Chapter II. Questions and Answers.

1. Introduction.

The English language possesses specific sentence categories whose primary function is to express a request for information. Sentences belonging to these categories are called "interrogative sentences" or "questions". According to the rules of English discourse, a question asked by one discourse participant to another creates a positive obligation on the part of the addressee either to provide the requested information (i.e. give an "answer"), or to explain why he doesn't (give a "reply" in a more general sense). This chapter contains a discussion of formal methods for representing the contents of questions and the contents of answers, which make it possible to account for semantic relations between questions and answers - most importantly, for the correctness of a given answer with content $A$ in response to a question with content $Q$.

We should like to characterize the content of a question ("what it is that a question asks") and the content of an answer ("what it is that an answer describes") in such a way that a precise account can be given of how the correctness of an answer depends on the state of the world. Whereas the contents of "isolated assertions" have received much attention in studies concerning philosophical logic and formal semantics (where they are analysed as "propositions", i.e. as functions from interpretations or possible worlds to truthvalues), there is not yet much agreement about the proper semantic analysis of questions and answers. It should be pointed out here, that answers cannot be equated with "isolated assertions". Answers are not "stand-alone" utterances: they depend on context for proper interpretation.

The syntactic forms of answers come in such a wide variety of forms, that one may doubt whether they should all be treated as expressing the same kind of semantic object. The examples (1)-(15) give an impression of the variety of possible answers of the same question.

Did John go to the movies yesterday? (1)

may be answered by

Yes. (2)
Yes, he did. (3)
That's what he did. (4)
He went to the movies yesterday. (5)
He finally went. (6)

1) Secondary functions of questions have been widely recognized. Discussions of such secondary uses of questions (e.g. Churchill, 1978; Goody, 1978) indicate that they may always be analysed as "parasitic" on the primary use of requesting information.
No, Susan's out of town.  
Susan's out of town. 

The range of possible answers to a wh-question is just as wide.

Which girls did you like at Bill's party?

may be answered by

Jane and Mary

The girls we almost ran into in the hallway

None.

I liked Jane and Mary.

Jane and Mary are the ones I liked.

Well, the only friend of Bill's that I can barely stand at all
is Susan, and she's out of town you know.

This variety of examples also suggests that it would be attractive to treat certain forms of answers as semantically "basic", and to explain other forms as somehow "derived"; but what kinds of answers to pick out for the privileged status of "semantically basic" is still a matter of debate, as we shall see.

The next section will sketch and criticize some proposals which analyse questions and answers in terms of propositions (Hamblin (1973), Karttunen (1977), Groenendijk and Stokhof (1981)). Proposals of this sort assume that answers may be analysed independently of the question, as expressing propositions. This assumption is challenged in section 3. Section 4 discusses a proposal by Hausser (1980) which, for wh-questions, focusses on answers which are noun phrases rather than full sentences. Undesirable features of his treatment are pointed out.

Section 5 presents my own proposal, which also focusses on "short answers". This proposal, which provides the theoretical background for the treatment of questions and answers in the question-answering system PHLIQA1 (Medema et al., 1975; Bronnenberg et al., 1978), is closer in spirit to Whately (1826) and Tichý (1978) than to Hausser.

One of the points which will emerge from the discussion in this chapter, is that semantic correctness is only one of the conditions that an adequate answer must fulfill. A computer program for question answering must also embody pragmatic strategies which determine what kind of a correct answer it wants to give. This issue is discussed in the final section of the present chapter.
2. Characterizing the Content of a Question in Terms of its Propositional Answers.

2.1. Hamblin: Questions as Sets of Possible Answers.

Hamblin's (1973) extension of Montague's "English as a Formal Language" (1970) treats questions and answers. Answers are implicitly equated with isolated assertions, and analysed as propositions. Questions are analysed as sets of propositions: the propositions expressed by possible answers to the question. A correct answer can then simply be defined as a proposition which is true and is included in the proposition set expressed by the question.

The possible propositional answers to a yes/no question in Hamblin's analysis are, plausibly enough, the assertion corresponding to the question, and the negation of that assertion. A yes/no question is therefore analysed as a set which contains a proposition and its negation. For instance,

\[ \text{Does John walk?} \]  \hspace{1cm} (1)

would be analysed as

\[ \{ \neg \text{WALK(JOHN)}, \neg \rightarrow \text{WALK(JOHN)} \} \]  \hspace{1cm} (2)

Besides yes/no questions, Hamblin treats singular wh-questions, like

\[ \text{What dog walks?} \]  \hspace{1cm} (3)

which are interpreted as "mention-one" questions; e.g., (3) is read as a request to assert about some entity that it is a walking dog. The possible answers to (3) that Hamblin considers are sentences like

\[ \text{Fido is a dog and he walks.} \]  \hspace{1cm} (4)
\[ \text{Fido is a dog which walks.} \]  \hspace{1cm} (5)
\[ \text{Fido is a walking dog.} \]  \hspace{1cm} (6)

which express propositions which can be represented by formulas of the form

\[ \text{WALK}(a) \& \text{DOG}(a) \]  \hspace{1cm} (7)

\[ ^{2} \text{Strictly speaking, Hamblin analyses assertions as sets of propositions. But unlike most questions, they are singleton sets.} \]
where $a$ is a logical proper name. Question (3) is therefore analysed as the set of propositions

$$\{ P \mid \exists x: P = \neg (\text{walk}(x) \& \text{dog}(x)) \}$$

(8)

Hamblin focusses on "mention-one" readings of wh-questions, but this is not because of any essential properties of his approach. For example,

**Which dogs walk?**

(9)

may be read as a "mention-all' question, requesting its addressee to assert about some set that its elements are all the dogs that walk. In Hamblin's spirit, this question (i.e., its possible answers) would be represented by the formula

$$\{ P \mid \exists X: P = \neg (X = \{ x \mid \text{dog}(x) \& \text{walk}(x) \}) \}$$

(10)

Hamblin's representation of the content of a question means that, at the logical level, answering a question with content $Q$ would consist in finding an "explicit" formula (i.e., one which does not quantify over propositions) which denotes a proposition $A \in Q$ such that $\neg A$. For yes/no questions this would amount to finding out which one of the two possible answers denotes true. For wh-questions, where the set of possible answers is defined by a formula of the form

$$\{ P \mid \exists x: P = \neg R(x) \},$$

(11)

finding the logical representation of an answer would consist in finding a logical proper name $i$ such that $R(i)$.

2.2. **Karttunen: Questions as Properties of True Answers.**

Karttunen's (1977) proposal for dealing with the semantics of questions derives from Hamblin's but differs from it on some points. He describes an extension of Montague's "Proper Treatment of Quantification in Ordinary English" (Montague, 1973) which accommodates indirect questions (embedded whether- and which-clauses). The analyses of whether- and which-clauses are intended to carry over directly to yes/no questions and which-questions, respectively. 3)

3) Karttunen proposes to do this by equating questions with assertions of the form "I ask you to tell me..." I do not see how this could have any advantages above assuming the usual speech act analysis which distinguishes different illocutionary forces such as questioning, asserting, etc. Nothing hinges on this aspect of Karttunen's proposal, however. What I call "the content of the question", i.e. the semantic object of the "question-operator", would correspond to the direct object of the relation representing the verb "tell" in Karttunen's treatment.
Karttunen views answers as propositions. These answer-propositions are not to be equated with isolated assertions, however, but must be "processed" in the "context" of the question they answer. A question is analysed as the property of those propositions which correspond to true answers. A (full sentence) answer with content $A$ in response to a question with content $Q$ can then be defined to be correct simply iff $\forall Q(A)$.

