MASSACHUSETTS INSTITUTE OF TECHNOLOGY
A. I. LABORATORY

Artificial Intelligence
Memo No. 282

March 1973

GRAMMAR FOR THE PEOPLE: FLOWCHARTS OF SHRDLU'S GRAMMAR

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ABSTRACT

The grammar which SHRDLU uses to parse sentences is outlined in a series of flowcharts which attempt to modularize and illuminate its structure. In addition, a short discussion of systemic grammar is included.

Work reported herein was conducted at the Artificial Intelligence Laboratory, a Massachusetts Institute of Technology research program supported in part by the Advanced Research Projects Agency of the Department of Defense and monitored by the Office of Naval Research under Contract Number N00014-70-A-0362-0003.

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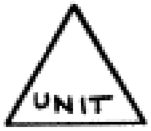
The purpose of these flowcharts is to make available to the general, non-SHRDLU-hacking public, the parser which SHRDLU uses. There have been many who have tried to decipher its code; most have either become hopelessly entangled or painfully made their way through its web. Now, at last, even you can have in your home a complete set of SHRDLU flowcharts. Besides making the code generally more comprehensible, the flowcharts de-emphasize the linearity of the parsing program and instead organize it into modules. Thus the reader can see the outline of a large part of the process at a fairly high level and only later turn to another page to ponder the details. Hopefully, their availability will encourage other system implementers to use the parser as a front end and will spark some cross-cultural communication between the non-computing linguistic community and AI language workers.

These flowcharts are best read with a copy of Winograd's thesis or book by your side. Although a few characteristics of systemic grammer are mentioned below, its basic philosophy is not detailed here. Neither is the design and operation of PROGRAMMAR, the language in which the parser is written. Working through the PROGRAMMAR examples in the thesis(page 153 in the thesis version or page 98 in the book) is a good preliminary exercise in following the operation of the grammar. Of course, the charts are also meant to be a guide for reading the code; they explicate the crucial sections, avoiding some of the kludges which make the grammar difficult to decipher. You should not expect, however, that the correspondence between the flow charts and either other source will be perfect. The thesis explicates a more complete grammatical theory than that which the program embodies; in addition, feature names sometimes differ radically. While the charts stick more closely to the program than to the thesis, several sections of code have been omitted and/or "misrepresented," most notably the backtracking sections (precisely because they are mostly ad hoc). Don't be thrown by such differences. You are not missing anything or being stupid; they are (hopefully) intentional.

A FEW WORDS ABOUT SYSTEMIC GRAMMAR

Form vs. Function

A basic dichotomy which systemic grammar considers is that between the form and function of a particular unit. Form refers to the internal structure of a unit, what constituents it can have, how they must be arranged and what dependencies exist among them. Function considers a unit's place in the "higher order of things" : what roles it can play in higher constituents and what dependencies it enters into. For example, the form of an NG may be represented as several non-independent slots which need to be filled; the NG program is primarily concerned with filling those slots and amassing features (e.g. number and person). Its function is indicated by the places in other programs from which it is called: as the object of a preposition, first or second object of a verb, subject of a clause, constituent of an ADJG(e.g. as big as the ball) etc.

The form of a unit is evident in the flowcharts detailing its program; a unit's functions are indicated by the places where an attempt to parse it is made (i.e. where  is found) There are clearly a multitude of functions for a unit. Remember that there are also many and varied forms. For example, an NG containing "anything" has a different form from the garden-variety filled-slot NG and the form of a VG cannot be easily detailed in a slot-and-filler account, though a program does a good job of describing its form.

Of course, a constituent's function may affect its form. A primary use of features in this parser is to communicate such effects up and down the tree. CLAUSE may call NG with the initial feature OBJ, which specifies objective case for any pronoun the NG may come up with. NG, in turn, may call CLAUSE with the initial features RSNG (rank-shifted noun group) ING (as in "Dancing Bulgarian dances is great fun."), which allows the clause to have no subject or a possessive subject and requires it to have an ING verb group. A good thing to focus on in reading the flowcharts is the effect of such features. Often a program will, as its first action, dispatch to pieces of code which know how such functional features affect form.

More on Features

While we're on the subject, more about the features a systemic grammar uses. So far we've been referring to their syntactic relevance and how they direct the parsing process. One of systemic grammar's claims to fame is that features have both syntactic and semantic significance, thus partially bridging the gap between syntax and semantics which has been recently so lamented. For example, the feature

DEF on an NG not only constrains its form but also tells us that a specific object or objects are being referred to (e.g. the happy smiling rabbit) The feature INT, given to clauses with intensive verbs such as BE, tells us structurally to expect an NG, ADJG or PREPG acting as a complement after the verb but also indicates that the complement will be a property of the subject of the sentence as in "The rabbit is cute." Similarly, an RSQ (rank-shifted qualifier) clause has a definite structure in whch one of its constituents will be the noun it is modifying. It also gives us the semantic information that the object being referred to by the entire NG must satisfy the semantic constraints of the RSQ. Finally, a TIME NG has a very definite structure and must contain a time word such as "yesterday" or "month" (as in "last month"); it has obvious semantic significance in that we know it affects the time referred to by the utterance, which would otherwise be determined solely by the tense.

The flowcharts indicate when some of the more important features are added to nodes. (Notice that one way features are added is by sending initial features along in the attempt to parse) There are, in addition, decision points based on testing for a particular feature - the most relevant of these are also noted in the flowcharts. Most feature names are either found in the thesis or are interpretable from their spellings with a little thought. TOOB2, for example, is the feature of a verb which takes an RSNG TO as its second object as "I asked him to scratch my back." In this sentence, "him", an NG, is the first object, while the CLAUSE RSNG TO "to scratch my back" is the second. TRANSINT refers to a verb which takes an object and a complement as "I <u>consider</u> him an idiot." A most important feature, REL-NOT-FOUND, is marked on an RSQ clause which has not yet determined which of its constituents' places its RELHEAD (the noun it is modifying) will take.

This treatment of features implies some uniformity in their use; actually features serve three distinct purposes in this parser. The form of a given constituent is clearly indicated by its features; its function is also so marked, although this information is somewhat redundant with the contents of the registers.(see below) All of the features relating to function could be easily derived using the registers and some simple tree-traversing. A third, very different use of features is as temporary variables during the parsing process. REL-NOT-FOUND, for example, is only temporarily attached to a clause and is not a feature referring to either function or form which remains on a node at the end of the parsing process. Such features serve to direct the parsing process but are not an end result of it.

Registers

Certain of the subparts of a constituent will always be crucial to its semantic analysis; such subparts are kept in registers so they will be readily available to the semantic specialists as well as later syntactic processes. The name of a register is in general an obvious give-away for its meaning: SUBJECT,OBJ1, LOGICAL-SUBJECT,(in passive sentences), MVB(main verb). HEAD is the register used to hold the head noun of an NG or the head adjective of an ADJG; RELHEAD holds the NG which an RSQ modifies and is used by the RSQ CLAUSE program when it looks around for its missing constituent. Such registers add no theoretical power to the parser, since a constituent can always be found by moving around the parse tree, but they add to the ease of program writing, reading and documentation; they are another way which shows up clearly in these flowcharts for constituent programs to communicate information among themselves.

OPERATION OF THE PARSER

As explained in more detail in the thesis, the parser works, as do most such parsers, by building a parse tree. Each node is marked as to features, daughters, parent, words it contains and relevant registers. Semantics are initially present only at the word level; such definitions are stored in the dictionary. At crucial points in the grammar programs (which are indicated on the flowcharts as "CHECK SEMANTICS") semantic specialists are called.They combine the semantics of the components into a semantic structure for that part of the unit parsed so far. At least one semantic specialist exists for each syntactic unit. NG, for example, boasts two: one which handles that part of the NG through the noun, and the second which worries about the semantics of qualifiers occurring after the noun. Such a specialist can also report that it's not happy with the combination of words the parser came up with for this constituent; its complaint usually causes the unit to pop off its last-parsed constituent or, in more radical cases, to throw up its hands and return a failure message to the program which called it. This semantic guidance prevents an attempt to parse "The girl gave the boy plants to water" analagously to "The girl gave the house plants to charity." and is one of the more interesting features of the parsing strategy.

LEGEND FOR READING THE FLOWCHARTS

Each page of the flowcharts is titled; in addition, pages are labelled with <name of unit> / <page within that unit> and such designations are used on other pages to refer to this section of the flowcharts, e.g. NG/1 or CL/10.

△ UNIT FEATURES — PARSE unit with given features (equivalent to a call to PARSE)

△ "WORD" — PARSE this particular word (equivalent to a call to PARSE with NIL as the first argument)

LABEL — LABEL in grammar programs, local to the page it appears on.

(*LABEL*) — LABEL in grammar programs. The code at this label is accessed from some other page in the flowcharts.

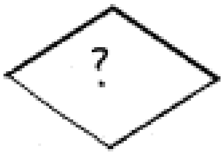
(*LABEL* CL/5) — LABEL in grammar programs. The code at this label is detailed on the page indicated under the label. (Apologies for the confusing closeness of this notation and the one above it.)

Three branches leading from an attempt to PARSE

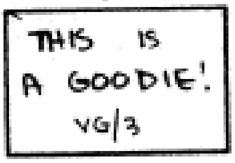
→ : taken if attempt succeeds

—+→ : taken if attempt fails

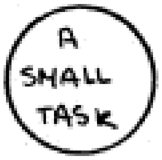
o—→ : taken if parse succeeds and there are no more words left in the sentence



Brench point, relevant test is detailed inside diamond.



A large task which is detailed on another page headed by this name and designated by unit/ number below. These may le considered the primary modules of the grammar.



A small task, not detailed anywhere else because what it says here should be enough for you to get the idea. More details may be found in the actual code if you're interested.

FEATURE

Features being checked for are in capital letters and underlined. Unless otherwise noted, features referred to belong to the constituent currently being parsed.

an example of some text

A relevant piece of an utterance which, to be parsed, passes through this particular point in the program. The underlined constituent is the part which is particularly relevant, often what would be parsed by the nearest call to PARSE.

—|→ FAIL

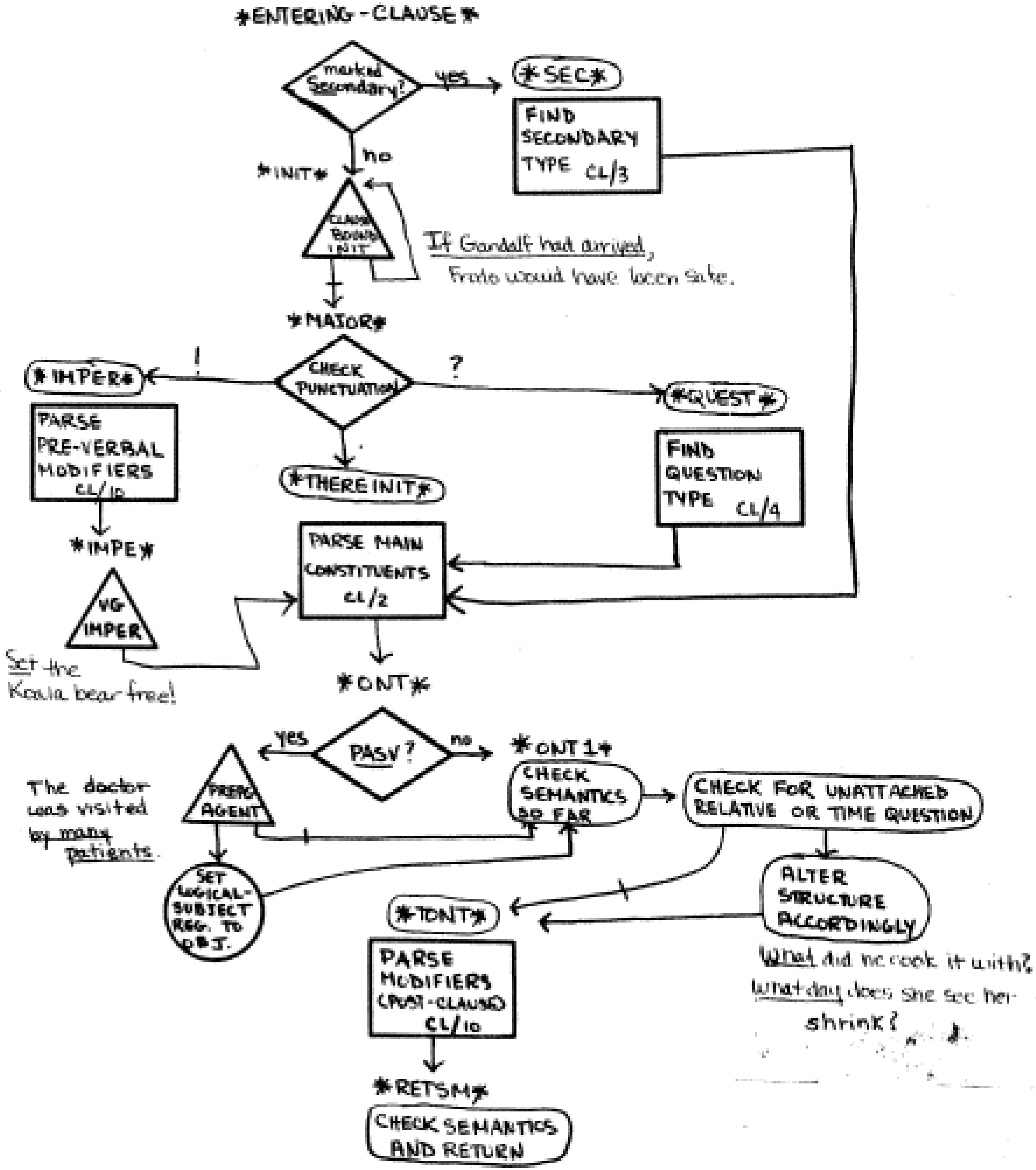
The program called to parse this constituent returns a failure message.

