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SCHEMA-SHIFT STRATEGIES TO UNDERSTANDING STRUCTURED TEXTS IN NATURAL LANGUAGE

by

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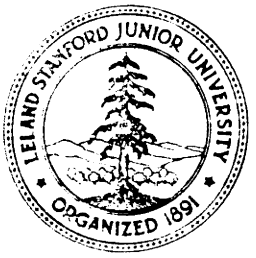

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ABSTRACT

This report presents BAOBAB-2, a computer program built upon MYCIN [Shortliffe, 1974] that is used for understanding medical summaries describing the status of patients. Due both to the conventional way physicians present medical problems in these summaries and the constrained nature of medical jargon, these texts have a very strong structure. BAOBAB-2 takes advantage of this structure by using a model of this organization as a set of related schemas that facilitate the interpretation of these texts. Structures of the schemas and their relation to the surface structure are described. Issues relating to selection and use of these schemas by the program during interpretation of the summaries are discussed.

Key-words: natural-language comprehension, discourse structure, schemas, knowledge-based systems.

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This report is a more detailed version of the paper "Understanding medical jargon as if it were a Natural Language" to appear in the Proceedings of the 6th international Conference on Artificial intelligence to be held in Tokyo in August 1979.

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1 introduction

Work on memory by psychologists, in particular [Bartlett, 1032], led to the conclusion that human beings faced with a new situation use large amounts of highly-structured knowledge acquired from previous experience. Bartlett used the word "schema" to refer to this phenomenon. [Minsky, 1975], in his famous paper, proposed the notion "frame" as a fundamental structure used in natural language understanding, as well as in scene analysis. I will use the former term schema in the rest of this paper, in spite of its general connotation.

In many systems, the use of schemas relies on the assumption that intelligence results from the application of large amounts of specialized knowledge, in contrast with theories advocating the application of general mechanisms with smaller data bases. General mechanisms have been applied, for example, in systems based on theorem proving [Nilsson 1971]. Huge amounts of knowledge started being encoded in the so-called expert systems, such as DENDRAL [Buchanan et al,, 1980).

The main thesis defended by Bartlett was that the phenomenon of memorization and remembering was both constructive and selective. The hypothesis was more recently revived by psychologists working on discourse structure, for example [Collins et al., 1978], [Bransford & Franks, 1971], [KIntsch, 1976). Various experiments performed on subjects who were told stories and then asked to describe what they had remembered showed that not only do people forget acts but they add some. Moreover, they are unable to distinguish between what they have actually heard and what they have inferred.

A subset of the ideas expressed by Minsky has been implemented in so-called frame-based languages. A few formalisms have been proposed that I outline by describing schema-based languages such as KRL [Bobrow and Winograd, 1977], the "units package" [Stefik, 1979], and FRL [Roberts & Goldstein, 1977].

A schema contains slots. They can be viewed as variables which will be bound to data. Each slot contains "facets" (FRL), "aspects" (Units package) or "descriptors" (KRL) which specify how to fill the slots, for example the type of values acceptable (numeric, strings of characters), the range of possible values, values to assign by default or attached procedures describing what to do if the slot is filled in (this is a way to make inferences.) Slots may be organized into hierarchical schemas, in which case values may be inherited from a schema to a more specialized one. This hierarchy and concomitant inheritance avoids duplication of common properties.

People hearing a story make assumptions that they might revise or refine as more information comes in to confirm or contradict them. Making such assumptions entails building (or retrieving) models of the expected text contents. A corollary of this process is that, if the story adequately fits the model people have in mind, the story will be understood more easily.

Although it is difficult to give a formal definition of what constitutes a coherent text, it is an accepted notion that sentences that compose it are linked by some kinds of cause-effect relationships, chronological orderings, and the like. Flashbacks are not contradictory with coherence, but they can make the text more difficult to comprehend. The texts dealing with specific domains seem to be structured in terms of topic. Consequently, an important problem to face is recognizing the different topics and deciding when a "shift of topic" occurs.

A sample of the possibilities of the program follows here, before the discussion of how they have been achieved. Figure 1 below displays a short dialogue between a physician and BAOBAB-2. Note that the generation of English is somewhat heavy; its main purpose is to be non-ambiguous. The physician's inputs appear in bold letters after the double asterisk. Any other printing comes from the program.

I am ready

** THIS IS A 26 YEARS OLD MALE PATIENT

fly understanding is:
The age of the patient is 26
The sex of the patient is male

** FIVE DAYS AGO, HE HAD RESPIRATORY-TRACT SYMPTOMS

What is his name?

** JO

My understanding is:
The name of the patient is Jo
Respiratory-tract is one of the symptoms that the patient had

mm A COUPLE OF DAYS BEFORE THE AOMISSION, HE HAD A MALAISE

Please give me the date of admission

** MARCH 12, 1979

My understanding is:
The patient uas admitted at the hospi tai 3 days ago
Malaise is one of the symptoms that the patient had 5 days ago

Figure 1. Short sample dialogue.

The rest of this report describes the principles and methods that led to implement a program displaying such behavior.

2 Related work and goals

AI research has recently explored strategies to recognize shifts of topic occurring during dialogues or written texts. One issue faced in doing so is the necessity to narrow the space of possible referents of a linguistic object by focusing at different levels of detail. Thus, [Grosz, 1977] studies the role of focus in the interpretation of utterances and its relation to domain structure. She uses the task structure to resolve definite noun phrases in task-oriented dialogues. [Sidner, 1979] extended this work to determine the use of focusing in the resolution of pronoun references and other kinds of anaphors occurring in dialogues. [Rosenberg, 1977] studies how themes were linked through references in newspaper articles.

Another major reason for focusing is "to avoid death by combinatorial explosion? The fear of such an explosion is mainly motivated by the large amount of inferences possible if ail the possible frames are activated; whereas, in fact, some of them might rule out others, thus enabling the space of possible inferences to be pruned. This issue is also raised by [Charniak, 1978].

Embodying world knowledge in frames [Minsky, 1976) or scripts [Abelson, 1973] [Schank and Abelson, 1976) led to the development of programs achieving a reasonably deep level of understanding, for example [Charniak, 1977], GUS [Bobrow et al., 1977], NUDGE [Goldstein & Roberts, 1977], FRUMP [DeJong, 1977] and SAM [Cullingford, 1976].