Possible answers to yes/no questions are defined just as in Hamblin's treatment. Wh-questions are again viewed as mention-one questions, but they are treated in a slightly different way. For instance, the possible answers to

$Which\ girl\ sleeps?$ (1)

which are considered, are not the answers of the form

$Mary\ is\ a\ girl\ who\ sleeps.$ (2)

but the answers of the form

$Mary\ sleeps.$ (3)

The possible answers in Karttunen's treatment are the answers expressing propositions which can be represented by formulas of the form

$Sleep\ (i)$ (4)

such that $i$ is a logical proper name and $\text{gir}l\ (i)$ is true. Question (1) is therefore analysed as the propositional concept

$\forall \lambda P: \forall P \& \exists x: \text{gir}l(x) \& P = \sim Sleep(x)$ (5)

Analysing the content of a question as the property of its true answers, as Karttunen does, rather than the set of its possible answers, as Hamblin proposed, does not lead to essentially different consequences. The same class of answers is accounted for, in an equally simple way. Because of this, one might prefer the Hamblin treatment, since the content of a question is a "simpler" object in this treatment; Karttunen assigns a higher level of intensionality to the content of a question than Hamblin does.

2.3. Answer-Propositions in Context.

The present subsection discusses a departure from Hamblin's ideas, made by Karttunen's treatment, concerning the decision as to what to take as a paradigmatic propositional answer to a mention-one question. This decision has immediate consequences for the role which the meaning of the "wh-nounphrase" plays in the content of a question. Consider question (1) again,

$Which\ girl\ sleeps?$ (1)

with its two answers (2) and (3).

$Mary\ is\ a\ girl\ who\ sleeps.$ (2)

$Mary\ sleeps.$ (3)
If (1) is answered by (3), this utterance of (3) "implicitly states" (as Hamblin puts it) that Mary is a girl. The propositions which Hamblin counts as answers are therefore analyses of sentences like (2) rather than (3), which means that answers like (3) have to be treated as somehow elliptical.

Karttunen’s answers have the form (3) rather than (2); this amendment suggests a different kind of account of the situation, which has attractive features. There is some plausibility in the idea that an answer should not be treated as an isolated assertion, but should be processed in the context created by the question instead. In this case, what an answer communicates does not necessarily coincide with the assertion of the truth of the expressed proposition; instead, it communicates the (possibly more specific) fact that this proposition constitutes a true answer to the preceding question. What an answer with content $A$ communicates in the context of a question with content $Q$ is the information that $^\sim A \land (A \in Q)$. For instance, in the context of a question with content

$$\{P \mid \exists x: \text{GIRL}(x) \land P = ^\sim \text{SLEEP}(x)\}$$

(4)

(i.e., assuming the Karttunen amendment of Hamblin’s proposal as far as the placement of the predicate GIRL is concerned), an answer with content

$$^\sim \text{SLEEP} (\text{MARY})$$

(5)

communicates the information that

$$\text{SLEEP} (\text{MARY}) \land (^\sim \text{SLEEP} (\text{MARY}) \in \{P \mid \exists x: \text{GIRL}(x) \land P = ^\sim \text{SLEEP}(x)\}$$

(6)

which is logically equivalent to

$$\text{SLEEP} (\text{MARY}) \land \text{GIRL} (\text{MARY})$$

(7)

Thus what is "implicitly stated" by (3) is exactly the difference between what it communicates as an isolated assertion (i.e., the proposition it expresses) and what it communicates in the context of the question.

A problem with Karttunen’s variant arises, however, when readings of wh-questions which require exhaustive answers are considered. If

$$\text{Which girls sleep?}$$

(8)

is read as requesting the assertion of a proposition which indicates the extension of the set of sleeping girls, the set of its possible answers may be represented as
\{P \mid \exists X : P = \neg (\{x \mid \text{gir}(x) \& \text{sleep}(x)\} = X)\} \tag{9}

There seems to be no way of avoiding that the predicate \text{gir} is involved in the answer propositions, if these are required to be exhaustive.

2.4. Groenendijk and Stokhof: Exhaustiveness.

Groenendijk and Stokhof (1981, 1982) propose an alternative extension of Montague's (1973) "Proper Treatment of Quantification in Ordinary English", in which they try to accommodate embedded wh-clauses. They mention the possibility that their analyses might carry over to direct question sentences, although they express strong reservations as to whether this is in fact the case. Groenendijk and Stokhof's proposal differs from Karttunen's PTQ-extension in two important ways. One is, that they treat "mention-all" readings of wh-clauses, rather than "mention-one" readings. The second difference is, that they describe the propositional concepts which constitute the contents of questions in a different way than Karttunen.

To handle certain complications concerning the interaction between wh-noun-phrases and "ordinary" quantifiers, Groenendijk and Stokhof introduce nested abstractions over possible worlds – something which cannot be expressed in Montague's intensional logic IL. Groenendijk and Stokhof therefore adopt TY2 (Gallin, 1975) – a variant of IL which has variables ranging over possible worlds, and can therefore express intension- and extension-operators by lambda-abstraction and function-application respectively. Groenendijk and Stokhof's treatment, applied to direct questions, would analyse the content of a wh-question as a property of propositions (a "propositional concept") – the property of being a true answer to the question. For instance:

\textit{Who walks?} \tag{1}

expresses the propositional concept

\[(\lambda w : (\lambda i : \text{ext}_i (\text{walk}) = \text{ext}_{w_i} (\text{walk})))] \tag{2}

(Notation: \text{w} and \text{i} range over possible worlds; \text{ext}_j (F) is a mnemonic notation for \text{F} (j), that I use when \text{j} is of the type "possible world", standing for "the extension of \text{F} in \text{j}".)

Assuming this treatment, an answer with content \text{a} given in reply to a question with content \text{q} is correct iff \(q = a\).

The possibility of accounting for the mention-all reading of wh-questions is clearly important for a computer system providing automatic question-
answering services. In such situations, mention-all readings often are more plausible than mention-one readings. I also find some plausibility in Groenendijk and Stokhof's suggestion that the mention-all reading is needed in the semantics of wh-clauses embedded under "know". Nevertheless, wh-questions can under certain circumstances be adequately answered by giving partial information. In section 5.4 I shall come back to this and present a treatment which covers both cases.

2.5. Problems with Rigid Designators.

In the present section I shall take a closer look at the kinds of answers which are accounted for by the treatments of questions and answers in the previous subsections. Consider, for instance, the content of the question

\[ \text{Who walks?} \]

which Hamblin's treatment analyses as

\[ (\lambda P: \exists x: P = \neg \text{walk}(x)) \]

According to this treatment, a valid answer to this question would be any sentence asserting a true proposition which can be expressed by a formula of the form

\[ \neg \text{walk}(b) \]

where \( b \) is a rigid designator. As examples of such assertions, sentences like

\[ \text{Mary walks.} \]

are usually cited.

Answers of this kind are problematic at two levels. It is problematic whether they ought to be expressible in the logical language, and it is problematic whether they are expressible in natural language. I shall now discuss both these problems.

There are intrinsic problems with the assumption that an intensional logical language contains a logical proper name for every individual.\(^4\) It implies that the number of individuals in the domain is denumerable, and the same for all possible worlds. This severely constrains the descriptive power of the language. (See Potts, 1976.)

