparing the number of constructable predicability trees that would result in M-constraint violations with those that would produce no violations. Binomial probabilities were used to determine these comparisons. Twelve of the 84 subjects violated the M-constraint, according to the data. The intuitions of three subjects produced predicability trees with more than one violation, thus a total of 16 violations occurred. (See the Appendix for predicability trees of all subjects. See subjects 1-15, 1-24, 1-31, 3-5, 3-7, 3-12, 3-17, 5-1, 5-5, 5-9, 5-23 and 5-26 for violations of the M-constraint.) Only 4.4 in every 100,000 predicability trees constructable with seven predicates and six terms would not violate the M-constraint. The data indicated that 86% of the predicability trees constructed from the subjects' judgments did not violate the M-constraint. The probability that this occurred by chance alone is statistically significant ( $p < .001$ ).

Three first grade subjects violated the M-constraint producing a total of six violations. The intuitions of one

subject produced two violations, and another subject three violations. All six violations involved the event predicate such that event properties were assigned to some objects but not to others.

Three third grade subjects produced single M-constraint violations and one third grader produced two violations. One violation occurred, as was the case with the first grade subjects, when event properties were assigned to some objects and not to others. One violation was a result of assigning the predicate is lonely to what was defined as milk. Another violation occurred because, according to the subject, it was possible for an event to be lonely.

The third grade subject who produced two violations defined the term fop as reflection which he concluded could be lonely and tall but not heavy. The same subject defined the term conferva as protection which was thought of as heavy. Although the association of lonely with fop and heavy with conferva as the subject defined these two terms resulted in M-constraint violations, the predicate is lonely paired with the correct definition of fop, and likewise, the predicate is heavy with conferva do not result in anomalous statements.

Five fifth grade subjects produced single M-constraint violations. Four of these five violations involved the event predicate. In three of these instances subjects assigned living characteristics to things like parties and

fiestas which resulted in violations. For example, one subject reported that a fiesta could be asleep, sick and lonely but not tall or heavy. Another subject said that a party could be asleep but not tall, heavy or sick. In this particular situation, the subject was not only asked whether it would be the people at the party that were asleep, or the actual party that was asleep, but he was also asked whether the party would actually be asleep or whether calling it asleep would be the same as calling it boring. After the interviewer determined that the subject would not use a metaphor when judging whether the statement was sensible, the subject continued to agree that a party could actually be asleep. Another subject replied that if all the people at a party left then the party itself would be lonely. The other violation that involved the event predicate occurred when the subject agreed that it was sensible to pair all terms with the predicate is an hour long with the exception of the target word fop which he defined as man. This fifth grader concluded that a fop could not be an hour long because "he isn't made that way".

The final M-constraint violation among fifth graders occurred when a subject responded that a tench (defined as fish) could be sick, asleep, lonely and heavy but could not be tall. Several subjects who had defined a tench as a fish when originally asked whether it could be tall replied that it was not possible, however they changed their

response when asked whether the tench could be tall if it were measured when standing on its tail.

A total of sixteen M-constraint violations occurred from the intuitions of eighty-four subjects. Eleven of these violations (69%) involved the event predicate.

Only two of the 84 subjects would not guess the meaning of one or more of the target words after hearing them in context. Both of these subjects were first graders and the judgments of neither subject violated the M-constraint. The predominant ontological distinction that was made by both subjects was the separation of living from nonliving entities.

The third research question examined the developmental trend in ontological knowledge structure. Intuitions of the subjects indicated greater differentiation of ontological knowledge with age. Results of a Chi-square analysis evaluating differences in the number of expected versus obtained category differentiations by grade level showed statistical significance. ( $\chi^2=26.93$ ;  $p<.01$ ) The proportion of grade one subjects expected to make one, two or three category distinctions was fewer than the proportion who actually made those distinctions, whereas expected proportions for four or more distinctions exceeded the obtained proportions for the same grade. This trend was reversed for third and fifth grade subjects. (Table 6)

The judgments of all but four first grade subjects

signified a distinction between living and nonliving entities. Three first graders did not make the distinction and one subject defined all of the target words as living things, thus the distinction was not relevant. All of the third and fifth grade subjects made the living-nonliving distinction.

About half of the subjects in this study who included both plant and animal terms among their definitions assigned living things predicates like is sick and is asleep to both the plant term and the animal term. Additionally, 58% did not misapply the animal predicate is asleep to the plant term. A developmental effect involving the plant and animal predicates was also observed among these subjects. Not only did 58% of the first grade subjects make this distinction, 60% of the third graders and 84% of the fifth graders also made the distinction.

A total of 14 first grade, 16 third grade and 23 fifth grade subjects included a liquid and a solid object among their definitions. Thirty-five percent of these first grade subjects made the distinction between liquid and solid objects, whereas 62% of the third grade and 78% of the fifth grade subjects made such a distinction. (See Table 7).

Nearly all of the third and fifth grade subjects clearly distinguished the physical objects category from the event category. A partial distinction between these two

Table 6

Chi-Square Analysis showing number of ontological category distinctions per grade level.

		Number of Category Distinctions			
		1 & 2	3	4	5 & 6
GRADE  LEVEL	One	15*	8	7	2
	Three	3	5	11	6
	Five	1	4	9	13
TOTAL		19	17	18	21

\*The values in each cell are the obtained frequencies.  
 $\chi^2=26.93$ ;  $df=6$ ;  $p<.01$

categories was made by most of the first grade subjects. Sixty-two percent of the first graders assigned event properties to physical objects, whereas only 29% of this age group associated physical dimensions with events. These results are shown in Table 8.

Some other developmental trends that were manifested involved the predicate is lonely. Of those subjects who distinctly included the human category among their definitions (78% of the first graders, 96% of the third graders, and 100% of the fifth graders), none of the first grade subjects separated this category from the other ontological categories via the predicate is lonely and only eight percent of the third grade subjects and four percent of the fifth grade subjects made such a distinction.

The predicate is lonely was commonly associated with nonliving objects among first grade subjects, and less likely to be paired with nonliving objects among the older subjects. As was stated above, all but one first grade subject included both living and nonliving terms among their definitions. Forty-four percent of these first graders agreed that nonliving things could be lonely while 24% of the third graders and only seven percent of the fifth graders made such a determination. One first grade subject who had defined the target word dosser as a basket, when asked why it was silly for a basket to be lonely replied, "it can't be lonely because it has all the other

Table 7

Percentage of subjects distinguishing living from nonliving, plants from animals, and liquids from solids by grade.

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Category Distinctions	first		third		fifth	
	Total N*	%	Total N	%	Total N	%
Living-Nonliving	31	87	25	100	27	100
Plant-Animal	12	58	15	60	25	84
Liquid-solid	15	35	16	62	23	78

---

\*Total N is the number of subjects who included members of both categories among their target word definitions.

Table 8

Percentage of subjects by grade associating event predicates with physical objects and physical object predicates with events.

Category Distinction	First Total		Third Total		Fifth Total	
Event predicates with physical objects	N*	%	N	%	N	%
	32	59	25	16	27	7
Physical object predicates with events	16	25	22	4	26	0**

\*Total N is the number of subjects who included members of both categories among their target word definitions.

\*\*The M-constraint violators who misapplied the predicates "is lonely" and "is asleep" with the event term are included among those who did not misapply physical object predicates with events because they did not misapply the physical object predicates "is tall" or "is heavy" with the event term.

baskets around it." It was common for those first grade subjects who agreed that nonliving things could be lonely to support their judgments with a response such as the one stated above indicating that the state of loneliness depended only on the presence of other objects. The criterion for loneliness for third and fifth grade subjects, on the other hand, was usually the presence of feelings which, in turn, eliminated nonliving objects.

Research question four examined presence of the M-constraint in response patterns across levels of both verbal and nonverbal ability as well as differences in ontological category differentiation across ability levels. Both high and low functioning subjects produced predicability trees with no violations. The range of scores on the verbal ability measure of those subjects whose intuitions conformed to the M-constraint was well over four standard deviations. The range of scores on the nonverbal ability measure for nonviolators was 90 percentile ranks. Subjects who scored zero on the decontextualization task as well as those who scored as high as 13 and 14 also conformed to the M-constraint. Additionally, of the 12 subjects who violated the M-constraint, their ability levels as measured by the verbal, nonverbal and decontextualization tasks were well distributed above and below the means and medians for their age groups. Five of the violators obtained verbal scores

greater than the mean for their age group, five obtained scores less than the mean and two scores were within one standard score of the mean. Two of the 12 violators obtained nonverbal percentile ranks greater than the median for their age group, nine obtained percentile ranks less than the median and one scored within five percentile ranks of the median. The decontextualization scores for the violators were scattered above and below the median as well. Five scored above the median, five scored below the median and two subjects scored within one-half a point of the median, all for their age group.

An examination of the number of category distinctions by ability level indicated comparable distribution of the number of distinctions in ontological categories across ability levels. Grade levels were examined individually. Scores were divided into three ability levels: high, medium and low. The range of scores included in a level was determined by natural division in the frequency distributions for each set of scores by grade level and by test. Obtained frequencies per number of category distinctions per ability level for grades one, three and five are shown in Tables 9, 10 and 11 respectively.

Pearson product moment correlations showing the relationship between the number of category distinctions and verbal ability level for each grade level indicated neither statistical nor practical significance at all three

grade levels. Scores from two subjects were eliminated from the first grade analysis because the definitions of the target words represented only one ontological category for one subject and two categories for the other subject. Representation from the six terms of only one or two ontological categories is an insufficient number of possible ontological categories to obtain an adequate estimate of these subjects' ontological knowledge structure. The correlation between the verbal ability measure and number of category distinctions for grade one was .09. (df=29;  $p > .10$ )

Two correlation coefficients were calculated for grade three subjects, also to control for the number of ontological categories represented by the target word definitions. The correlation between verbal ability and number of category distinctions for third grade subjects whose definitions represented four and five ontological categories was .28 (df=13;  $p > .10$ ); the correlation between verbal ability and number of category distinctions for third grade subjects whose definitions represented six ontological categories was .07 (df=10;  $p > .10$ ).

The correlation between verbal ability and number of category distinctions for fifth grade subjects was .09. (df=26;  $p > .10$ ).

Table 9

Number of ontological category distinctions per verbal and nonverbal ability levels for grade one subjects.

		Number of Category Distinctions		
		1 & 2	3	4 & 5
VERBAL	Low (low<111)**	4*	3	1
ABILITY	Medium (111<medium<120)	5	3	8
LEVEL	High (120<high)	3	4	1
Total		12	10	10
NONVERBAL	Low (low<31)***	3	2	3
ABILITY	Medium (31<medium<71)	6	6	4
LEVEL	High (71<high)	3	2	3
Total		12	10	10

\*The values in each cell are obtained frequencies.

\*\*Verbal ability scores are standard scores.

\*\*\*Nonverbal ability scores are percentile ranks.

Table 10

Number of ontological category distinctions per verbal and nonverbal ability levels for grade three subjects.

		Number of Category Distinctions		
		2 & 3	4	5 & 6
VERBAL	Low (low<107)**	1*	5	1
ABILITY	Medium (107<medium<118)	6	1	3
LEVEL	High (118<High)	1	4	3
Total		8	10	7
NONVERBAL	Low (low<36)***	3	3	1
ABILITY	Medium (36<medium<64)	4	4	3
LEVEL	High (64<high)	1	4	2
Total		8	11	6

\*The values in each cell are obtained frequencies.

\*\*Verbal ability scores are standard scores.

\*\*\*Nonverbal ability scores are percentile ranks.

Table 11

Number of ontological category distinctions per verbal and nonverbal ability level for grade five subjects.

		Number of Category Distinctions		
		4	5	6 & 7
VERBAL	Low (low<108)**	3*	3	3
ABILITY	Medium (108<medium<118)	0	6	5
LEVEL	High (118<high)	2	0	5
Total		5	9	13
NONVERBAL	Low (low<36)***	1	5	2
ABILITY	Medium (36<medium<64)	2	2	9
LEVEL	High (64<high)	2	2	2
Total		5	9	13

\*Values in each cell are obtained frequencies.

\*\*Verbal ability scores are standard scores.

\*\*\*Nonverbal ability scores are percentile ranks.

## CHAPTER FIVE

## DISCUSSION

The results indicated that the subjects' ability to acquire vocabulary from context as measured by this decontextualization task was correlated with verbal ability for all three age groups. The findings of Sternberg, et al, (1982) and of Van Daalen-Kapteijs and Eishout-Mohr (1981) indicating that the ability to induce the meaning of unknown words from verbal context was statistically significantly correlated with verbal aptitude were supported with these results. Sternberg, et al cited correlations with a decontextualization task of .56 with vocabulary, .65 with reading comprehension and .62 with a general measure of intelligence. Van Daalen-Kapteijs and Eishout-Mohr reported that subjects with high verbal comprehension scores scored significantly higher than subjects with low verbal comprehension scores on a task measuring decontextualization skills.

The decontextualization task used in this study was significantly correlated with nonverbal aptitude only at the first grade level. The correlation between nonverbal intelligence and the decontextualization task was close to zero for the third and fifth grade subjects.

Hence, results suggested that this task was not a consistent predictor of intelligence across grade levels. The strongest relationship between both verbal and

nonverbal ability measures and the decontextualization task was displayed at the first grade level which suggested that the task was a relatively good predictor of both verbal and nonverbal ability at this age level. It also appeared to be a fair predictor of verbal intelligence at the third and fifth grade levels, accounting for 16% and 9.6% of the variance respectively. However, performance on the task inadequately predicted nonverbal intelligence for these grade levels.

Subjects' judgments regarding the ontological properties of the target words conformed to the M-constraint significantly beyond chance level, regardless of whether they demonstrated understanding of the meanings of the words. These findings concurred with the results of previous research (Keil, 1983a) indicating that children's judgments regarding the ontological properties of unknown words heard in verbal context appeared to be directed by the M-constraint.

The judgments of 14% of all of the subjects violated the M-constraint producing a total of 16 violations. Eleven of those 16 violations involved the event predicate or term. Gerard and Mandler's (1983) study indicated that most of the violations produced by their subjects also involved the event predicate in some way. Keil (1983b) investigated this predicate further and found that when a misapplication of either the event term or the event predicate resulted in

an M-constraint violation it was due to the application of events to a physical object predicate rather than to the application of physical objects to event predicates. The results of this study showed violations that occurred when event predicates were misapplied to physical objects more often (eight out of eleven times) than when physical object predicates were misapplied to events. Only three out of ten times did the violations occur due to a misapplication of the event term. These results indicate that the event category was involved in M-constraint violations more than any other ontological category. However, a more thorough investigation of this category would be necessary before its effects on the integrity of the M-constraint could be determined.

One two-dimensional object was included among all the definitions generated from the contexts. The third grade subject who defined the term fop as a reflection assigned animate predicates such as is sick, is asleep, and is lonely to this term as well as assigning height (is tall) to this term, but the subject did not assign weight (is heavy) to the term. This produced an M-constraint violation. Carey (1986) suggested that when spatial predicates are assigned to two-dimensional objects M-constraint violations are likely to occur, which is in fact what happened in this study. It is possible that there are categories like two dimensional objects that do not conform

to the hierarchical organization in ontological knowledge that is presumably created by the M-constraint.

Conclusions regarding this issue cannot be drawn based on one case, however.

Another M-constraint violation occurred when a fifth grade subject concluded that it was not possible for a tench (defined as a fish) to be tall. Even though this subject maintained her position that a fish could not be tall after being questioned about different ways to measure it, one should question whether she was confusing what was linguistically clumsy with what was conceptually unsuitable in this case. This is questioned because several other subjects changed their position from disagreeing to agreeing with the sensibleness of the statement "The fish is tall" when asked whether it could be tall if it were stood up on its tail to be measured.

The remaining three violations were a result of a misapplication of the predicate is lonely. It is possible that one of the criteria that these subjects were using to evaluate loneliness was the presence or absence of other objects. They would have to be using other criteria as well, otherwise the violations would not have occurred. Misapplication of the predicate is lonely with inanimate objects will be discussed later in this chapter.

Even though these results indicated few M-constraint violations as compared to the number of subjects whose

judgments conformed to the M-constraint, violations did occur. Keil's theory of ontological knowledge does not accommodate M-constraint violations, however. Therefore, explanations for these violations should be sought. It is possible that there are flaws in the M-constraint creating violations that involve only certain categories. It is also possible, however, that there is a gap between the true ontological knowledge structure and expression of this knowledge structure through language.

Exceptions to the rule should not be the sole focus of the argument though. The M-constraint was present in the intuitions of the most of the subjects regarding ontological properties of unknown words, thus imposing a hierarchical organization on their ontological knowledge structure. This was evident across the three age groups. Moreover, not only was the M-constraint displayed across developmental levels but greater differentiation in ontological knowledge with age was displayed as well. The developmental trends manifested in this study were comparable to those described in Keil's research (1979, 1983b).

The living-nonliving distinction was the predominant distinction made by the first grade subjects. This result supported Keil's (1979) results indicating that the primary ontological distinction made by kindergarten subjects was the living-nonliving distinction. The plant-animal

distinction indicated greater differentiation with age as did the liquid-solid distinction. Although the liquid-solid distinction was made by greater than half of both the third and fifth graders, the third grade subjects exhibited greater difficulty expressing the bases for the differentiation. When asked why ghee could not be tall or short many replied that they could not explain it. One third grader replied that it could not be tall or short because it was "wettened". The fifth graders, on the other hand, were better able to articulate their reasons for assigning no solid dimension to a liquid. Several fifth grade subjects responded that ghee could not be tall or short because it was a liquid, and therefore, could not have height. Perhaps if there is such a phenomenon as a transitional period from lesser to greater differentiation of ontological knowledge then many of these third grade subjects were still in transition from classifying liquids and solids as members of the same ontological category to distinguishing between the two types of objects. Even though 62% of the third graders indicated that a liquid could not be assigned the same dimensions as a solid object several of them clearly had difficulty telling the interviewer why this was the case.

An asymmetry in the division of the basic categories of physical objects and events was noticed as the results of Keil's (1983b) study indicated. Although many first grade

subjects did not clearly make the distinction between the event category and the physical object category, several of these children appeared to make a partial distinction between these two categories. More than half of the subjects who included these categories among their definitions assigned event properties to physical objects, whereas only about a fourth assigned physical object properties to events.

The results showed very few subjects who distinguished the animal from the human category as indicated by the terms associated with the predicate is lonely. These findings were similar to those reported by Keil (1979) who suggested that the ontological framework of nine-year-old children is the same as that adult framework with the exception of the collapse of the human and other animal categories and of the event and abstract object categories. (An abstract object category was not included in this investigation.) Keil's research indicated that most adults differentiated between humans and nonhuman animals, whereas most nine-year-old children did not.

Sixteen first grade subjects misapplied the predicate is lonely to inanimate objects whereas only eight third and three fifth grade subjects did. Based on the responses given by these subjects the predicate is lonely seemed to mean something different for many of the first grade subjects than it did for the third and fifth grade

subjects. As was stated in Chapter Four, the state of loneliness depended on the absence of other objects for first graders, whereas the response given the older subjects more clearly indicated that loneliness represented an emotion.

In sum, the intuitions of the most of the subjects in this study regarding the ontological properties of an unknown word in verbal context conformed to the M-constraint. Ontological knowledge structures were constrained by the M-constraint across grade levels and showed greater differentiation in category distinction with age. Thus, the acquisition of word meanings at the ontological level appeared to be influenced by the M-constraint across age groups. These results supported previous research of Keil (1979, 1983a, 1983b).

The results went beyond providing additional support for Keil's (1979, 1983a, 1983b) research, however. The claim that there are domains of knowledge at which humans exhibit equal competence, was supported in this investigation. The M-constraint was present in the ontological knowledge structure of subjects regardless of ability level. Violators of the M-constraint represented a wide range of ability levels as well. Thus, even though significant variability in the performance on intelligence tests was displayed, the constraint governing the acquisition of concepts at the ontological level was present in the

vocabulary acquisition task at all ability levels. That is, subjects with low as well as high verbal and/or nonverbal ability test scores, and subjects who obtained low as well as high scores on the decontextualization task all indicated the presence of the M-constraint in their judgments on the properties of the target words.

Furthermore, even though a developmental effect in the number of ontological category differentiations was manifested, an increase in category differentiation as a function of ability level was not manifested.

The rate at which individuals acquire verbal concepts varies significantly, and perhaps largely because there is considerable variability in inductive skills among humans. The acquisition of verbal concepts is described by many as an inductive process and one that requires the ability to draw relevant inferences (see Jensen, 1981; Markman, 1989; Sternberg and Powell, 1983). Largely because of this, it is considered to be a skill that is representative of human intelligence. [See Jensen (1981), Sternberg (1985), and Sternberg and Powell (1983) for their rationale supporting the proposed relationship between vocabulary and intelligence.] Even though there are considerable individual differences in the rate at which children acquire the meaning of new words it still seems to be an extremely fast process for all children. Chomsky (1988) states:

At the peak period of vocabulary growth, the child masters words at quite an astonishing rate, perhaps a dozen a day or more....The speed and precision of vocabulary acquisition leaves no real alternative to the conclusion that the child somehow has the concepts available before experience with language and is basically learning labels for concepts that are already part of his or her conceptual apparatus. (pp. 27-28)

Chomsky is suggesting that there is an "apparatus" present in all of us which governs concept acquisition. It is possible that children do possess a priori theories that dictate concept acquisition and therefore the acquisition of word meanings as well. How much of this process then is predetermined and universal?

The acquisition of conceptual knowledge appears to be constrained at the ontological level, as the results of this study as well as the works of Keil maintain. However, this is conceptual knowledge in its most elementary form. It is possible that there are more constraints on conceptual knowledge than just the M-constraint that are actually constant among humans. Ellen Markman (1989) in her review of the literature on categorization of concepts in children implies that concept acquisition may perhaps be constrained at several levels resulting in a reduction of the hypothesis space, and therefore, increased efficiency in acquiring new concepts. She states:

...even extremely young children, expect certain constraints on the possible meaning of words...they do not consider thematic relations as possible meanings for words despite the fact that they consider them good ways of organizing the environment in a way that conflicts with the way that language is organized. But children may have implicit hypotheses about the possible meanings for words that help them acquire the constraints on word meanings so that when they believe that they are learning a new word, they shift their attention from thematic to categorical organization.

(Markman, 1989, pp. 26-27)

Not only may the tendency for children to organize their environment according to thematic relations be abandoned in favor of taxonomic classification when acquiring the meaning of a new word, but other organizational constraints may dictate the acquisition of word meanings. For example, although children may not explicitly comprehend the laws of asymmetry and transitivity, and the law of mutual exclusivity, these laws appear to direct their judgments enabling rapid acquisition of new concepts (Markman, 1989). Thus, constraints that limit the hypothesis space by forcing such things as hierarchical organization of categories by way of the laws of transitivity and asymmetry should not be ignored when analyzing a skill linked with individual differences in cognitive capacity.

