CS224N/Ling 237 Homework #1 Solutions

Due Monday, 14 April 2003, 5pm

26 points total

A.

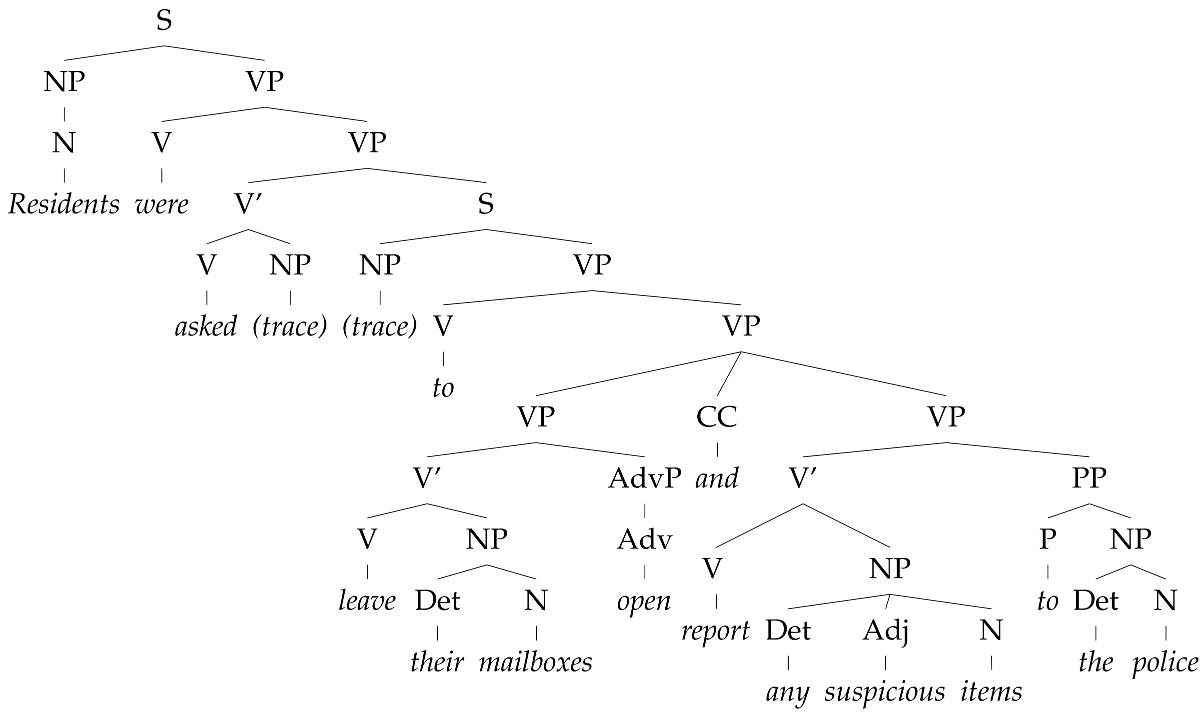
1. Provide a phrase structure tree representation for these sentences, and briefly justify or discuss controversial points. Particularly important is that you should place nodes over the groups of words that are constituents, but you should also give suitable labels for those constituents, as discussed in M&S, chapter 3, or in section. (However, there isn't a unique right answer: we'll accept things that are reasonable.)

   (a) Residents were asked to leave their mailboxes open and report any suspicious items to the police.