\(^4\) In an extensional language this is less problematic. See footnote in Chapter IV, Section 2.
One curious consequence of the assumption of a fixed set of rigid designators is demonstrated by Groenendijk and Stokhof’s system, in which

\[ \text{Who walks?} \]  

(1)

would be analysed as

\[ (\lambda w: (\lambda i: \text{ext}_i (\text{walk}) = \text{ext}_w (\text{walk}))) \]  

(5)

thus requiring a correct answer to specify the complete extension of the predicate walk, i.e. to specify for every individual in the domain whether it walks or doesn’t. As Karttunen (1977) noticed in rejecting a different treatment with this property, this seems to be asking too much. The question (1) asks for a specification of those who do walk, not of those who do not. A correct answer to (1) is not expected to give the same information as a correct answer to

\[ \text{Who doesn’t walk?} \]  

(6)

It might seem easy to devise a variant of Groenendijk and Stokhof’s treatment which is less overdemanding: analyse (1) not as (5), but as

\[ (\lambda w: (\lambda i: \text{ext}_i (\{ x \mid \text{walk}(x) \}) = \text{ext}_w (\{ x \mid \text{walk}(x) \}))))) \]  

(7)

However, in a language with rigid designators for all individuals, (7) is equivalent to (5).

Another problem with the propositions in terms of logical proper names is that they usually cannot be expressed in natural language. The English words for the integers may be viewed as corresponding to rigid designators. The case of proper names for people is already more complicated; and for most things, natural languages provide no proper names, nor other means of rigidly referring to them.

Besides answers in terms of proper names, other kinds of answers must therefore be accounted for: answers which identify an individual in terms of contingent properties, as in

\[ \text{The hungriest dog in the neighbourhood walks.} \]  

(8)

and answers which do not uniquely identify any individuals at all, as in

\[ \text{Some dog walks.} \]  

(9)

It should also be noted that answers of the form (8) or (9) may sometimes be more interesting for the questioner than an answer in terms of proper names. This matter is taken up again in section 6.
3. Against the Primacy of Full-Sentence Answers.

The treatment of questions and answers that will be developed in section 5 of this chapter comes from a rather different perspective than the treatments discussed so far. One important difference concerns the decision as to what kinds of answers to treat as "basic". In the treatment presented here, answers which have the form of a noun phrase are viewed as the basic ones, whereas the proposals in the Hamblin tradition assume that an answer has the form of a complete sentence expressing a proposition. The present section compares the merits of these alternative views.

The decision to treat sentences rather than noun phrases as "basic answers" is defended explicitly by Belnap and Steel (1976). As an example they discuss the question

\[
\text{What is the freezing point of water, in degrees Fahrenheit, under standard conditions?} \tag{1}
\]

They write:

Suppose the respondent replies to (1), not with the full sentence "The freezing point of water under standard conditions is 32°F", but merely with the noun "32". Obviously, its status as an answer, indeed, its very meaning, depends upon the context of its utterance. So, since we are now preparing the way for a formal analysis in which we shall not want any assertoric meanings to be dependent on context, we shall not count "32" as a direct answer to (1). Rather, we shall treat it as merely an abbreviated way of saying "The freezing point of water under standard conditions is 32°F", and we shall call it (after Hamblin 1958) a coded answer. Coded answers, including gestures and nods as well as words, are, because of their efficiency, of enormous importance in communication, but they must always be code for complete and unabbreviated sentences.

(p. 14)

Belnap and Steel express in an explicit way an idea which is implicit in many other treatments of questions: the assumption that a declarative sentence which is uttered in answer to a question may be viewed as independently expressing a proposition, in the same way as the contextless isolated assertions which have so far been the main topic of study of philosophical logic and formal semantics. This assumption, however, is false. One phenomenon demonstrating this relates to an often observed ambiguity which is exhibited by declarative sentences when they are taken out of context. For instance,
\[ \text{John went out with Mary yesterday.} \] (2)

may express various things, such as:

\begin{align*}
\text{What happened yesterday is that John went out with Mary.} & \quad (3) \\
\text{Mary is the one that John went out with yesterday.} & \quad (4) \\
\text{John is the one who went out with Mary yesterday.} & \quad (5) \\
\text{Yesterday is when John went out with Mary.} & \quad (6) \\
\text{It is the case that John went out with Mary yesterday.} & \quad (7)
\end{align*}

As Whately noted as early as 1826,\textsuperscript{5} precisely this ambiguity disappears in the context of a question – the topics in the answers depend on the "questioned" elements in the questions. For instance, the sentences (3) - (7) above would be appropriate paraphrases of answer (2) in the context of the following questions:

\begin{align*}
\text{What happened yesterday?} & \quad (8) \text{ for (3)} \\
\text{Who did John go out with yesterday?} & \quad (9) \text{ for (4)} \\
\text{Who went out with Mary yesterday?} & \quad (10) \text{ for (5)} \\
\text{When did John go out with Mary?} & \quad (11) \text{ for (6)} \\
\text{Did John go out with Mary?} & \quad (12) \text{ for (7)}
\end{align*}

From this we may infer that any answer to a question must be interpreted in the context of the question it answers. This holds for full-sentence answers just as well as for "minimal answers" in the form of noun phrases. There is thus no reason, from this point of view, to give one or the other a privileged status.

Before presenting our own treatment of questions and answers, which takes minimal answers as "basic", in section 5, another treatment which shares this feature is discussed in section 4. The comparison between the full-sentence answer and the minimal answer approaches will be taken up again in section 5.5.


Hausser (1980) presents a PTQ extension dealing with questions and answers which, unlike the Montague-style treatments discussed before, focusses on "minimal" answers. Wh-questions are assumed to be answered by noun phrases.

Hausser's treatment of wh-questions is rather limited. It does not treat questions involving noun phrases with "which", for example, but only wh-

\textsuperscript{5} See Prior and Prior (1955).
questions of the form "who + verb phrase" or "what + verb phrase" - i.e.,
the case where the range of the "querification" does not have to be explicitly
described in the expression representing the question, but where this range
may be assumed to be a semantic type of the logical language.
Hausser analyses the content of a question as a property of NP-denotations.
For instance

\[ \textit{Who walks?} \] \hspace{1cm} \text{(1)}

is analysed as

\[ (\lambda P: P(\text{walk})). \] \hspace{1cm} \text{(2)}

The content of a minimal answer is analysed as an NP-denotation, where
an NP-denotation is construed like in Montague (1973), as a function from
one-place predicates to truthvalues.
For instance, the minimal answer

\[ \textit{A boy.} \] \hspace{1cm} \text{(3)}

is analysed as

\[ (\lambda F: \exists x \in \text{boys}: F(x)). \] \hspace{1cm} \text{(4)}

An answer with content \( A \) in response to a question with content \( Q \) is
correct iff \( Q \ (A) \). This correctness criterion is too tolerant, since it accepts as
a correct answer any noun phrase which, combined with the question, yields a
true sentence. For instance, if those who walk are the boys John, Peter and
Harry, all of the following answers to question (1) are treated as correct:

\[ \textit{John, Peter and Harry.} \] \hspace{1cm} \text{(5)}
\[ \textit{John} \] \hspace{1cm} \text{(6)}
\[ \textit{No girls} \] \hspace{1cm} \text{(7)}

Let us now see how Hausser's approach works if it is applied to questions
involving "which-nounphrases". Mention-one readings of such questions can
be brought under the scope of Hausser's treatment without much difficulty.
For instance,

\[ \textit{Which boys walk?} \] \hspace{1cm} \text{(8)}

when viewed as a paraphrase of
Who is one of the boys that walk?

may be represented as

\[(\lambda P: P((\lambda x: x \in \{y \in \text{BOYS} \mid \text{WALK}(y)\})))\]

There is a problem, however, with mention-all readings of which-questions. Consider, for instance, the mention-all reading of (8), which may be paraphrased as

Who are the boys that walk?