Ail the works mentioned so far (and this one as well) have a common feature: They do not interpret sentences in isolation, rather, they interpret in the context of an ongoing discourse and, hence, use discourse structure. BAOBAB-2 also explores issues of (a) what constitutes a model for structured texts and (b) how and when topic shifts occur. However, BAOBAB-2 is not interested in inferring implicit facts that might have occurred between facts

actually stated in a text or explaining intentions of characters in stories which are main emphasis of works using scripts or plans. Rather, BAOBAB-2 focuses on coherence of texts, which is mainly a task of detecting anomalies, asking the user to clarify vague pieces of information or disappointed expectations, and suggesting omissions.

The domain of application is the medical summaries for which processing so far [Sager, 1978] has mainly consisted of filling in formatted grids and where no interactive behavior has been exhibited. The program objective is to understand a summary typed in "medical natural jargon" by a physician, interacting with her or him either to ask questions or to display what it has understood.

The program utilizes a model of what medical summaries typically look like, which guides the comprehension. This model consists of a set of related schemas, described below. For example, it knows that there is a main character who is the patient. This patient presents symptoms. He is admitted to the hospital. A physician observes signs. Some exams are performed, cultures are taken and eventually results are obtained. The physician is expected to describe the status of a patient. The program uses both its medical knowledge and its model of the usual description of a medical case to interpret the dialogue or the text . and produce an internal structure usable by MYCIN, which then attempts to make a diagnosis.

BAOBAB-2 behaves like a clerk or a medical assistant who knows what the physician has to describe and how a malady is ordinarily presented. it reacts to violations of the model, such as a description ignoring symptoms or the mention of a culture that has been drawn but for which no result is ever given. it does not attempt to use its knowledge to infer any diagnosis but, in certain cases, can draw inferences that will facilitate MYCIN's task. BAOBAB-2 uses these to establish relationships between the concepts stated in order to interpret what is said; for example, it knows that "semi-coma" refers to the state of

consciousness of the patient and "hyperthyroidism" to a diagnosis. A potential use of the program is to allow the physician to volunteer information before or during the consultation. This feature would decrease a common user frustration at having to wait for the computer protocol before mentioning a crucial symptom.

BAOBAB-2 is comprised of: (a) a parser, mapping the surface input into an internal representation; (b) a set of schemas, representing a model of the kind of information that it is ready to accept and the range of inferences that it will be able to draw; (c) episode-recognition strategies, making possible the focus on particular pieces of the texts; (d) a generator of English used to display in a non-ambiguous fashion what has been understood. The generator was previously existent in MYCIN and has already been described in [Shortliff e, 1974]. The main emphasis here will be on the description of schemas and schema-activation strategies. These techniques have been successfully implemented, using INTERLISP [Teitelman, 1975], in a program connected with MYCIN's data base, running on the DEC KA-10 at SUMEX.

3 Schemas and their relations.

3.1 introduction

As noted earlier, medical summaries have a stereotypic structure. They can be viewed as a sequence of episodes, which correspond to phrases, sentences, or groups of sentences dealing with a single topic, These topics constitute the model and are represented by schemas. Understanding the content of an episode leads to building one or more internal clauses referring to the same schema. Processing and understanding a text consists of mapping episodes in the text onto schemas that constitute the model.. Matching

a schema can be "discontinuous", that is, two episodes referring to the same schema need not necessarily be juxtaposed (they might be separated by an episode referring to another schema). We will refer to this phenomenon as a temporary schema shift.

A typical scenario is as follows: The medical case is introduced by giving general information such as the date and the reason for admission to the hospital. Then the patient is presented (name, age,,..). Symptoms (noted by the patient) and signs (observed by the physician) are described. A physical exam is usually performed and cultures are taken for which results are pending or available. The latter case are described in detail. The structure of such a text can be captured in a sequence of schemas, as shown in Figure 2. These texts are usually well structured or at least coherent, that is, redundancies can appear but discrepancies are rather rare (if there are any, they must be detected); expectations are usually satisfied.

A typical BAOBAB-2% schema contains domain-specific knowledge and tessembies frames [Minsky, 1975] or scripts [Schank and Abelson, 1975]. information associated with slots are expected values, default values and attached procedures. it is currently a subset of possibiiities that can be found in frame representation languages such as KRL [Bobrow and Winograd, 1977].

Thus, attributes relating to the same topic are gathered into schemas. There is some overlap between them, such as "weight", which can account for the identification of the patient as well as data of a physical exam. Each schema contains two types of slots: global slots (comments, creation date, author's name, how to recognize the schema, what is the preferred position of the schema within summaries) and individual slots that are clinical parameters. Each individuai slot contains "facets" specifying how to fill it in or the actions to undertake when it is filled in (by procedural attachment).

3.2 An example of schema

if one looks at the $DESCRiPT schema, the first three global slots are used for documentation, whereas the following four are used for strategies of schema shifts, which will de described later. Then, six individual slots define the schema; each of them owns "facets". Some of the slots (EXPECT, TRANS, LEGALVALS, CHECK, PROMPT) were already existent in the knowledge representation of MYCIN. Others have been created in order to endow the program with abilities of intervention during the course of the dialogue. For example, when the slot TOBEFILLED is true, it means that the value of the variable must be asked if the physician does not provide it. The WHENFILLED feature specifies a procedure to run as soon as the slot is filled in. This is the classical way of making inferences. For example, SETSTATURE specifies narrower ranges of weight and height of a patient according to her/his age.

```
$DESCRIPT
---------
  AUTHOR: BONNET
  CREATION-DATE: OCT-10-78
  COMMENT: Patient identification
  CONF I RMED-BY:    (NAME AGE SEX RACE)
  TERM1 NATED-BY:    ($SYMPTOM)
  SUGGESTED-BY:      (WEIGHT HEIGHT)
  PREF-FOLLOWED-BY: ($SYMPTOM)

  NAME,
          EXPECT: ANY
          TRANS:    ("the name of" *)
          TOBEF I LLED:   T
          WHENF ILLED: DEMONNAME

  AGE
          EXPECT:    POSNUMB
          TRANS:     ("the age" of *)
          CHECK :    (CHECK VALU 0 108.9 (LIST "Is the patient really"
                      VALU "years old?") T)
          TOBEF I LLED:   T
          WHENFILLED:  SETSTATURE

  SEX
          EXPECT:    (MALE FEMALE)
          TRANS:     ("the sex of" *)
```

```
        TOBEFILLED:  T
        WHENFILLED: SEXDEMON

RACE
        EXPECT:   (CAUCASIAN BLACK ASIAN INDIAN LATINO OTHER)
        TRANS: ("the race of" *)

WEIGHT
        EXPECT:   POSNUMB
        TRANS :   ("the weight of" *)
        CHECK:    (CHECK VALU LIGHT HEAVY (LIST "Does the patient
                   really weigh' VALU "kilograms?") T)


HEIGHT
        EXPECT: POSNUMB
        CHECK:    (CHECK VALU SMALL TALL (LIST "Is the patient
                   really" VALU "centimeters tall?") T)

                          .
                          .
```

Figure 2. Schema of a patient description.