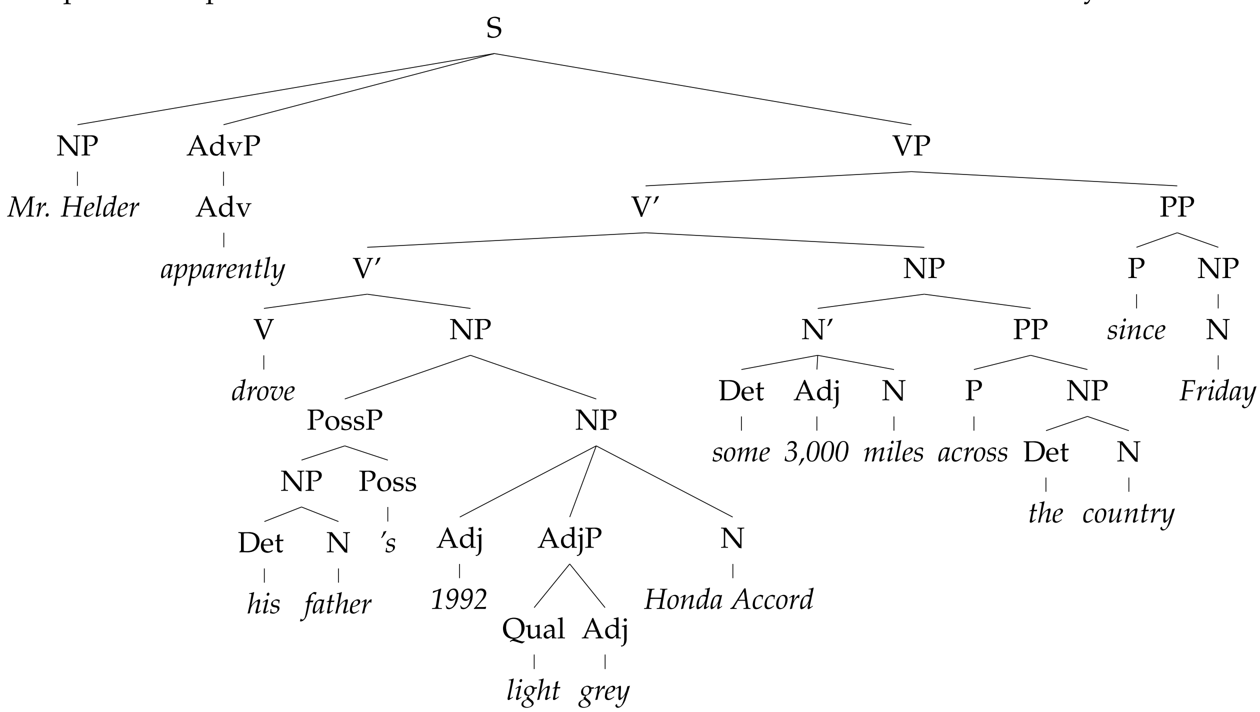
   (b) Mr. Helder apparently drove his father's 1992 light gray Honda Accord some 3,000 miles across the country since Friday.

   Answer: [2 pts]

   (a) For this sentence, some of the tricky points were the traces of the NP ”residents” – as well as serving as the subject of the sentence, this phrase is also the object of ”asked” and the subject of the verb phrase beginning ”to leave”. The word ”open” was also difficult, as it seems to belong more with the verb ”leave” than to modify ”mailbox”.



(b) The tricky part of this sentence was how to group the modifiers. The important thing was to ensure that constituents were grouped together. For this sentence, the following items are clearly constituents: ″light grey″, ″Honda Accord″, ″1992 light grey Honda Accord″. Some controversial points may be where to attach ″apparently″, as it could be seems to modify the entire sentence, and how to group ″3,000 miles across the country″. The possessive phrase ″his father′s″ could also have been treated in a number of ways.