RETSM

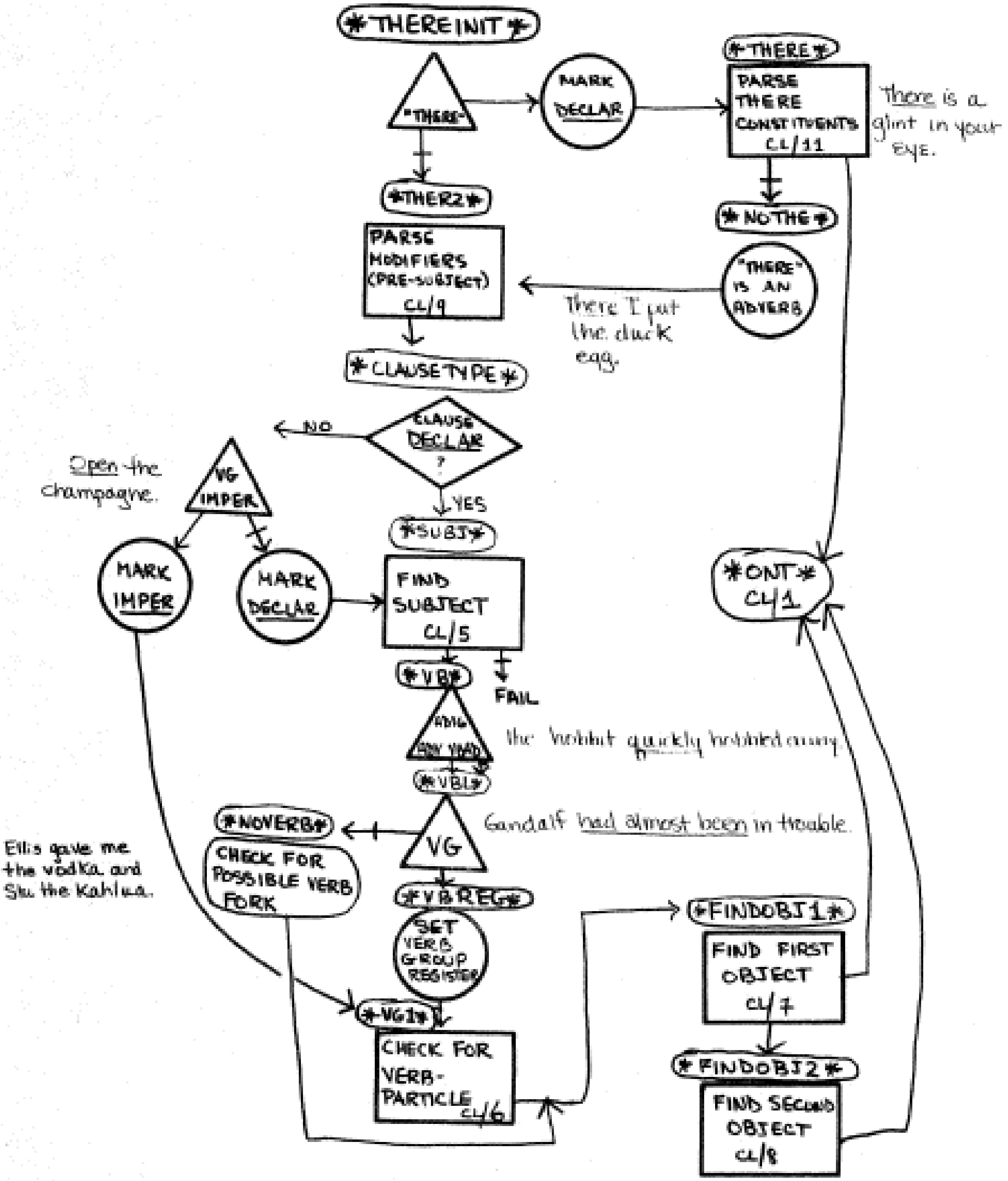
is the usual label for the place in each unit's program where final semantics work is done and the program returns its parsed constituent which is then attached to the tree.

In general, the flowcharts parallel the code well enough so that the correspondences are obvious. In one case, this not true. In the flowcharts for finding the first and second object in a clause, a great deal of the work is checking features of the verb and, should the parse of a suitable object succeed, marking the clause suitably and setting an appropriate register. This work is "hidden" in the subroutine CANPARSE, whose arguments are: number of object (1 or 2); unit to parse if the verb is appropriately marked; feature with which to mark clause if parse succeeds.

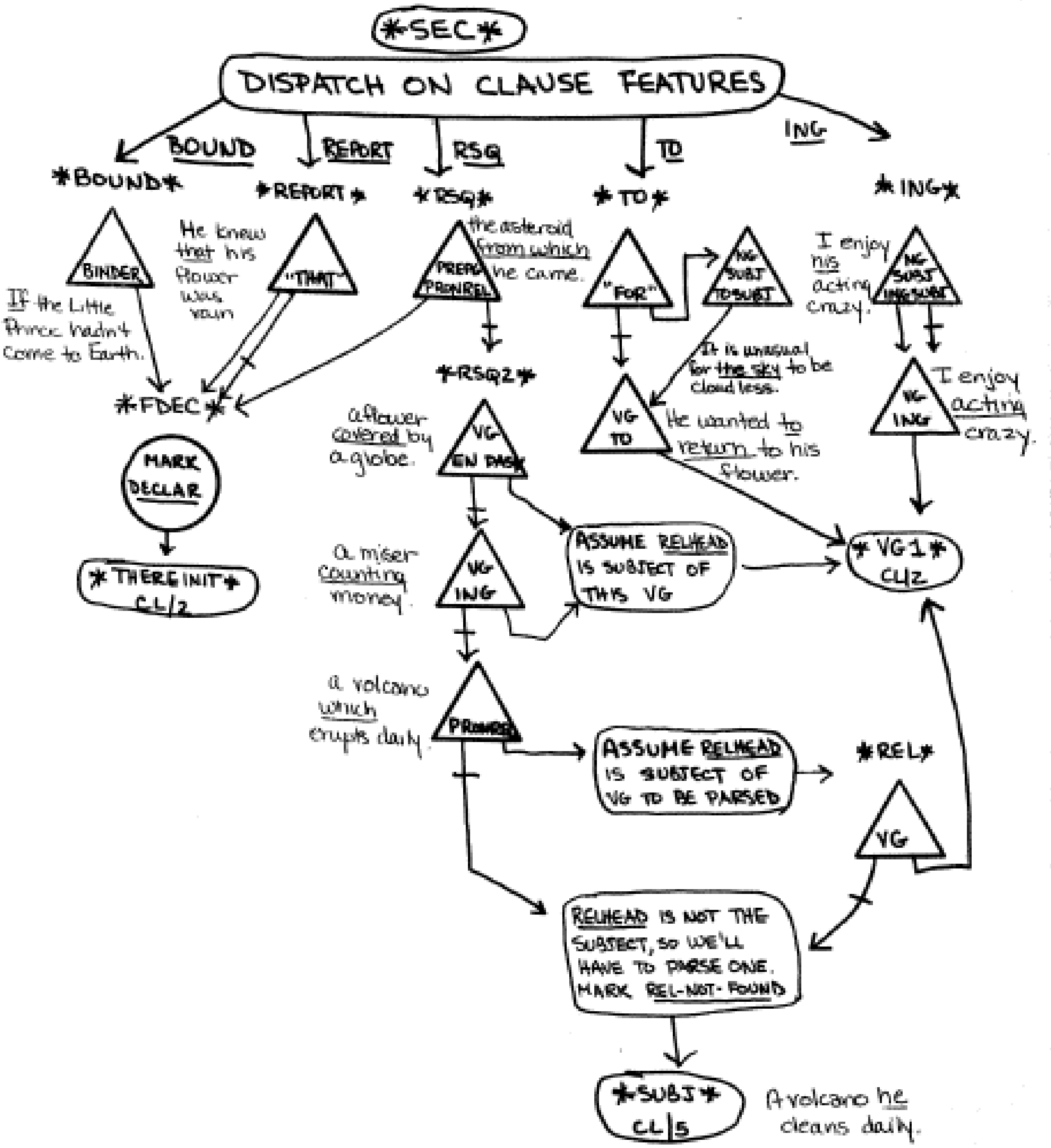
FIND CLAUSE TYPE (THIS IS THE BEGINNING- GOOD LUCK!)


ENTERING-CLAUSE
marked Secondary?
yes
SEC
FIND SECONDARY TYPE CL/3
no
INIT
CLAUSE BOUND INIT
If Gandalf had arrived, Frodo would have been safe.
MAJOR
CHECK PUNCTUATION
!
?
.
IMPER
PARSE PRE-VERBAL MODIFIERS CL/10
IMPE
VG IMPER
Set the Koala bear free!
QUEST
FIND QUESTION TYPE CL/4
THERE INIT
PARSE MAIN CONSTITUENTS CL/2
ONT
PASV?
yes
no
PREP AGENT
The doctor was visited by many patients.
SET LOGICAL-SUBJECT REG. TO OBJ.
ONT 1
CHECK SEMANTICS SO FAR
CHECK FOR UNATTACHED RELATIVE OR TIME QUESTION
ALTER STRUCTURE ACCORDINGLY
What did he cook it with?
What day does she see her shrink?
TONT
PARSE MODIFIERS (POST-CLAUSE) CL/10
RETSM
CHECK SEMANTICS AND RETURN