3.3 Slots

A schema is comprised of two kinds of slots: (a) global slots, which, apart from documentary information (author, comments, etc.) are standard and part of the control structure of the schema-shift strategies; and (b) nonglobal slots, typical of a schema and not usually shared among several schemas. Global slots are mainly used to recognize a schema, which means how deciding whether a part of the text being analyzed suggests or confirms a schema, or how the confirmation of a schema causes another one to be abandoned. The slots confirmed-by and *suggested-by* point to lists of slots belonging to the schema. The first defines the schema (characteristic slots), the other is nonessential for confirming the schema. The slots terminated-b and *pref-followed-by* specify relationships of mutual exclusion and partial ordering between schemas. Ail these slots are described in more detail in the section devoted to strategies for activating schemas. Nonglobal slots are always attributes grouped within schemas. They are, in turn, schemas whose slots are called "facets" [Roberts & Goldstein, 1977).

3.4 Facets

3.4.1 Expected and legal values

Expect is used for single-valued parameters (one value at a time), whereas *legalvals* is used for multiple-valued parameters (several values simultaneously possible). They both give a list of possible values for an attribute.

3.4.2 Linguistic information

Tram always contains a phrase in English describing the parameter; it is used for generating the system comprehension. Prompt contains a question, in English, that asks the

user about the corresponding parameter. In addition to the usual way MYCIN asks information, it is used to clarify a recognized "fuzzy" concept. For example, "The patient drinks 6 cans of beer every morning" leads to ask *Is the patient alcoholic?* since the system has evidently no knowledge about alcoholic beverages, but can recognize such key-words as "drink" or "alcohol". *Check* contains a question expressing the surprise of the program whenever a value has been given outside the normal range.

3.4.3 Tobefilled

If the *tobefilled* facet of an attribute is set to T (true), it means that the slot has to be filled. Concretely, this means that if the slot has not yet been filled when the schema is abandoned, the attached request will be carried out. This does not necessarily mean that the parameter is essential from a clinical point of view; it can also be essential for communication purposes.

3.4.4 Procedural attachment

In BAOBAB-2, the first kind of procedural attachment allows associated actions to be carried out depending on conditions local to the slot. It is analogous to demons of [Selfridge, 1959] or [Chernlak, 1972). The pointer is called *Whenfilled*. The possibilities are described below.

The second kind of attachment is used to specify how to fill a slot and is mentioned last. It is called *Predicate.* They make possible to:

a) Produce inferences: if the attribute of a clause that has just been built has an attached procedure, it can trigger the building of another clause; for example, INFERFEVER is run as soon as the temperature is known and can lead to a clause like "The patient is (not) febrile".

b) Narrow a range of expected values: The limits of possible values are a priori (0 120) kilograms (range by default). The range is narrowed according to the age of the patient as soon as the latter is known.

c) Make predictions: An event like "a lumbar puncture" can cause predictions about "csf data" (not about their value, but about the fact that they will be mentioned). These predictions will be checked and appropriate questions will be asked If they are disappointed.

d) Dynamically modify the grammar: A semantic category like <PATIENT> can be updated by the name of the patient as soon as it is known. This update is done by the procedure DEMONNAME as shown in figure 2.

e) Specify how to fill a slot: Sometimes a procedure expresses how to match a category more conveniently than a data structure. This kind of procedure has been called a "servant". For example, how to match a <VALUE> is expressed by the fact that it points to its corresponding <ATTRIBUTE>. This is much simpler than examining the list of 600 values in the dictionary.

3.4.6 Default values

in BAOBAB-2, I have distinguished between three kinds of default values.

a) Some parameters have actual default values that are negations of symptoms in some sense; for example, *Temperature* has 98.6 as a default value (negation of fever) and *State-of-consciousness* has "alert" as default (negation of something wrong).

b) Other parameters depend on the result of a medical exam or procedure and their default value is simply unknown. To point out an unknown value to the physician might make him remember that the procedure has been carried out. An example of such a default value is "the state of the chest," which depends on an x-ray.

c) Finally, some parameters Inherit a value from another variable, for example, the date of a culture could reasonably be the date of admission to the hospital.

Note that any default value assumed by the program Is explicitly stated. This feature allows the user to override the default value If s/he disagrees with it. This caution is indispensable because a default value might be used later by the consultation program and therefore be taken Into account in the formation of the diagnosis.

3.6 Other schemas

The $EXAM schema (see figure 3) contains knowledge about the physical exam that physicians usually perform after the admission of the patient at the hospital.

```
$EXAM schema (physical exam)
-L-------------I------------
  CONFIRMED-BY: (RASH RESPRATE PULSE BP MENSIGN CXRAB RASHES OCNERVE)
  SUGGESTED-BY: (WEIGHT HEIGHT TEMPERATURE)

  RASH

     LEGALVALS: (PURPURIC PETECHIAL)
     TRANS: (the "types of rash which" * "has")

  TEMPERATURE
     EXPECT: POSNUMB
     TRANS: ("the temperature of " *)
     WHENFILLED:  INFERFEVER
     BYDEFAULT:  98.6

  RESPRATE

     EXPECT:  POSNUMB
     TRANS: ("the respiratory rate of " *)
     PROMPT: ("What is the respiratory rate of" *)
     TOBEFILLED: T

  PULSE

     EXPECT:  POSNUMB
     TRANS: ("the pulse of " *)
     PROMPT: ("What is the pulse of" *)
     TOBEFILLED:  T
```

MENSIGN

LEGALVALS: (MENINGISMUS BRUDZINSKI KERNIG STIFFBACK)
TRANS: (" the signs that the patient showed ")
PROMPT: ("Did the patient show any sign? ")

CXRAB

TRANS: (* 's "X-ray" is "abnormal")
LABDATA: T
BYDEFAULT: NOTKNOWN

RASHES

TRANS: (* has "a rash or cutaneous lesions")
PROMPT: ("Does" * "have any cutaneous lesions or rash on
physical examination?")
BYDEFAULT: NOTSAME

OCNERVE

TRANS: (* has "evidence of ocular nerve dysfunction")
PROMPT: ("Does" * "have evidence of ocular nerve dysfunction?")
BYDEFAULT: NOTSAME

Figure 3. Schema describing a physical exam.