A representation like

\[(\lambda P: P((\lambda X: X = \{y \in \text{BOYS} \mid \text{WALK}(y)\})))\]

would lead to the acceptance of answers which are, to say the least, quite misleading. For instance, in any state of affairs where at least one happy boy walks, the answer

No sad boys

represented, for instance, as

\[(\lambda F: \exists z \in P^* (\{z \in \text{BOYS} \mid \text{SAD}(z)\}: F(y)))\]

would count as correct.\(^6\)

An advantage of Hausswer's "tolerance", however, is that it can account effortlessly for certain question/answer pairs which are problematic in treatments which implement more specific requirements concerning the question/answer relationship. Consider, for instance, the question

Who does every man love?

with the answer

A woman

in the reading where a different man may love a different woman. Within

\(^6\) Notation: \(P^* (X) = \text{def} \{Y \mid \text{Y} \in X \& Y \neq \emptyset\} \)
Hausser's approach, there is no problem in giving one of the readings of (15) the representation

\[
(\lambda P: \forall x \in \text{men}: P (\lambda y: \text{love}(x,y)))
\]

while the answer (16) would be represented as

\[
(\lambda F: \exists z \in \text{women}: F(z))
\]

which, in combination with the representation of the question, would yield the proposition

\[
\forall x \in \text{men}: \exists z \in \text{women}: \text{love}(x,z)
\]

5. The PHILQA1 Treatment: Questions and Answers as Describing Sets of Individuals.

5.1. Introduction.

The previous sections reviewed some recent proposals which try to give an explicit semantic analysis of the contents of questions and answers. Section 2 discussed treatments which analyse the contents of questions in terms of their propositional answers, and indicated serious problems with these treatments (section 2.5). Section 3 showed that there is in fact no basis for a privileged status of propositional answers. Section 4 therefore turned to Hausser's proposal, which treats short answers as semantically basic, but found his treatment to the question-to-answer relationship too "tolerant" for our purposes.

The present section presents an extended version of the theory underlying the treatment of questions by the question answering system PHILQA1 (Medema et al., 1975; Bronnenberg et al., 1980). This theory, like Hausser's, treats short answers as basic; in its semantic properties it differs considerably from both Hausser's treatment and the propositional treatments. Subsection 5.2 of the present section discusses the analysis of questions. Subsection 5.3 discusses the analysis of answers and the question-to-answer relationship for a limited version of the theory, which only deals with definite answers. Section 5.4 discusses a revised version, which deals with indefinite answers as well. Section 5.5 discusses full-sentence answers from the perspective of our theory.
5.2. Questions.

The perspective on questions which is embodied in the theory presented here may be formulated as follows.\textsuperscript{7} A yes/no question presents a proposition (a function from states of affairs to truthvalues), and requests its addressee to indicate which value this function has for the actually obtaining state of affairs. Similarly, a wh-question presents a function from states of affairs to sets of individuals, and requests the addressee to indicate what value this function has for the actually obtaining state.

Thus, every question is viewed as describing an object: a set of individuals in the case of a wh-question, a truthvalue in the case of a yes/no question. The answer to a question must then give a different identification of that same object. The answer to a yes/no question must specify whether the truthvalue is \textit{true} ("Yes") or \textit{false} ("No"), while the answer to a wh-question may name all the designated individuals. It is not difficult to decide how a theory embodying this perspective will represent the content of a question: this content is represented by an expression which denotes the object which the question describes. For instance,

\begin{equation}
\text{Which boys walk?}
\end{equation}

is represented as

\begin{equation}
\{x \in \text{BOYS} \mid \text{WALK}(x)\}
\end{equation}

while

\begin{equation}
\text{Does John walk?}
\end{equation}

is represented as

\begin{equation}
\text{WALK(JOHN)}.
\end{equation}

Multiple wh-questions

Multiple wh-questions can be treated by extending the treatment of simple wh-questions in a straightforward way. Such questions describe a set of n-tuples rather than a set of individuals.

\textsuperscript{7} The view put forward here has a long history. Whately (1826) expressed ideas which clearly went in this direction (see Prior and Prior, 1955). He emphasizes particularly the uniformity between wh-questions and yes/no questions which is, at the semantic level, achieved by this perspective. Tichý (1978a) formulates it in terms that I find sympathetic as well. His distinction between empirical and mathematical questions, however, seems to be difficult to maintain as linguistically valid. (See section 7.1, note 1, for further discussion of this point.)
Which boys love which girls?

is thus represented as

\[ \{ u \in \text{BOYS} \times \text{GIRLS} \mid \text{LOVE}(u) \} \]

(Notation: the variable \( u \) ranges over ordered pairs; the operator \( \times \) forms the Cartesian product of two sets; \( n \)-place relations are rendered as predicates on \( n \)-tuples, so \( \text{LOVE} \) is a predicate on pairs. Thus, (6) denotes the set of ordered pairs containing a boy and a girl such that the boy loves the girl.)

5.3. Answers.

Among the wide range of possible answers to questions, the treatment presented here focusses on the shortest possible forms: the so-called "minimal answers". In Section 5.5 below, I shall indicate how more elaborate formulations may be accounted for in terms of this treatment of minimal answers and present further arguments showing that this perspective compares favorably with the more usual procedure of treating the shorter forms as elliptical forms of full sentences.

A minimal answer to a yes/no question is either "yes" or "no" while a noun phrase identifying or describing the set of individuals belonging to the set described by the question is a minimal answer to a wh-question. For instance:

\( \text{Which girls at Susan's party did you like?} \)  

has all of the following responses among its possible minimal answers:

\( \text{Jane and Mary.} \)

\( \text{The girls that we almost ran into in the hallway.} \)

\( \text{None.} \)

\( \text{Some of the girls that Bill brought.} \)

---

8) Quantification over Cartesian products is independently motivated. It is needed to represent readings of sentences which exhibit the phenomenon of "cumulative quantification". An example of this may be observed in the sentence

600 Dutch firms have 5000 American computers.

when we read it as being equivalent to

The number of Dutch firms which have American computers is 600, and the number of American computers possessed by Dutch firms is 5000.

Elsewhere I have shown how such readings may be systematically generated by allowing noun phrases to combine into quantifiers which have Cartesian products (e.g., in this case, the product of the set of Dutch firms and the set of American computers) as their range (see Scha, 1981). Therefore, this manner of rendering multiple wh-questions is more attractive and less ad hoc than it may first appear.
Among these answers, definite and indefinite answers should be distinguished. A definite answer has a form which shows that if it is felicitously used at all, it uniquely defines one set of individuals (whether it successfully identifies this set to the questioner is another matter; we shall come back to that). Answers (2), (3) and (4) above are examples of this. An indefinite answer has a form which allows (and even suggests) that there are different sets satisfying the description it presents. Answer (5) above is an example of this. We shall focus first on definite answers. Indefinite answers will be dealt with in the next sub-section.

If it is correct, a definite minimal answer to a question describes the same object as the question. Therefore it may be represented by a logical expression which denotes the same object as the expression representing the content of the question. Here are some examples of questions and minimal definite answers with their corresponding logical expressions.