2. PP attachment ambiguity question. You are given the following grammar.

```
NP -> Det N
NP --> NP PP
PP --> P NP
N --> {sandwich, pickle, boy, table}
Det --> {the, a}
P --> {with, for, on}
```

(a) How many parses do the following phrases have? You should probably do the first couple yourself; for the later ones, you'll probably want to look at C.2, below to find the answer automatically.

i. the sandwich on the table
ii. the sandwich on the table with a pickle
iii. the sandwich on the table with a pickle as a condiment
iv. the sandwich on the table with a pickle as a condiment on the side

The sequence of numbers that one gets in this way are the Catalan numbers. You can find out more about them on the web.[1]

Answer: [2 pts] We have the following:

i. Only one possible parse (the sandwich (on (the table)))
ii. Two possible parses:
(the sandwich (on (the table (with (the pickle)))))
(((the sandwich (on (the table))) (with (the pickle)))

iii. Five possible parses (nouns shortened for simplicity):
((the s) (on (((the t) (with (the p))) (as (a c))))
((the s) (on ((the t) (with ((the p) (as (a c)))))
(((the s) (on (the t))) (with ((the p) (as (a c)))))
(((the s) (on ((the t) (with (the p))))) (as (a c)))
((((the s) (on (the t))) (with (the p))) (as (a c)))

iv. Forteen possible parses (not shown)

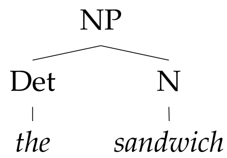
(b) Suppose a top-down parser tried to parse the phrase:

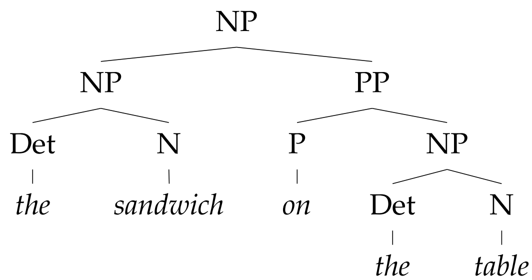
the sandwich on the table with a pickle as a condiment

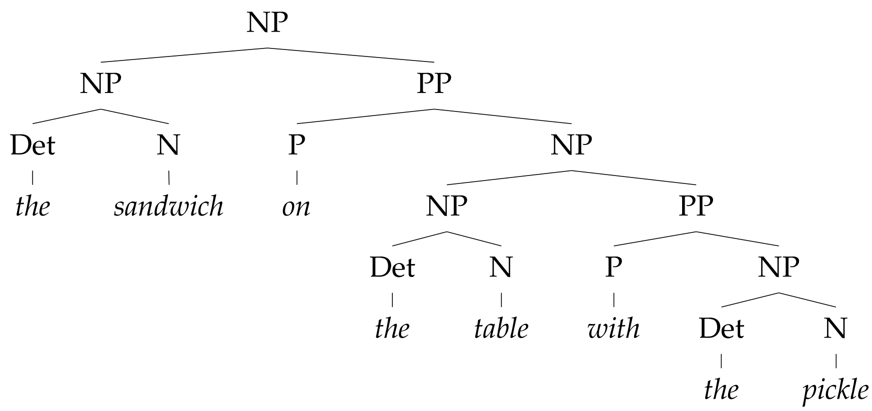
with the above grammar. Where more than one rule appears for an expansion, our parser attempts them in top-to-bottom order. Assume that the parser can predict or match found words perfectly (that is, do not consider parses generating different words from those in the string). Our top-down grammar would attempt parses for this NP that do not consume all of the input before arriving at a complete parse. Draw the first three partial parses that the parser would consider.

Answer:[1 pt]

[1] Oops! That's another way to learn the answer to this question.