Keil's (1989) research on concept acquisition in children and the shift in focus from characteristic to defining features indicated that even the judgments of kindergartners regarding category membership, which appeared to be based strictly on characteristic features, exhibited biases that prohibited transformations in terms across ontological categories regardless of the similarity in characteristic features of terms involved. Thus, the process of concept acquisition in children of kindergarten age and perhaps even younger does not seem to be atheoretical. Certain constraints appear to govern judgments regarding category membership.

However, the presence of such constraints across ability levels lends a new element to the understanding of intelligence and cognition among humans. Perhaps if innate, species specific constraints are at least partially, if not largely, responsible for the ease at which children acquire new concepts then we need to address the parts of cognition where little or no variability in performance is exhibited.

Obviously no conclusions can be drawn at this point regarding exactly what a priori assumptions are precursors to knowledge acquisition. Keil (1989) states:

In many cases there may be highly specific sets of coherent beliefs that children have already entertained, but in other cases these beliefs can only be inferred

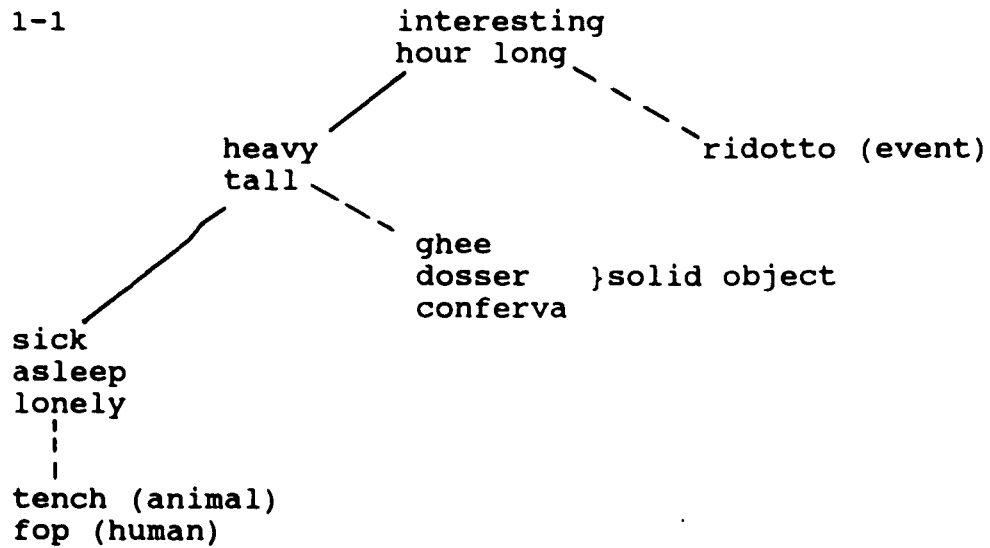
from preferences about mechanisms underlying phenomena that they have never considered before. Moreover, identification of the domain or domains that give rise to those biases will require an extensive series of follow-up studies devoted solely to that question. The final decision about whether the children really have an implicit theory specific to some class of phenomena will rest on a detailed characterization of the domains of knowledge that give rise to their judgments, in particular on the level of abstraction of those domains and on the extent to which they are directly linked to the phenomena in question. (p. 282)

Thus, it not only becomes necessary to clearly identify the domains responsible for cognitive competencies but to precisely identify the constraints on these domains. Only then will it be possible to determine whether these constraints are universal, and consequently, to gain a greater understanding of cognition and individual differences among humans.

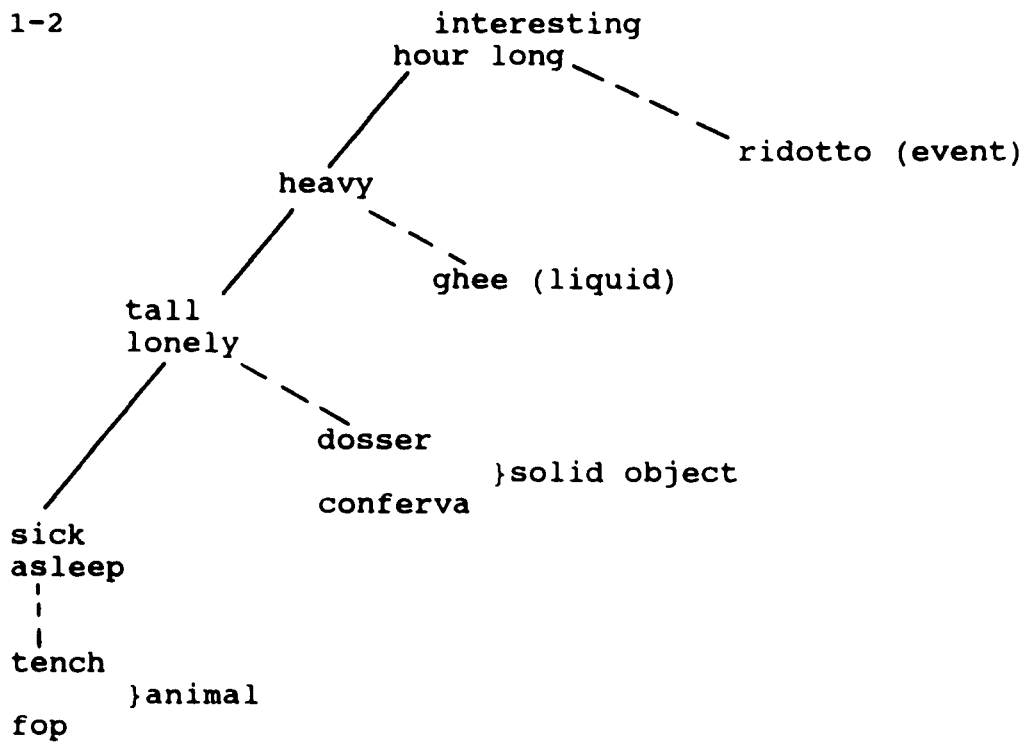
## APPENDIX

## GRADE ONE SUBJECTS

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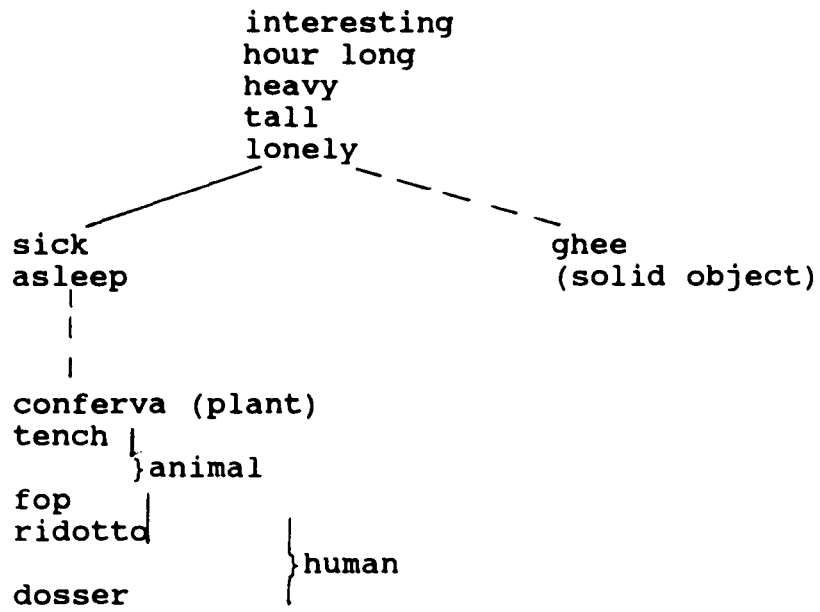


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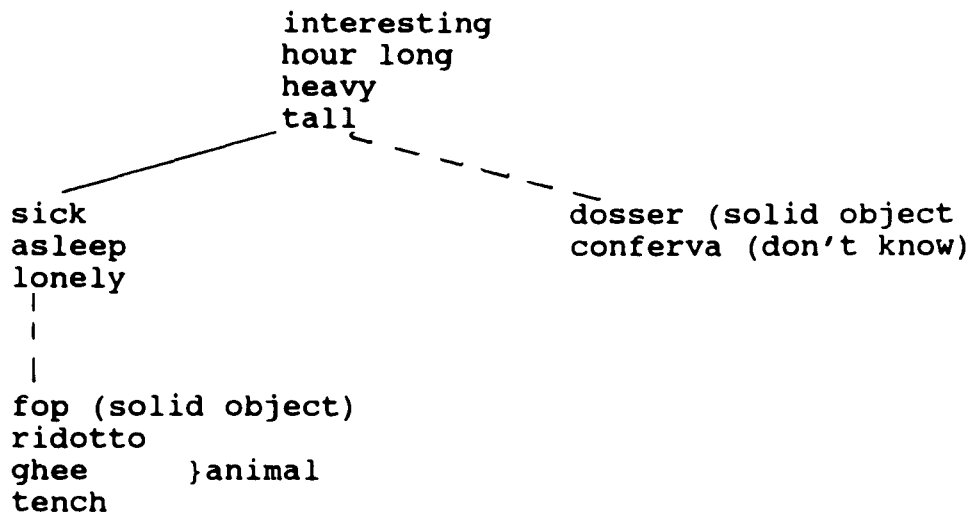




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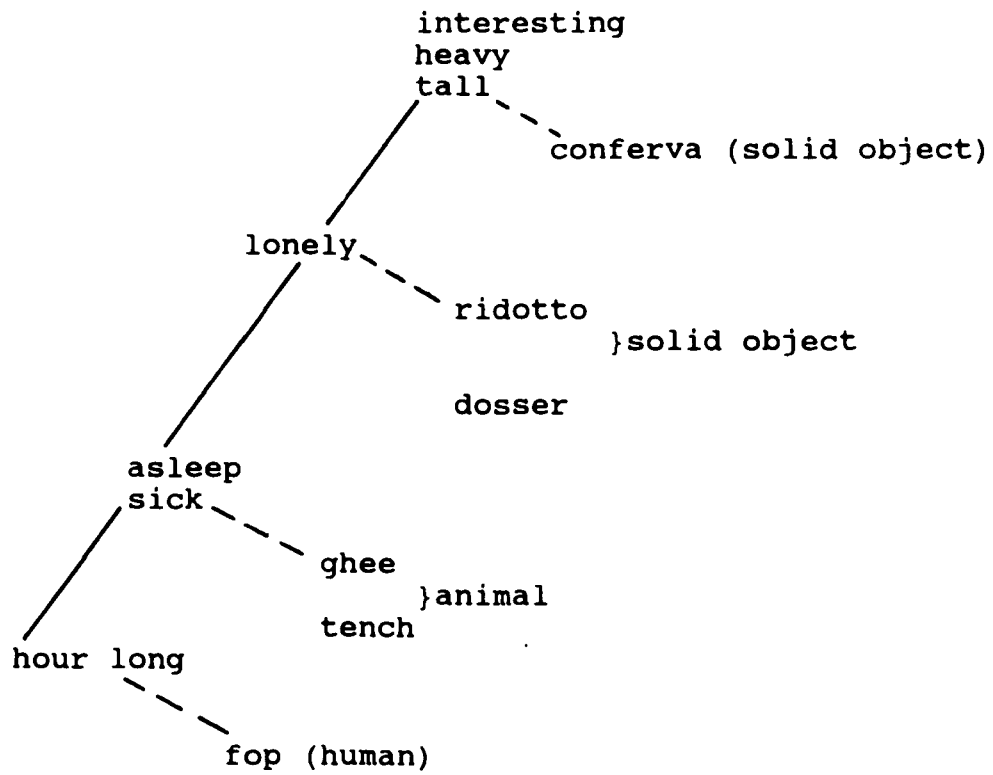


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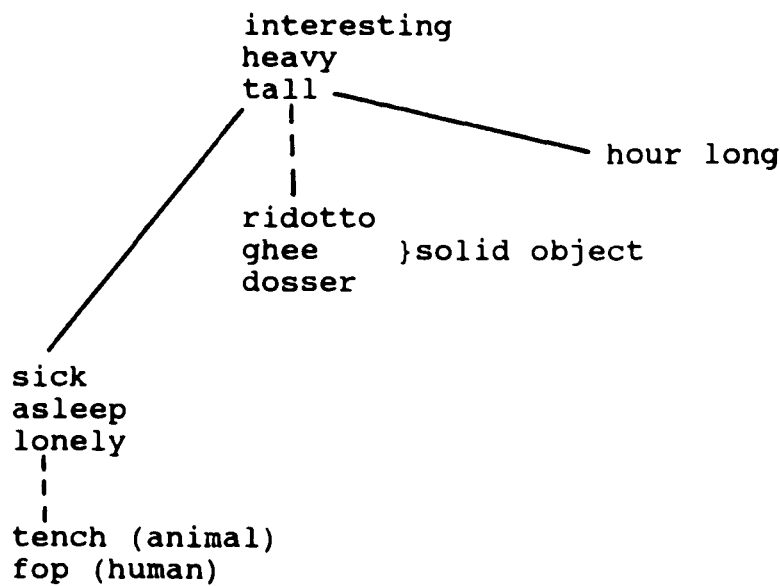


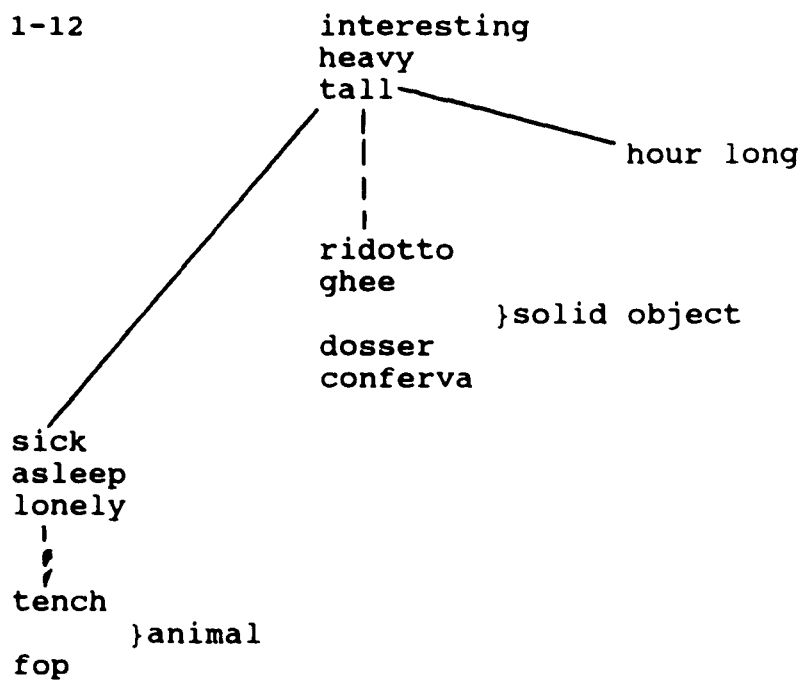
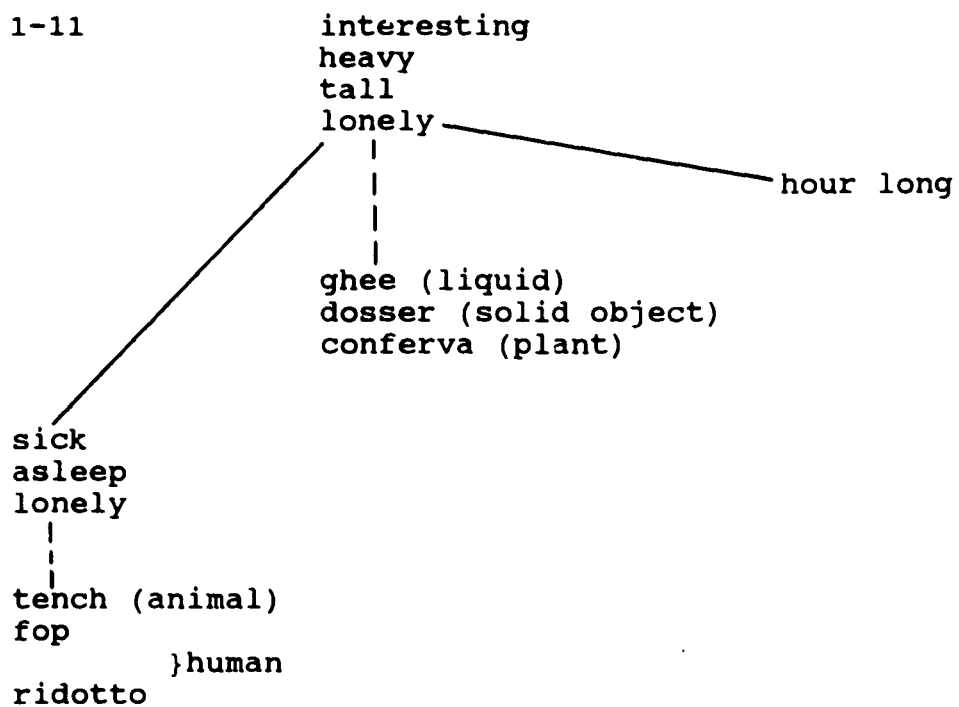


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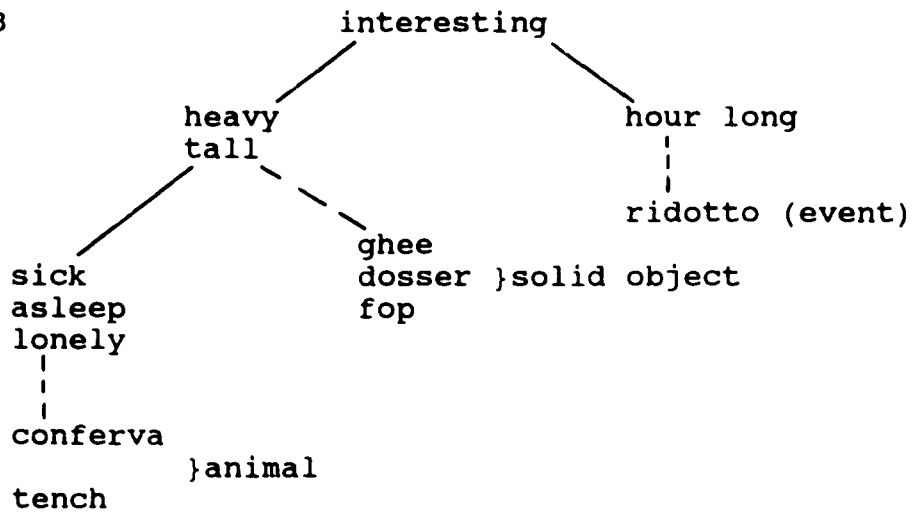


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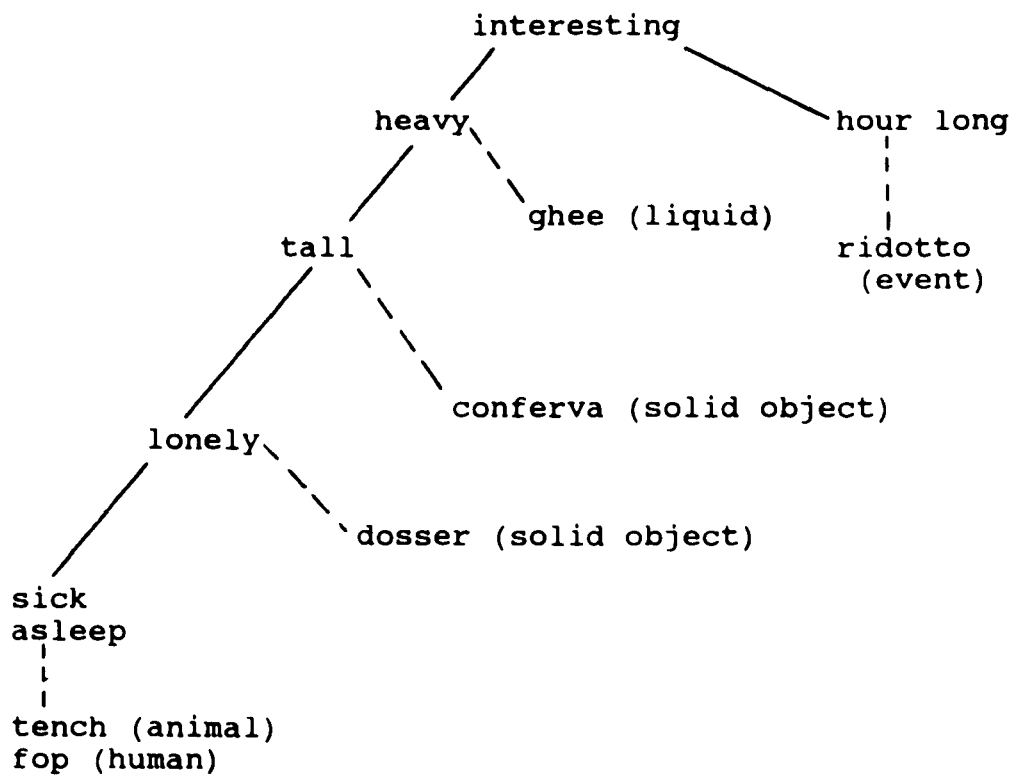




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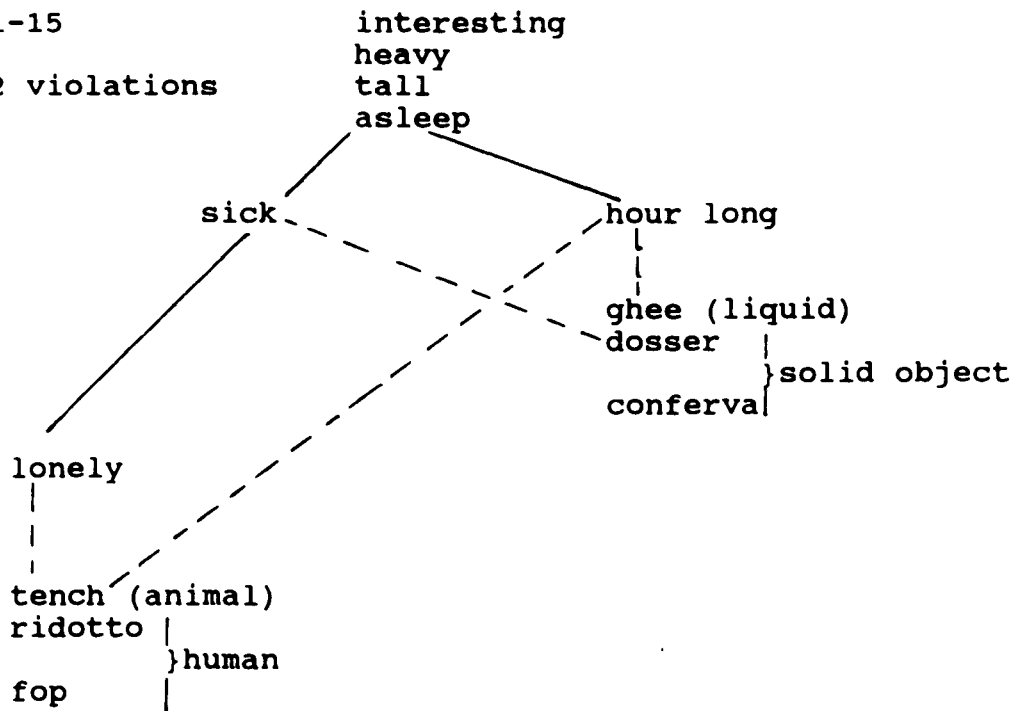