An example of internal representation of an episode follows. The statement:

"... the temperature went up to 103 and he observed weakness in his legs."

is an episode that corresponds to the $SYMPTOMS schema. Two Internal clauses are built out of it. The first requires an inference in order to be used by MYCIN. This Inference is performed by the attached procedure INFERFEVER (see Figure 3):

(TEMP 103) ----> (FEBRILE YES).

The second is straightforward: (SYMP WEAKLEGS). Note that if no state of consciousness is mentioned, it will be Inferred that "the patient is alert" (by default). Furthermore, at least one symptom should be given somewhere.

Figure 4 shows the set of schemas that constitute a model of summary. It only shows how the clinical parameters are clustered within the schemas and the sequencing preferences linking them.

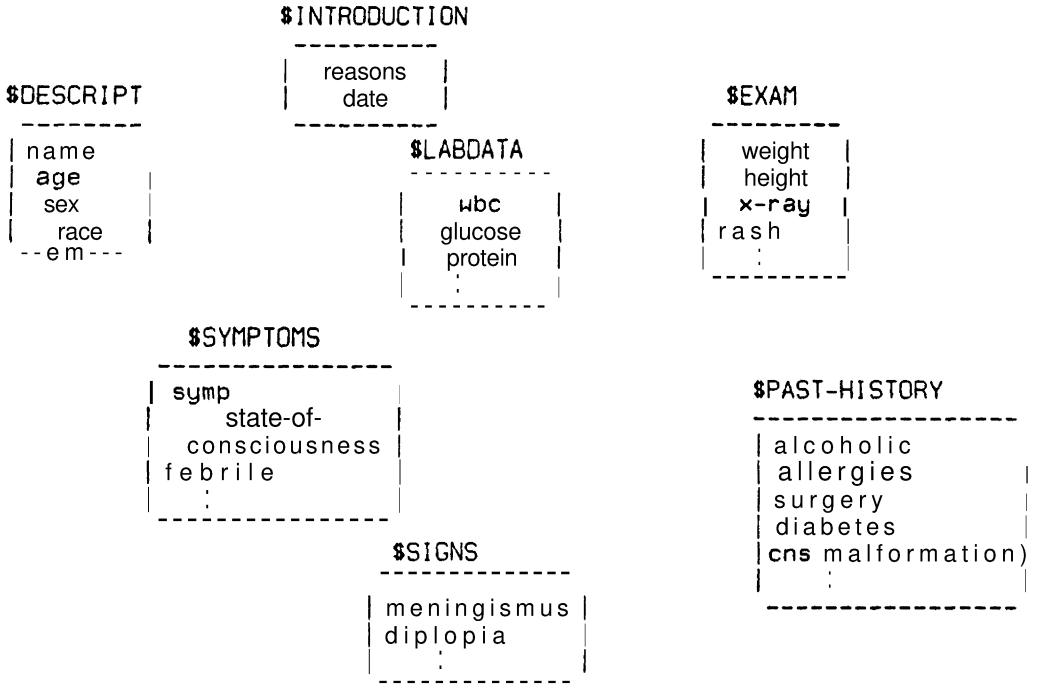

Figure 4. Set of schemas.
(Arrows indicate sequencing preferences.)

4 The grammar

In a technical domain where specialists write for specialists, terseness of style is so widespread ("T 101.4 rectal") that a syntactic parsing does not provide enough additional information to justify its utilization to comprehend texts in such a domain. [1] instead, a

[1] This mainly occurs because subtleties gained from syntax are not represented, given the overall purpose of the system.

computer program can use a semantically oriented grammar. This grammar makes the parsing process unambiguous and therefore very efficient. Justifications can be found in **[Burton, 1976] [Hendrix, 1976].**

The parser uses a context-free augmented grammar, "augmented" having the same meaning as in "augmented transition network" [Woods, 1970). A grammar rule specifies the syntax, a semantic verification of the parse tree resulting from the syntactic component and a response expression leading to build one or several clauses. The grammar is an extension of the one described in [Bonnet, **1978].** It is divided into specific rules and nonspecific rules.

Specific grammar rules are associated with the slots of schemas and describe the way they could be mentioned at the surface level. Categories used in the rules are things like <patient>, <sign>, <diagnosis>. This link between the grammar and the schemas provides a means to try, by priority, those grammar rules that are appropriate to the schema in focus. The notion of grammar rules in focus can be viewed as an extension of **[Grosz,1977]'s** notion of focusing mentioned above. Furthermore, it is a means to postpone the risk of combinatorial explosion due to the large number of grammar rules (itself due to the specificity of the categories used in the productions).

Nonspecific grammar rules use general concepts such as <attribute>, <object>, <value>, commonly used to represent knowledge in systems. This kind of rule is general enough to be used in other domains; but once the syntax has been recognized, they do need a semantic check in order to make sure that, say, values and attributes fit together; hence, the importance of the "augmentation" of the grammar.

Specific grammar rules enable the system **to** recognize very peculiar constructions. For **example,120/98 and 98F** do not belong to well-known syntactic classes but have to be recognized as values for blood pressure and temperature. Grammar rules such as:

<VITAL> -----> <BP> <HIGH/LOW>
<VITAL> -----><TEMP> <TEMPNUM> /<TEMP><NUM> (DEGREES)

are used to parse "*B P 130/94*" *or* "*T 98F* ". The category <TEMPNUM> has an attached procedure, a specific piece of code that recognizes F as Farenheit, detaches **it** from 98, verifies that 98 is a reasonable value for **a** temperature, and finally returns 98 degrees as the **value of** the temperature.

The augmentation makes possible the rejection on semantic grounds of inputs that are syntactically valid with respect to the grammar. A CF-augmented grammar has the power of an ATN (the augmentation plays the role of the conditions that one **can** associate with the arcs). Purely semantic rules will have T (for TRUE) as an augmentation function. When **a** grammar category is satisfied by a surface word (e.g., <symptom> by "malaise"), the category is bound to this value. A binding is represented by a dotted pair such **as** (<patient> . Jo). According to the tradition, categories or concepts to be recognized are represented between brackets, **whereas** words of the vocabulary are as such.