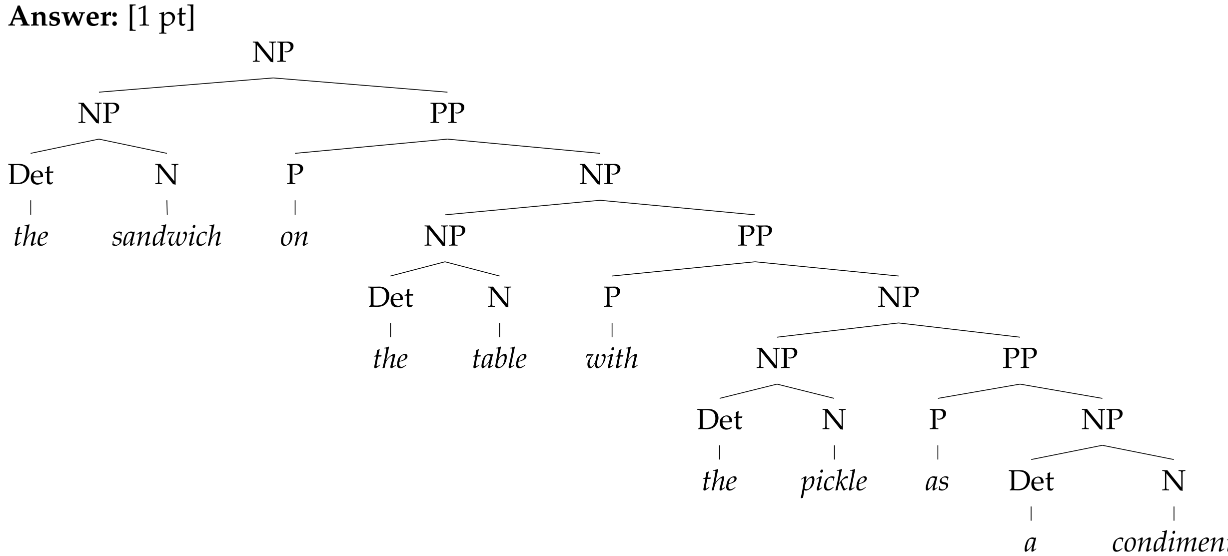
i.


ii.


iii.


(c) Which complete parse would our parser come up with first?

Answer: [1 pt]



B.

Let's use a very simple grammar (where S is the start symbol, and terminals are shown in italic)

S	→	NP VP	N	→	*cats*
VP	→	V	N	→	*claws*
VP	→	V NP	N	→	*people*
NP	→	NP RelCl	Comp	→	*that*
NP	→	N	V	→	*scratch*
RelCl	→	Comp V	V	→	*bite*

Simple (non-tabular) parsing strategies, or in particular, recognizers, can be implemented using a state representation where there is a list (stack or queue) for elements being processed and another for the input sentence. We will assume that sort of representation for the questions here, so a state can be represented on one line. Since drawing search trees as trees can get rather difficult with such representations, we can use two devices:

- We can draw the tree as an indented list, where the indentation of the lines shows the depth of the tree. (This is an especially natural way to think of things when used with depth-first search, since then the order of lines down the page corresponds to the order in which things are done depth first, but it can equally represent any other navigation of a search tree: it's just a tree on its side.)
- We can assume an 'oracle' which at any point chooses only the move (or moves) that leads to a successful parse of the sentence. This allows us to abbreviate things by leaving out all the dead ends. If a sentence only has one parse, or we are only showing one parse, we can also omit the indentation. This corresponds to showing the succession of states down one branch of the search tree – we're ignoring search control, and just showing the moves that we're interested in.

Important notation: We use uppercase latin for nonterminals, lowercase latin for terminals, and greek letters for possibly empty sequences of categories (terminal or nonterminal) – except for α which is either a single category or the empty string, and X which can be either a nonterminal or a terminal. We use a bar over categories or sequences of categories that are predicted versus categories that have been found.

Here is a method for LR (bottom-up shift-reduce) parsing, where we want to parse a string as a particular category. Note that it assumes that the right hand end of a list of symbols counts as the top of the stack. One starts with the initialization in Begin, and then one can do any of the other moves any number of times in any order. Parsing is successful if the sequence of moves ends with a state that fullfills the Halt criterion. Combining these moves with a search algorithm would give an LR parser.