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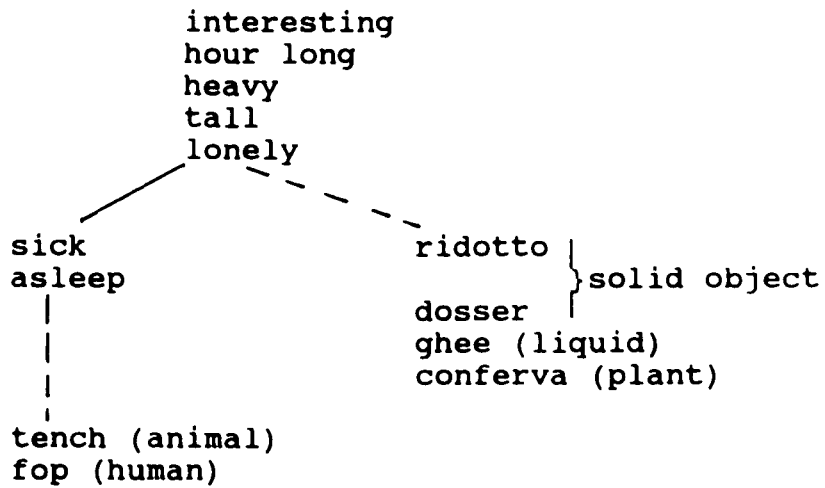


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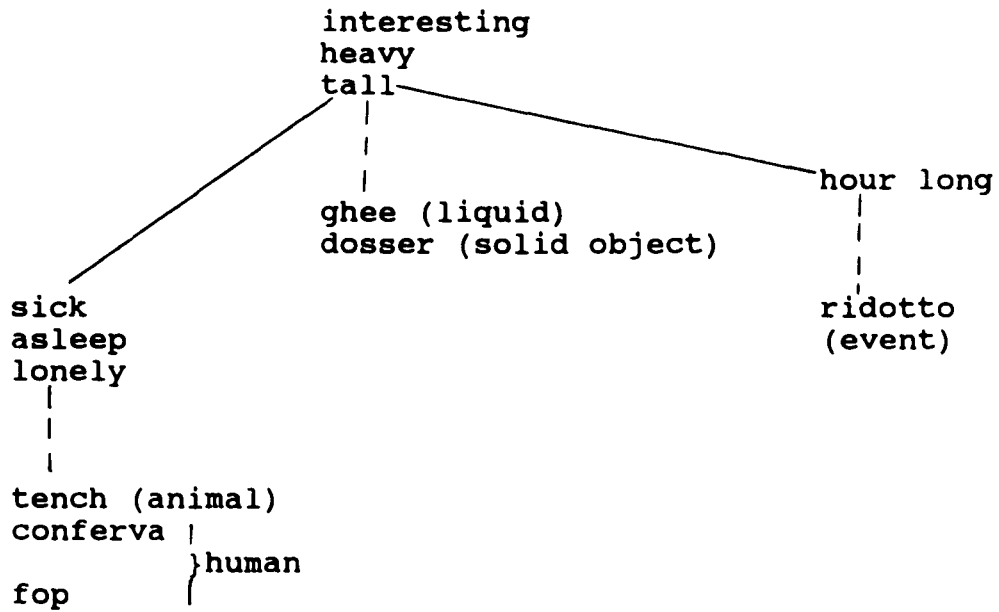
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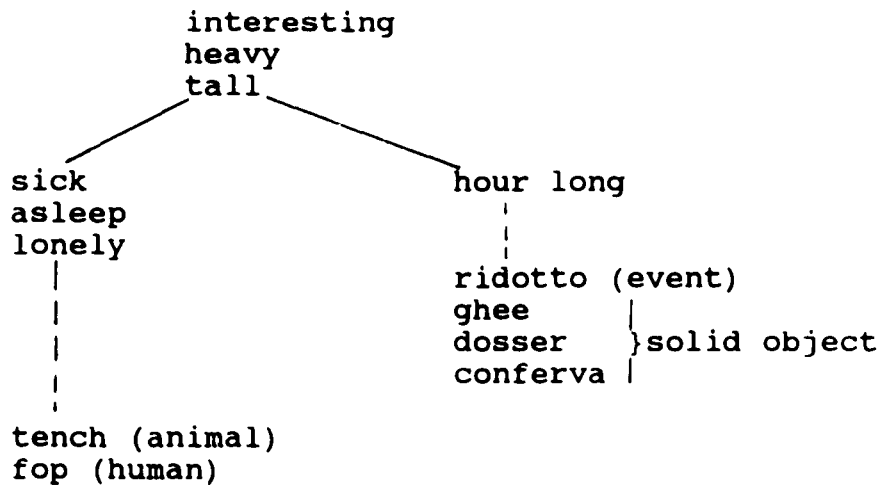
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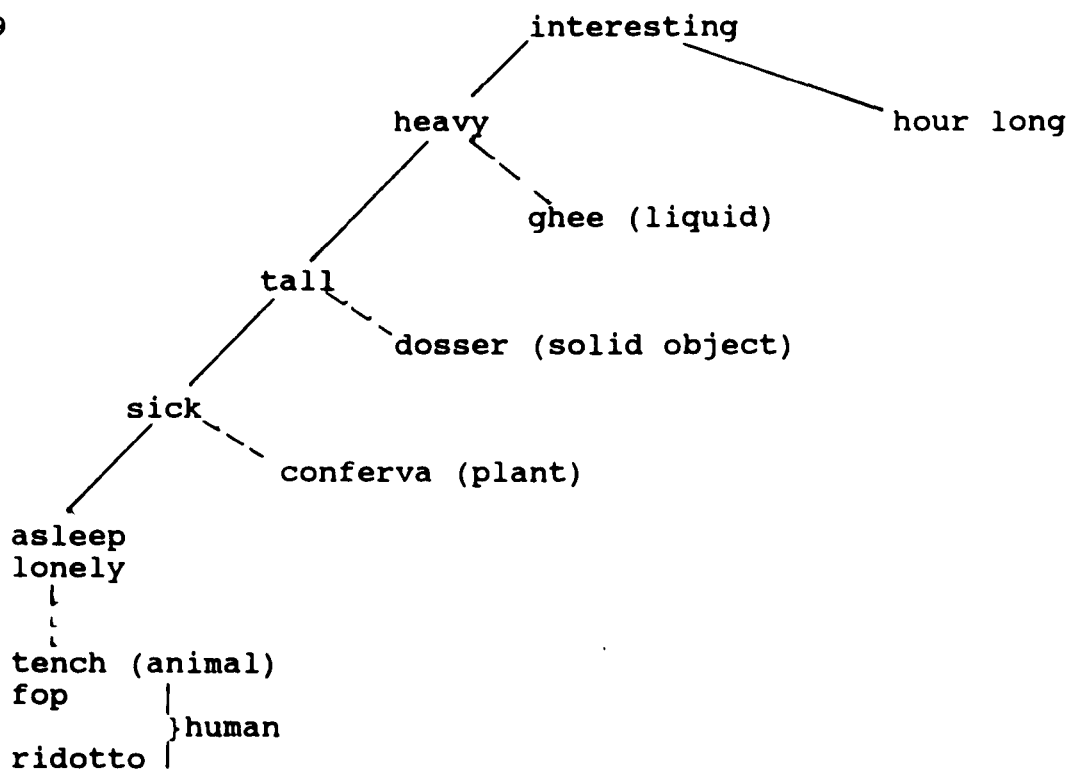
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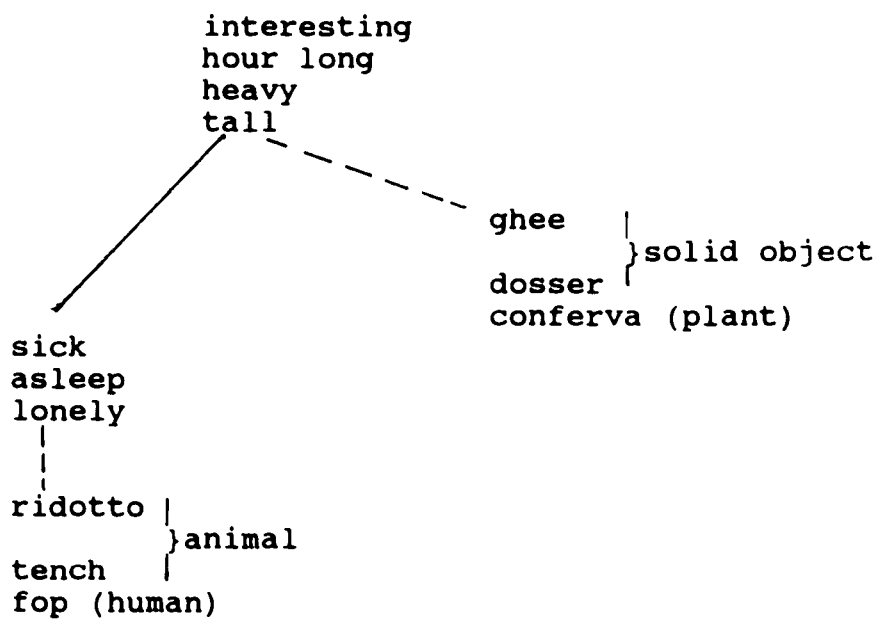
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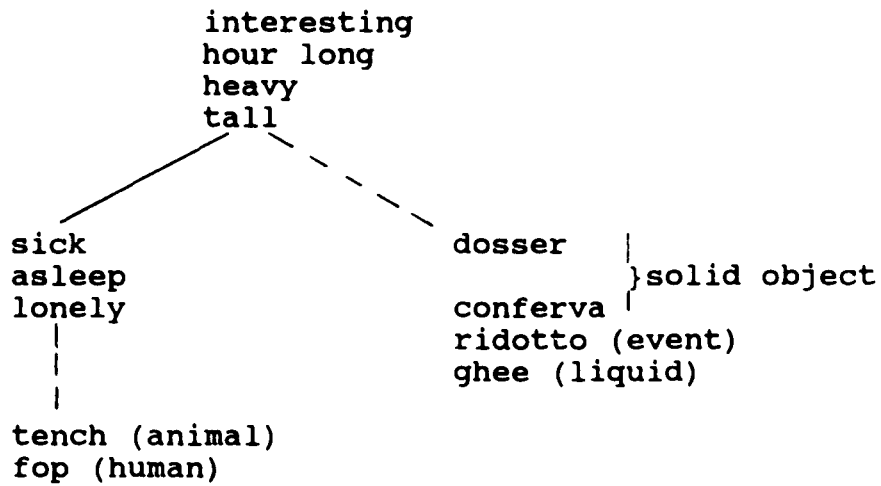


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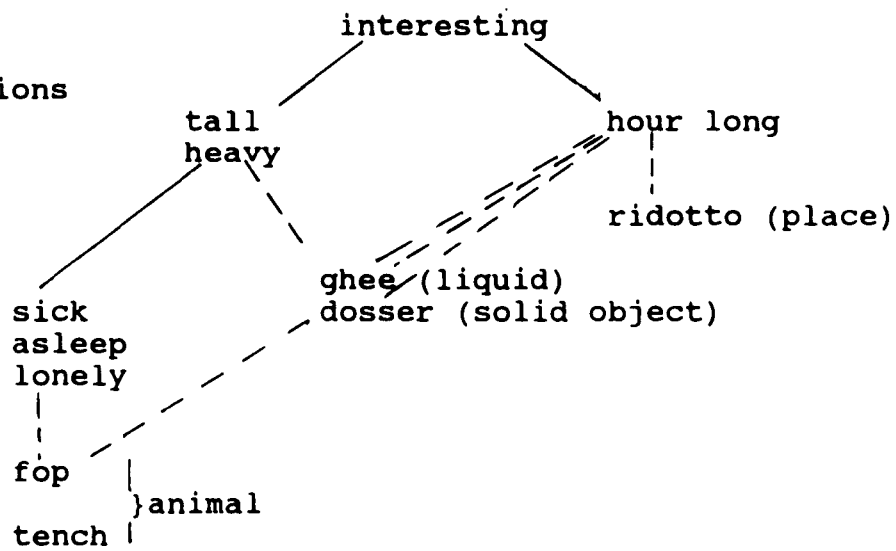


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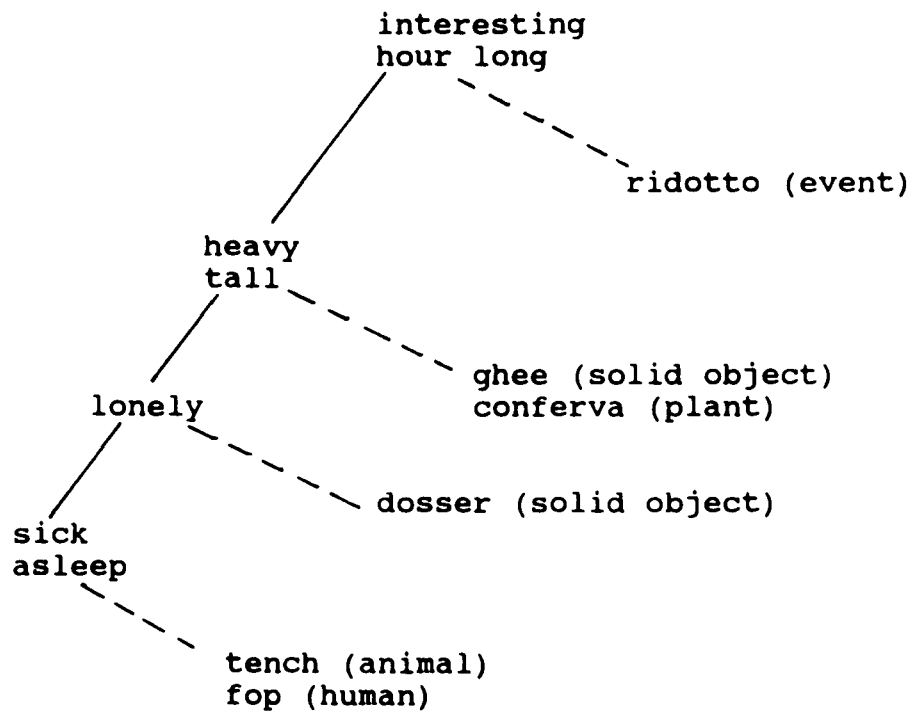
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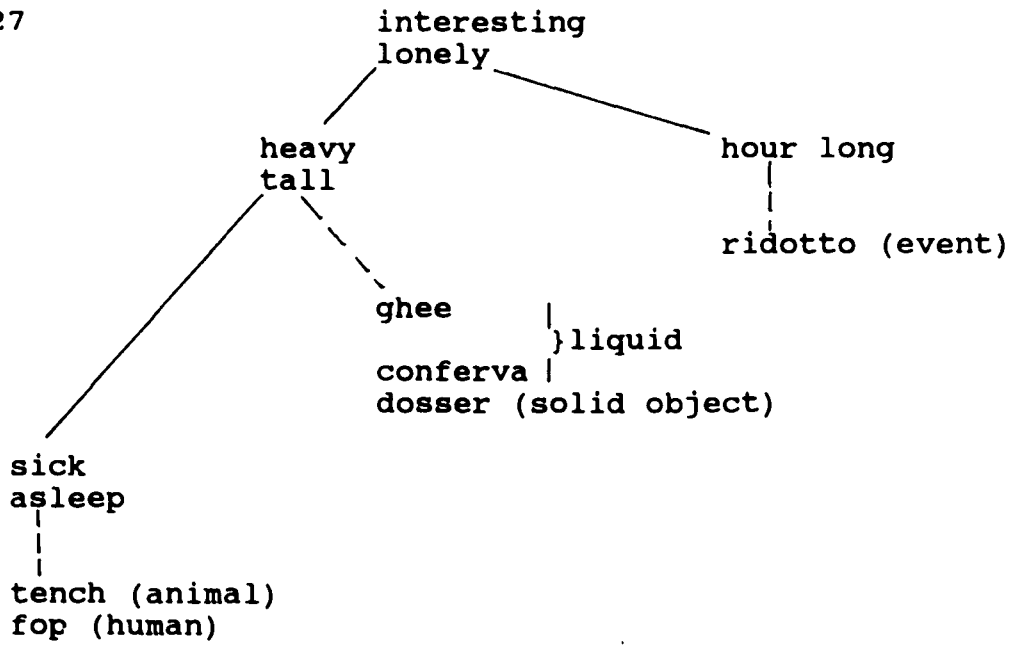
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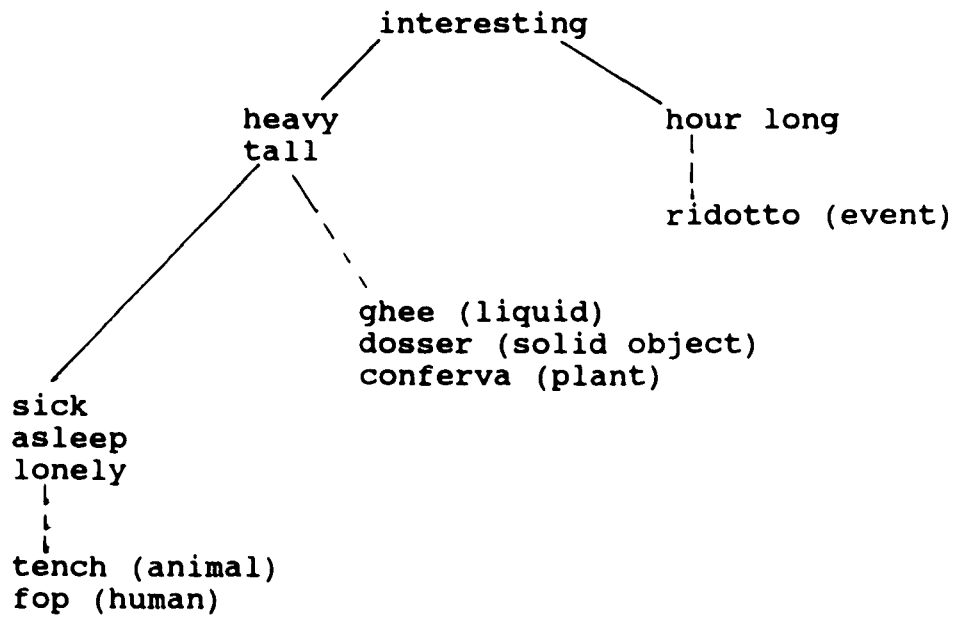
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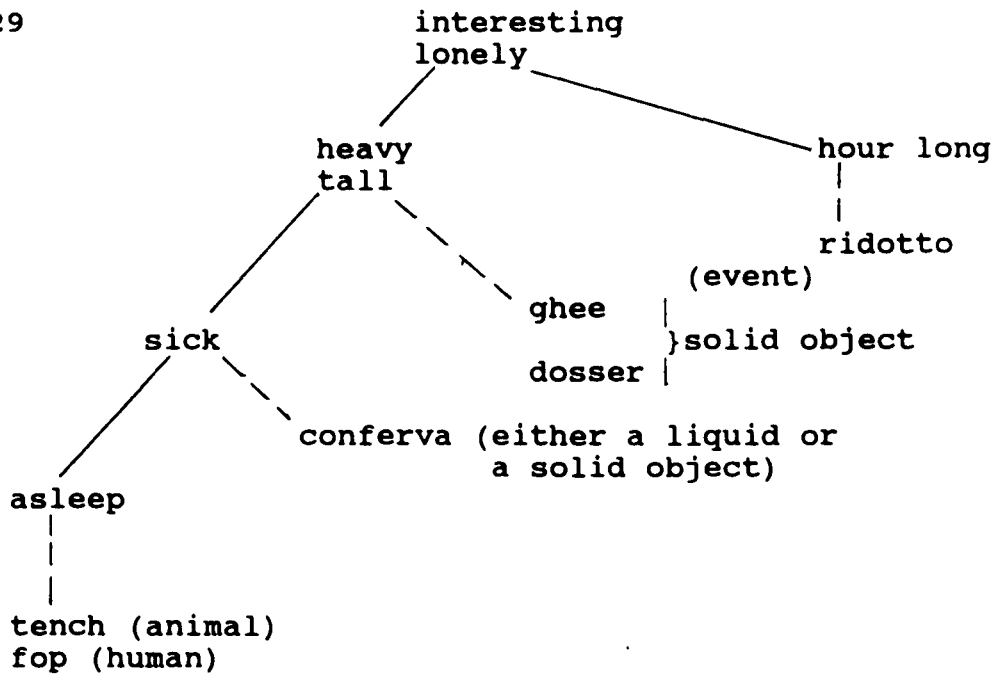
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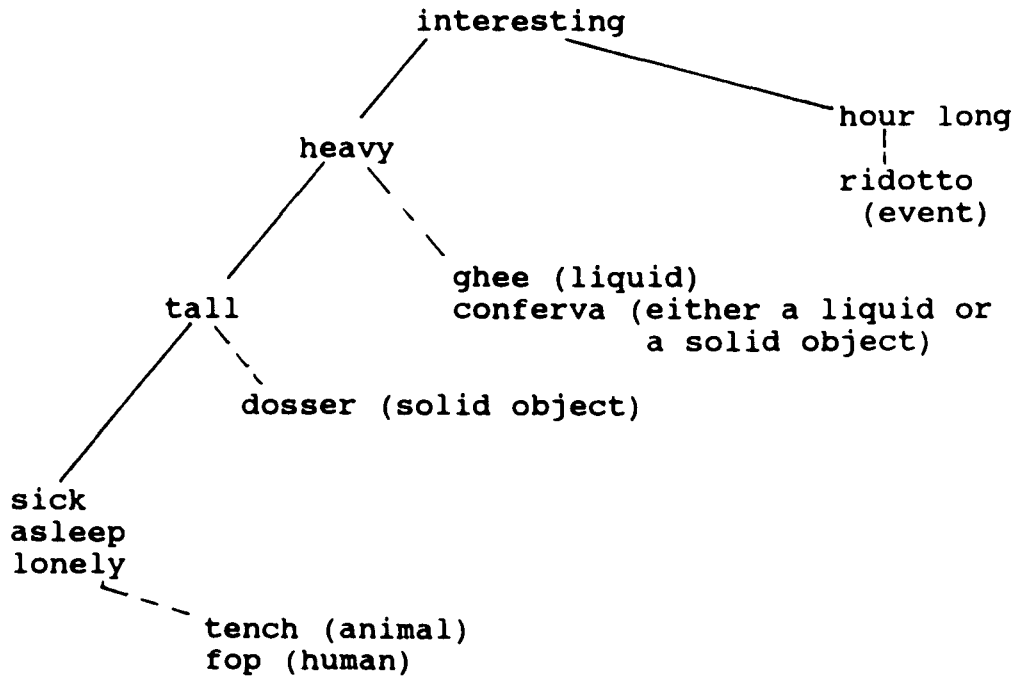
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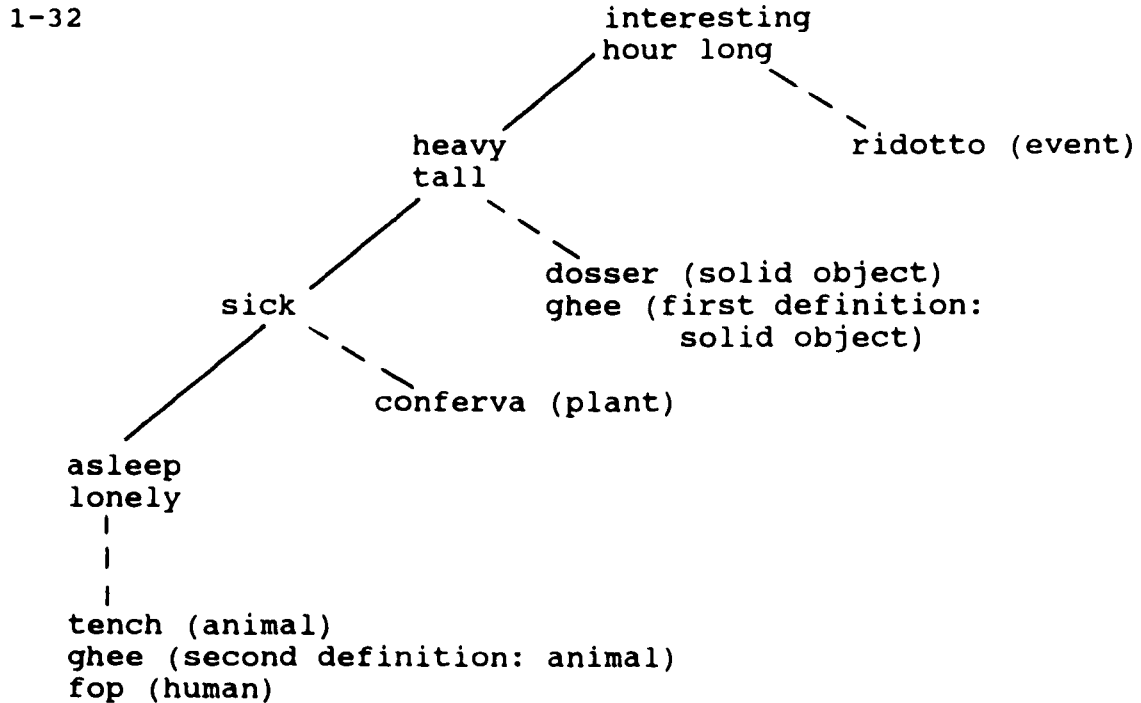
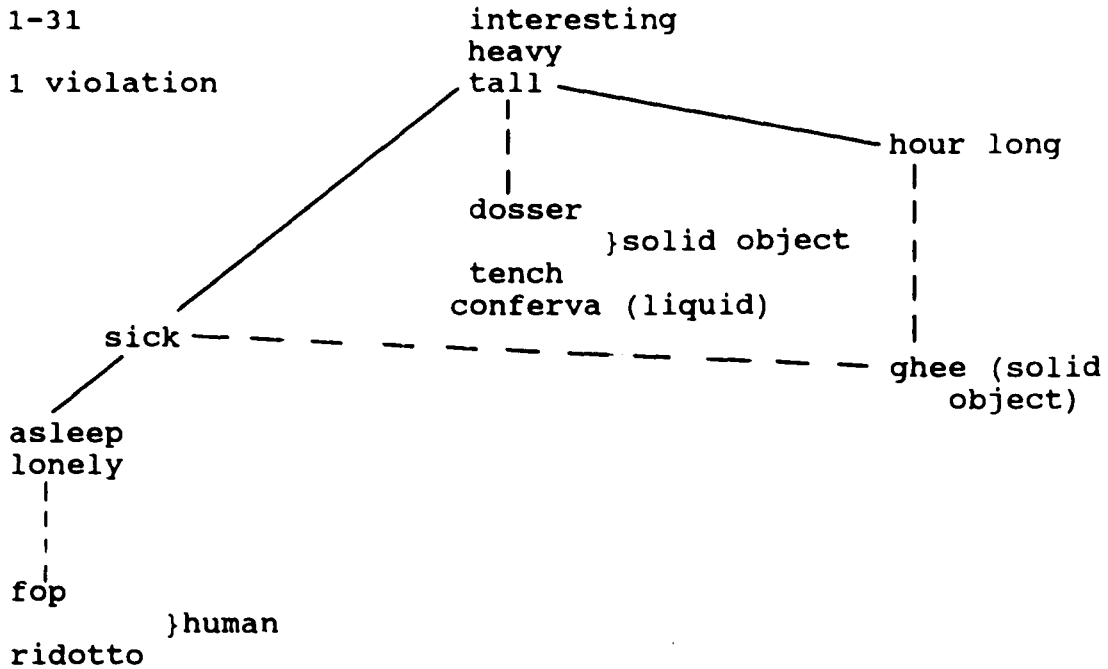