Q:  Does John Walk?  
     \text{WALK(JOHN)}  
     \text{(6a)}  
     \text{(6b)}

A1:  Yes.  
     \text{TRUE}  
     \text{(7a)}  
     \text{(7b)}

A2:  No.  
     \text{FALSE}  
     \text{(8a)}  
     \text{(8b)}

Q:  Who walks?  
     \{ x \mid \text{WALK(x)} \}  
     \text{(9a)}  
     \text{(9b)}

A1:  The boys.  
     \text{BOYS}  
     \text{(10a)}  
     \text{(10b)}

A2:  John and Peter  
     \{ \text{JOHN, PETER} \}  
     \text{(11a)}  
     \text{(11b)}

Note that neither in the case of a yes/no-question, nor in the case of a wh-question, does a minimal answer independently express a proposition. Although in the case of a yes/no-question a minimal definite answer describes a truthvalue, it must do so by means of a logical constant; in the case of a wh-question a minimal definite answer describes a set of entities. In both cases, the proposition expressed by a minimal definite answer with content $A$ is constructed by taking into account the question with content $Q$ which
provided the context for it: it is the proposition $Q = A$.\textsuperscript{9)} For instance, the proposition expressed by (7) as an answer to (6) is

$$\text{WALK(John)} = \text{TRUE},$$

(12)

the proposition expressed by (8) as an answer to (6) is

$$\text{WALK(John)} = \text{FALSE},$$

(13)

the proposition expressed by (10) as an answer to (9) is

$$\{x \mid \text{WALK}(x)\} = \text{BOYS},$$

(14)

the proposition expressed by (11) as an answer to (9) is

$$\{x \mid \text{WALK}(x)\} = \{\text{John, Peter}\}.$$  

(15)

An answer with content $A$ may now be defined to be \textit{correct} if it is given in answer to a question with content $Q$, and $Q = A$ is true in the interpretation of the logical language corresponding to the actual world.

It is clear from the above examples that an answer is only counted as correct if it is \textit{complete}. For instance, if, in addition to John and Peter, Harry walks as well, (11) is counted as a false answer to (9). This means that the treatment of \textit{wh}-questions presented so far treats only complete answers to "mention-all" readings. In the next section, partial answers to \textit{wh}-questions will be introduced.

\textsuperscript{9)} For the case of negative questions, the negation is treated as part of the illocutionary force of such questions instead of having it inside their propositional content. For instance, assuming the illocutionary force operator \textsc{negative-question} for negated questions and \textsc{answer} for minimal answers, analyses of the following form result:

\begin{itemize}
\item \textbf{Q:} \textit{Doesn't John walk?}
\textsc{negative-question (WALK(John))}
\item \textbf{A1:} \textit{Yes (he does)}
\textsc{answer (TRUE)}
\item \textbf{A2} \textit{No (he doesn't)}
\textsc{answer (FALSE)}
\end{itemize}

If \textsc{answer}'s in the context of \textsc{negative-question}'s are now treated the same way as in the context of regular \textit{question}'s, the answer "Yes" results in the proposition $\text{WALK (John)} = \text{TRUE}$, while the answer "No" results in the proposition $\text{WALK (John)} = \text{FALSE}$. 

5.4. **Indefinite Answers.**

The previous subsection only treated definite answers. There are also allowable answers, however, which lack definite reference. A question like

\[
\text{Who did you bring?} \tag{1}
\]

may be correctly (and informatively) answered by

\[
\text{Two Hungarian linguists} \tag{2}
\]

without further identifying the individual items that were brought.

The treatment of the previous section can be modified so as to accommodate answers of this kind, in the following way. Indefinite answers are represented as sets. For instance, (2) is represented as

\[
P_2 (\{ x \in \text{LINGUISTS} \mid \text{HUNGARIAN}(x) \}) \tag{3}
\]

(Notation: \(P_n(A)\) stands for the set of subsets of \(A\) which have cardinality \(n\).) To put definite answers on the same level, they are represented as singleton sets. For instance, (4) is rendered as (5):

\[
\text{John and Peter} \tag{4} \\
\{ \{\text{JOHN}, \text{PETER} \} \} \tag{5}
\]

Thus, an answer to a wh-question identifies a set of objects and expresses that the object described by the question is one of these. The proposition expressed by an answer with content \(A\) given in reply to a question with content \(Q\) is defined as: \(Q \in A\). The definition of correctness is modified accordingly: a question with content \(Q\) is correctly answered by an answer with content \(A\) iff \(Q \in A\).

**Multiple noun phrase answers.**

Answers consisting of multiple noun phrases fit the same treatment. Disjunction between noun phrases is naturally rendered by the union operation. For instance:

\[
\text{John or two of his girlfriends.} \tag{6a} \\
\cup (\{\text{JOHN}\}, P_2 (\text{GIRLFRIENDS (JOHN)})) \tag{6b}
\]
Conjunction between noun phrases is rendered by means of the Cartesian product. For instance:

\[ \text{Two dogs, three girls and John.} \]  
(7a) \hspace{1cm} (for: \( P_2(\text{DOGS}) \times P_3(\text{GIRLS}) \times \{\text{JOHN}\}) \), apply: (\( \lambda u: \text{set} (u) \))  
(7b)

where \( \times \) is the operator which forms the Cartesian product, and \( \text{set} \) is an operator which, applied to an n-tuple, yields the set consisting of the elements of the n-tuple.

**Definite noun phrases as partial answers.**

Wh-questions such as:

\[ \text{Who walks?} \]  
(8)

may sometimes be answered by

\[ \text{John and Peter} \]  
(9)

when the answer is not intended to be an exhaustive list. This phenomenon can be described by introducing a second interpretation of definite noun phrases. In addition to the reading

\[ \{\{\text{JOHN, PETER}\}\} \]  
(10)

(9) may also be assigned the reading

\[ \{X | \{\text{JOHN, PETER}\} \subseteq X\} \]  
(11)

Similarly, an indefinite noun phrase may express a partial answer:

\[ \text{Two Hungarian linguists} \]  
(12)

is then not only rendered as

\[ P_2(\{x \in \text{LINGUISTS} \mid \text{HUNGARIAN}(x)\}) \]  
(13)

(in the exhaustive reading), but also as

\[ \{X | \exists Y \in P_2(\{x \in \text{LINGUISTS} \mid \text{HUNGARIAN}(x)\}); Y \subseteq X\} \]  
(14)
In this way, the fact that the same wh-question may be correctly answered by complete answers and by partial answers may be accounted for.\textsuperscript{10} In this approach, wh-questions are always viewed as asking for exhaustive answers (except in the case of "quantifying in" – see section 6 below).

5.5. Full-Sentence Answers.

In the treatment just sketched, the content of a minimal answer can be determined directly without any kind of reference to the syntactic/semantic structure of the question. The proposition expressed by the minimal answer in the context of the question is then constructed in a completely compositional way by combining the content of the answer with the content of the question.

With full-sentence answers, on the other hand, the situation is a little more complicated. Full-sentence answers often present a minimal answer embedded in a partial repetition of the question. Our treatment would involve "extracting" the minimal answer out of such questions.

Consider, for instance, the question

\begin{equation}
\text{Which back-end processors did Akzo buy?}
\end{equation}

which is represented as

\begin{equation}
\{ x \in \text{BEPs} \mid \text{BUY} (\text{AKZO}, x) \}
\end{equation}

The answer

\begin{equation}
\text{Akzo bought six INTEL chips.}
\end{equation}

is represented as\textsuperscript{11}

\begin{equation}
P_6 (\text{INTEL-CHIPS})
\end{equation}

\textsuperscript{10} Answers may be ambiguous between a complete and an incomplete reading. In spoken language, disambiguation seems to be often accomplished by intonation: a final falling intonation contour indicating a closed (i.e. complete) answer and the definite absence of closing markers indicating an open (i.e. incomplete) answer.