Begin Place the predicted start symbol on top of the stack (i.e., with a bar over it)

- (Shift) Put the next input symbol on top of the stack
- (Reduce) If γ is on top of the stack and $A \to \gamma$, replace γ by A.
- (Reduce attach) If $\overline{A}\gamma$ is on top of the stack and $A \to \gamma$, remove $\overline{A}\gamma$

Halt Halt with success if the stack is empty and there is no more input

For instance, here is a successful parse of *cats scratch people*:

Stack	Input	Operation
$\overline{S}$	*cats scratch people*	Begin
$\overline{S}$ *cats*	*scratch people*	Shift
$\overline{S}$ N	*scratch people*	Reduce
$\overline{S}$ NP	*scratch people*	Reduce
$\overline{S}$ NP *scratch*	*people*	Shift
$\overline{S}$ NP V	*people*	Reduce
$\overline{S}$ NP V *people*		Shift
$\overline{S}$ NP V N		Reduce
$\overline{S}$ NP V NP		Reduce
$\overline{S}$ NP VP		Reduce
		Reduce attach
		Halt

1. [Warm-up question!] Suppose we didn't have a start symbol, we just wanted to know if there is *some* category from which the whole string can be generated. This makes some linguistic sense. Sometimes a 'sentence' in a newspaper (or the Stanford Bulletin) is just a noun phrase, and people commonly respond to questions (like *When will you get around to the asssignment?* with fragments such as PPs (*During next week.*). How would one modify [hint: simplify!] the above parser specification for this case?

   Answer: [1 pt] Begin: start with the processing list empty
   Delete the "Reduce attach" operator Halt with success if the stack contains a single nonterminal category, and there is no more input

2. Top-down parsing.

   (a) Give a similar specific set of operations that implement a top-down, left-to-right (LL) parser. (Hint: you will want to predict a lot more categories than in the above example!)

   (b) Trace the successful parse move sequence for the sentence *cats scratch people* using the grammar above. Assume that we are literally doing top-down parsing right to the level of guessing words.

   (c) Suppose we added one or more rules that rewrote things as empty to the grammar. (In particular, you might consider the rule NP → e, and parsing the sentence *cats bite*.) Does your top-down parser need modification to handle this case correctly? If so, how? If not, say briefly why not?

   Answer: This time we interpret the left hand end of the processing stack as the top (we invert directionality just to make things more human readable: so that symbol sequences appear on the stack in the same order as in English sentence structures).

   (a) [2 pt]

   Begin Place the predicted start symbol on top of the stack (i.e., with a bar over it)

   - (Expand) If $\overline{A}$ is on top of the stack and $A \to \gamma$, replace $\overline{A}$ by $\overline{\gamma}$ (in reverse order, depending on how you view your stack operations).
   - (Pop) If $\overline{x}$ is on top of the stack and x is the next input symbol, remove both $\overline{x}$ and x.

- (Halt) Halt with success if the stack is empty and there is no more input

(b) [1 pt] Example parse (top of the stack is to the left):

Stack	Input	Operation
$\overline{S}$	*cats scratch people*	Begin
$\overline{NP}\,\overline{VP}$	*cats scratch people*	Expand
$\overline{cats}\,\overline{VP}$	*cats scratch people*	Expand
$\overline{VP}$	*scratch people*	Pop
$\overline{V}\,\overline{NP}$	*scratch people*	Expand
$\overline{scratch}\,\overline{NP}$	*scratch people*	Expand
$\overline{NP}$	*people*	Pop
$\overline{people}$	*people*	Expand
		Pop
		Halt

An alternative way to do things would be to replace the Pop operation here with a Shift operation, as above, and an attach operation (If $X\overline{X}$ is on top of the stack, remove both). As a final remark, of course, in practice we would certainly never want to be explicitly guessing the expansions of preterminals top-down like this!

(c) [1 pt] A parser like the above will handle a grammar with empties perfectly well. A nonterminal is changed into an empty sequence of predictions, which are instantly satisfied, and it will the go on parsing any remaining goals (or else could terminate if the processing stack is empty).