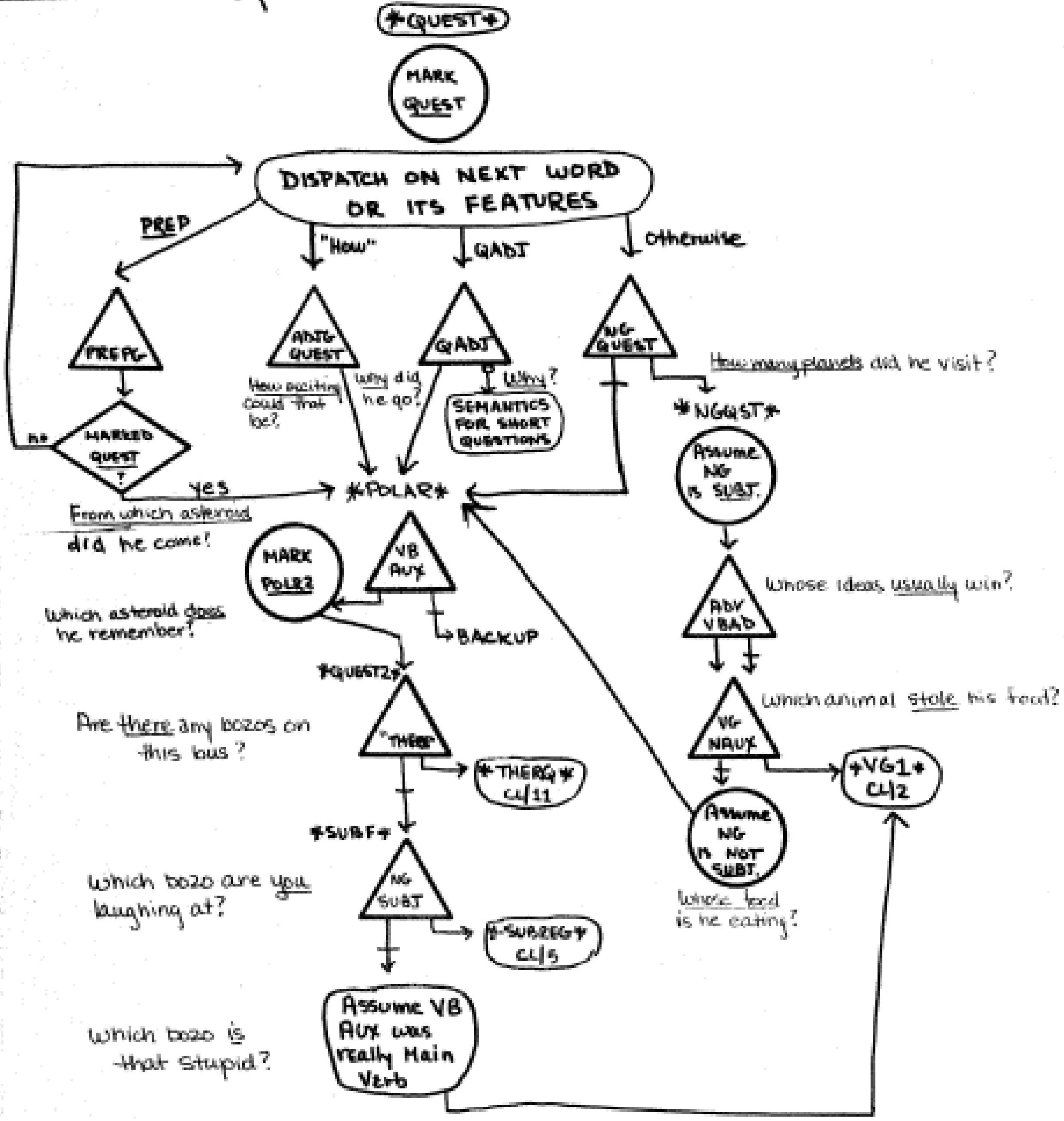
PARSE MAIN CONSTITUENTS



FIND SECONDARY TYPE

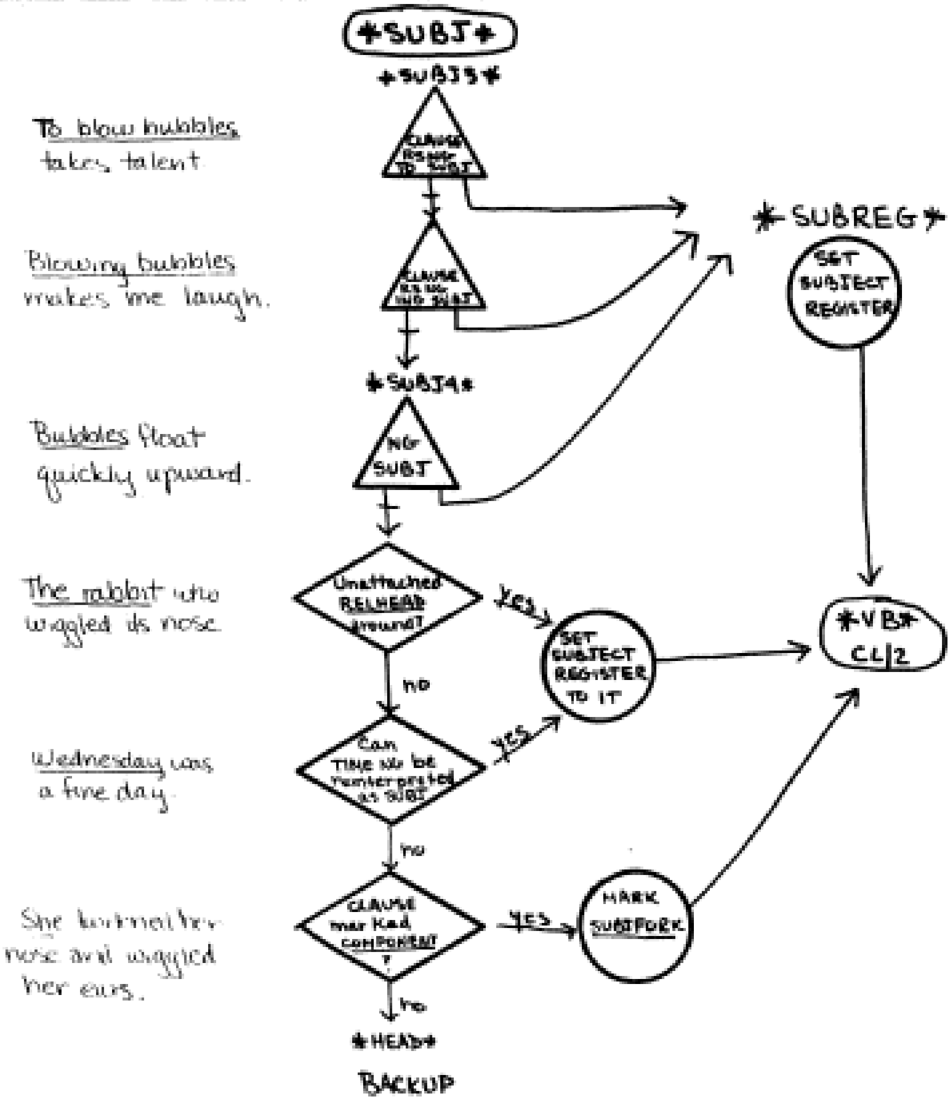

SEC
DISPATCH ON CLAUSE FEATURES
BOUND
REPORT
RSQ
TO
ING
BOUND
REPORT
RSQ
TO
ING
BINDER
If the Little Prince hadn't come to Earth.
He knew that his flower was vain
"THAT"
PREP PRONREL
the asteroid from which he came.
"FOR"
NG SUBJ TOSUBJ
I enjoy his acting crazy.
NG SUBJ INGSUBJ
It is unusual for the sky to be cloudless.
FDEC
RSQ2
VG TO
He wanted to return to his flower.
VG ING
I enjoy acting crazy.
MARK DECLAR
a flower covered by a globe.
VG EN PASV
THERE INIT CL/2
a miser counting money.
VG ING
ASSUME RELHEAD IS SUBJECT OF THIS VG
VG1 CL/2
a volcano which erupts daily.
PRONREL
ASSUME RELHEAD IS SUBJECT OF VG TO BE PARSED
REL
VG
RELHEAD IS NOT THE SUBJECT, SO WE'LL HAVE TO PARSE ONE. MARK REL-NOT-FOUND
SUBJ CL/5
A volcano he cleans daily.

FIND QUESTION TYPE

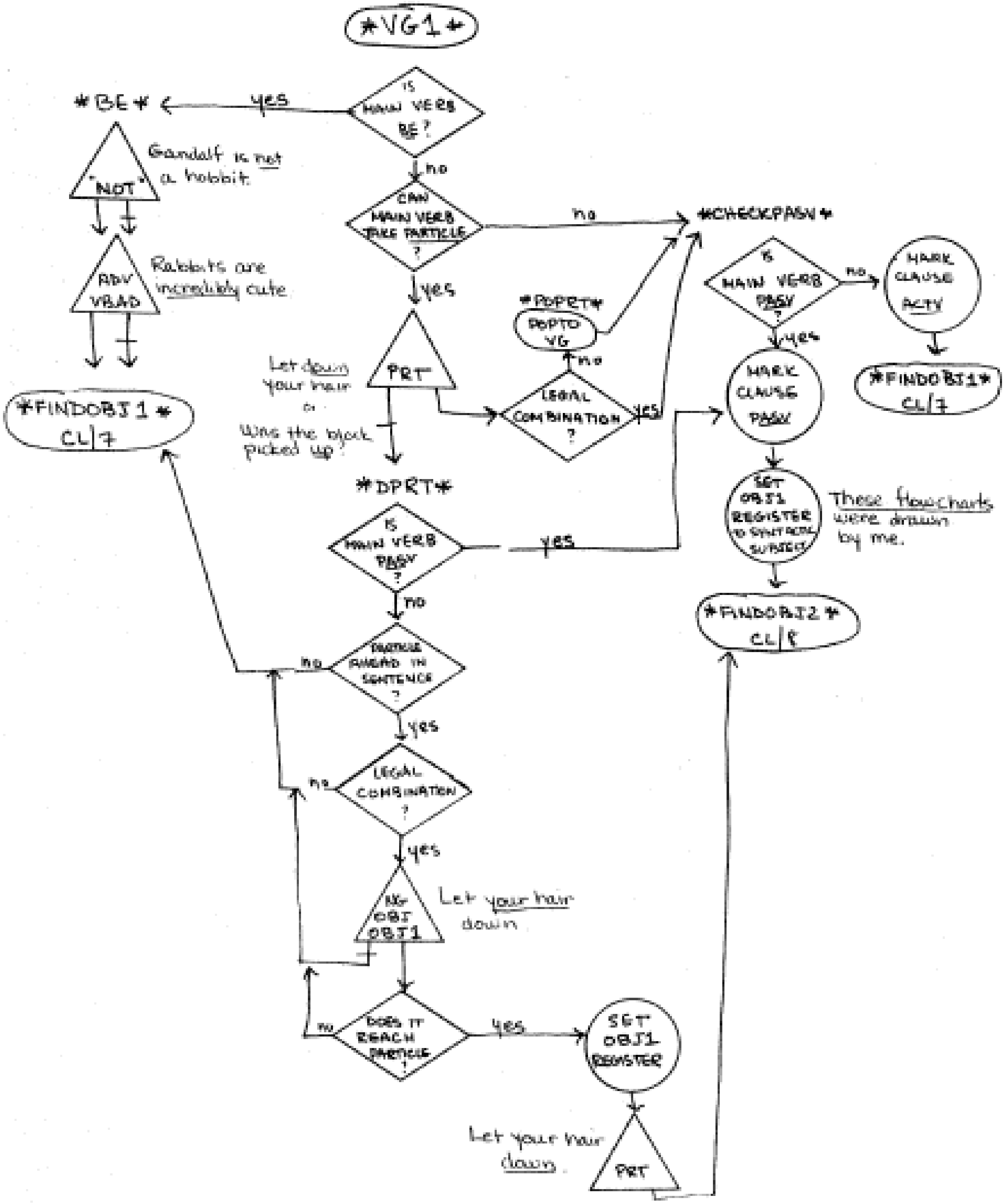

QUEST
MARK QUEST
DISPATCH ON NEXT WORD OR ITS FEATURES
PREP
"How"
QADJ
Otherwise
PREPG
ADJG QUEST
QADJ
NG QUEST
How many planets did he visit?
How exciting could that be?
Why did he go?
Why?
SEMANTICS FOR SHORT QUESTIONS
NGQST
NO
MARKED QUEST ?
yes
POLAR
From which asteroid did he come?
Assume NG is SUBJ.
MARK POLR2
VB AUX
Which asteroid does he remember?
BACKUP
Whose ideas usually win?
ADV VBAD
QUEST2
Which animal stole his food?
Are there any bozos on this bus?
"THERE"
VG NAUX
THERQ CL/11
VG1 CL/2
SUBF
Assume NG is NOT SUBJ.
Whose food is he eating?
Which bozo are you laughing at?
NG SUBJ
SUBREG CL/5
Assume VB AUX was really Main Verb
Which bozo is that stupid?