\textsuperscript{11} Analysing a full-sentence answer thus involves assessing how its syntactic structure and its constituents match those of the question-sentence, so that the minimal answer which is embedded within the answer-sentence may be "extracted". Since semantic rather than syntactic matters are focussed on throughout this book, no proposals about the precise details of this correspondence between question-sentences and answer-sentences will be given.
Combining the answer-expression (4) with the question-expression (2) in the usual way, yields the following expression for the proposition communicated by answer (3) in the context of question (1):

\[ \{ x \in \text{BEPS} \mid \text{BUY (AKZO, } x) \} \in P_6 (\text{INTEL-CHIPS}) \]  

(5)

It is not possible to construct (5) as a reading of sentence (3) without taking the question-context into account. To view answers as isolated propositions is therefore not a viable strategy.

To take another example: the answer to the question

*Who stole my bicycle?*  

(6)

may not only be

*John.*  

(7)

but also, correctly but less helpfully:

*The people who stole your bicycle.*  

(8)

or the rather bizarre sentence

*The people who stole your bicycle stole your bicycle.*  

(9)

which, though even more conspicuously uncooperative, can still function as an answer to (6). If we were to treat (9) as a proposition in its own right, however, it would be logically equivalent to:

*Every dog which doesn’t like cats doesn’t like cats.*  

(10)

(10), however, is clearly a non-sequitur to (6) while (9) is not. This fact can not be explained from the more proposition-oriented perspectives. It offers no problems to the perspective presented here.

6. Quantifying into Questions.

6.1. Introduction.

In all examples discussed so far, the illocutionary act of asking a question could be represented as \text{ASK}(C), where \text{ASK} is the operator indicating the illocutionary force, and \( C \) is an expression representing the semantic content of the question (a proposition in the case of yes/no questions, a function from states of the world to sets of individuals in the case of wh-questions). The illocutionary force operator was "bracketed out" during most of the discussion so far, since this discussion focussed entirely on the contents of questions.
Though it is often assumed that this "division of labor" between illocutionary force and semantics is generally valid, there exist counter-examples which complicate the situation. In the present section these shall be dealt with.

Wh-questions display a kind of quantifier scope ambiguity which does not seem to arise for assertions and which cannot be accounted for in the above scheme. An example of this is shown by the question

\[ \text{What is the price of each of Akzo's computers?} \]

if we consider the reading which requests for each of Akzo's computers a specification of its price.

6.2. The "Compound Speech Act" Analysis.

It has been suggested before, that the speech act of "asking" need not be viewed as an elementary action, but may be analysed in terms of the illocutionary force of "requesting" and a predicate which describes what the addressee of the question is expected to do with the question content. Applying such an analysis creates the "space" which is necessary to express the quantifier scope ambiguity in questions like (1) above.\(^{12}\)

The ask-operator above may thus be split into two parts: an operator bring-about, applicable to expressions of the logical language, and a predicate identified which is true for an individual iff it is being identified. Instead of ask \((C)\) we now get bring-about \((\text{identified}(\check{C}))\). For instance

\[ \text{Which boys walk?} \]

is represented not as

\[ \text{ask}(\{x \in \text{boys} \mid \text{walk}(x)\}) \]

but as

\[ \text{bring-about}(\text{identified}(\{x \in \text{boys} \mid \text{walk}(x)\})) \]

The compound structure of the illocutionary force operator now creates the possibility to represent the quantifier scope ambiguity that seems to be present in question sentences like (1). Sentence (1) above may now be assigned two readings: the implausible one which assumes that all Akzo's computers have the same price is rendered as

\(^{12}\) Grosz (1982) suggests applying this idea to an analysis of "asking" proposed by Cohen and Perrault (1979).
BRING-ABOUT( IDENTIFIED
   ([ιy | ∀x ∈ AKZO-COMPUTERS: y = PRICE(x)]))

(5)

and the more plausible one which asks for a list of prices is rendered as

BRING-ABOUT ( ∀x ∈ AKZO-COMPUTERS:
   IDENTIFIED (PRICE(x)))

(6)

The sentences which led Belnap to include the "size-specification" feature in the question-operator of his erotetic system (Belnap and Steel, 1976, section 1.31) display a special case of the phenomenon treated this way. Formulated most unambiguously, these questions take the form "What's an example of a...", "What are some of the...", "What are at least three...", etc.

These cases can be dealt with along the same lines as (1) above. For instance,

What is the price of two of Akzo's computers?

(7)

has two readings, which can be rendered in a way which is exactly analogous to (5)-(6) above:

BRING-ABOUT ( IDENTIFIED
   ([ιy | ∃2 x ∈ AKZO-COMPUTERS: y = PRICE(x)]))

(8)

BRING-ABOUT ( ∃2 x ∈ AKZO-COMPUTERS:
   IDENTIFIED (PRICE(x)))

(9)

6.3. A Proposal by Groenendijk and Stokhof.

An ingenious treatment along different lines was put forward in Groenendijk and Stokhof's (1981) proposal for the semantics of embedded wh-clauses, that we discussed in section 2.4 of this chapter, in which question (1) is analyzed as

(λw: (λi: ∀x ∈ AKZO-COMPUTERS:
   exti (PRICE(x)) = extw (PRICE(x))))

(10)

(Notation: w and i range over possible worlds; exti (F), where j has the type "possible world", stands for F(j), and yields the extension of F in j). To understand that this is in fact correct, it may help to realize that, as Groenendijk and Stokhof point out, the universal quantification can be seen
as an abbreviation for a conjunction. (10) is then equivalent to

\[(\lambda w: (\lambda i: \text{ext}_i (\text{PRICE} (c_1)) = \text{ext}_w (\text{PRICE} (c_1)) \ & \text{ext}_i (\text{PRICE} (c_2)) = \text{ext}_w (\text{PRICE} (c_2)) \ & \ldots \ldots \ldots \ldots \ldots \ & \text{ext}_i (\text{PRICE} (c_n)) = \text{ext}_w (\text{PRICE} (c_n))))\],

where \(c_1, \ldots, c_n\) are the proper names of all Akzo's computers.

This treatment works only for the case of "each" however, because it exploits a particular property of universal quantification which does not apply to other quantifiers. For instance, if one would try to treat

\[\text{What is the price of one of Akzo's computers?}\]

along the same lines, one would get

\[(\lambda w: (\lambda i: \exists x \in \text{AKZO-COMPUTERS} \cdot \text{ext}_i (\text{PRICE} (x)) = \text{ext}_w (\text{PRICE} (x))))\]

Since the existential quantifier can be viewed as an abbreviation for a disjunction, (13) is equivalent to

\[(\lambda w: (\lambda i: \text{ext}_i (\text{PRICE} (c_1)) = \text{ext}_w (\text{PRICE} (c_1)) \ \lor \ \text{ext}_i (\text{PRICE} (c_2)) = \text{ext}_w (\text{PRICE} (c_2)) \ \lor \ldots \ldots \ldots \ldots \lor \text{ext}_i (\text{PRICE} (c_n)) = \text{ext}_w (\text{PRICE} (c_n))))\]

Thus, Groenendijk and Stokhof's proposal lacks the generality that one should hope for.

6.4. The PHLIQA1 Treatment.

The present subsection present an alternative treatment of the problem described in section 6.1. This treatment, which has attractive computational properties, was employed in the PHLIQA1 system. It embodies a different analysis of the speech act of asking than the one presented in subsection 6.2.

As a point of departure, let us consider again the analysis of the contents of questions that was presented so far: the content of a yes/no question is a function from possible worlds to truthvalues, and the content of a wh-question is a function from possible worlds to sets of individuals. Questions are now viewed as displaying pragmatic objects, to be called "kernel questions", which have a one-to-one correspondence with their contents as
just described. The function QC assigns to any function \( q \) the kernel question QC \((q)\) which has \( q \) as its content.

