What programming languages lack is any general mechanism for deriving facts from other facts; each update to a data structure is done by a domain-specific procedure whose details are derived by the programmer from his or her own knowledge of the domain. This procedural approach can be contrasted with the declarative nature of propositional logic, in which knowledge and inference are separate, and inference is entirely domain independent.

A second drawback of data structures in programs (and of databases, for that matter) is the lack of any easy way to say, for example, "There is a pit in [2,2] or [3,1]" or "If the wumpus is in [1,1] then he is not in [2,2]." Programs can store a single value for each variable, and some systems allow the value to be "unknown," but they lack the expressiveness required to handle partial information.

Propositional logic is a declarative language because its semantics is based on a truth relation between sentences and possible worlds. It also has sufficient expressive power to deal with partial information, using disjunction and negation. Propositional logic has a third property that is desirable in representation languages, namely, compositionality. In a compositional language, the meaning of a sentence is a function of the meaning of its parts. For example, the meaning of "S1 4 A S1 2" is related to the meanings of "S1 4" and "S1 2." It would be very strange if "S1 4" meant that there is a stench in square [1,4] and "S1 2" meant that there is a stench in square [1,2], but "S1 4 A S1 2" meant that France and Poland drew 1-1 in last week's ice hockey qualifying match. Clearly, noncompositionality makes life much more difficult for the reasoning system.

As we saw in Chapter 7, however, propositional logic lacks the expressive power to describe an environment with many objects. For example, we were forced to write a separate rule about breezes and pits for each square, such as

\[
B_{1:1} \iff (P_{1:2} V P_{2:1})
\]

In English, on the other hand, it seems easy enough to say, once and for all, "Squares adjacent to pits are breezy." The syntax and semantics of English somehow make it possible to describe the environment concisely.

### 8.1.1 The language of thought

Natural languages (such as English or Spanish) are very expressive indeed. We managed to write almost this whole book in natural language, with only occasional lapses into other languages (including logic, mathematics, and the language of diagrams). There is a long tradition in linguistics and the philosophy of language that views natural language as a declarative knowledge representation language. If we could uncover the rules for natural language, we could use it in representation and reasoning systems and gain the benefit of the billions of pages that have been written in natural language.

The modern view of natural language is that it serves as a medium for communication rather than pure representation. When a speaker points and says, "Look!" the listener comes to know that, say, Superman has finally appeared over the rooftops. Yet we would not want to say that the sentence "Look!" represents that fact. Rather, the meaning of the sentence depends both on the sentence itself and on the context in which the sentence was spoken. Clearly, one could not store a sentence such as "Look!" in a knowledge base and expect to
recover its meaning without also storing a representation of the context—which raises the question of how the context itself can be represented. Natural languages also suffer from ambiguity, a problem for a representation language. As Pinker (1995) puts it: "When people think about spring, surely they are not confused as to whether they are thinking about a season or something that goes boing—and if one word can correspond to two thoughts, thoughts can’t be words."

The famous Sapir-Whorf hypothesis claims that our understanding of the world is strongly influenced by the language we speak. Whorf (1956) wrote "We cut nature up, organize it into concepts, and ascribe significances as we do, largely because we are parties to an agreement to organize it this way—an agreement that holds throughout our speech community and is codified in the patterns of our language." It is certainly true that different speech communities divide up the world differently. The French have two words "chaise" and "fauteuil," for a concept that English speakers cover with one: "chair." But English speakers can easily recognize the category fauteuil and give it a name—roughly "open-arm chair."—so does language really make a difference? Whorf relied mainly on intuition and speculation, but in the intervening years we actually have real data from anthropological, psychological and neurological studies.

For example, can you remember which of the following two phrases formed the opening of Section 8.1?

"In this section, we discuss the nature of representation languages ..."

"This section covers the topic of knowledge representation languages ..."

Wanner (1974) did a similar experiment and found that subjects made the right choice at chance level—about 50% of the time—but remembered the content of what they read with better than 90% accuracy. This suggests that people process the words to form some kind of nonverbal representation.

More interesting is the case in which a concept is completely absent in a language. Speakers of the Australian aboriginal language Camp Yimithirr have no words for relative directions, such as front, back, right, or left. Instead they use absolute directions, saying, for example, the equivalent of "I have a pain in my north arm." This difference in language makes a difference in behavior: Guugu Yimithirr speakers are better at navigating in open terrain, while English speakers are better at placing the fork to the right of the plate.

Language also seems to influence thought through seemingly arbitrary grammatical features such as the gender of nouns. For example, "bridge" is masculine in Spanish and feminine in German. Boroditsky (2003) asked subjects to choose English adjectives to describe a photograph of a particular bridge. Spanish speakers chose big, dangerous, strong, and lowering, whereas German speakers chose beautiful, elegant, fragile, and slender. Words can serve as anchor points that affect how we perceive the world. Loftus and Palmer (1974) showed experimental subjects a movie of an auto accident. Subjects who were asked "How fast were the cars going when they contacted each other?" reported an average of 32 mph, while subjects who were asked the question with the word "smashed" instead of "contacted" reported 41 mph for the same cars in the same movie.