CL/5

FIND SUBJECT

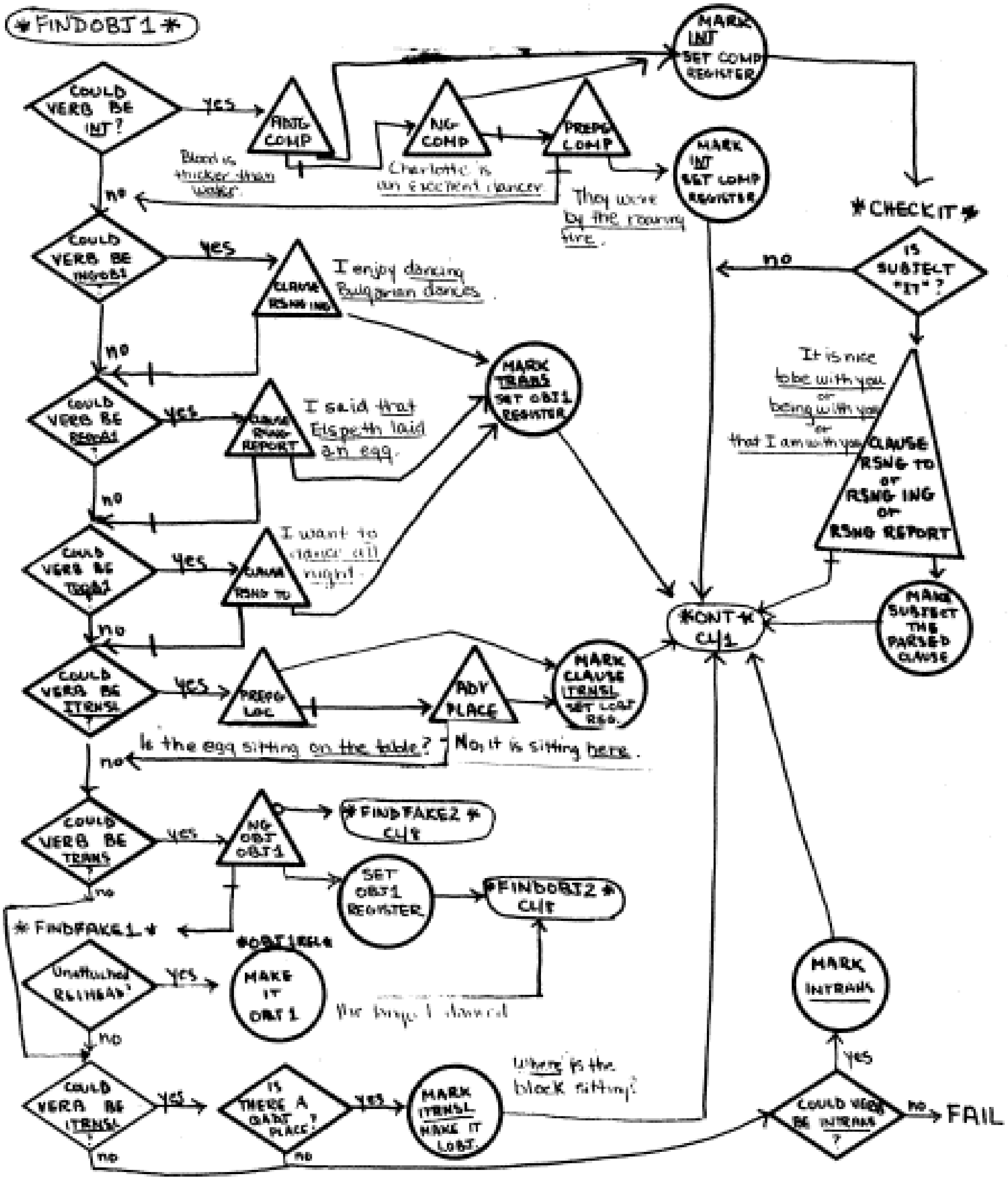

SUBJ
SUBJ3
To blow bubbles takes talent.
CLAUSE RSNG TO SUBJ
Blowing bubbles makes me laugh.
CLAUSE RSNG ING SUBJ
SUBJ4
Bubbles float quickly upward.
NG SUBJ
SUBREG
SET SUBJECT REGISTER
The rabbit who wiggled its nose
Unattached RELHEAD around?
YES
SET SUBJECT REGISTER TO IT
VB
CL/2
no
Wednesday was a fine day.
Can TIME NG be reinterpreted as SUBJ
YES
no
She twitched her nose and wiggled her ears.
CLAUSE marked COMPONENT ?
YES
MARK SUBJFORK
no
HEAD
BACKUP

CHECK VERB-PARTICLE COMBINATION

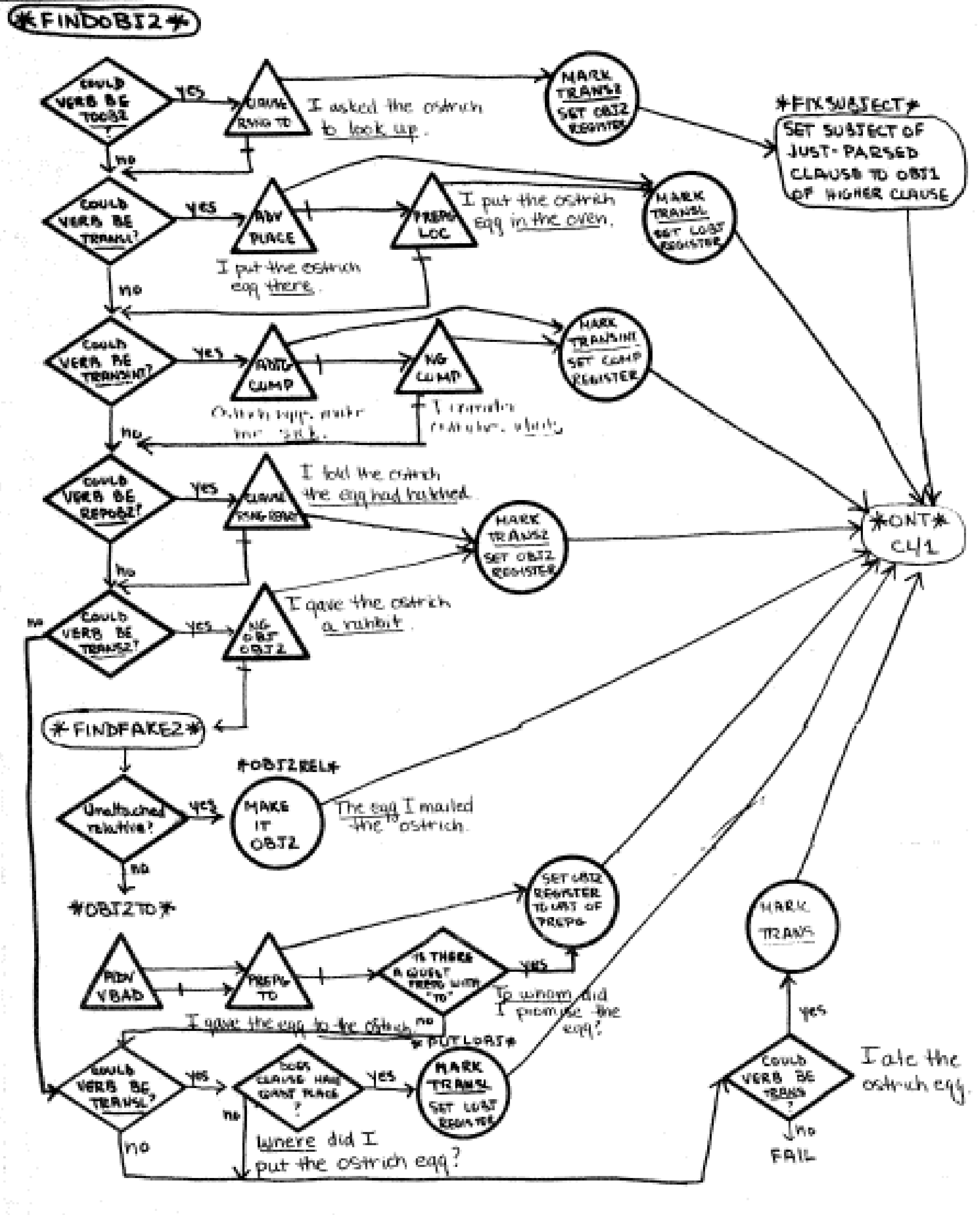


These flowcharts were drawn by me.

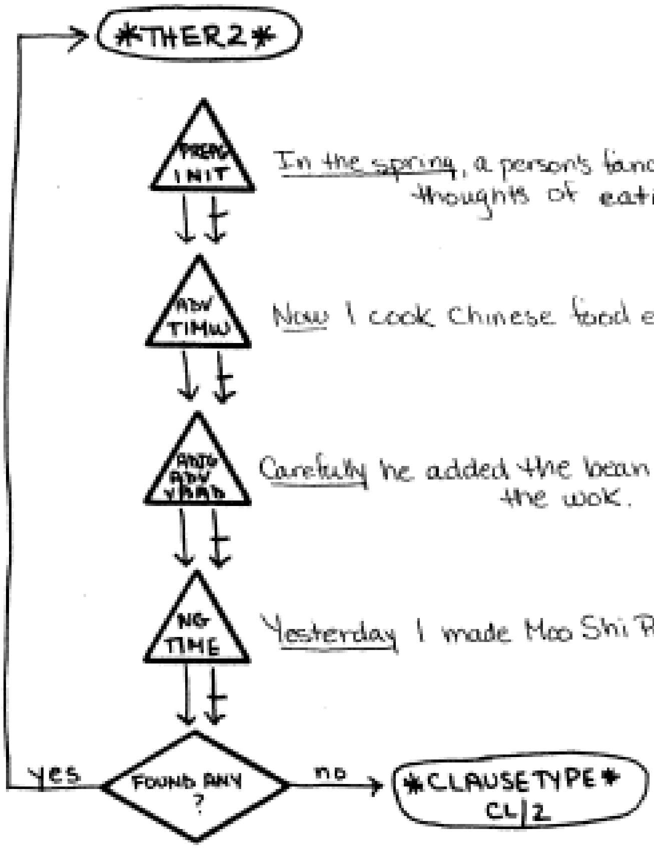
FIND FIRST OBJECT


FINDOBJ1
COULD VERB BE INT?
yes
ADJG COMP
Blood is thicker than water.
NG COMP
Charlotte is an excellent dancer.
PREPG COMP
They were by the roaring fire.
MARK INT SET COMP REGISTER
MARK INT SET COMP REGISTER
no
COULD VERB BE INGOBJ?
yes
CLAUSE RSNG ING
I enjoy dancing Bulgarian dances.
MARK TRANS SET OBJ1 REGISTER
no
COULD VERB BE REPOBJ?
yes
CLAUSE RSNG REPORT
I said that Elspeth laid an egg.
no
COULD VERB BE TOOBJ?
yes
CLAUSE RSNG TO
I want to dance all night.
no
COULD VERB BE ITRNSL?
yes
PREPG LOC
ADV PLACE
MARK CLAUSE ITRNSL SET LOBJ REG.
Is the egg sitting on the table? - No, it is sitting here.
no
COULD VERB BE TRANS?
yes
NG OBJ OBJ1
FINDFAKE2 CL/8
SET OBJ1 REGISTER
FINDOBJ2 CL/8
no
FINDFAKE1
Unattached RELHEAD?
yes
OBJ1REL
MAKE IT OBJ1
the boys I danced
no
COULD VERB BE ITRNSL?
yes
IS THERE A QADJ PLACE?
yes
MARK ITRNSL MAKE IT LOBJ.
Where is the block sitting?
no
no
CHECKIT
IS SUBJECT "IT"?
no
It is nice to be with you or being with you or that I am with you
CLAUSE RSNG TO or RSNG ING or RSNG REPORT
MAKE SUBJECT THE PARSED CLAUSE
CONT CL/1
COULD VERB BE INTRANS?
yes
MARK INTRANS
no
FAIL