This view is not incompatible with the speech act perspective on discourse. An illocutionary force operator DISPLAY may be assumed which operates on the question object as just described.\(^{13}\) Thus,

\[
\text{Which boys walk?} \quad (15)
\]

is analysed as

\[
\text{DISPLAY (QC } \{x \in \text{BOYS} \mid \text{WALK}(x)\})\quad (16)
\]

Example (1) above is now dealt with by allowing one question sentence to display not only a single kernel-question, but a set of kernel questions as well. Thus, (1) is analysed as

\[
\text{DISPLAY (for: AKZO-COMPUTERS, apply: } (\lambda x: \text{QC } \{\text{PRICE}(x)\})\)) \quad (17)
\]

Note that nothing has to change in the account of the question-to-answer relationship as it was described before: it simply applies separately to all kernel questions in the "display set" and their answers.

There is an important difference, however, between answering to a question-sentence displaying a set of kernel questions and answering to a question-sentence displaying a single kernel question: in the former case, the short form of the answer may be less informative than the full-sentence form. For questions about prices, for instance, the short form of the answer may be simply the value of the question content.

\[
\text{What is the price of the Illiac?} \quad (18)
\]

analysed as

\[
\text{DISPLAY (QC } \{\text{PRICE (ILLIAC)}\})\quad (19)
\]

is answered by the value of

\[
\{\text{PRICE (ILLIAC)}\}, \quad (20)
\]

\(^{13}\) Technical reformulations of results of speech act theory would be necessary, however. Many different kinds of utterances could be brought together under the common denominator of one illocutionary force called DISPLAY. What current speech act analyses account for in terms of the differences between illocutionary forces, would then be accounted for in terms of the differences between the kinds of objects displayed.
for instance

\[ 4.000.000 \] $ \quad (21) \]

If (1) is answered in this way, the answer is a list like

\[ 512.000 \] $, \ 56.000 \] $, \ 110.000 \] $ \quad (22) \]

It would be more informative to give answers in full-sentence form in this case. If for every element \( i \) in the extension of \( \text{AKZO-COMPUTERS} \), the proposition expressed by

\[ \{ \text{PRICE}(i) \} = V, \quad (23) \]

where \( V \) is the value of \( \text{PRICE}(i) \), would be formulated in English, the questioner would not only be informed of all the prices which occur among the prices of Akzo's computers, but would also find out which computer has which price.

In order to give the same information without having to resort to full-sentence answers, PHLIQA1 does not analyse (1) as (17), but as a slightly different expression, which also asks for an identification of the elements of the question-content which are "quantified in":

\[
\text{DISPLAY} \quad (\text{for: AKZO-COMPUTERS, apply: } (\lambda x:\ QC \left( \langle x, \{ \text{PRICE}(x) \} \rangle \right) ) ) \quad (24)
\]

PHLIQA1 answers every kernel-question by applying a function called \text{IDENTIFICATION} to the extension of its contents. Answering (24) is conveying the value of

\[
(\text{for: AKZO-COMPUTERS, apply: } (\lambda x:\ \text{IDENTIFICATION} (\langle x, \{ \text{PRICE}(x) \} \rangle ))) \quad (25)
\]

As shown in detail in section 7.2, this results in a answer-expression like

\[
\{ \langle \text{IBM}, \ 360/20, \ 65 \text{ KBYTE}\rangle, \ 95000 \rangle, \langle \text{PHILIPS, P1800, 240 KBYTE}\rangle, \ 312000 \rangle, \langle \text{PHILIPS, P800, 16 KBYTE}\rangle, \ 56000 \rangle \} \quad (26)
\]

which identifies every computer by its brand name, type number and core size, and every price by its numerical value in dollars.

"Quantifying in" by means of indefinite quantifiers may be brought under
the scope of this treatment, if "indefinite sets of kernel questions"
(represented as sets of sets of kernel questions) are allowed to be expressed
by an interrogative sentence. For instance,

\[ \text{What is the price of two of Akzo's computers?} \quad (27) \]

is, in the reading we are interested in now, analysed as

\[
\text{DISPLAY (for: } P_2(\text{AKZO-COMPUTERS}), \nn\text{apply: } (\lambda Y: (\text{for: } Y, \nn\text{apply: } (\lambda x: QC(\langle x, \{\text{PRICE}(x)\}\rangle))))} \quad (28)
\]

The argument of DISPLAY here denotes a set of sets of kernel questions. In
displaying such a set, the questioner requests that an arbitrary element of it
be answered. (If this extension is adopted, the treatment of "quantifying in"
with "each" must be adapted, as displaying a singleton set with as its element
a set of kernel questions.)

7. The Pragmatics of Answering.

7.1. Categories of Answers.

It is possible and desirable to make distinctions between different kinds of
complete correct answers, as the three answers (2), (3), (4) to question (1)
show.

Q: \( \text{Which numbers did John write on the blackboard?} \quad (1a) \)
\( \{ x \mid JWOB(x) \} \quad (1b) \)

A1: \( \text{The numbers that John wrote on the blackboard.} \quad (2a) \)
\( \{ \{ x \mid JWOB(x) \} \} \quad (2b) \)

A2: \( \text{The numbers that Mary wrote in the notebook.} \quad (3a) \)
\( \{ \{ x \mid MWIN(x) \} \} \quad (3b) \)

A3: \( \text{Five and seventeen.} \quad (4a) \)
\( \{ \{ 5, 17 \} \} \quad (4b) \)
While answer A1 is certainly correct, it is certainly never the desired answer. This may be explained by pointing out that it is *uninformative* – an answer with content A in reply to a question with content Q may be defined to be uninformative iff $Q \in A$ is logically equivalent to \text{true}.\textsuperscript{14)}

A2 and A3 are both informative answers, according to this definition. Which one is preferred, depends on the context in which the question is asked. Though A3 is in a sense more explicit, A2 may sometimes be more interesting.

A3 has a special property which is worth considering: it identifies the set of individuals the question asked about, without relying on any non-linguistic knowledge on the part of the hearer. Expression (4b) is an *L-determinate* expression (Carnap, 1947): an expression which has the same denotation for all interpretations of the language. The natural language formulation of this answer used the logical proper names which the English language contains for the individuals involved: "five" and "seventeen". For individuals belonging to a non-mathematical type, however, natural languages usually do not have logical proper names. L-determinate answers are therefore not always possible. The general case is, that an answer must rely on a certain amount of knowledge concerning contingent facts on the part of the questioner, in order to identify to him the individuals he asked about.

It may be observed that an adequate answer must give information about the identity or the properties of the individuals in the set described by the question. New information which only says something about the set as a whole is not enough. If (5) is answered by (6) or (7), for instance, a feeling of somewhat evasive behaviour on the part of the answerer results.

\begin{align*}
\text{Which IBM computers did you buy last year?} & \quad (5) \\
\text{Some computers.} & \quad (6) \\
\text{Three IBM computers.} & \quad (7)
\end{align*}

\textsuperscript{14)} This looks as if correct answers to mathematical inquiries are necessarily uninformative. This need not be the case, however, if the mathematical terms of natural language are translated into descriptive expressions, rather than logical ones. The mathematical metalanguage used to describe the semantics of English must be kept "inaccessible" for its objects: natural language expressions cannot refer to the notions underlying the formalism that is used for explicating their meaning. Therefore, for instance, in

\textit{Does two plus two equal four?}

"two", "four", "plus" and "equal" must be analysed as expressions with descriptive types. The definitions of mathematical notions must be introduced as contingent truths, and the "necessary truth" of mathematical propositions be explicated by quantifying over a subset of the possible worlds.