What follows **are** examples of the "syntax" of purely **semantic** rules:

<sentence> ----> <patient> <experience> <symptom> <time>
<symptom> -----> <modifier> <symptom>
<patient> -----> patient / <name>
<name> --------> (the name of the patient usually encountered at **the** beginning of the text)
<experience> --> complain of / experience / <have>
<symptom> -----> headache / malaise / chill / . .
<modifier> ----> severe / painful / . . .
<have> --------> has / had / . . .
<time> --------> <num> <time-unit> ago / on <date>
<time-unit> ---> day / week / . . .
<num> ---------> 1/2/3/...
<date> --------> **a date** recognized by **an** associated Lisp function

This subset of grammar enables the program to recognize inputs such as:
Napoleon complained of severe headache 3 days **ago** (1)
Bill experienced malaise on **sept-22-1978** (2)
Jane had chills on 1 O/l **0/78** (3)

Examples of purely syntactic rules are:

```
<SENTENCE>    ----> <NP> <VP>
<NP>          ----> <NOUN> / <ADJ> <NOUN> / <DET> <ADJ> <NOUN> /
                    <DET> <NOUN> /..
<VP>          ----> <VERB> / <VERB> <NP> / <VERB> <PREPP>
<PREPP>       ----> <PREP> <NP>
```

where <NP> stands for noun phrase, <VP> for verb phrase, <PREPP> for prepositional phrase and <PREP> for preposition. The set of rules will enabie the recognition of (1) deprived of the notion of time, as shown on the following syntactic tree.

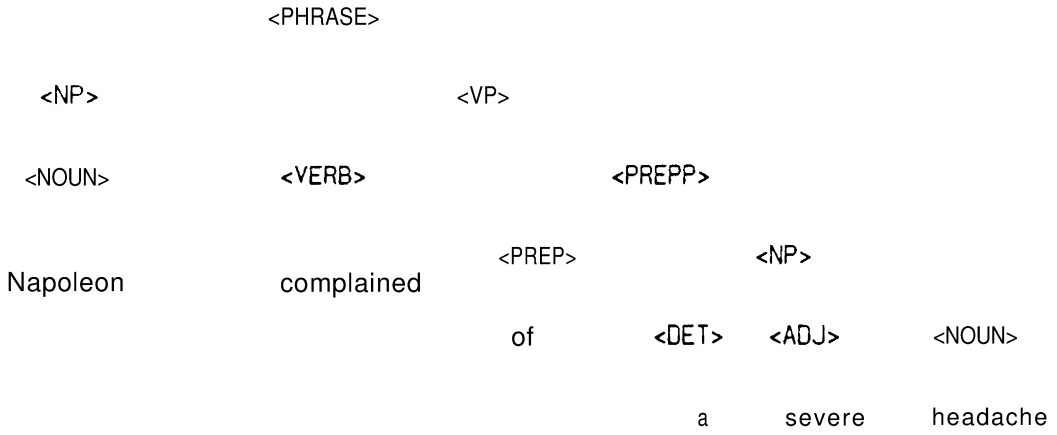

Figure 5. A conventional syntactic tree.

When the semantic component interprets such a syntactic tree, it checks that "<noun> should be matched by a person" (whereas the direct use of <patient> would make useless such a verification.) Sentences such as (4) and (5) below would thus be rejected.

(4) The boat complained of headache
(5) Bill complained of a severe leg

Numerous systems use a representation based on the notion of object-attribute-value triple with an optional associated predicate function. In such domains, one can define grammar rules such as:

```
<sentence>  -------> <object/attribute> <predicate-fn> <value>
<object/attribute> ------> <attribute> of <object> / <object> <attribute>
<object>    -------> patient / culture / organism / . . .
<attribute> -------> ISATTRIBUTE (attached procedure specifying how to
                     recognize an attribute)
<predicate-fn> ----> <same> / <notsame> / . . .
<same>      ------> is / has / ...
<value>     ------> ISVALUE (attached procedure specifying hou to
                            recognize the value of an attribute)
```

Figure 6. A set of syntaxico-semantic rules.

"Syntaxico"-semantic rules enable the recognition of sentences such as:

(6) The temperature of the patient is QQ
(7) The morphology of the organism is rod

The complete form of the rule is displayed below. CHECKAV (check **attribute value)** is a function of 2 arguments <ATTRIBUTE> and <VALUE> that returns "true" if the value matches the attribute, in which case the response expression is produced; otherwise, the semantic interpretation has failed.

```
((<OBJECT/ATTRIBUTE> <PREDICAT-FN> <VALUE>)                    (syntax)
 ((CHECKAV <ATTRIBUTE> <VALUE>)                                (augmentation)
  (LIST <PREDICATE-FN> <ATTRIBUTE> <VALUE>)))                  (response)
```

It is interesting to note that the predicate function is usually a verb phrase, the <ATTRIBUTE> of <OBJECT> sequence being a noun phrase as well as <VALUE>. This means that a syntactic structure is being implicitly used.

The interpreter is left-to-right and top-down, with backtracking. Whenever a grammar rule is satisfied but a part of the input remains to be analyzed, the remaining part is

given back to the control structure, which then can invoke special processes; for example, a conjunction at the head of the remaining input can trigger an attempt to **resolve it as an** elliptical input. in "English people love blonds and drink tea", the second part can thus be analyzed as "English people drink tea". The algorithm implemented for handling elliptical inputs has been inspired by LIFER **[Hendrix, 1976]**. When an input **fails to be recognized,** the interpreter assumes that a part of the input is missing or implicit, and it looks at the previous utterance. If parts of the input match categories used in the grammar rule satisfied by the previous input, it then assumes that the parts that have no correspondance in the new input can be repeated.