FIND SECOND OBJECT


FINDOBJ2
COULD VERB BE TOOBJ2 ?
YES
CLAUSE RSNG TO
I asked the ostrich to look up.
NO
MARK TRANS2 SET OBJ2 REGISTER
FIXSUBJECT
SET SUBJECT OF JUST-PARSED CLAUSE TO OBJ1 OF HIGHER CLAUSE
COULD VERB BE TRANSL?
YES
ADV PLACE
I put the ostrich egg there.
PREPG LOC
I put the ostrich egg in the oven.
MARK TRANSL SET LOBJ REGISTER
NO
COULD VERB BE TRANSINT?
YES
ADJG COMP
Ostrich eggs make me sick.
NG COMP
I consider ostriches white.
MARK TRANSINT SET COMP REGISTER
NO
COULD VERB BE REPOBJ?
YES
CLAUSE RSNG REPORT
I told the ostrich the egg had hatched.
MARK TRANS2 SET OBJ2 REGISTER
NO
COULD VERB BE TRANS2?
YES
NG OBJ OBJ2
I gave the ostrich a rabbit.
NO
ONT CL1
FINDFAKE2
Unattached relative?
YES
OBJ2REL
MAKE IT OBJ2
The egg I mailed the to ostrich.
NO
OBJ2TO
ADV VBAD
PREPG TO
IS THERE A QUEST PREPG WITH "TO"
YES
SET OBJ2 REGISTER TO OBJ OF PREPG
To whom did I promise the egg?
I gave the egg to the ostrich.
NO
PUTLOBJ
COULD VERB BE TRANSL?
YES
DOES CLAUSE HAVE QUEST PLACE ?
YES
MARK TRANSL SET LOBJ REGISTER
NO
Where did I put the ostrich egg?
NO
COULD VERB BE TRANS ?
YES
MARK TRANS
I ate the ostrich egg.
NO
FAIL

PARSE MODIFIERS (PRE-SUBJECT)



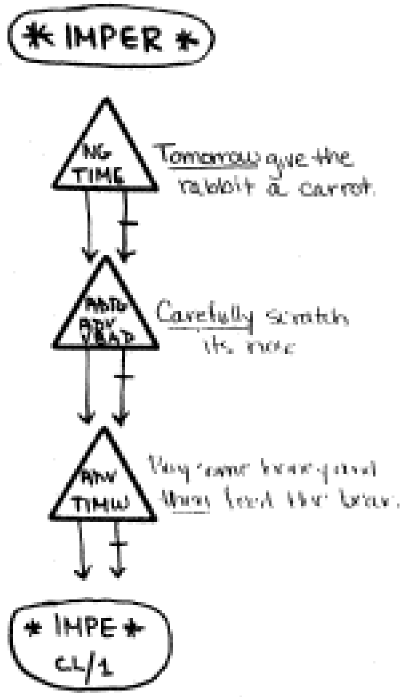
In the spring, a person's fancy turns to thoughts of eating.

Now I cook Chinese food every spring.

Carefully he added the bean sprouts to the wok.

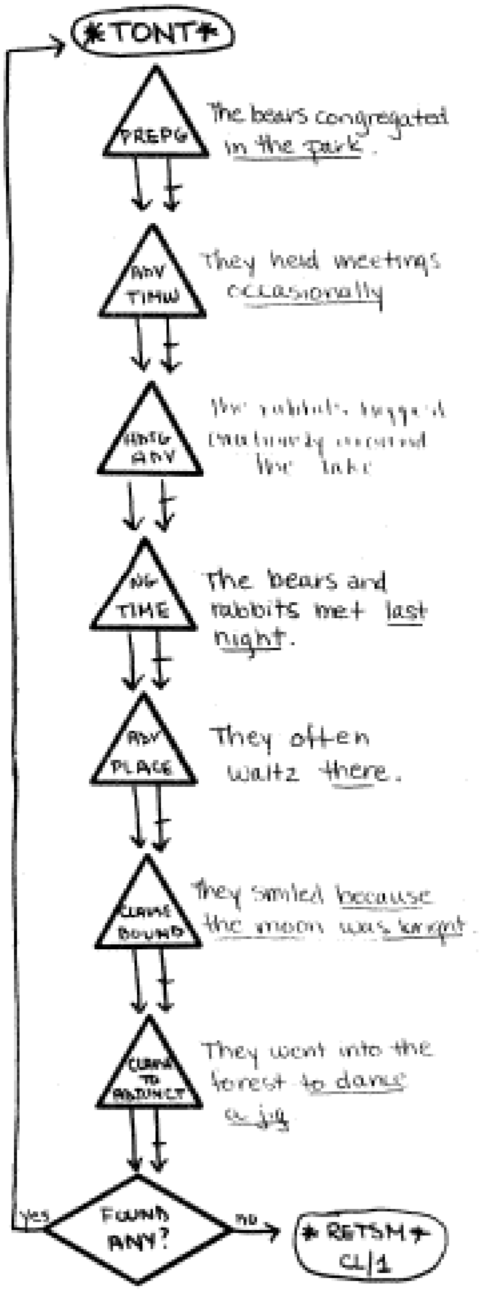
Yesterday I made Moo Shi Pork.

PARSE PRE-VERBAL MODIFIERS


IMPER
NG TIME
Tomorrow give the rabbit a carrot.
ADVG ADV VBAD
Carefully scratch its nose
ADV TIMW
they came home and then feed the bear.
* IMPE *
CL/1

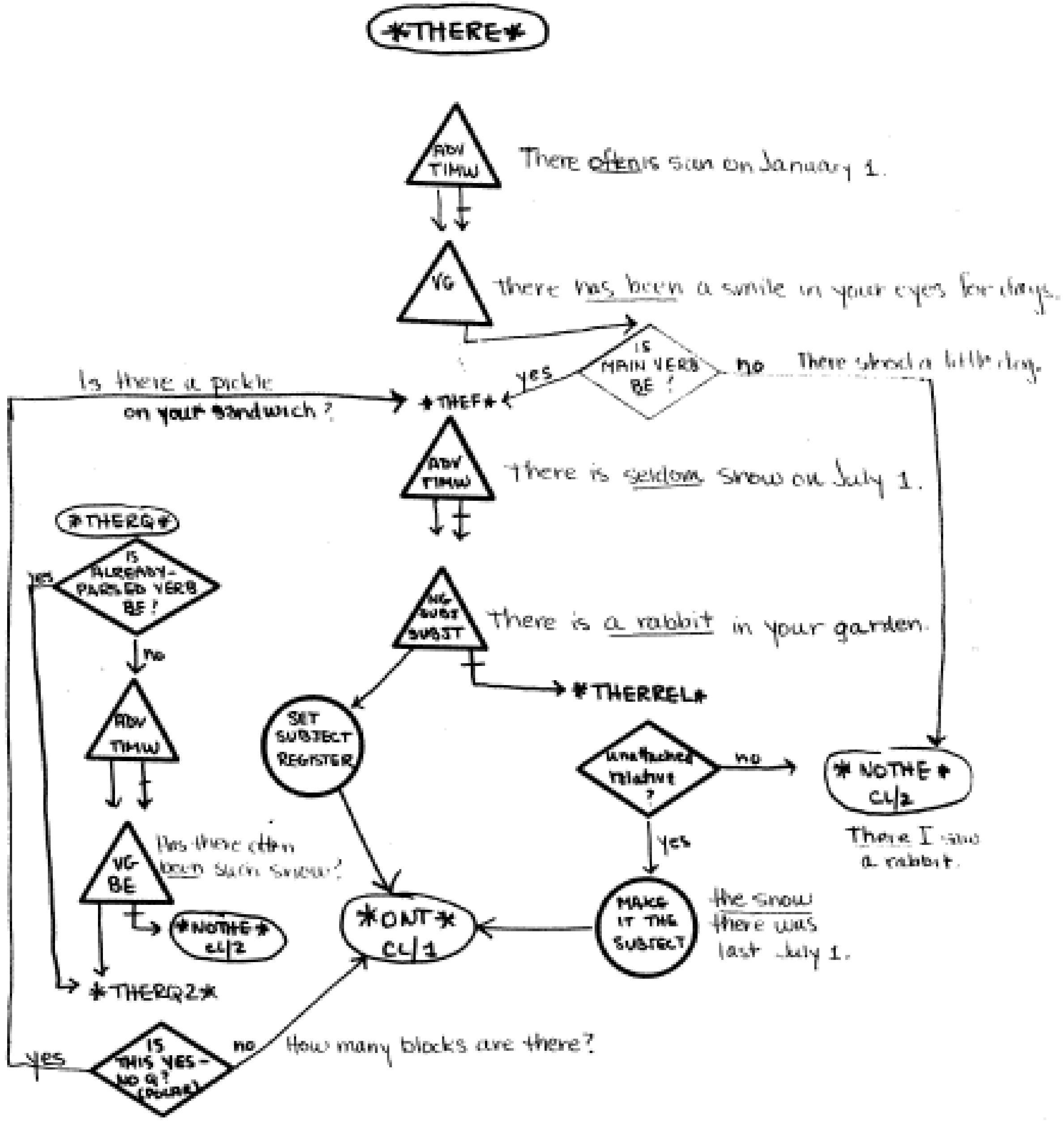
PARSE MODIFIERS (POST-CLAUSE)

C4/10

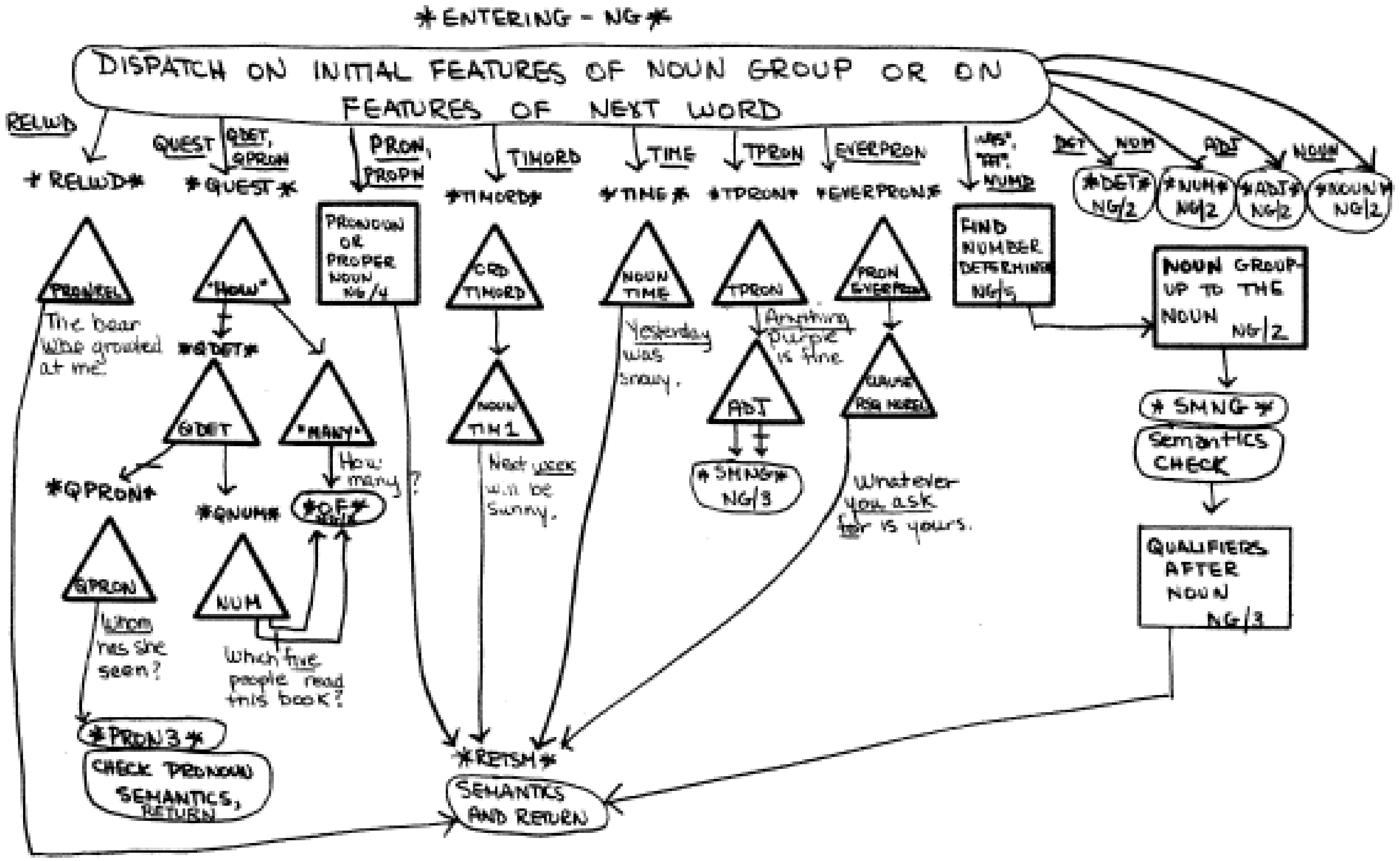

TONT
PREPG
The bears congregated in the park.
ADV TIMW
They held meetings occasionally
ADVG ADV
the rabbits hopped cautiously around the lake
NG TIME
The bears and rabbits met last night.
ADV PLACE
They often waltz there.
CLAUSE BOUND
they smiled because the moon was bright.
CLAUSE TO ADJUNCT
They went into the forest to dance a jig
FOUND ANY?
YES
NO
* RETSM *
CL/1