1-29



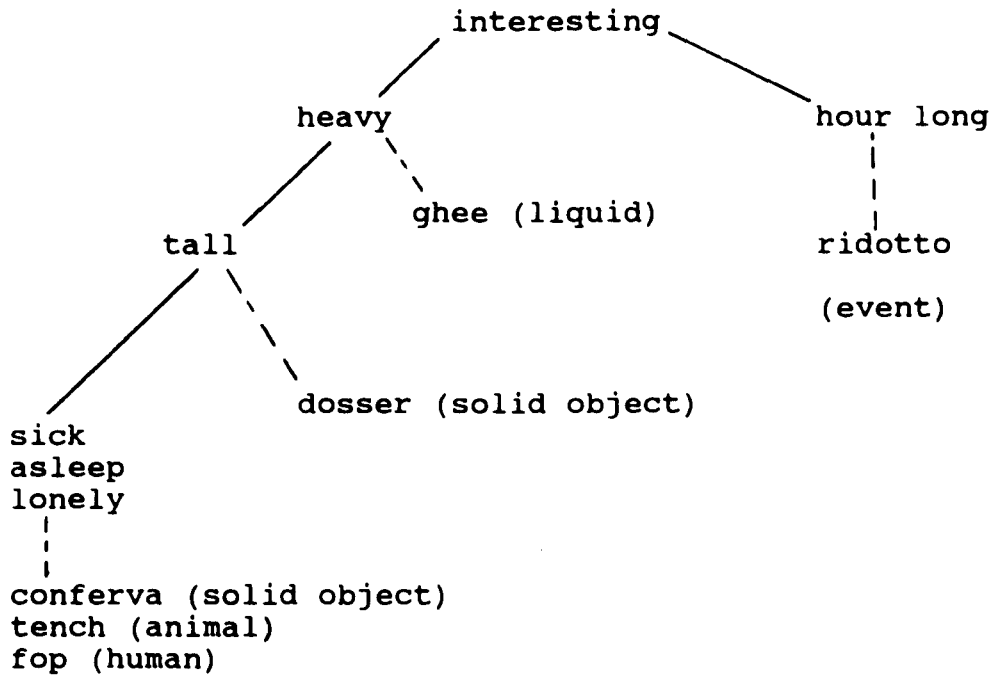
1-30



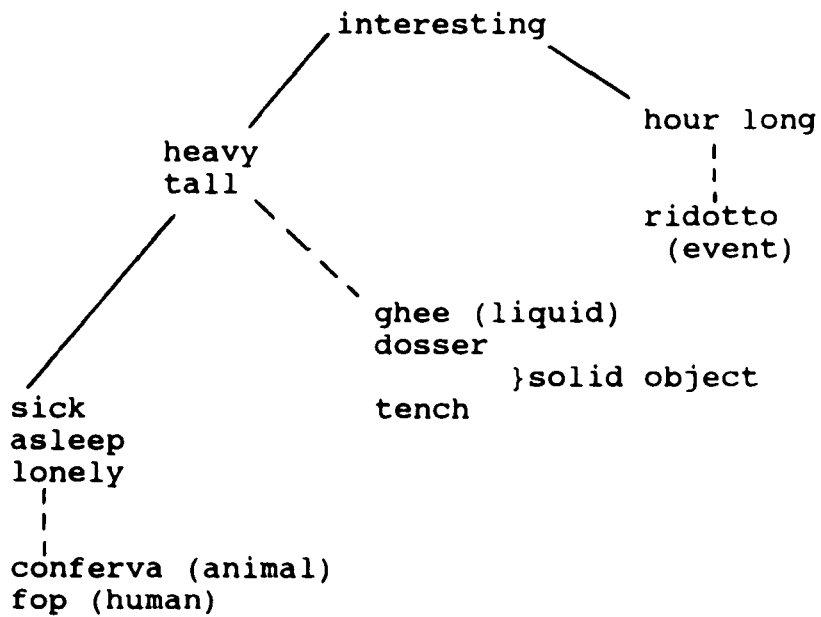


GRADE THREE SUBJECTS

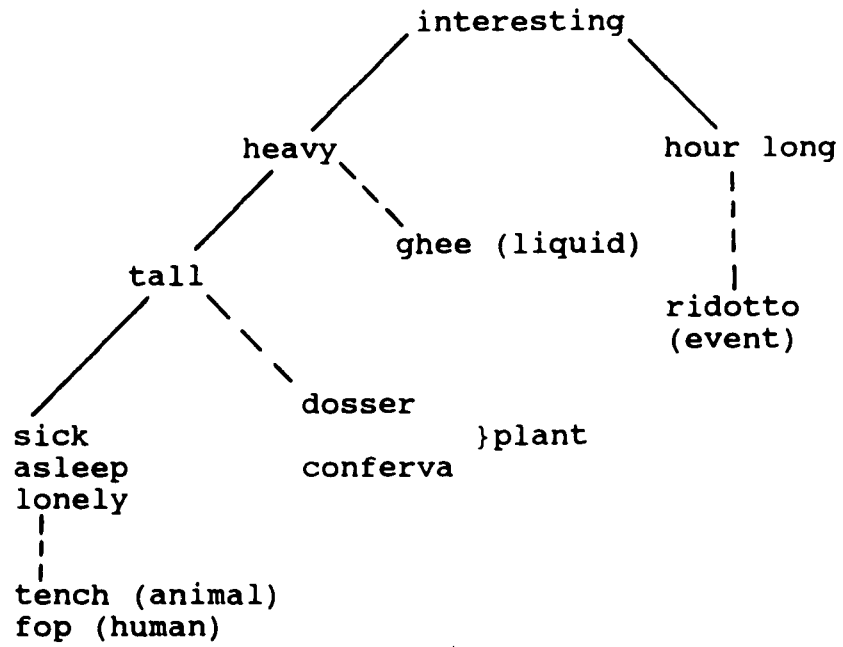
3-1



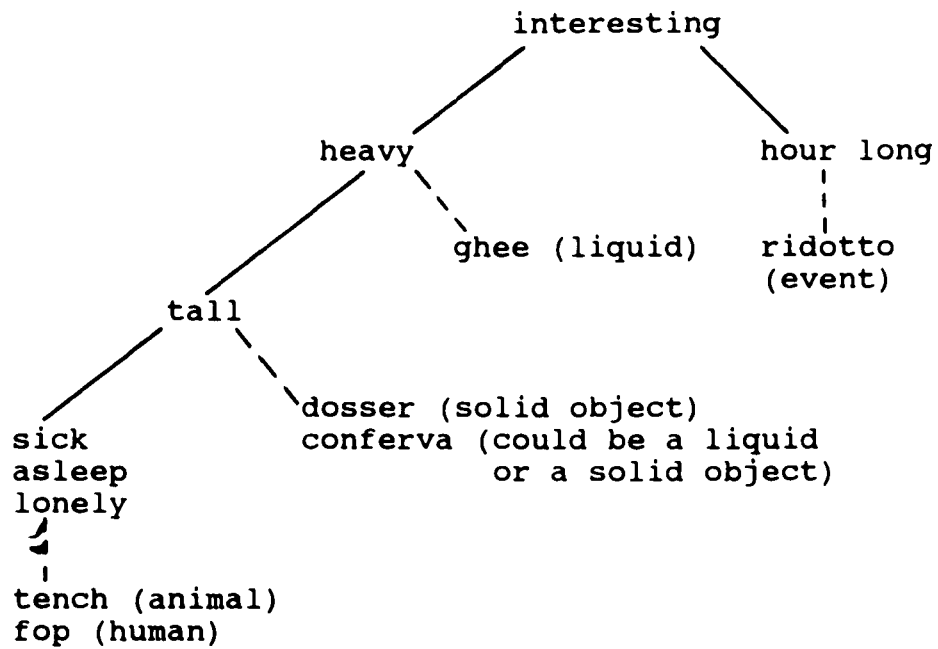
3-2



3-3

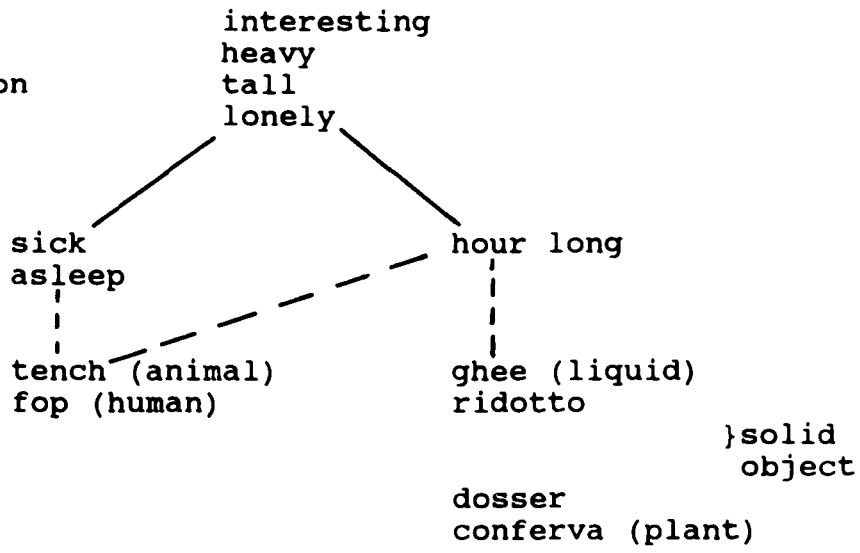


3-4

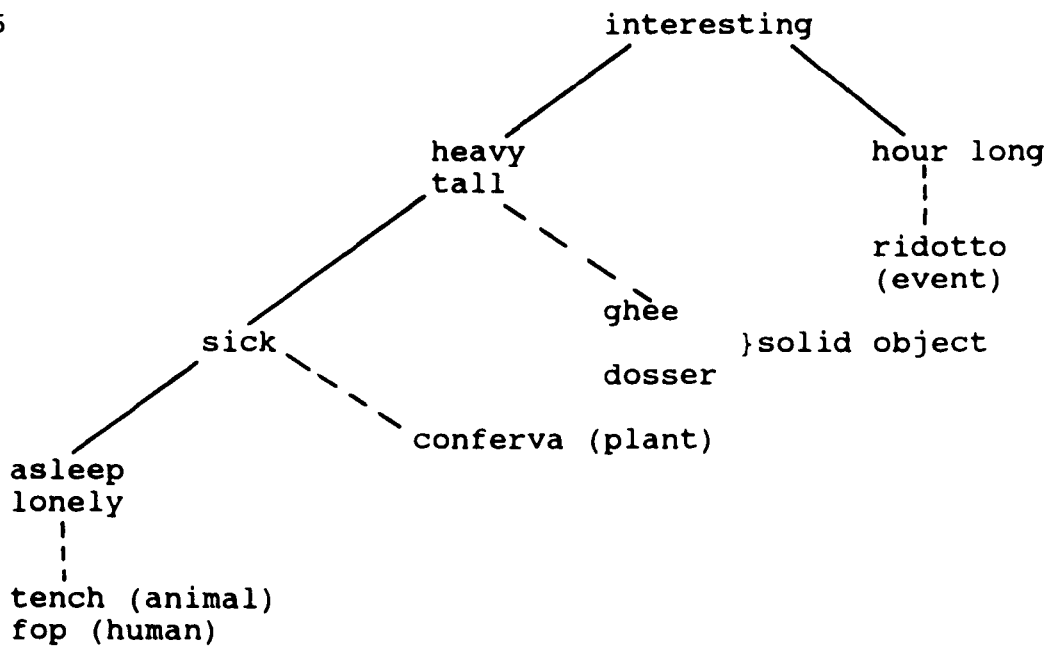


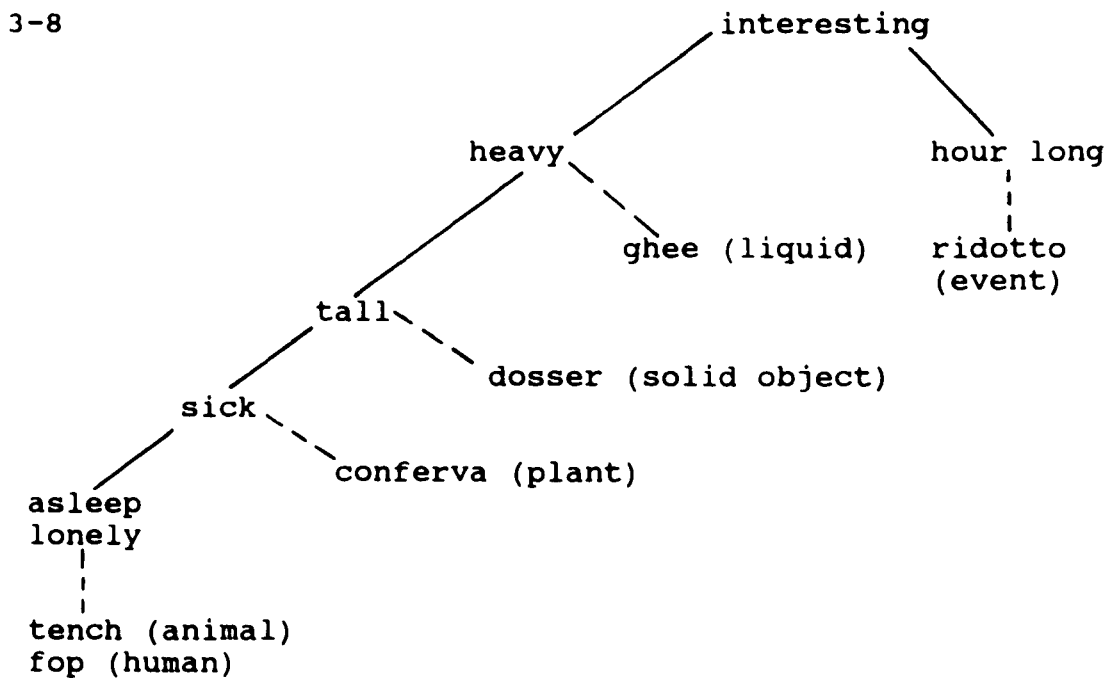
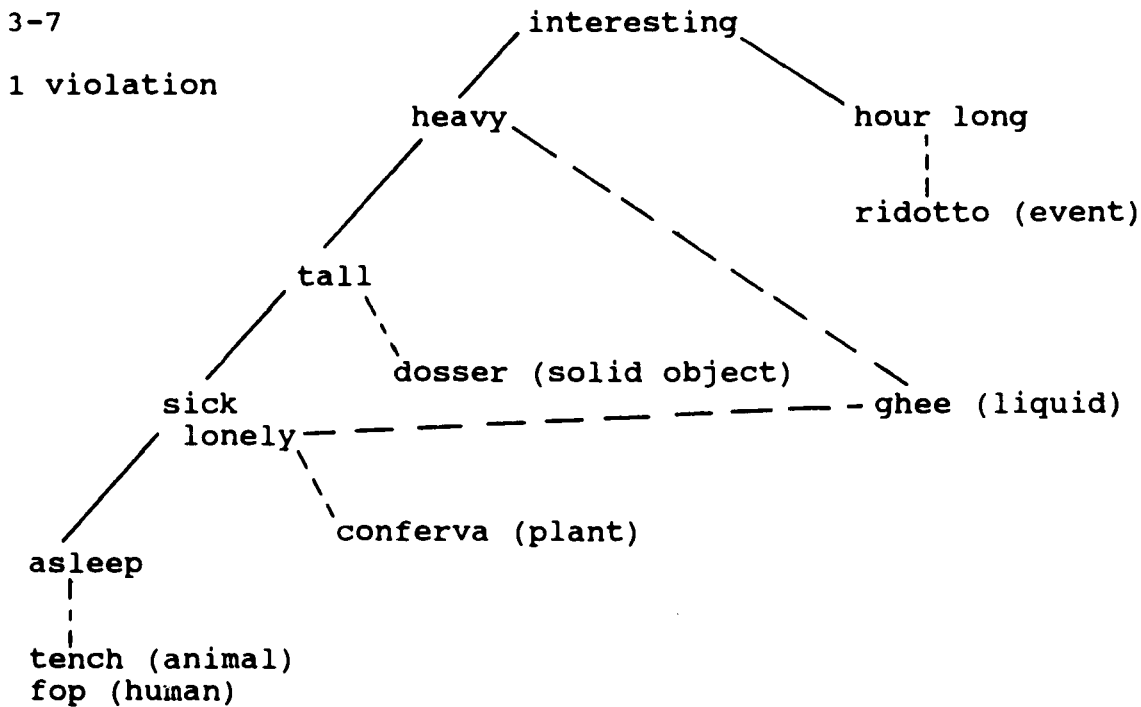
3-5