The following set of grammar rules (Figure 7) is intended to show how a sequence of symptoms can be recognized by using recursion. For example, "stiff neck, painful back and weak legs" is recognized by using the right recursion of (1) for the sequence at the top level and the right recursion of (3) inside each expression. For another expression, like "malaise symptoms", the left recursion is avoided by using an intermediate symbol in (4). When an expression appears in parenthesis, it means that it is optional.

```
<SYMPVALUES>
-----------
  GRAMMARS:    [((<SYMPVALUE> (AND)
                          (<SYMPVALUES>))>
                 (T (CONS (CAR <SYMPVALUE>)                    (1)
                          <SYMPVALUES>]


<SYMPVALUE>
----------
  GRAMMARS:
               [((<BAD> (<PREP>)
                        (<POSS>)                               (2)
                        <PART>)
                 (<PART> <BAD>)
                 (T (BODYEXPERT <PART> <BAD>)))

                ((<ADJ> <SYMPVALUE>)
                 (SYMPTOM OF <SYMPVALUE>)                      (3)
                 (T <SYMPVALUE> ))

                ((<SYMPVALUE1> SYMPTOM)                        (4)
                 (T <SYMPVALUE1>))

  PREDICATE:   ISASYMPVALUE

<SYMPVALUE1>
-----------
  PREDICATE:   ISASYMPVALUE


(ISASYMPVALUE
  [LAMBDA (X)**matches the value of a symptom**
    (COND
      ((FMEMB X (LGETP 'SYMP 'LEGALVALS))
        (CONS (CONS 'VALUE X)))
      ((FMEMB X (LGETP *STATE-OF-CONSCIOUSNESS 'EXPECT) )
        (CONS (CONS 'VALUE X]))

<PART>
-----
  POSSIBLEVALUES:    (HEAD BACK NECK LEG)


<POSS>
------
  POSSIBLEVALUES:    (HIS HER)

<ADJ>
----
  POSSIBLEVALUES:    (SEVERE SHAKING BITEMPORAL)
```

```
<BAD>
- - - -
   POSSIBLEVALUES:    (STIFF PAINFUL WEAK PAIN WEAKNESS)
   GRAMMARS:    ( ( (VERY <BAD>)
                    (T <BAD>) ) )
```

Figure 7. A set of grammar rules.

A nonterminal category is itself defined in terms of the grammar (the equivalent **of** the PUSH arc in the ATN formalism), which causes a recursive call of the interpreter until terminal symbols are reached.

A terminal category is itself defined by the list of its possible values; for example, <month> points to the 12 possible names together with their most common abbreviations. When a complete list is expressible by a procedure (the numbers between 1 and 12), it is more convenient to use the procedure than to define the list of ail the numbers between **1** and 12. in the latter case, a recognition procedure is associated with the category.

5 . Schema-shift strategies

it seems to me that **a** language describing choices between **schemas,** and therefore schema-shifts strategies, should include an attempt to answer the following questions: How is a schema focused, confirmed, abandoned? What are the links between them such **as** exclusive or sequencing relations?

5.1 Suggest vs. confirm

[Bullwinkle, 1977] (see also [Sidner, 1979]) makes the distinction between potential and **actual shifts** of focus, pointing out that the cues suggesting a new frame **must** be confirmed by **a** subsequent statement in order to avoid making unnecessary shifts. This phenomenon is handled in a different fashion in BAOBAB-2. instead of **waiting for the**

suggestion to be confirmed, a qualitative distinction is made between the slots of a frame. The ones marked as suggesting but not confirming are regarded as weak clues and will not lead to a shift of focus, whereas the ones marked as confirming (hence suggesting) are sufficiently strong clues to command the shift. This distinction can be illustrated by the following two examples.

> (1) The patient was found comatose. She was admitted to the hospital. A lumbar puncture was performed. She denied syncope or dipiopia...
>
> (2) The patient was found comatose. He was admitted to the hospital. The protein from csf was 58 mg%... (csf = cerebro spinal fluid)

In example 1, the lumbar puncture suggests "csf results" that are not given (weak clue). In example 2, a detail of csf result (strong clue) is given directly; in other words, the physician jumps into detail and the frame is directly confirmed.

5.2 Top-down vs. bottom-up

Sometimes the schema is explicitly announced, as in "Results of the culture". This is a name-driven invocation of the schema. More often, the instantiation of the schema is content-driven. The clues used are: the attributes associated with the schema, their expected values (if any), and other concepts that might suggest the frame. For example, "skin" is related to "rash", which belongs to the *physical* exam frame. These are indeed very simple indices. Research on more sophisticated methods for recognizing the relevant schema, such as discrimination nets, have been suggested in [Charniak, 1978].

5.3 Termination conditions

A simple case in which a schema can be terminated is when all its slots have been filled. This is an ideal situation that does not occur very often. Another case is when the intervention of a schema implies that another schema is out of focus which could but not

necessarily be the result of chronological succession. in general, this phenomenon occurs when the speaker actually starts the plot after setting the characters of the story. *There* is no standard way to decide when the setting is finished. However, as soon as the story actually starts, the setting could be closed and possibly completed with default values or with the answers to questions about whatever was not clear or omitted. A "terminated-by" slot has been created to define which schemas can explicitly terminate others; for example, the $SYMPTOM schema usually closes the $DESCRIPT schema (name, **age, sex,** race), as it is very unlikely that the speaker will give the sex of the patient in the middle of the description of the symptoms. This fact is due to the highly constrained nature of the domain.

5.4 Termination actions

When a schema is terminated, the program infers ail the default values of the unfilled slots. it also checks whether the expectations set during the story have been fulfilled. These actions **can** be performed only when a shift has been detecteci or at the end of the dialogue; otherwise, the program might ask too early about information that the user would indeed give later, In the case where a schema has been exhausted (all its slots filied), an a priori choice with regard to the next schema likely to appear is made. This choice is possible by using a *preferably-followed-by* pointer that, in the absence of a bottom-up (data-driven) trigger for the next schema, decides in a top-down fashion which one is the most probable at a given point.

5.5 Schema-grammar links

Specific grammar rules described earlier are always associated with clinical parameters and therefore with schemas. This link is interesting from two points of view:

a) The interpreter takes advantage of this relationship to try specific rules in order

of decreasing probability of the schema to be in focus. There is no quantitative notion of Probability, but the preferred sequencing causes not only grammar *rules* associated with schemas in activation to be tried by priority, but also the ones of the preferred successor, immediatly after, in case an unforeseen shift occurs. Rules are reordered whenever a schema-shift occurs, which explains that the more random a text is given, the longer it takes to be parsed.

b) The parser can examine the content of a schema during the semantic interpretation of an input. For example, it can check the correspondance of an attribute and a value. it can also trigger a question whose answer is needed to interpret the current input. Therefore, there is a two-way connection between schemas and the grammar. This link is one of the keystones of the interactive behavior of the program.

5.6 Comparison with story-grammars

Other methods have been proposed to take advantage of coherent structures of texts. Psychologists and linguists have attempted to draw a parallel between the structure linking sentences within a text with the one linking words within sentences. The notion of text-grammars grew out of this analogy, leading to the representation of the regularities appearing in such simple texts as fables as context-free rules.

[Rumelhart, 1976) describes a story as an introduction followed by episodes. An episode is an event followed by a reaction. A reaction is an internal response followed by an overt response, etc. The symbol "+" means "followed-by", the Kleene star "at least one" and "/" stands for the alternance.

