sentences to a knowledge base KB, we would call

$$\text{TELL}(KB,\ (\forall\, m, c\ \ Mother(c) = m\ \Leftrightarrow\ Female(m) \wedge Parent(m, c)))$$

and so on. Now if we tell it

$$\text{TELL}(KB, (Female(Maxi) \wedge Parent(Maxi, Spot) \wedge Parent(Spot, Boots)))$$

then we can

$$\text{ASK}(KB, Grandparent(Maxi, Boots))$$

ASSERTIONS
QUERIES
GOALS

and receive an affirmative answer. The sentences added using TELL are often called **assertions**, and the questions asked using ASK are called **queries** or **goals** (not to be confused with goals as used to describe an agent's desired states).

Certain people think it is funny to answer questions such as "Can you tell me the time?" with "Yes." A knowledge base should be more cooperative. When we ask a question that is existentially quantified, such as

$$\text{ASK}(KB,\ \exists\, x\ \ Child(x, Spot))$$

SUBSTITUTION
BINDING LIST

we should receive an answer indicating that Boots is a child of Spot. Thus, a query with existential variables is asking "Is there an x such that ...," and we solve it by providing such an x. The standard form for an answer of this sort is a **substitution** or **binding list**, which is a set of variable/term pairs. In this particular case, the answer would be $\{x/Boots\}$. (If there is more than one possible answer, a list of substitutions can be returned. Different implementations of ASK do different things.)

7.4 LOGICAL AGENTS FOR THE WUMPUS WORLD

MODEL-BASED AGENTS
GOAL-BASED AGENTS

In Chapter 6 we showed the outline of a knowledge-based agent, repeated here in slightly modified form as Figure 7.2. We also hinted at how a knowledge-based agent could be constructed for the wumpus world, but the limitations of propositional logic kept us from completing the agent. With first-order logic, we have all the representational power we need, and we can turn to the more interesting question of how an agent should organize what it knows in order to take the right actions. We will consider three agent architectures: **reflex** agents[8] that merely classify their percepts and act accordingly; **model-based agents**[9] that construct an internal representation of the world and use it to act; and **goal-based agents** that form goals and try to achieve them. (Goal-based agents are usually also model-based agents.)

The first step in constructing an agent for the wumpus world (or for any world) is to define the interface between the environment and the agent. The percept sentence must include both the percept and the time at which it occurred; otherwise the agent will get confused about when it saw what. We will use integers for time steps. A typical percept sentence would be

$$Percept([Stench, Breeze, Glitter, None, None], 5)$$

[8] Reflex agents are also known as **tropistic** agents. The biological term *tropism* means having a tendency to react in a definite manner to stimuli. A heliotropic plant, for example, is one that turns toward the sun.

[9] Note that this usage of "model" is related but not identical to its meaning as a world referred to by a sentence.