1 violation

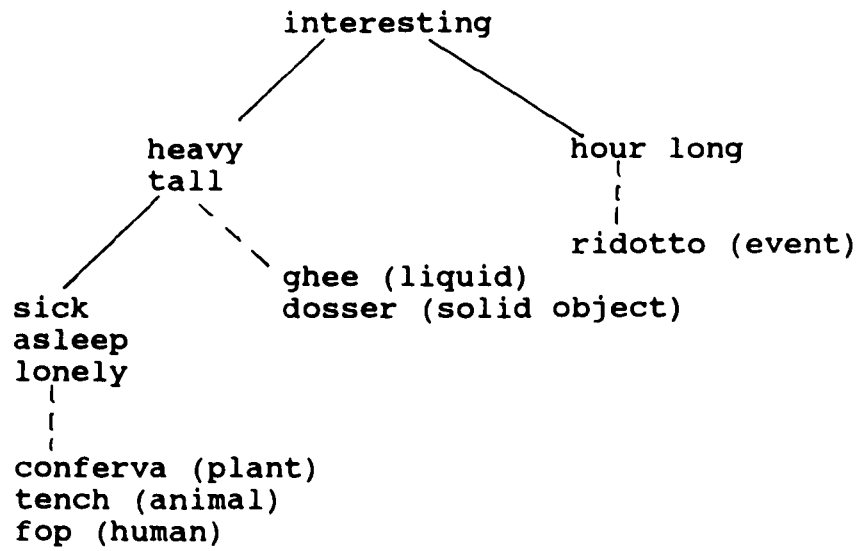


3-6

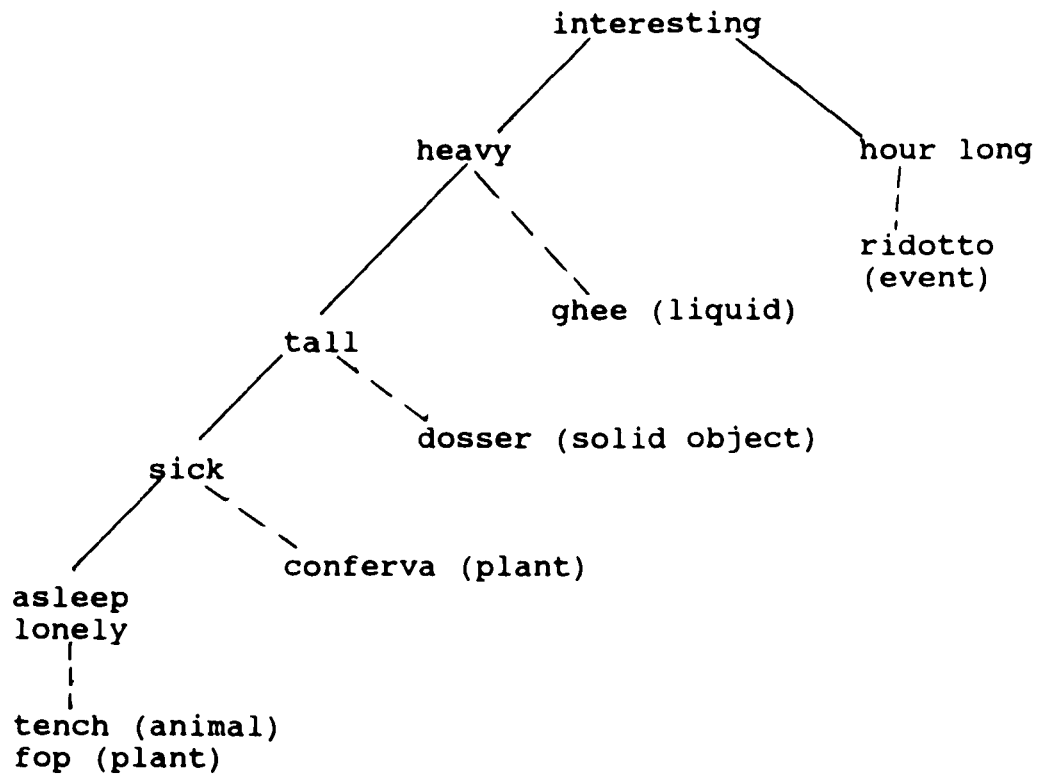




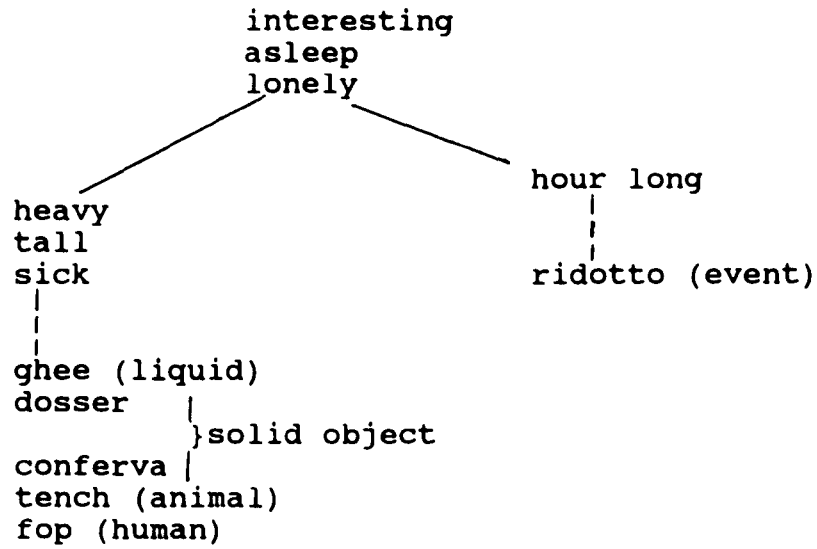
3-9



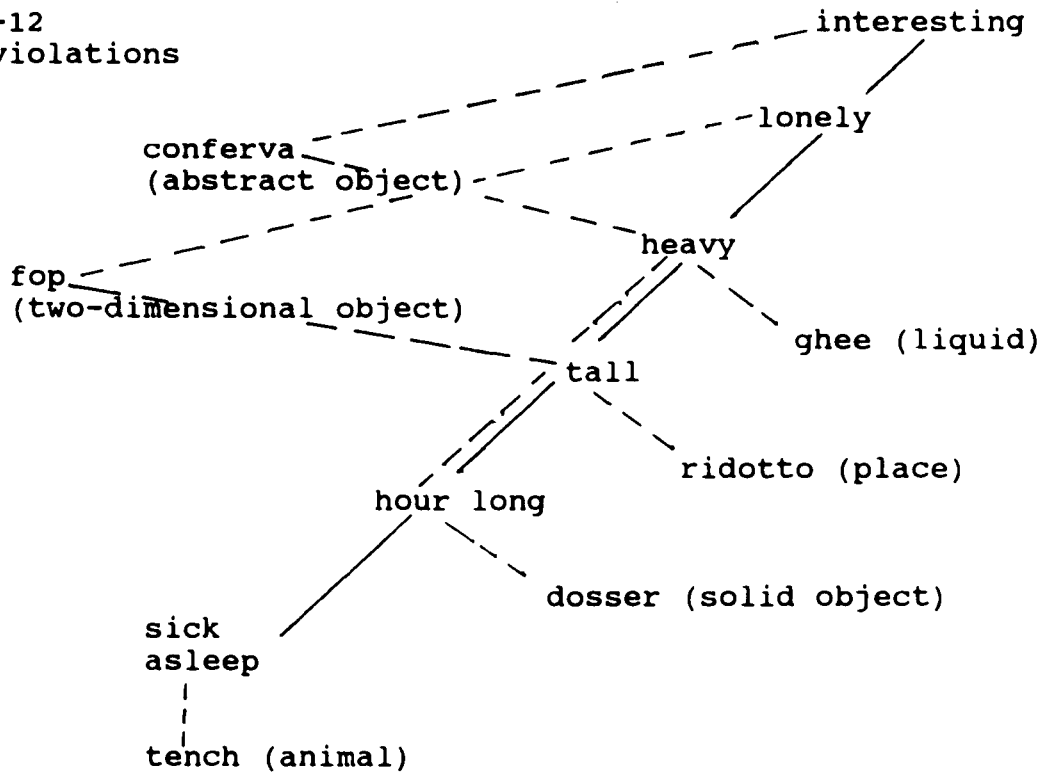
3-10



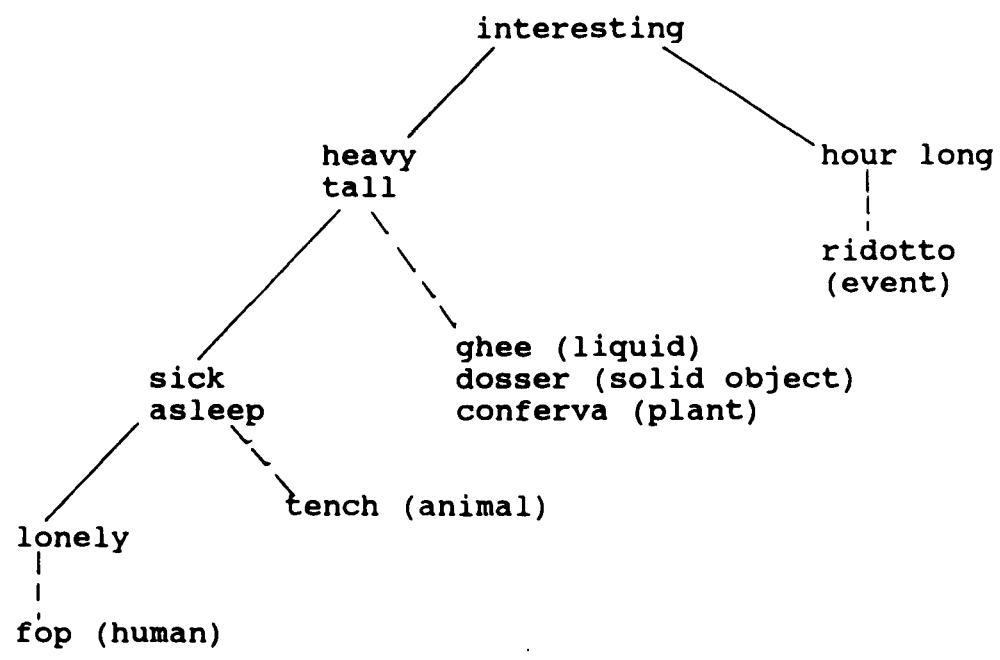
3-11



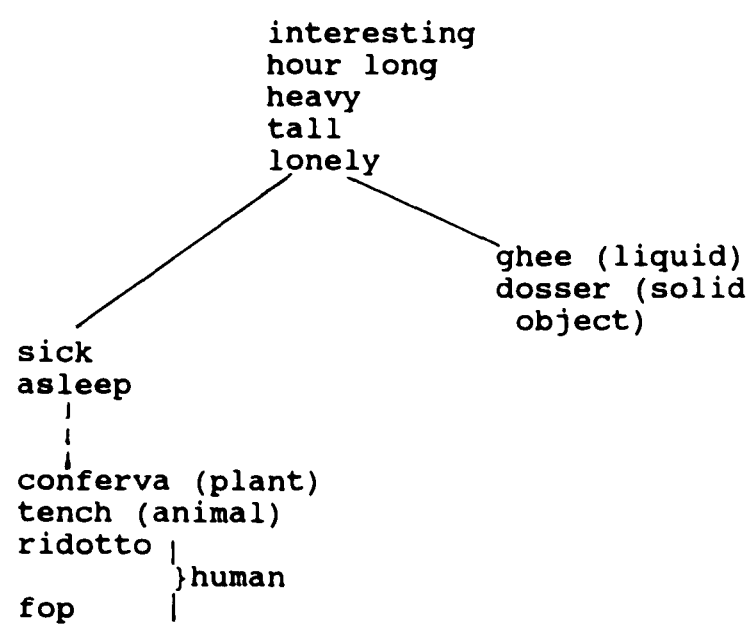
3-12  
2 violations



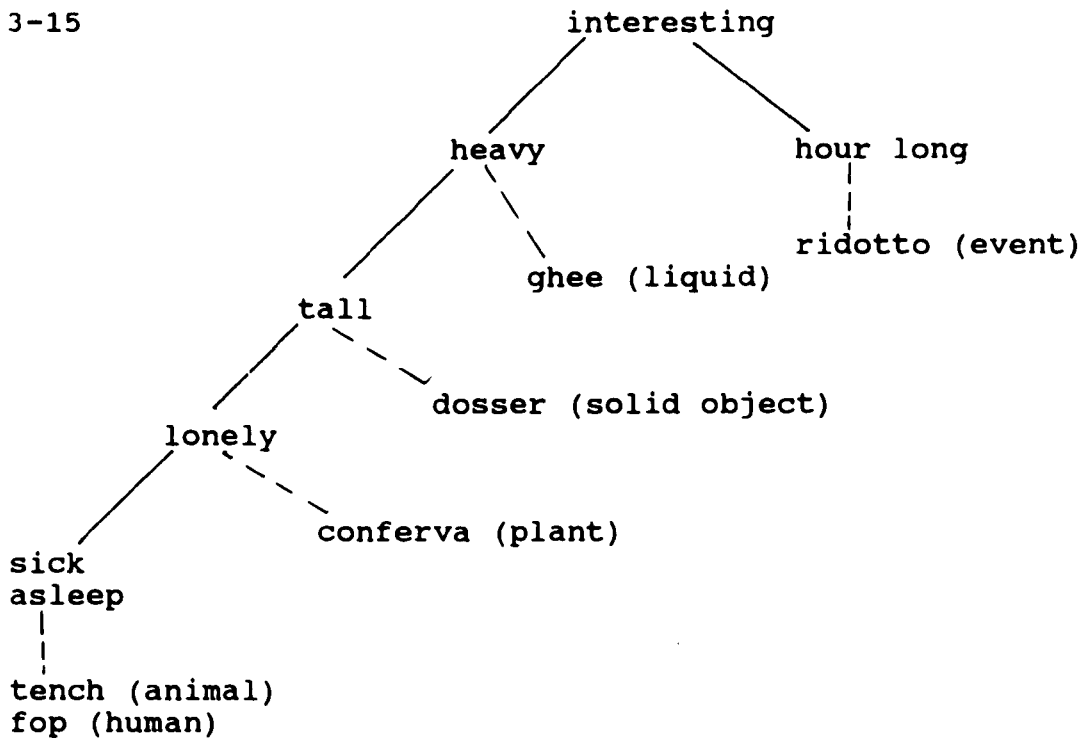
3-13



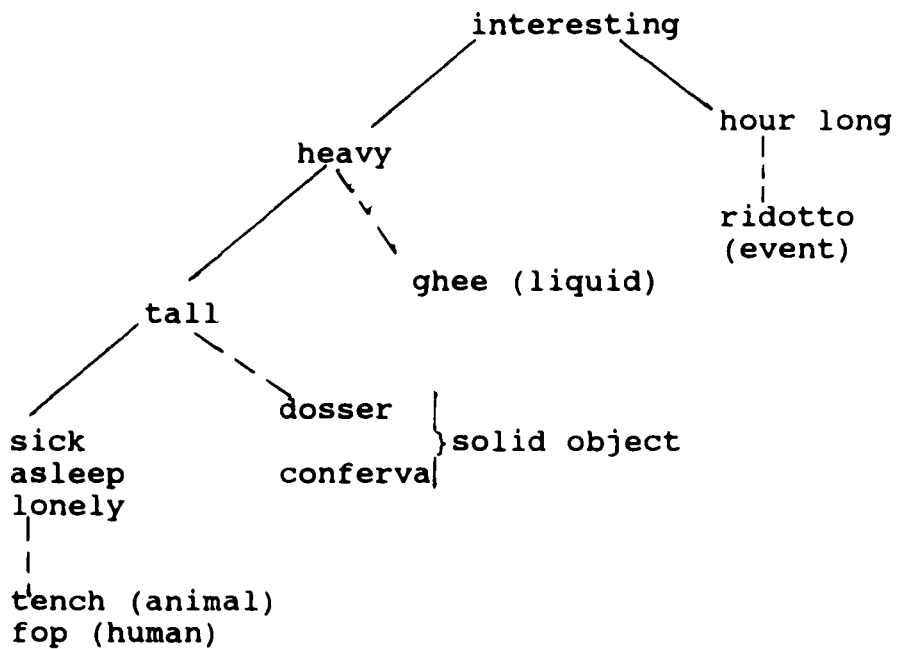
3-14



3-15

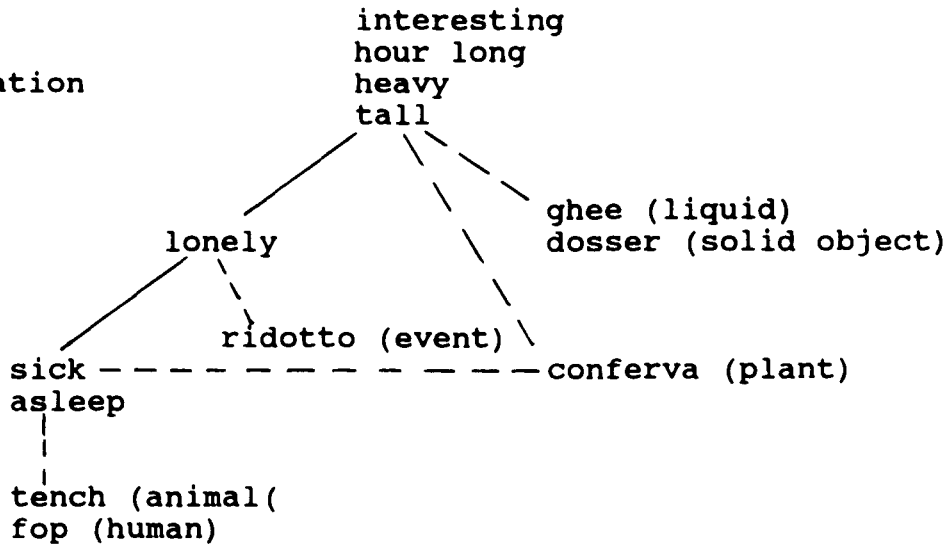


3-16

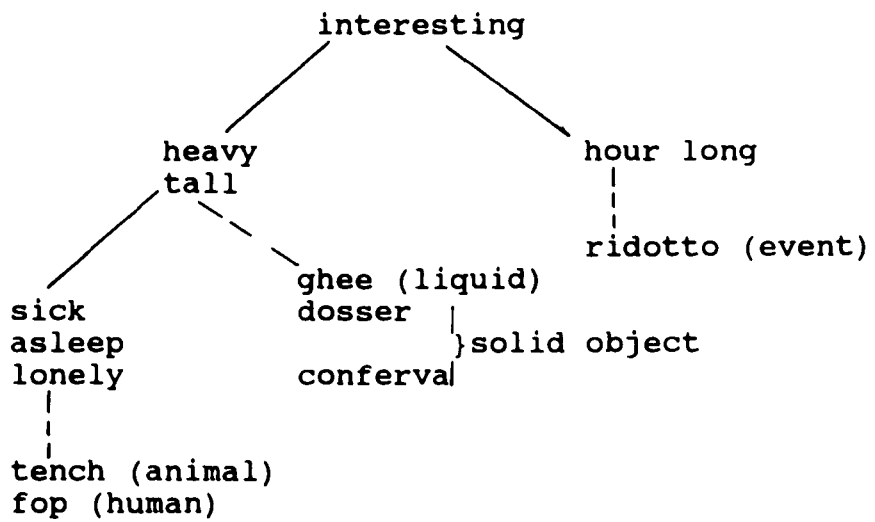


3-17

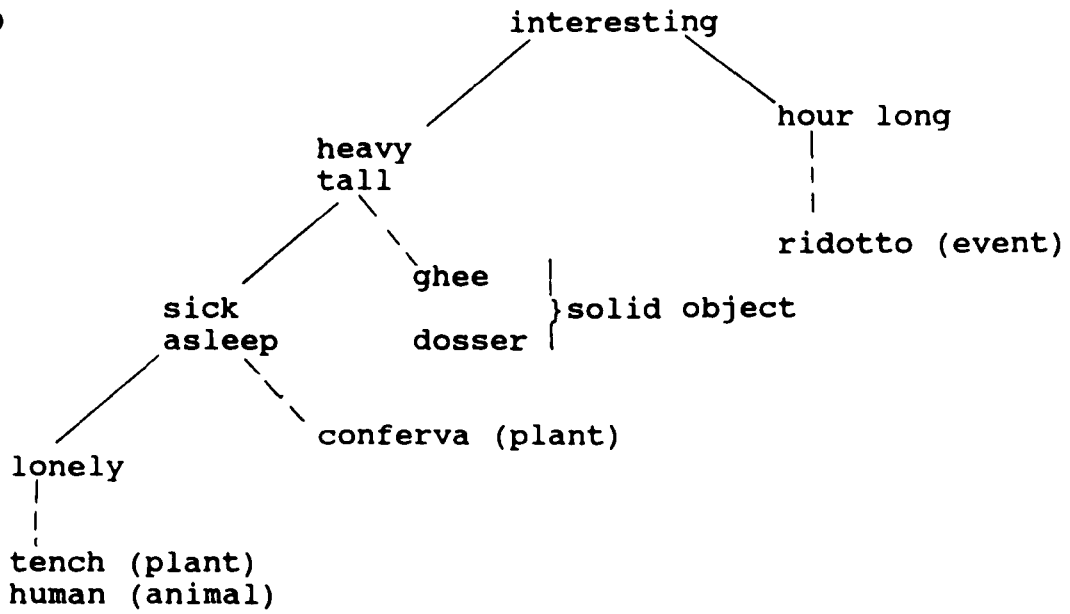
1 violation