Syntactic rules

Story ⟶ Introduction + Episode
Introduction ⟶ State*
Episode ⟶ Event + Reaction
Event ⟶ Change of state
Event ⟶ Action
Event ⟶ Event + Event
Reaction ⟶ Internal response + overt response
Internal response ⟶ Emotion / Desire / . . .

Figure 8. Part of a story-grammar proposed by Rumelhart.

A simple observation supporting the parallel is that two sentences in sequence usually bear some kind of relation to each other (often implicit, the word "therefore" not being necessarily present), otherwise the juxtaposition would be somewhat bizarre. Recognizing a paragraph as a sequence of sentences "at a syntactic level" leads to building a tree structure further usable by a semantic component.

Although this formalism is enticing, it has not yet been applied to text analysis in a computer program. I shall try to explain below the reasons I suspect for this. [1]

The limits of the analogy between phrase structure and text structure can be easily ascertained. [Winograd, **1977]** underlines the limits of a generative approach by pointing out that **"there** are interwoven themes and changes of scene which create a much more complex structure than can be handled with a simple notion of constituency".

Furthermore, even if one can give an exhaustive list of words satisfying <noun>, it is difficult to determine how to match a <consequence> or an <overt response>. It follows

[1] Text-grammars have been applied for automatic generation of stories [Klein, **1975]**.

that satisfying a grammar rule is not easy to define, Even if we can predict that a determiner will precede an adjective or a noun, it is much more difficult to foresee that an *emotion* will be followed by a *reaction,* or at least not with the same regularity. It also seems that the "syntactic" category of a phrase is strongly domain-dependent. A given sentence may be a *consequence* or a reason according to the context. This phenomenon occurs less frequently with traditionally syntactic categories.

In addition, flashbacks are commonly used when people tell stories: In particular, a "consequence" might very well precede the explanation of an event. Chronological order is not often respected as in *Van Gogh had difficulties to wake up. He had drunk a lot the night before*. Along the same lines, elliptical phenomena (incomplete inputs) seem difficult to resolve; if one can determine the missing part of a sentence by reference to the syntactic structure of the previous sentence, it is not easy to guess the non-stated event that has caused a reaction. The "syntactic" categories of text-grammars correspond more or less to schemas. The model defined in BAOBAB-2 merely defines a partial ordering or links of a preferred ordering between schemas. It follows that the *introduction* might be absent or that *signs* might precede *symptoms* without the text being regarded as incoherent. Violations of the idealisic model only cause requests for clarification or additional information. They make the comprehension process more difficult but do not impede it.

6 Direction for future work

For the time being, the grammar is not very large (about 200 rules); Only seven schemas have been implemented. In order to be able to parse efficiently more complicated texts, involving symptoms which might imply different infections (with interactions between them), a computer program will need more sophisticated clues to determine which schema is

the most appropriate to apply in priority. Furthermore, certain concepts are currently ignored because their relevance to medical knowledge is not always straightforward. For example, an infection acquired by a member of the patient's family or even the patient's occupation could give hints to the physician during the early stage of the diagnostic formation.

7 Conclusion.

The strategies outlined above could be applied to a broad range of structured texts. The approach rests on the assumption that their scenario can be seen as sequences of episodes identifiable by the program, in order to be integrated into appropriate schemas. Therefore, clustering attributes into frame-like structures must make sense in the domain of application. The episodes could simultaneously refer to several schemas, that is, the schemas associated could have slots in common. Furthermore, it should be possible to define partial-ordering links between schemas. The relationships could be rather loose but the more constrained they are, the better this feature would work.

Expert systems usually need some kind of understanding to communicate in natural jargon with various users (expert, consultant, student). The technique described here (breaking down the knowledge into schemas that should correspond to different pieces of texts, associating semantic grammar rules with the schemas, and using strategies for recognizing episode shifts) should be applicable in such domains.

8 Examples of sessions with Baobab-2

The physician types the input in upper case after the double asterisk; BAOBAB-2's responses are in lower case, Generation of what the program has understood is somewhat "heavy" for the main purpose is to be unambiguous. An actual summary written by a

physician has been chosen, slightly simplified, broken down into inputs, and given as a dialogue to facilitate the interactions. A few comments have been inserted on the right for . sake of illustration. Names of **schemas** start with a **$.**

In the first example, the exposition of the summary does not satisfy the model (mainly because expectations are not fullfilled) which therefore causes interventions from the program. Questions are asked, analogous to the way MYCIN asks them. In the other two examples, the model is satisfied; the dialogue follows a normal course.

8.1 First example

** A 19 YEARS OLD BOY WITH PETECHIAL RASH, LETHARGY AN0 POSI TI VE BRUOZI NSKI ' S SI GN.

Patient's name?

(The $DESCRIPTION schema has been activated by the beginning of the input, then there is a schema-shift hence the request for the missing name)

** BI LL

My understanding is:
The name of the patient is Bi l l
The age of the patient is 19 years
The sex of the patient is male
Petechial is one of the types of rash which the patient has
Lethargy is one of the symptoms that the patient had
Brudzinski is one of the signs that the patient showed

** HE HAD AN LP

My understanding is:
A lumbar puncture has been performed on the patient

** BYE

(Disappointed expectations trigger requests for csf results)

What is the total WBC count of the CSF?

** 9500

What percent of the WBCs in the CSF were polys?

** *70*

What is the protein value (mg/100cc) in the CSF?

** 32

What is the glucose value (milligrams percent) in the CSF?

** 12

8.2 Second example

** REASONS FOR ADMISSION: CHILLS HEADACHE MALAISE (sets *up expectations)*

So I will expect chill headache malaise as values for symptoms

** DATE OF ADMISSION: DECEMBER 25 1978

My understanding is that:
the patient was admitted at the hospital 4 days ago

** HISTORY OF THE PRESENT ILLNESS *(announces*

Ok. *$identification)*

** PAT IS A 26 YEAR OLD CAUCASIAN FEMALE

My understanding is that:
the age of the patient is 26 years
the race of the patient is Caucasian
the sex of the patient is female
the name of the patient is Pat

** ONE DAY PRIOR TO ADMISSION SHE EXPERIENCED CHILLS AND HEADACHE *(shift to $symptoms)*

My understanding is that:
chill is one of the symptoms that the patient had 5 days ago
headache is one of the symptoms that the patient had 5 days ago
(time inferences)

** ONE DAY AFTER SHE HAD A MALAISE

My understanding is that:
malaise is one of the symptoms that the patient had 4 days ago

** A LUMBAR PUNCTURE WAS PERFORMED *(weak clue to $labdata)*

fly understanding is that:

a lumbar puncture has been performed on the patient .