A treatment along these lines may avoid the separation between mathematical and empirical propositions we find in Tichý (1978ab).
7.2. **Pragmatic Strategies.**

From this discussion, it should be clear that semantic considerations alone do not determine what an adequate answer to a given question is. Semantic considerations do impose important boundary conditions: an answer must at least be correct and informative. Whether a wh-question asks for an identification of separate individuals or for a characteristic property of a set, however, is a different matter which cannot be decided by considering the linguistic form of the question only but depends on the non-verbal context in which the question is asked. If an identification of individuals is what is desired, a model of the epistemic state of the questioner is needed if one is to guarantee that the identification will be successful.

For a computer question answering system, a complete model of the epistemic state of the questioner is obviously not available. But a system which does not answer isolated questions but conducts longer "dialogues" may gather useful information about the questioner's knowledge and interests from the "history" of the dialogue. The dimensions of the subject domain that are used to describe the objects in questions are probably different ones than those that should be used in the answers. Follow-up questions triggered by a similar previous question indicate what the dimensions are that the questioner is interested in. So far, successfully implemented systems do not use dialogue history in this way, however. They use a different strategy: relying on plausible general assumptions.

For instance, a system which answers "exam questions" about its model of a visual scene which at the same time is displayed on a screen may identify objects in this scene by means of definite descriptions in terms of the properties displayed on the screen. The answers given by the SHRDLU system (Winograd, 1972) belong to this category. The problem of constructing the appropriate definite descriptions was studied more thoroughly in the context of the HAM-RPM system (Wahlster et al., 1978).

For a system like HAM-RPM, two phases can be clearly distinguished within the process of answering a wh-question about the objects in a visual scene. The first involves finding the objects described by the question, i.e. constructing an internal representation of this set of objects in terms of logical proper names. In the second phase it is decided how to identify these objects to the questioner, in terms of the visual features of the scene, in a way which is informative and maximally efficient.

For the practice of question-answering, indefinite answers are important because very often the objects that a question asks about cannot be uniquely identified. In that case, it may nevertheless be possible to give a satisfying indefinite answer.

The fact that the information which would uniquely identify an object is
lacking in a data base is not always an accident. Often, those who query a
data base about certain kinds of objects are not so much interested in the
identity of these objects, as in certain of their properties. Two examples of
data bases where this situation is quite common are the REL data base about
ships and their cargo, and the PHLIQA1 data base, about computers and
their users. 15

REL gives for certain kinds of objects no property that could possibly
identify it, but only its category. For instance, the question

What is on the upper vehicle storage area of the USS Ogden? (1)

receives the answer

\begin{itemize}
\item torpedoes
\item torpedoes
\item torpedoes
\item torpedoes
\item torpedoes
\item torpedoes
\item torpedoes
\item torpedoes
\item torpedoes
\item torpedoes
\end{itemize}

which means "ten torpedoes".

In the PHLIQA1 program, some salient attributes are distinguished for
every kind of object. As an answer to a question about objects of a given
kind, the values of these attributes are given for every object in the answer-
set. For instance, the question

Which computers did Akzo buy? (3)

would be represented as something like

\[ \{ x \in \text{COMPUTERS} \mid \text{BUY (AKZO,} x) \} \] (4)

For a given data base, the evaluation of (4) (i.e. its transformation into a
simplest equivalent expression in terms of logical proper names; see Chapter
IV, section 2) may yield

\[ \{ C_{10}, C_{12}, C_{48} \} \] (5)

where \( C_{10}, C_{12} \) and \( C_{48} \) are logical proper names for individual computers.
These logical proper names have no natural language equivalents – and if

15) REL is described in Henisz-Thompson and Thompson (1978). The above example is from a
"live" session I conducted with the system on August 17, 1979.
they had, this would not be what the questioner would be interested in. Therefore, the PHLIQA1 system does not directly evaluate the expression which represents the question content. First, the function IDENTIFICATION is applied to it. This function expresses how different kinds of entities may be described to the questioner. Depending on the type of its argument, it is further translated into an expression which indicates in detail how the elements of the "question-set" will be described. For instance, (4) is first transformed into

\[
\text{(for:} \{x \in \text{COMPUTERS} \mid \text{BUY (AKZO, x)}\}, \\
\text{apply: IDENTIFICATION})
\]  

(6)

and when the type of the arguments of the application of IDENTIFICATION is taken into account, this is further translated into

\[
\text{(for:} \{x \in \text{COMPUTERS} \mid \text{BUY (AKZO, x)}\}, \\
\text{apply: (} \lambda y: \langle \text{BRAND}(y), \\
\text{TYPE}(y), \\
\text{CORESIZE}(y) \rangle \rangle)
\]

(7)

which is, for the data base just considered, equivalent to

\[
\text{(for:} \{C_{10}, C_{12}, C_{48}\} \\
\text{apply: (} \lambda y: \langle \text{BRAND}(y), \\
\text{TYPE}(y), \\
\text{CORESIZE}(y) \rangle \rangle)
\]

(8)

and to

\[
\{ \langle \text{BRAND}(C_{10}), \text{TYPE}(C_{10}), \text{CORESIZE}(C_{10}) \rangle, \\
\langle \text{BRAND}(C_{12}), \text{TYPE}(C_{12}), \text{CORESIZE}(C_{12}) \rangle, \\
\langle \text{BRAND}(C_{48}), \text{TYPE}(C_{48}), \text{CORESIZE}(C_{48}) \rangle \}
\]

(9)

Thus, if instead of (4), (7) is evaluated, the result might be:

\[
\{ \langle \text{IBM, 360/20, 65 KBYTE} \rangle, \\
\langle \text{PHILIPS, PI800, 240 KBYTE} \rangle, \\
\langle \text{PHILIPS, P800, 16 KBYTE} \rangle \}
\]

(10)

Note that the simple way in which PHLIQA1 gives its indefinite answers is only applicable within certain limitations. The comprehensibility of the answer relies on the fact that the questioner can often infer from a value
(such as "IBM", "360/20", "65 kbyte"), which aspect of a computer this value describes (i.e. brand, type, coresize). This is not necessarily always the case. A more generally applicable method would also indicate in the answer the identification function that was used in obtaining the values. Such an answer might then be rendered in English as "an IBM of type 360/20 with 65 kbytes of core, a Philips of type P1800 with 240 kbytes of core and a Philips of type P800 with 16 kbytes of core".

8. Conclusion.

Interrogatives are natural candidates for serving as an interface medium between people and computer systems which provide information on request. An automatic data base access system with suitable deductive capabilities is designed to fulfill exactly the expectations a natural language user may have when he asks a question to a conversation partner who is obedient and conscientious, although unimaginative and literal-minded. Natural language question-answering systems of this sort are the subject of this book.

In a question-answering system with a modular structure, it is useful to make use of separate modules for understanding the incoming question and for answering it on the basis of the information in the knowledge base of the system. The question understanding module must communicate to the answer computation model the "content" of the question; a precise specification of what the desired information is. Formulating the content of questions in a precise way so that it is possible to give a model-theoretic account of the connection between the content of a question and the equally precisely described content of a correct answer is a necessary precondition, in my opinion, of performing the question answering task satisfactorily. The present chapter reviewed the literature on this topic and presented an original proposal for dealing with many of the more difficult problems in an adequate way. This approach was in large part implemented in the PHLIQA1 question-answering system. The structure and operation of this system are described in the following chapter.