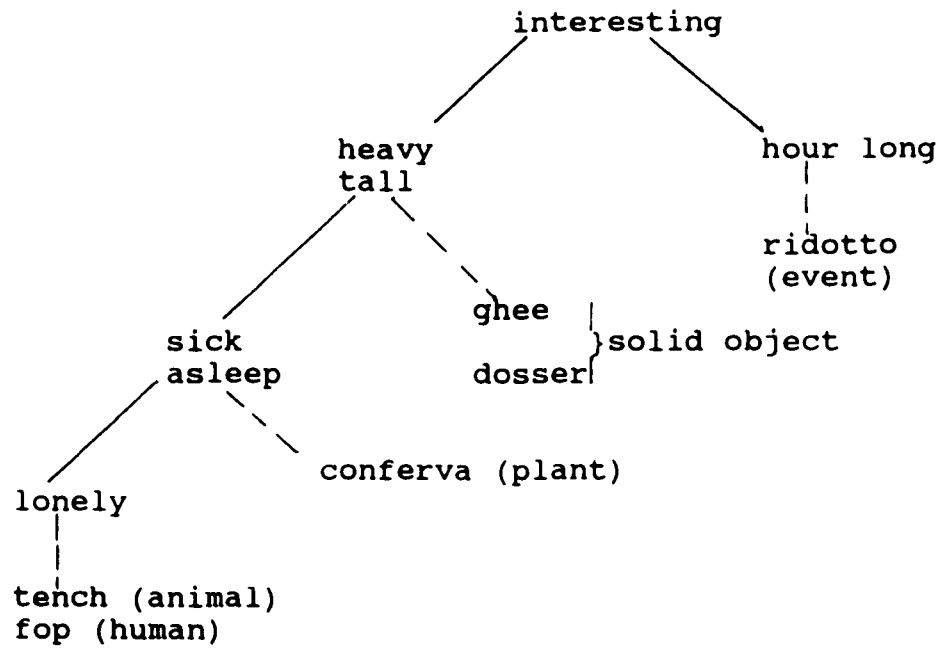
3-18



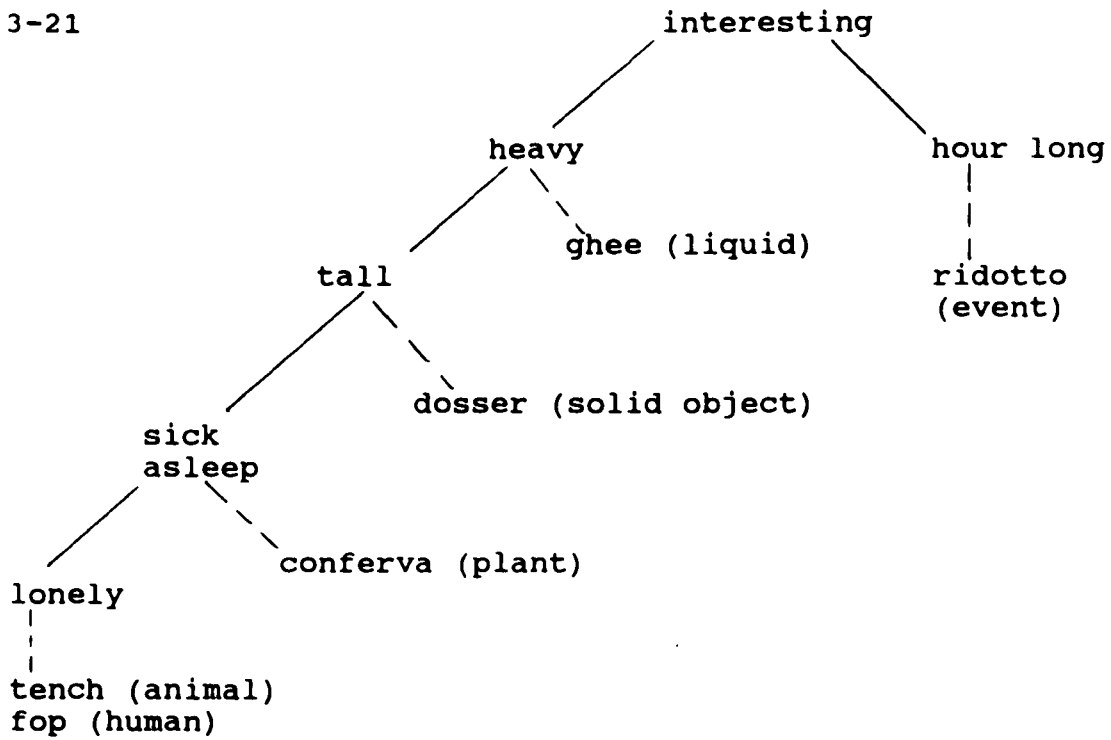
3-19



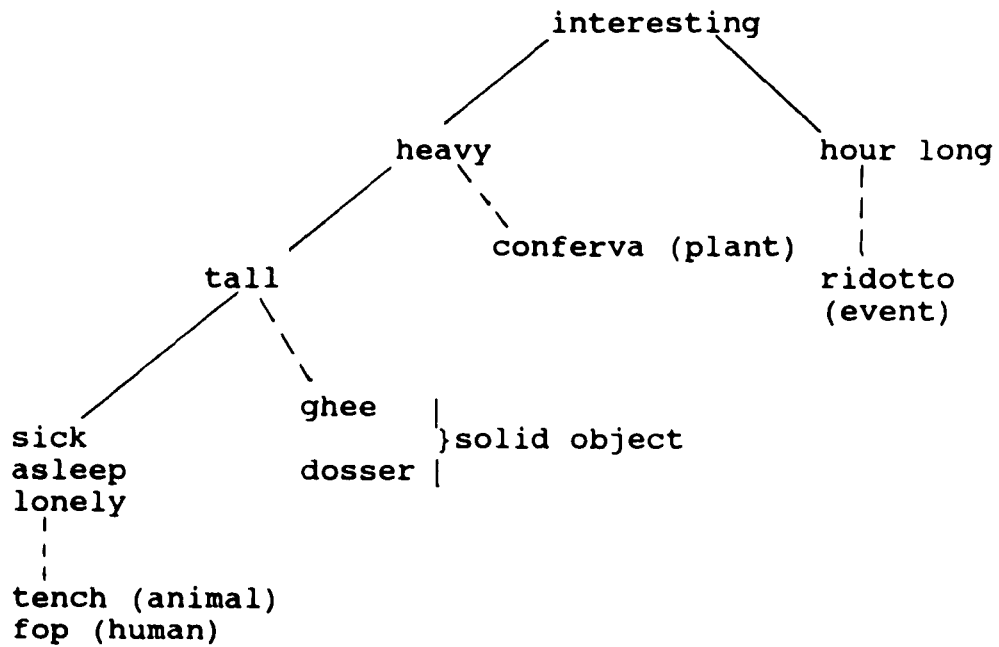
3-20



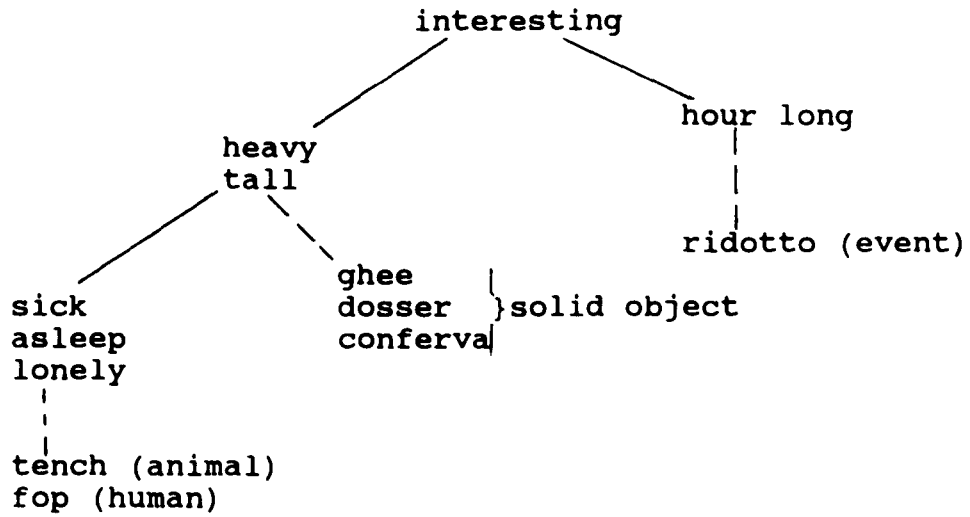
3-21



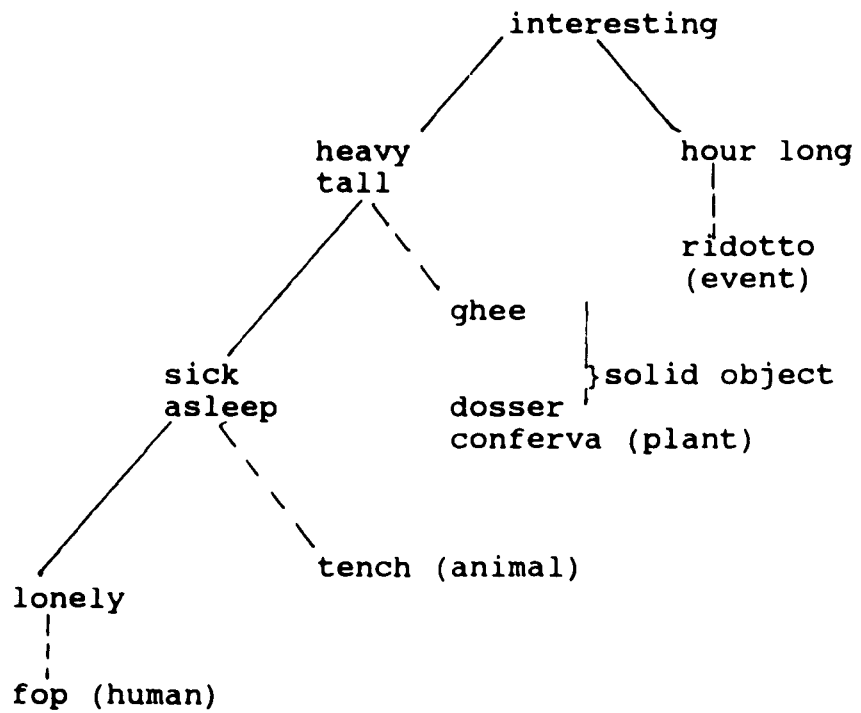
3-22



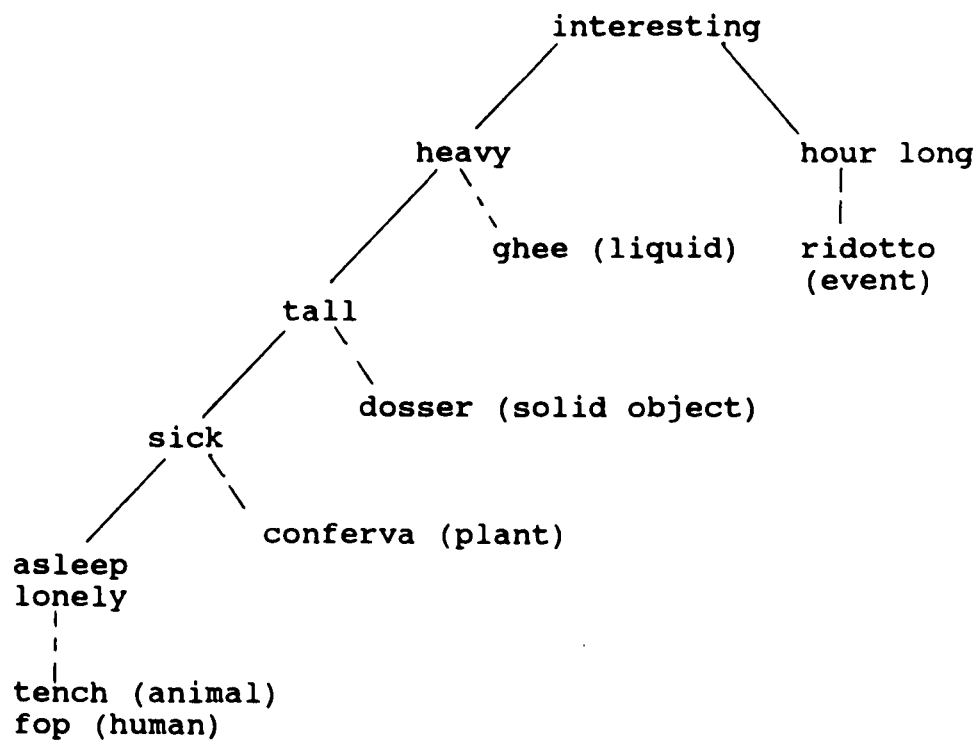
3-23



3-24



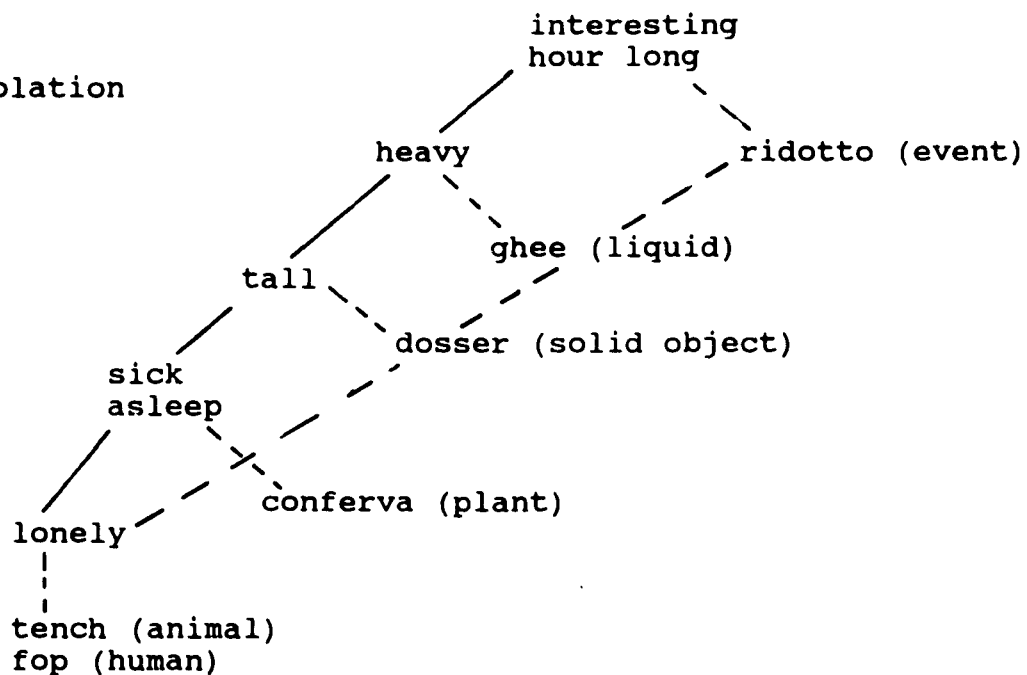
3-25



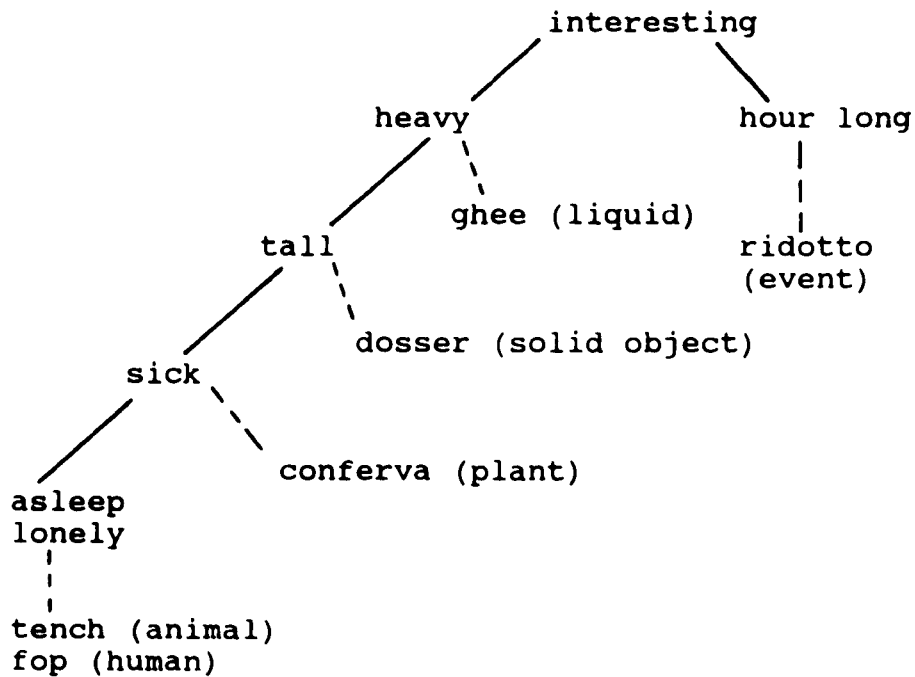
FIFTH GRADE SUBJECTS

5-1

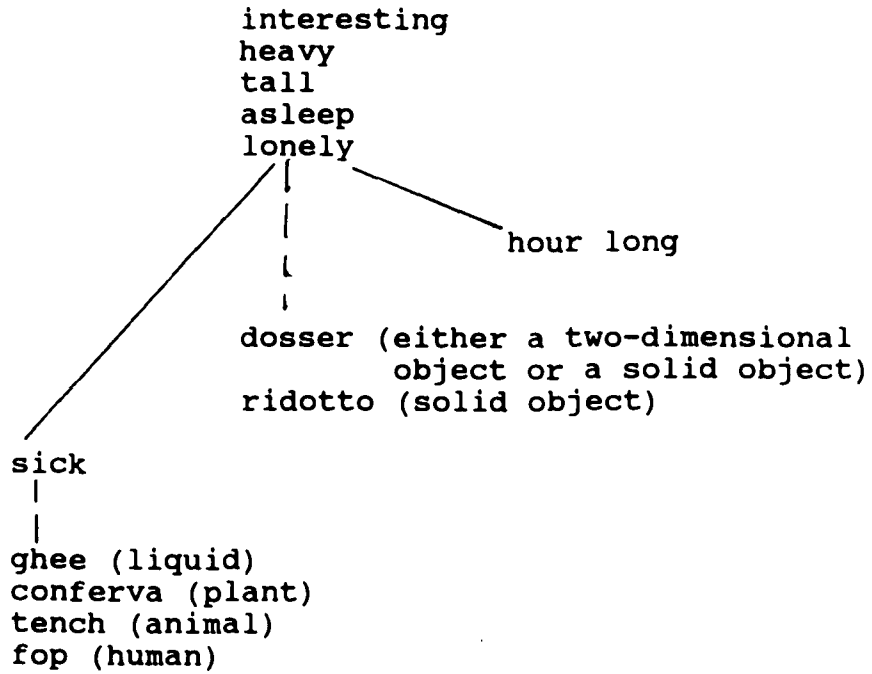
1 violation



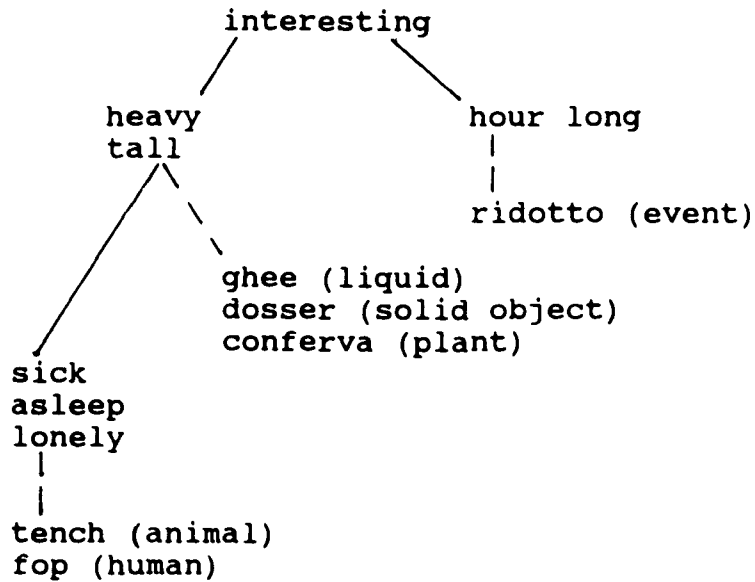
5-2



5-3

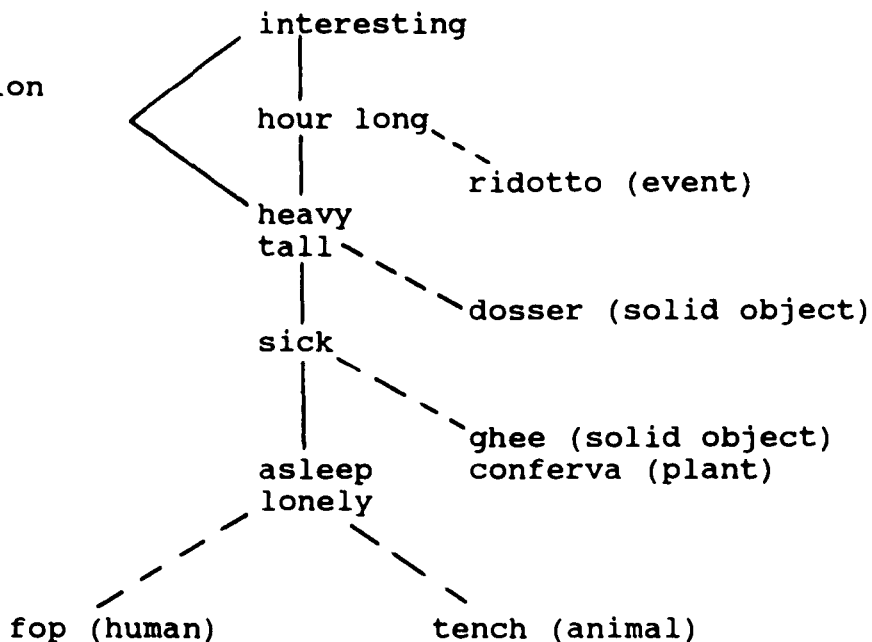


5-4