CL/11

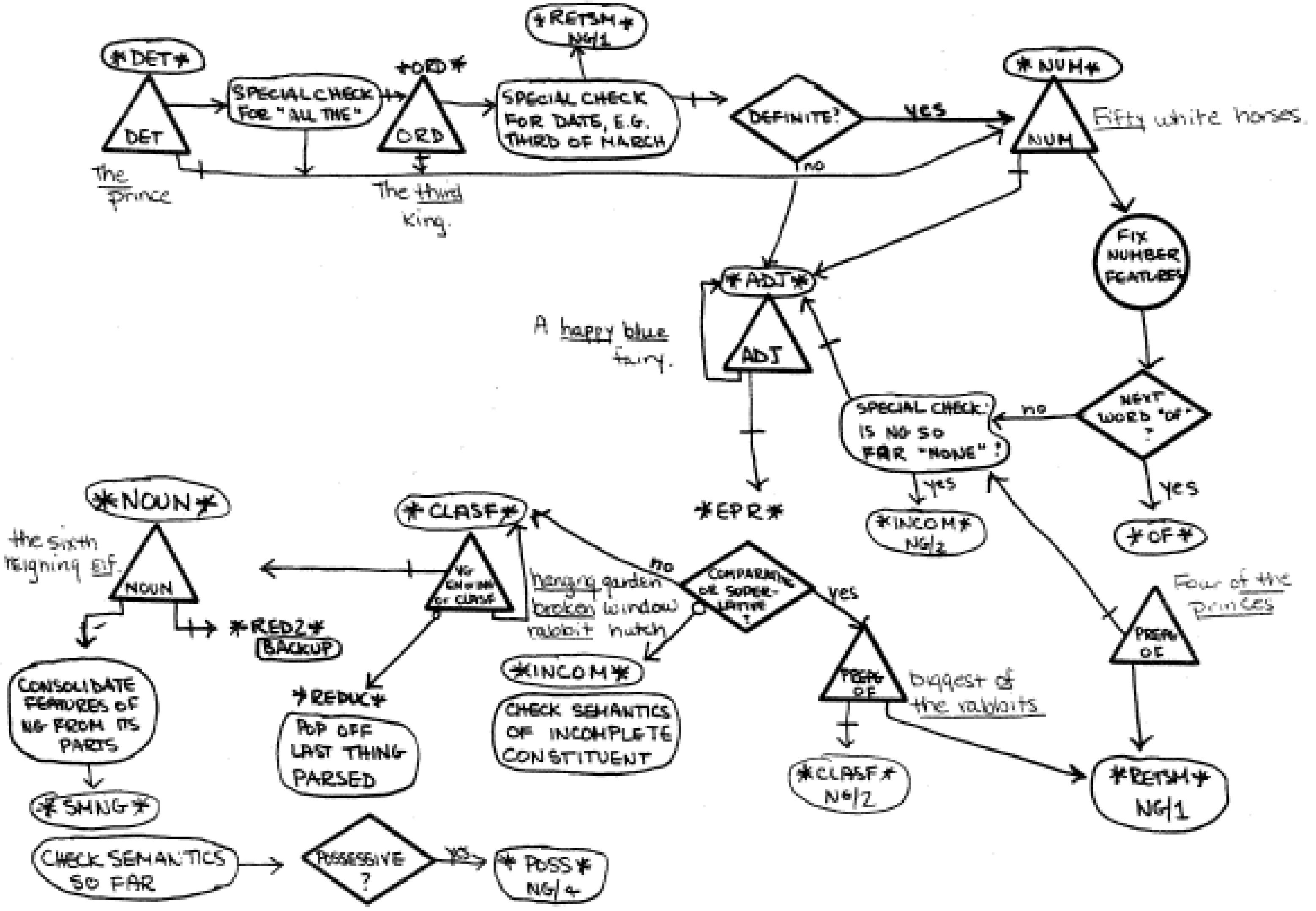
PARSE THERE CONSTITUENTS


THERE
ADV TIMW
There often is seen on January 1.
VG
there has been a smile in your eyes for days.
IS MAIN VERB BE ?
yes
no
There stood a little dog.
Is there a pickle on your sandwich ?
THEF
ADV TIMW
There is seldom snow on July 1.
THERQ
IS ALREADY-PARSED VERB BE ?
yes
no
ADV TIMW
VG BE
Has there often been seen snow?
NOTHE CL/2
THERQ2
IS THIS YES-NO Q ? (POLAR)
yes
no
How many blocks are there?
NG SUBJ SUBJT
There is a rabbit in your garden.
THERREL
SET SUBJECT REGISTER
unattached relative ?
no
yes
NOTHE CL/2
There I saw a rabbit.
MAKE IT THE SUBJECT
the snow there was last July 1.
ONT CL/1