** SHE DENIED SYNCOPE OR PHOTOPHOBIA *($symptoms and $signs)*

My understanding is that:
syncope is not one of the symptoms that the patient had
photophobia is not one of the symptoms that the patient had

** SOCIAL HISTORY: OCCASIONAL ALCOHOL USE

Do you suspect recent alcoholic history in Pat? *(clarification)*

** NO

fly understanding is that:
the patient is not an alcoholic

** PHYSICAL EXAM *(announces $exam)*

Ok.

** WEIGHT 110 POUNDS

My understanding is that:
the weight of the patient is 43.3 kgms

** TEMP 101 DEGREES P 30 BP 110175 RR 28

My understanding is that:
the temperature of the patient is 101
the pulse of the patient is 90
the blood pressure of the patient is 110/75
the respiratory rate of the patient is 28 breaths/minute

** SKIN, NORMAL *(leads to a clause via*

fly understanding is that: *inference)*
the patient does not have a rash or cutaneous lesions

** NECK: MARKEO NUCHAL RI GI OI TY *(idem)*

My understanding is that:
meningismus is one of the signs that the patient showed

** BRUDZINSKI'S SI GN WAS POSI TI VE

My understanding is that:
Brudzinski is one of the signs that the patient showed

** LAB DATA *(announces $labdata)*

Ok.

** CSF RESULTS *(sets a context)*

Ok.

** WBC *3500* *(understood in context)*

My understanding is that:
the WBC from the CSF is 3500

** PROTEIN 56

My understanding is that:
the CSF protein is 56

** GLUCOSE 45 MG%

My understanding is that:
the CSF glucose value is 45

** PERIPHERAL CBC *(sets another context)*

Ok.

** WBC 235 *(understood in context)*

My understanding is that:
the white count front the patient 's peripheral
CBC (in thousands) is 235

** THE VALUE OF WBC IS 225 *(corrects a mistyping)*

Instead of 235 ? *(making sure that it*

** YES *was meant)*

My new understanding is that: The crhite count from
the patient's peripheral CBC (in thousands) is 2 2 5

** BYE

I have assumed the fol lowing by default: *(inferences by default)*
the state of consciousness of the patient is alert
the patient's X-ray is not abnormal
the patient is not inmunosuppressed
Do you agree?

** THE PATI ENT IS I MMUNOSUPPRESSED *(overrides a default value)*

My new understanding is that: The patient is inmunosuppressed
Do you agree?

** YES

bye.

8.3 Third example

Ready

** REASONS FOR ADMISSION: HEADACHE, LETHARGY AN0 FEVER

So I will expect HEADACHE LETHARGY FEBRILE as symptoms

** DATE OF ADMISSION ON MARCH 14

That was 6 days ago.
My understanding is
the patient was admitted at the hospital 6 days ago

** BARBARA IS A 3 YAER OLD WHITE FEMALE

=YEAR *(spelling corrector)*
My understanding is
the age of the patient is 3 years
the race of the patient is Caucasian
the sex of the patient is female
the name of the patient is Barbara

mm ONE DAY PRIOR TO ADMISSION, SHE BECAME LETHARGIC

My understanding is
lethargy is one of the symptoms that the patient had 7 days ago

** SHE COMPLAINED OF HEADACHE AND HAD A TEMPERATURE OF 101 DEGREES

My understanding is
headache is one of the symptoms that the patient had
the temperature of the patient is 1 0 1
the patient is febrile

** A PHYSICIAN OBTAINED A COMPLETE BLOOD COUNT

My understanding is
the results of a recent CBC of the patient are available

** A LUMBAR PUNCTURE WAS PERFORMEO

My understanding is
a lumbar puncture has been performed on the patient

** WEIGHT 33 LBS

My understanding is
the weight of the patient is 17.7 kgms

** HEIGHT 1.03 METER

Is the patient really 103.0 centimeters tall?
(Asking for confirmation because it seems tall for 3 years)
(Y or N) ** YES
My understanding is
the height of the patient is 103 cms

** BP 120/70 P 140

My understanding is
the blood pressure of the patient is 120/70
the pulse of the patient is 140

** RR 28 T 101 *(redundancy, the temperature was already known)*

fly understanding is
the respiratory rate of the patient is 28

** SK I N: PETECHI AE ON FACE AN0 SHOULDERS

MY understanding is
petechial is one of the types of rash which the patient has

** NECK: DEFINITE MENINGISMUS

My understanding is
meningismus is one of the signs that the patient showed

** LAB DATA: CSF RESULTS *(announces lab results; no clause is built)*

Ok.

** WBC 110 WITH 96% POLYS *(interpretation in the context of csf)*

My understanding is
the WBC from the CSF is 110
the percent of PMNs in the CSF is 96

** PROTEIN 25 MG% AND GLUCOSE 95

My understanding is
the CSF protein is 25
the CSF glucose value is 95

** PERIPHERAL CBC

Ok.

** WBC 12300

Is the white count from the patient's peripheral CBC (in thousands) really 12300?

Me physician had forgotten that a number of thousands was expected

** NO

Please enter the right value now

** 12.3

My understanding is
the white count from the patient 's peripheral CBC (in thousands) is 1 2 . 3

** WITH 76% POLYS AND 1% BANDS

My understanding is
the percent of PMN's in the CBC is 76
the percent of peripheral WBC's which are immature in the CBC is 1

** SIMULTANEOUS BLOOD GLUCOSE: 170

My understanding is
the simult aneous blood glucose value is 170

** BYE

I have assumed the following by default:

the state of consciousness of the patient is alert
the patient has not shown symptoms of mumps
it is unknown whether the patient's X-ray is abnormal
the patient does not have a rash or cutaneous lesions
the patient does not have evidence of ocular nerve dysfunction
the patient is not an alcoholic
the patient is not immunosuppressed
it is unknown whether the patient does have a tb risk factor
the patient is not a compromised host
the patient does not live in a crowded environment
the patient has not been recently exposed to a contagious disease
the patient has not undergone surgery
the infection was not acquired while the patient was hospitalized
the patient has not been seriously burned
there is not evidence of congenital malformation involving the central nervous system
the patient is not a diabetic
the patient is not a premature infant
it is unknown uhether the patient has had an injury or insult to, or defect in the central nervous system

You can change any of them i f you di sagree

** SHE HAS UNDERGONE SURGERY

I suppose it should replace the patient has not undergone surgery
Right?

** YES
Ok.
** GOOD-BYE

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