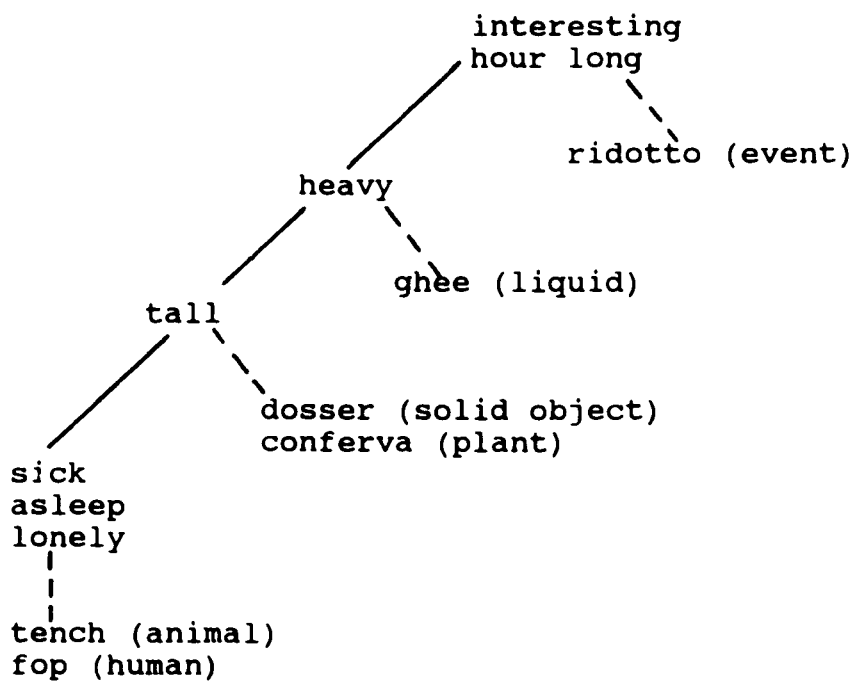


5-5

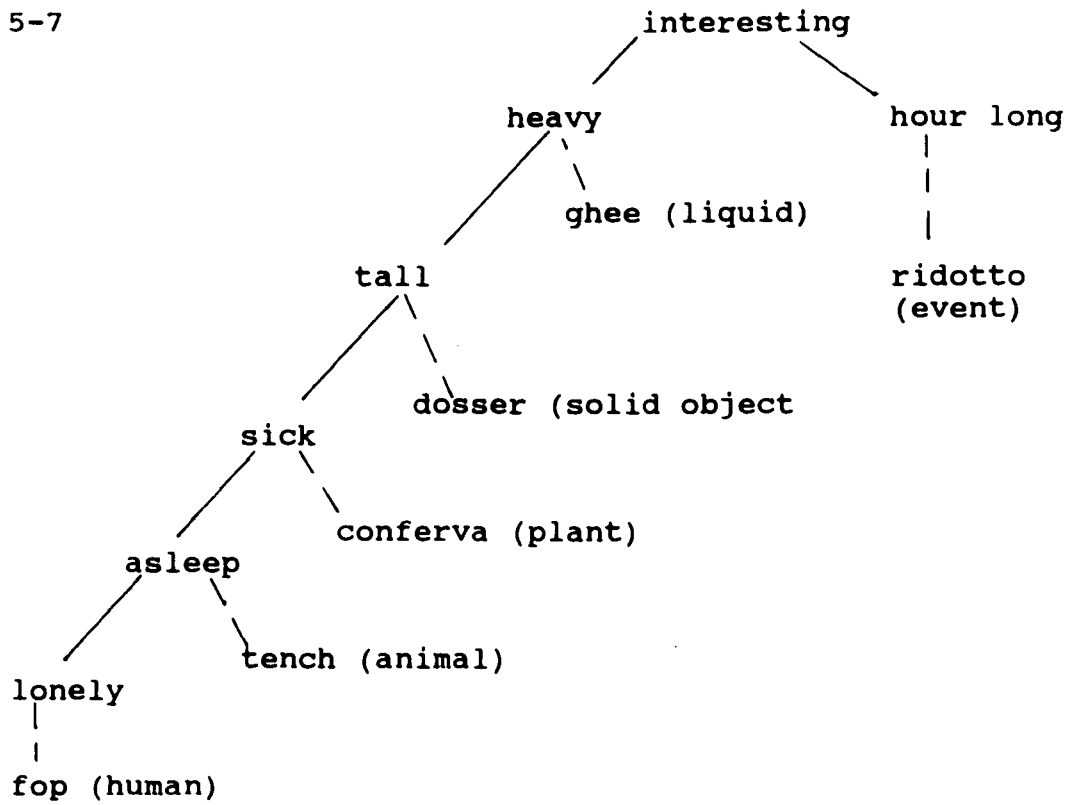
1 violation



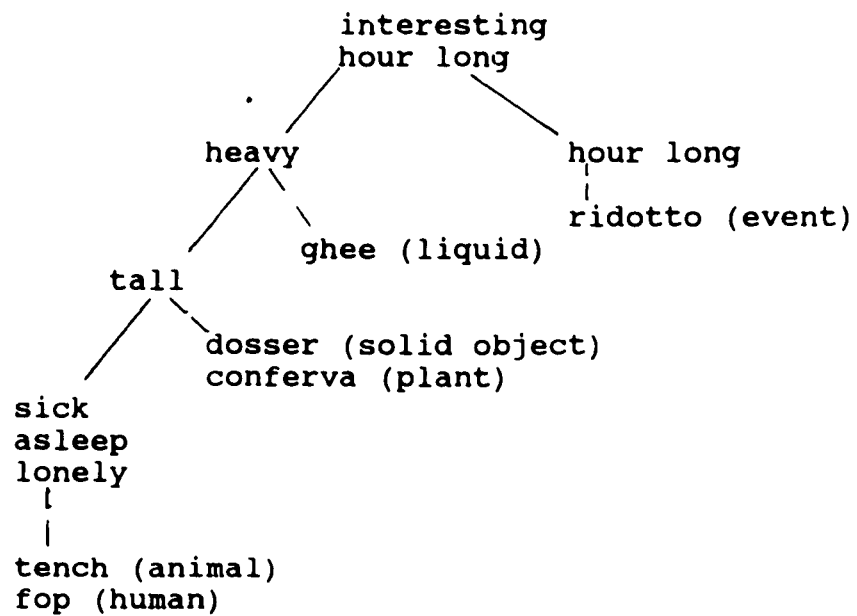
5-6



5-7

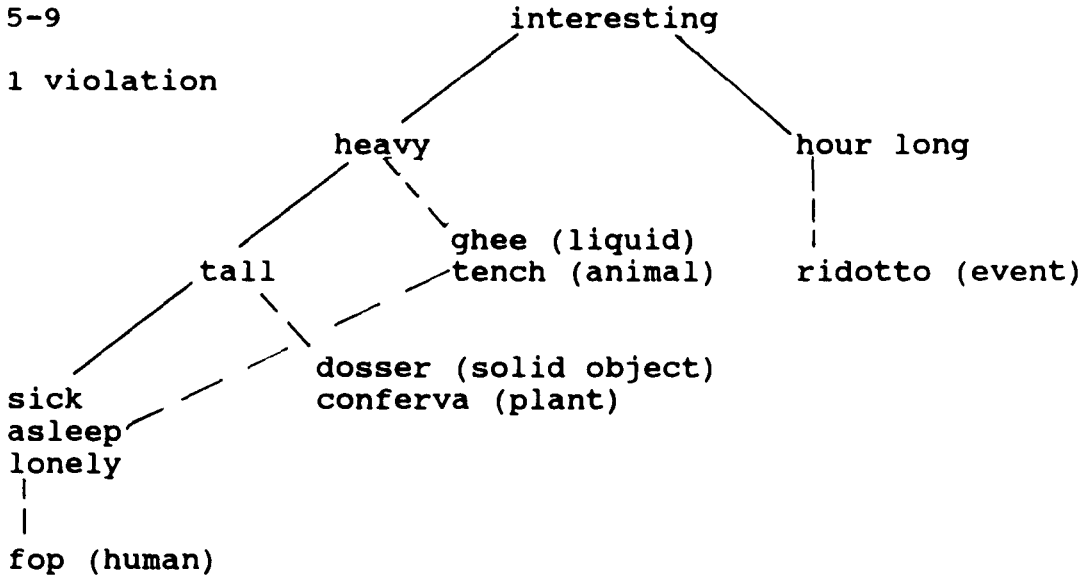


5-8

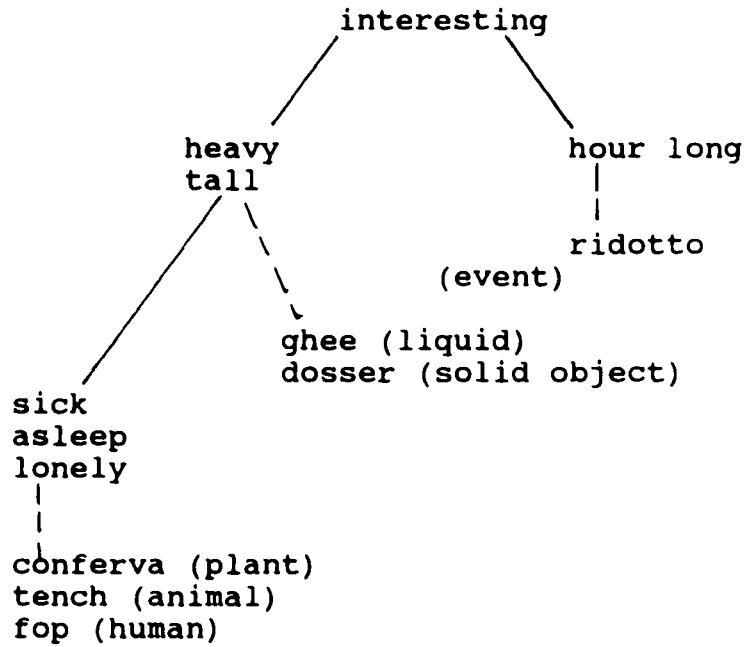


5-9

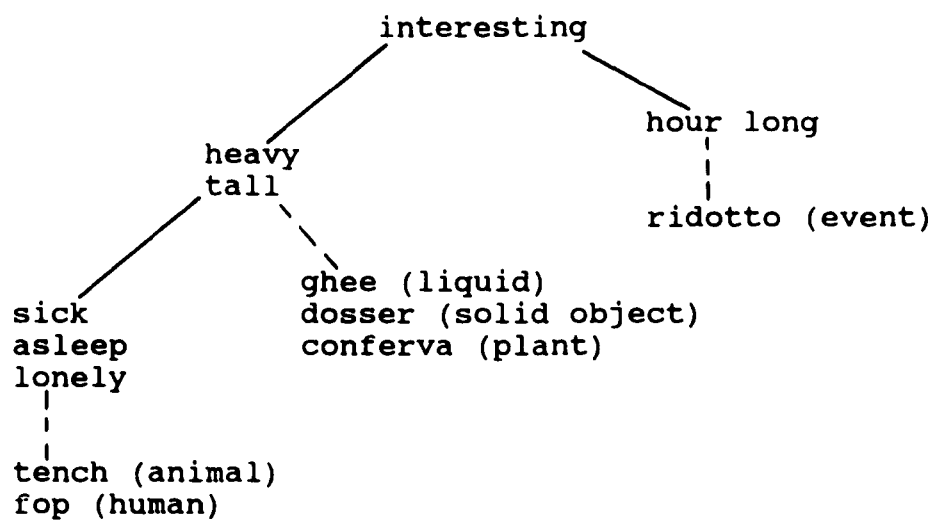
1 violation



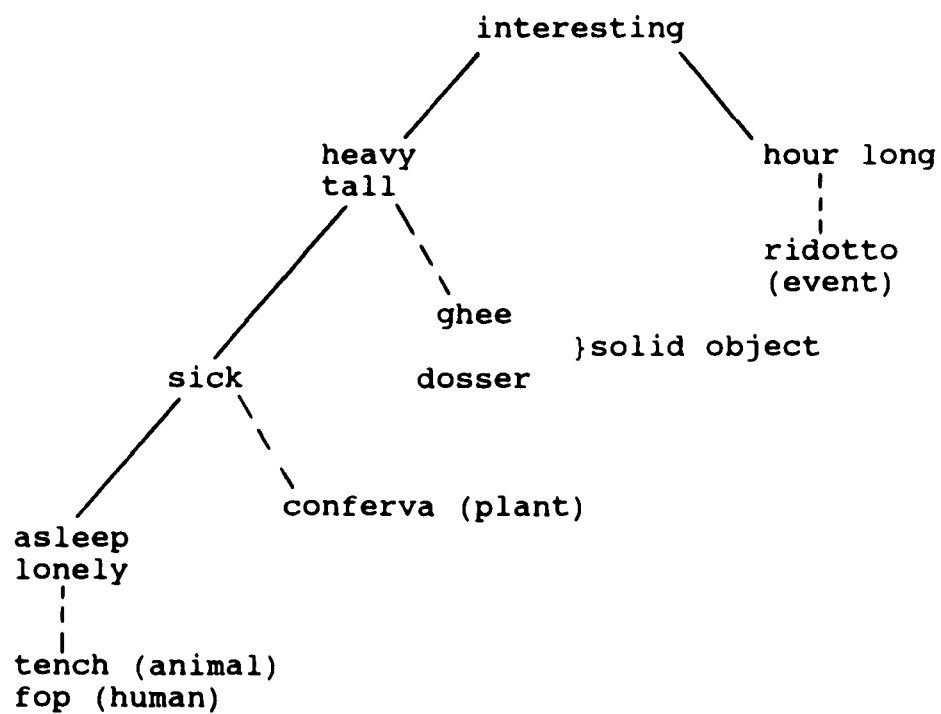
5-10



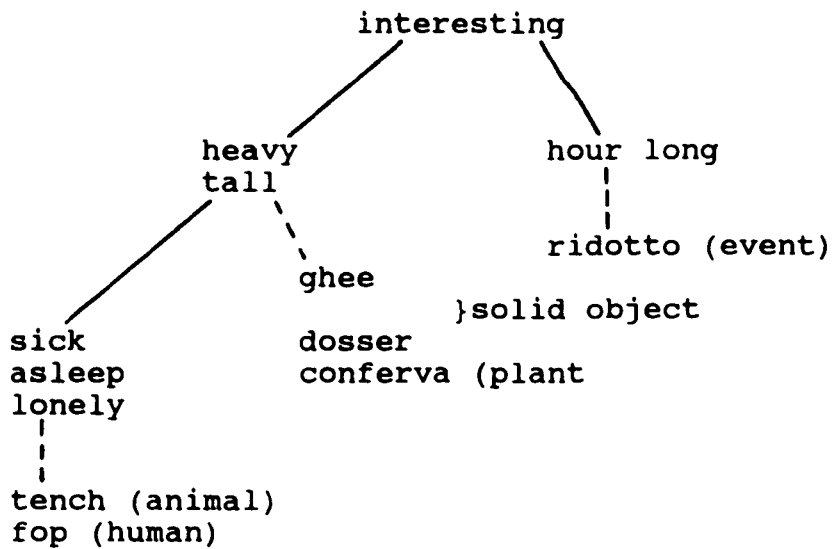
5-11



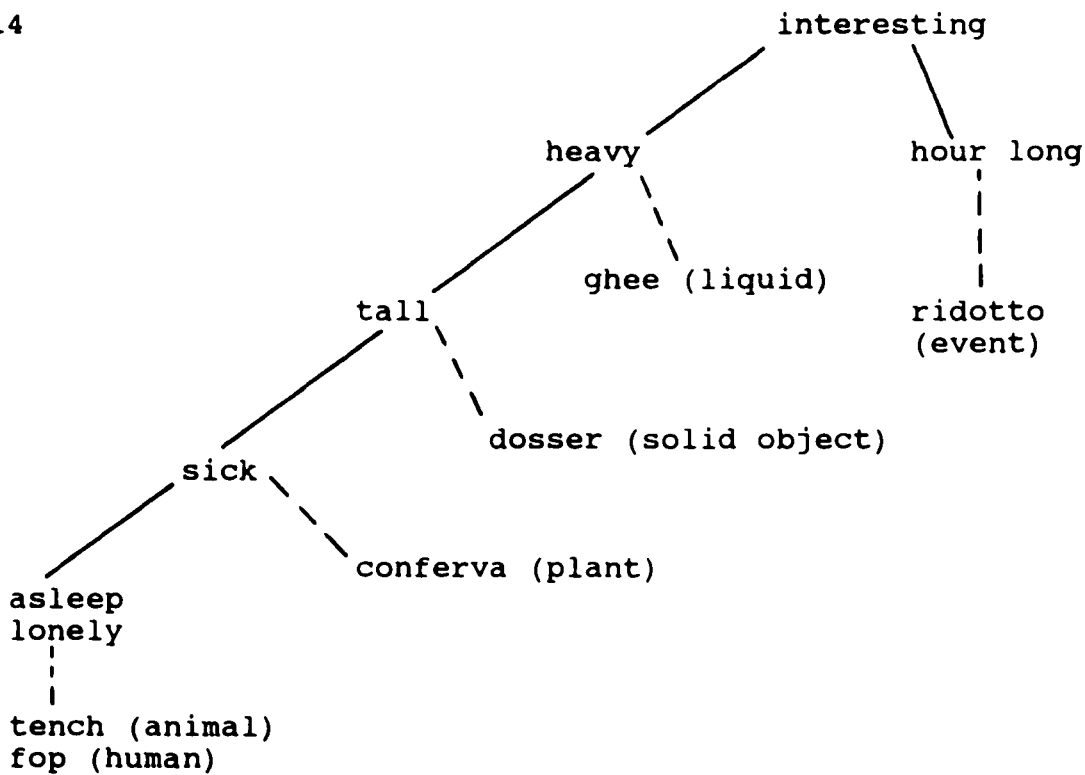
5-12



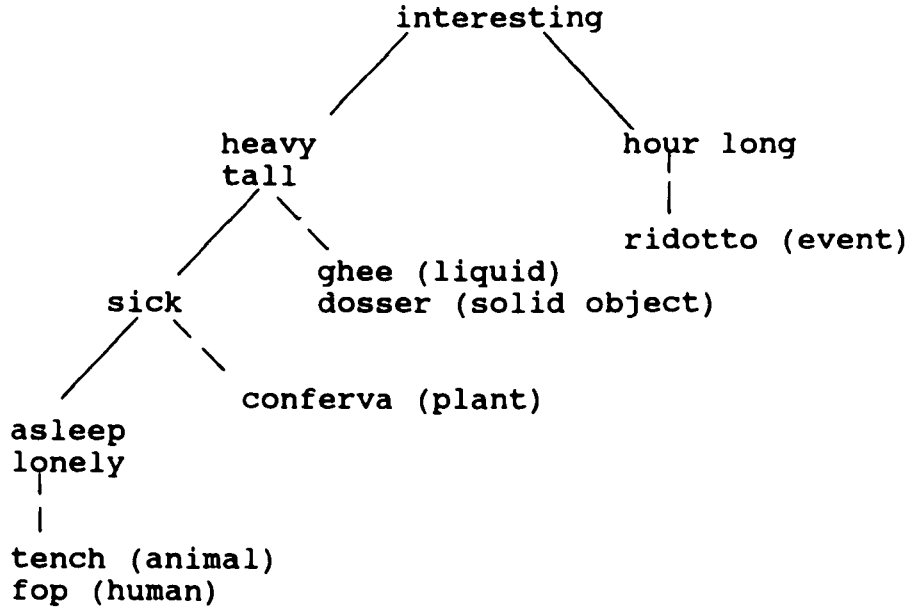
5-13



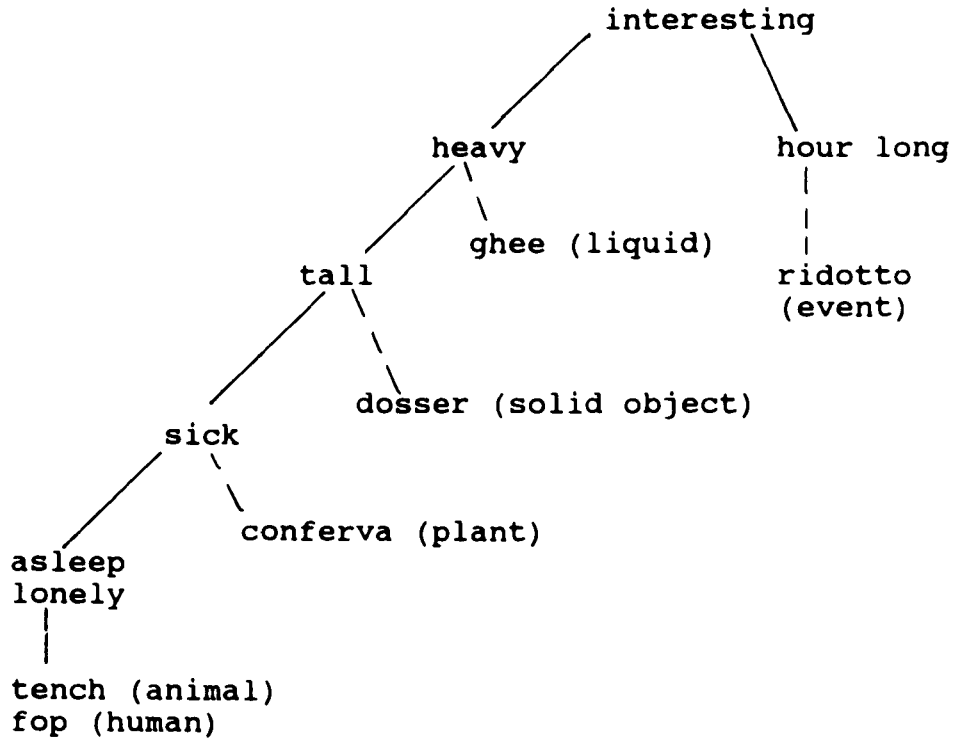
5-14



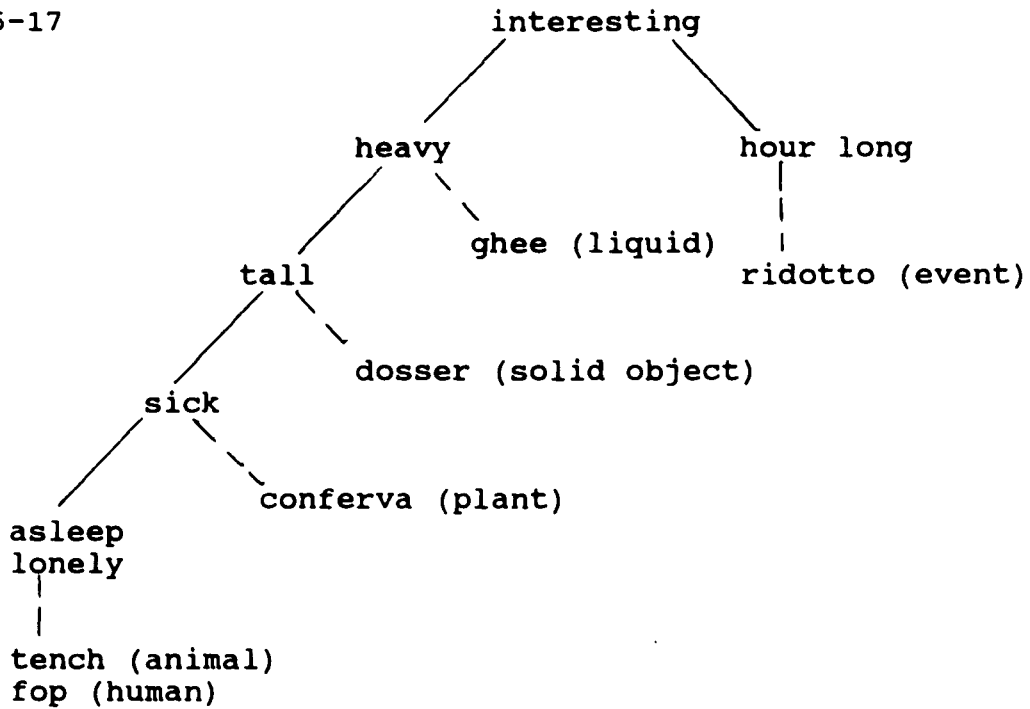
5-15