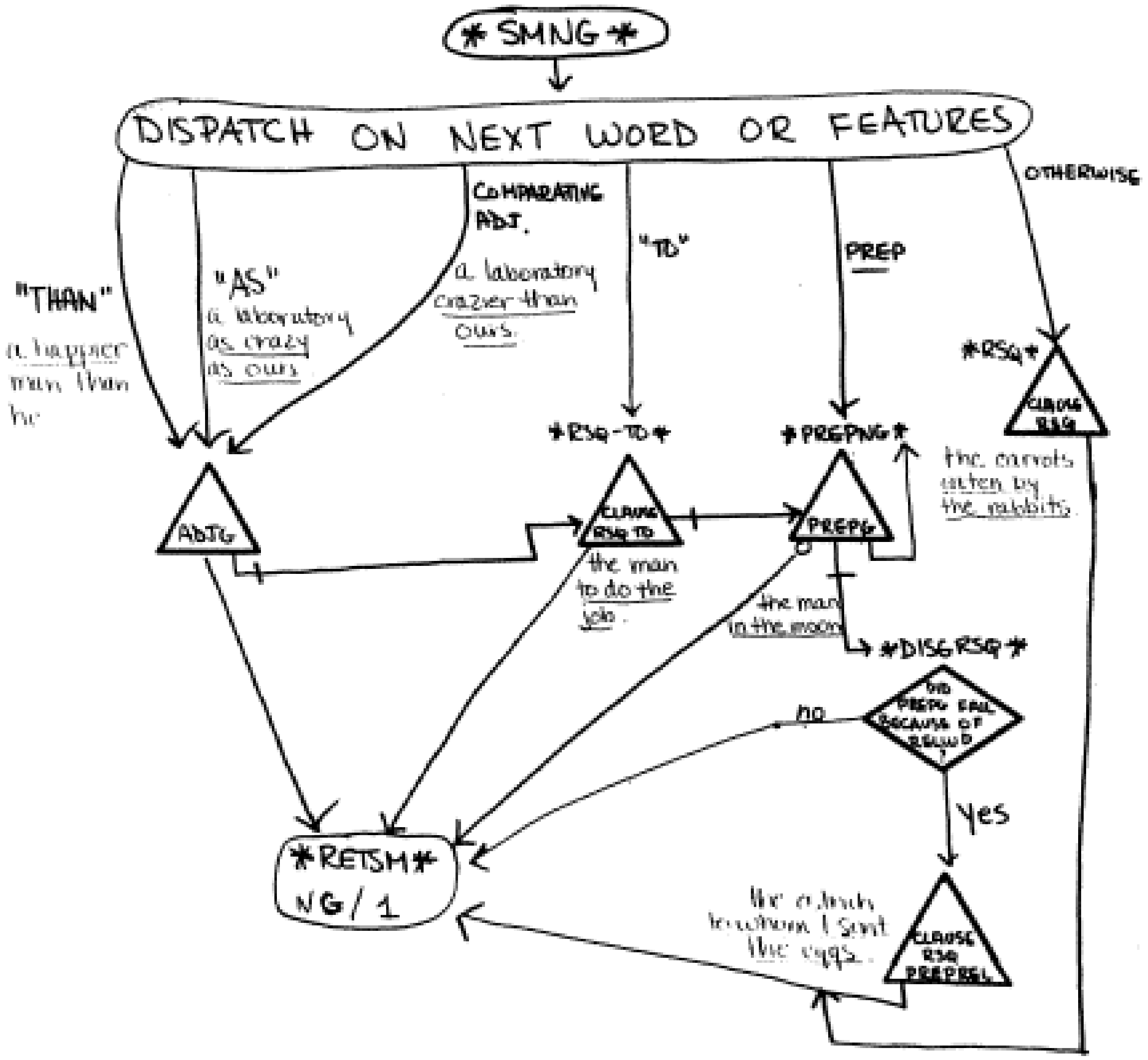
START TO PARSE A NOUN GROUP



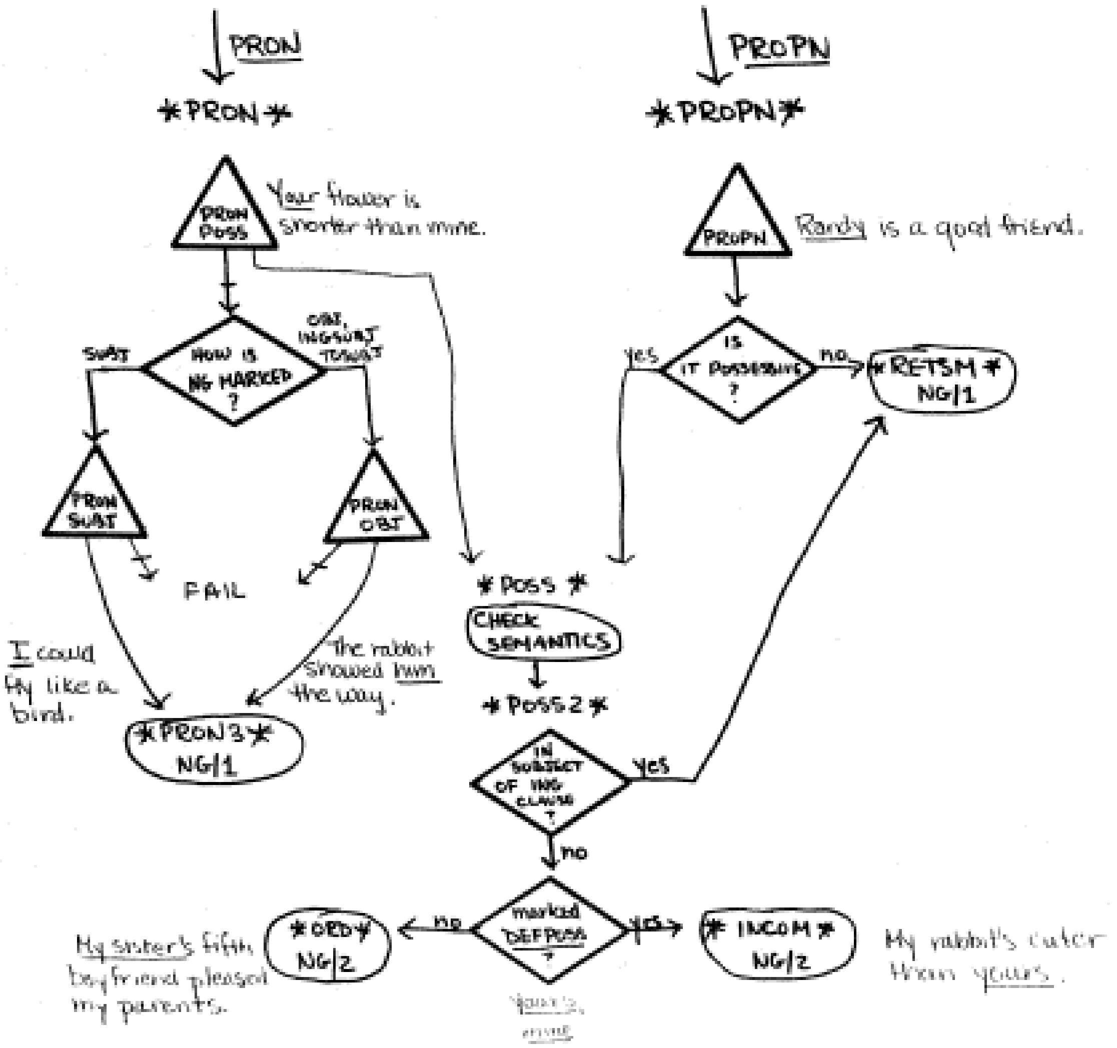
NOUN GROUP - UP TO THE NOUN



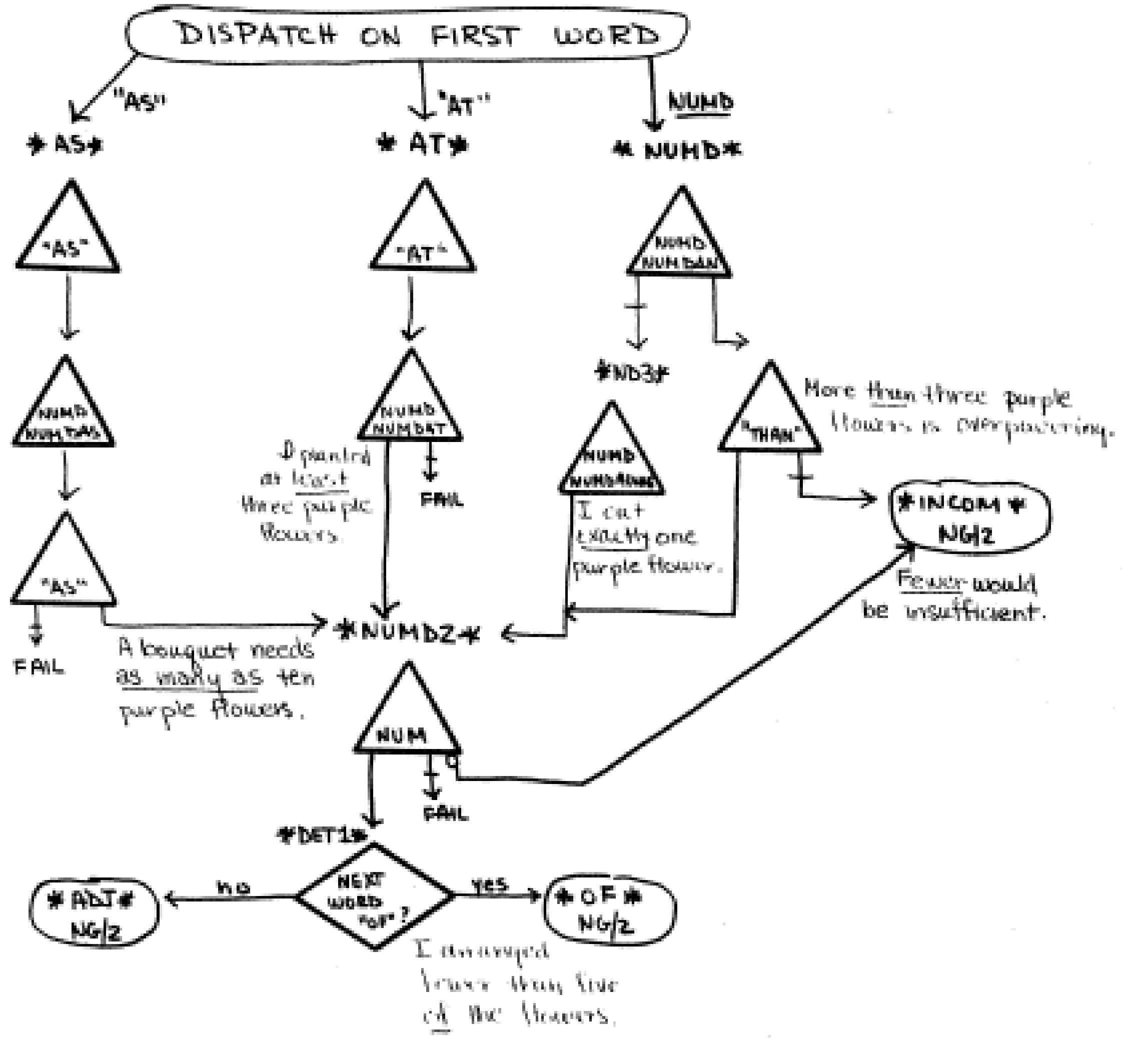
QUALIFIERS AFTER NOUN



PRONOUN OR PROPER NOUN



FIND NUMERICAL DETERMINER



More than three purple flowers is overpowering.

I planted at least three purple flowers.

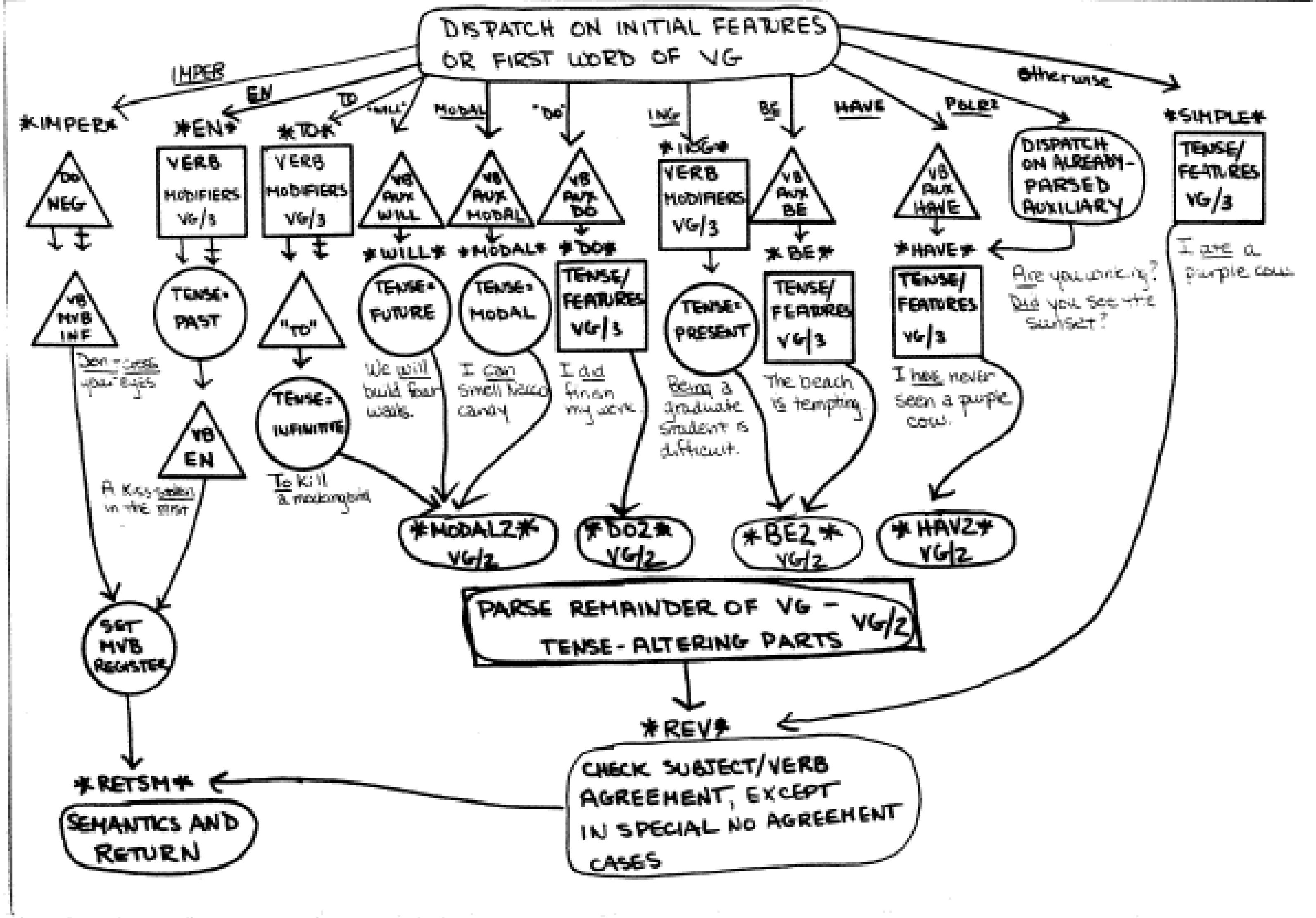
I cut exactly one purple flower.

Fewer would be insufficient.

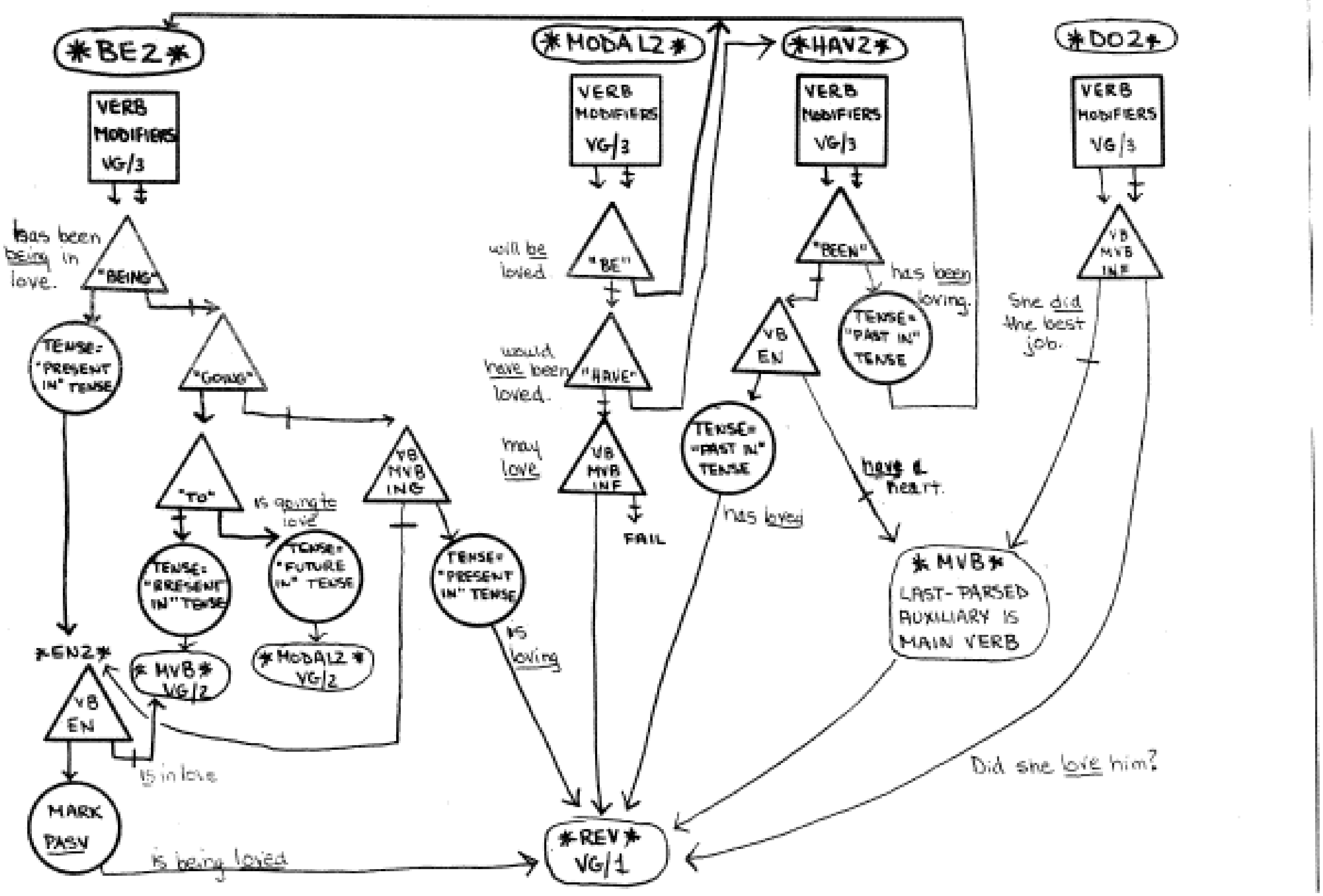
A bouquet needs as many as ten purple flowers.

I arranged fewer than five of the flowers.

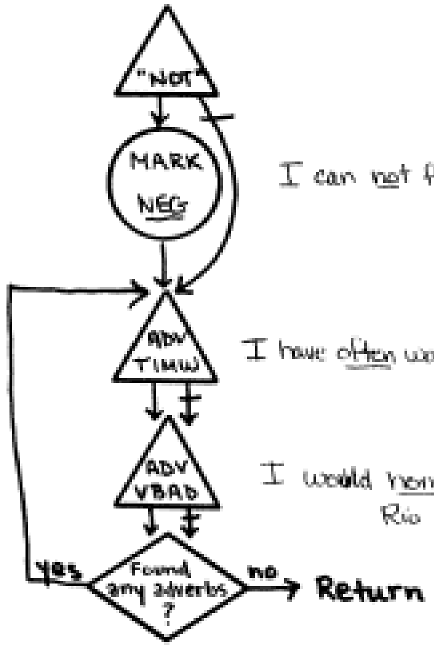
START A VERB GROUP - NUMBER-CARRYING PART



PARSE REMAINDER OF VG - TENSE-ALTERING PARTS



VERB MODIFIERS

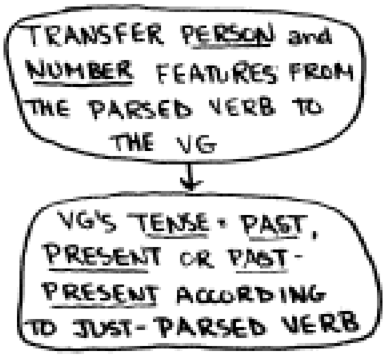


I can not fly to Rio today.

I have often walked down this street before.

I would honestly like to fly to Rio tomorrow

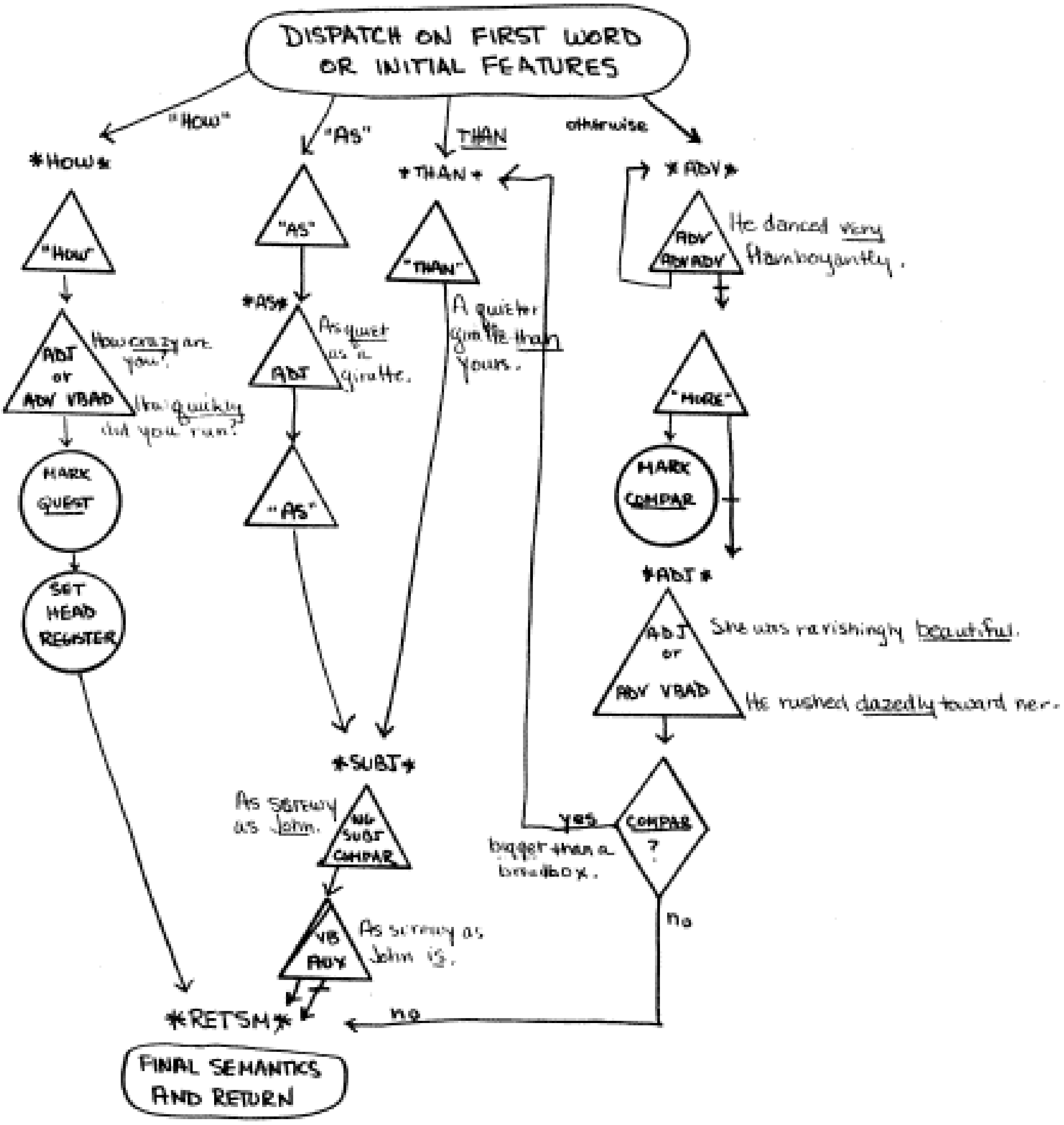
TENSE / FEATURES


TRANSFER PERSON and NUMBER FEATURES FROM THE PARSED VERB TO THE VG
VG'S TENSE = PAST, PRESENT OR PAST-PRESENT ACCORDING TO JUST-PARSED VERB

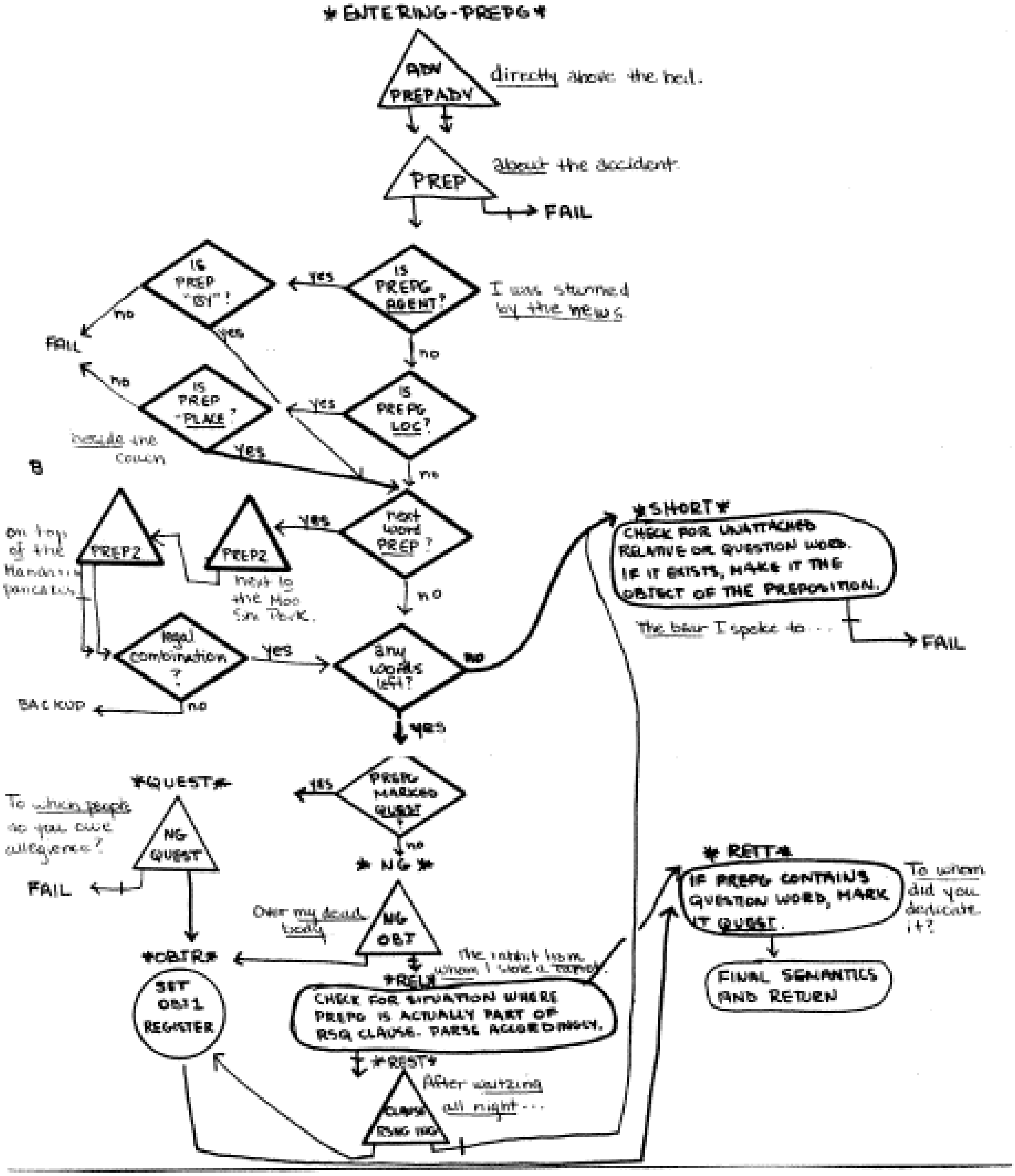
am : VFS
are = VPL

smiled = PAST
love : PRESENT
hit = PAST-PRESENT

PARSE ADJECTIVE GROUP



PARSE PREPOSITION GROUP


ENTERING-PREPG
ADV
PREPADV
directly above the bed.
PREP
about the accident
FAIL
IS
PREPG
AGENT?
I was stunned
by the news.
yes
IS
PREP
"BY"?
no
FAIL
yes
no
IS
PREPG
LOC?
yes
IS
PREP
"PLACE"?
no
beside the
couch
yes
B
no
next
word
PREP?
yes
PREP2
PREP2
on top
of the
Mandarin
pancakes
next to
the Hoo
Sin Park.
no
legal
combination
?
yes
BACKUP
no
any
words
left?
no
SHORT
CHECK FOR UNATTACHED
RELATIVE OR QUESTION WORD.
IF IT EXISTS, MAKE IT THE
OBJECT OF THE PREPOSITION.
The bear I spoke to . . .
FAIL
yes
PREPG
MARKED
QUEST
yes
QUEST
To which people
do you owe
allegiance?
NG
QUEST
FAIL
no
NG
Over my dead
body
NG
OBJ
OBJR
SET
OBJ1
REGISTER
the rabbit from
whom I stole a carrot.
RELX
CHECK FOR SITUATION WHERE
PREPG IS ACTUALLY PART OF
RSQ CLAUSE. PARSE ACCORDINGLY.
REST
After waltzing
all night . . .
CLAUSE
RSNG ING
RETT
IF PREPG CONTAINS
QUESTION WORD, MARK
IT QUEST.
To whom
did you
dedicate
it?
FINAL SEMANTICS
AND RETURN