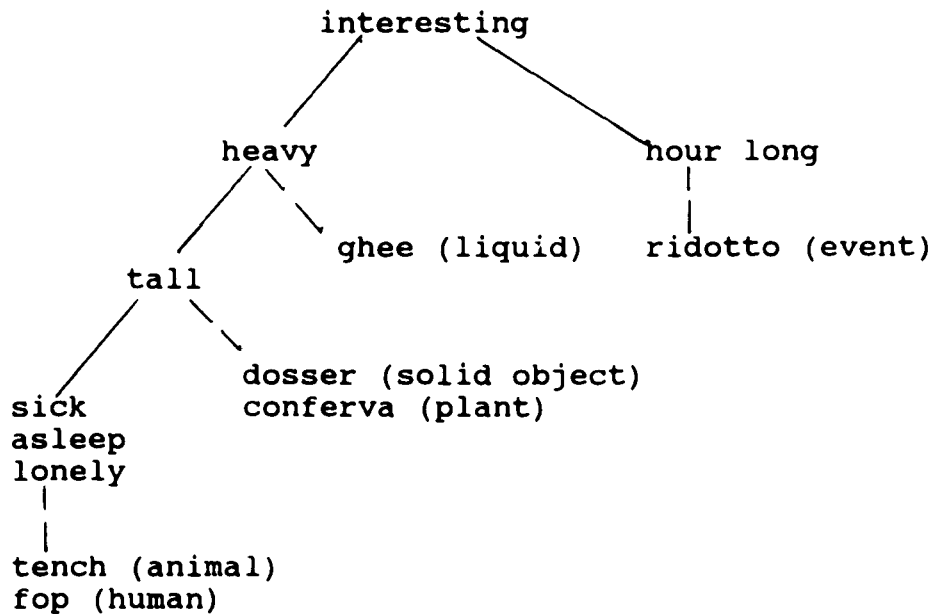
5-16



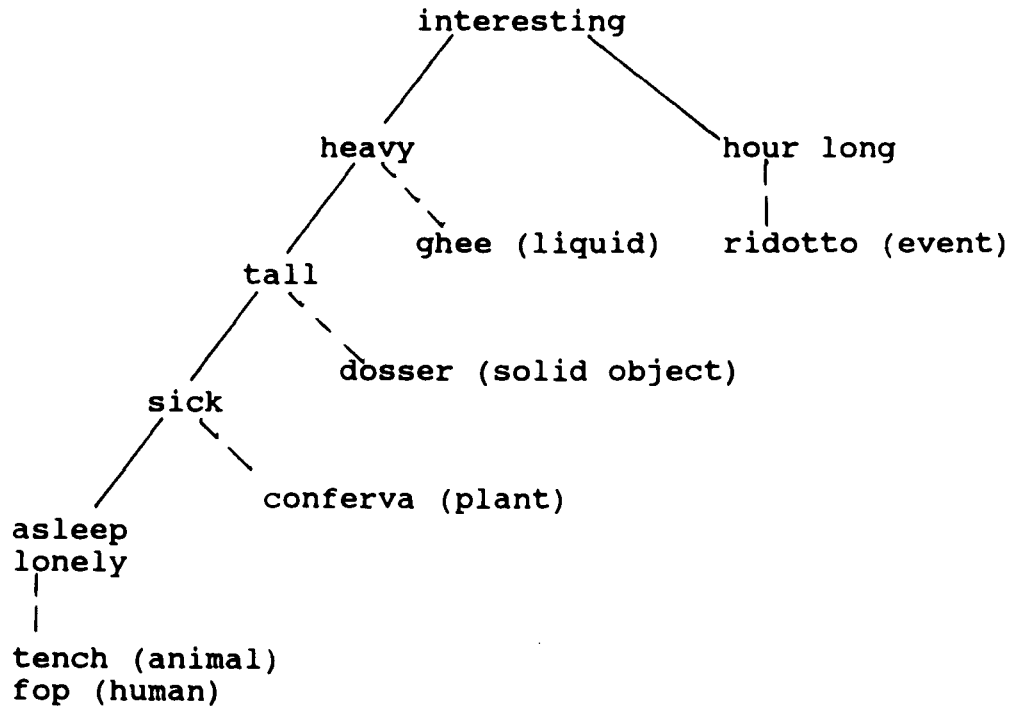
5-17



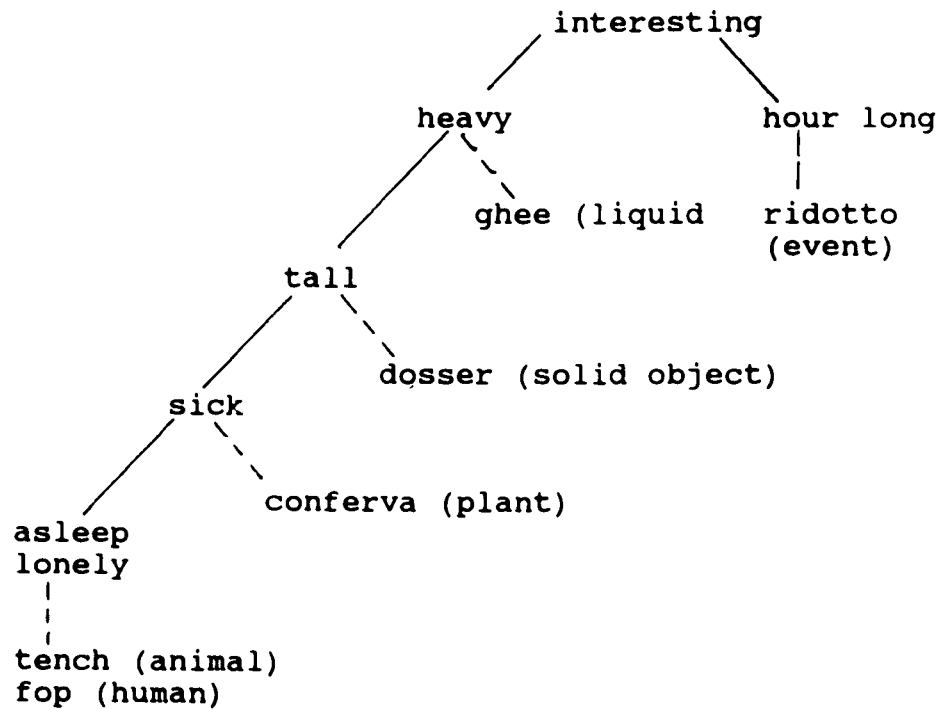
3-18



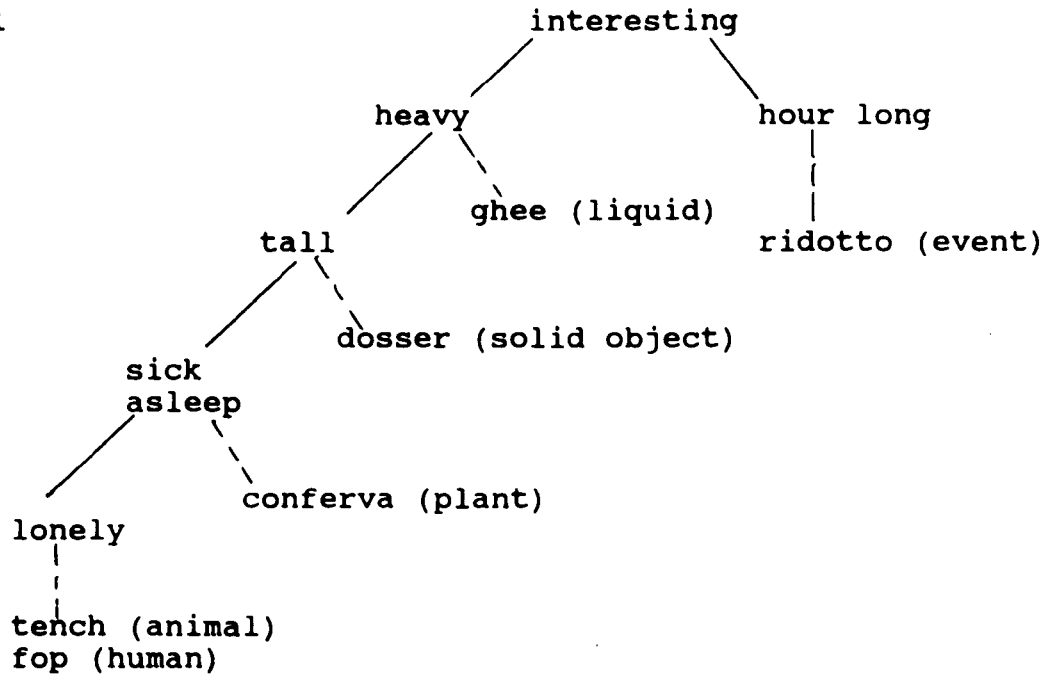
3-19



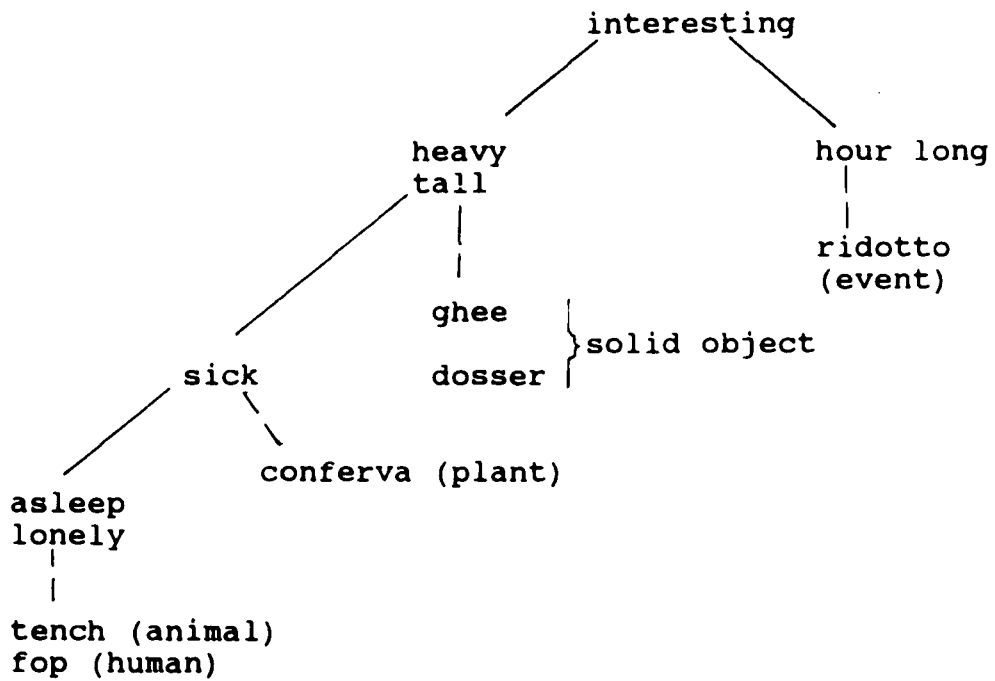
5-20



5-21

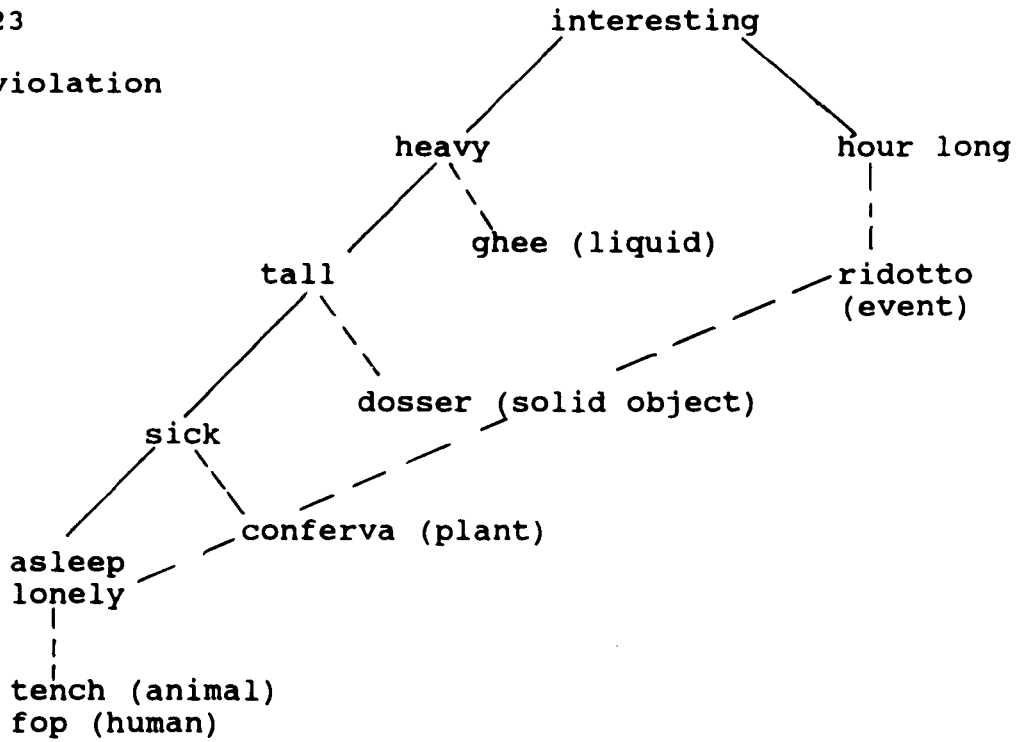


5-22

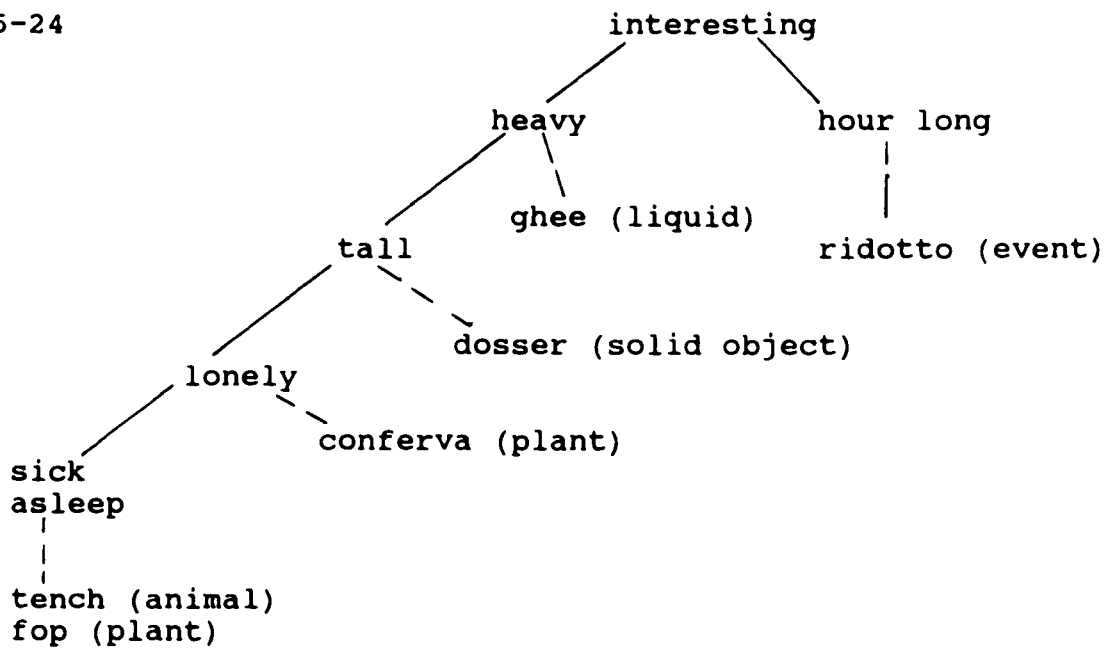


5-23

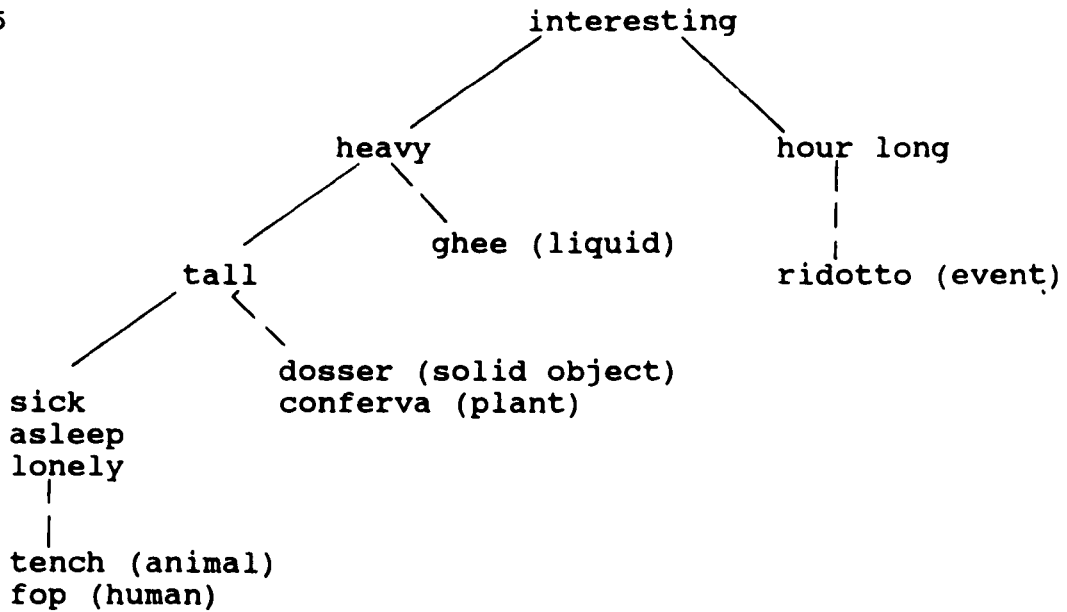
1 violation



5-24

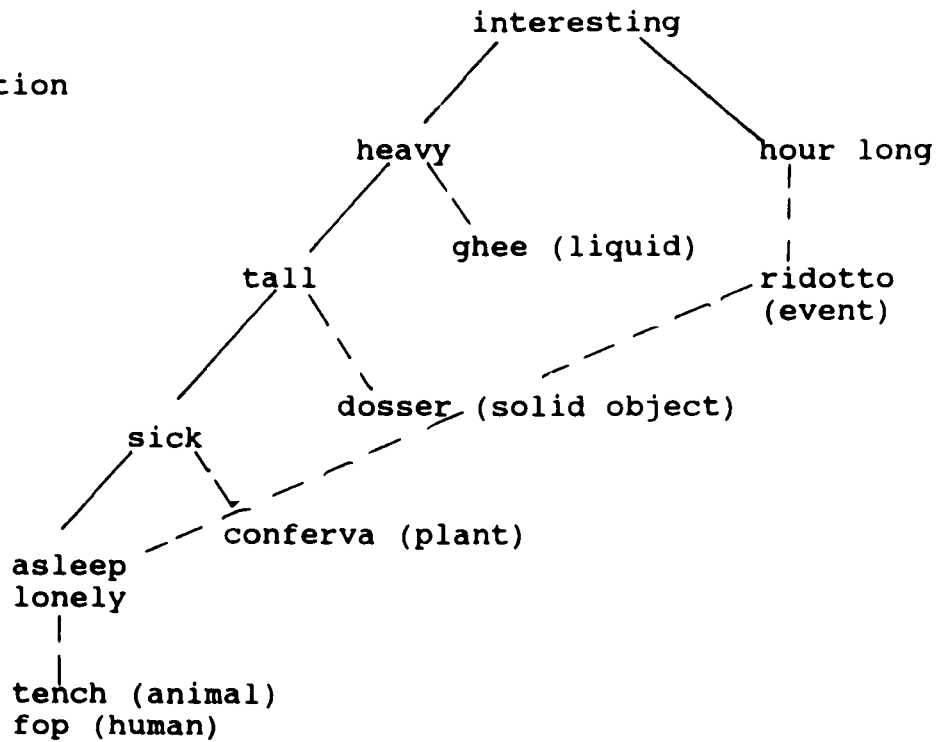


5-25

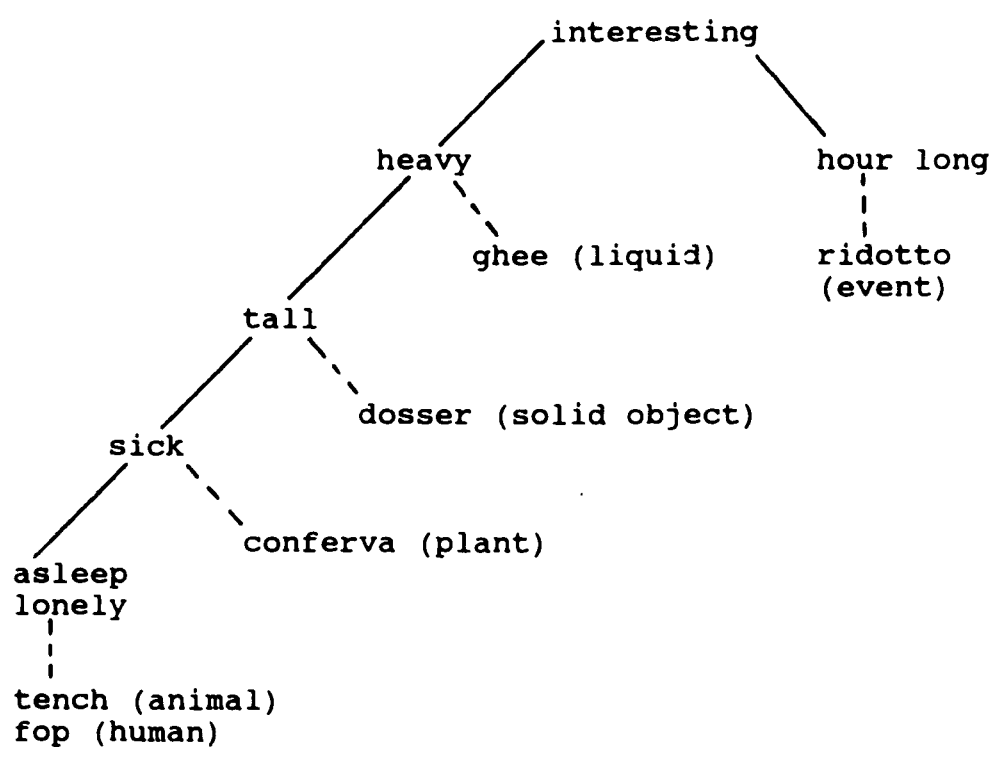


5-26

1 violation



5-27



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