3. We noted that top-down parsers have a problem with left-recursive rules. For example, they will have problems with the NP → NP RelCl rule in the grammar above. Joe Genius notes that this problem has a ready solution for this grammar. He rejigs his top-down parser to expand rules from right-to-left, rather than left-to-right.

   (a) Does this fix the problem for this grammar? Show the search tree of a top-down recognizer on the sentence *cats scratch people that bite*. This time, we do want the whole search tree, not just the successful path, but you can use the indented list notation. However, to make things less painful, assume that the input is represented as the part of speech sequence N V N Comp V, rather than the actual words, so as to avoid the final top-down prediction of terminals.

   (b) Since Joe is a genius, he knows that this isn't a full solution to the problem, because his new parser will have problems with right recursive rules like S → AdvP S. (For instance, we might suggest such a rule to parse *[Most of the time] I go to class*.) However, he comes up with the following ingenious idea. For each grammar rule, if it is left recursive, he will expand its categories from right-to-left, otherwise, he will expand it from left-to-right, as previously. (Carrying this idea through necessitates a number of further complexities involving maintaining a stack of parts of the sentence that one has parsed, but we'll leave the details to Joe to work out.) Is this a full solution to the problem of edge-recursion? If not, what kinds of grammar rules will still cause problems for Joe's parser? Give a realistic example of a place in English grammar where this problem turns up.

(c) We presented the problem with top-down parsing in terms of a problem handling left-recursive rules of the form $X \rightarrow X\ \gamma$. But the problem is actually a bit more general than that. What is the more general statement of when a top-down parser runs into trouble?

Answers:

(a) [2 pt]

Stack	Input	Operation
$\overline{S}$	*cats scratch people that bite*	Begin
$\overline{NP}\,\overline{VP}$	*cats scratch people that bite*	Expand
$\overline{NP}\,\overline{V}$	*cats scratch people that bite*	Expand
$\overline{NP}$	*cats scratch people that*	Pop
$\overline{N}$	*cats scratch people that*	Expand
Fail		
$\overline{NP}\,\overline{RelCl}$	*cats scratch people that*	Expand
$\overline{NP}\,\overline{Comp}\,\overline{V}$	*cats scratch people that*	Expand
Fail		
$\overline{NP}\,\overline{V}\,\overline{NP}$	*cats scratch people that bite*	Expand
$\overline{NP}\,\overline{V}\,\overline{NP}\,\overline{RelCl}$	*cats scratch people that bite*	Expand
$\overline{NP}\,\overline{V}\,\overline{NP}\,\overline{Comp}\,\overline{V}$	*cats scratch people that bite*	Expand
$\overline{NP}\,\overline{V}\,\overline{NP}\,\overline{Comp}$	*cats scratch people that*	Pop
$\overline{NP}\,\overline{V}\,\overline{NP}$	*cats scratch people*	Pop
$\overline{NP}\,\overline{V}\,\overline{NP}\,\overline{RelCl}$	*cats scratch people*	Expand
$\overline{NP}\,\overline{V}\,\overline{N}$	*cats scratch people*	Expand
$\overline{NP}\,\overline{V}$	*cats scratch*	Pop
$\overline{NP}$	*cats*	Pop
$\overline{NP}\,\overline{RelCl}$	*cats*	Expand
$\overline{NP}\,\overline{Comp}\,\overline{V}$	*cats*	Expand
Fail		
$\overline{N}$	*cats*	Expand
		Pop
Halt		
$\overline{NP}\,\overline{V}\,\overline{N}$	*cats scratch people that bite*	Expand
Fail		

Yes, it fixes the problem! (Infinite search paths are avoided, since the non-left-recursive part has to be found each time first.)

(b) [1 pt] No, it'd not work for rules that are simultaneously left and right recursive. A clear realistic case of this is coordination: NP $\rightarrow$ NP Conj NP. One would need to say something slightly cleverer to deal with the case of cycles below, too.

(c) [1 pt] In general, the top-down parser gets into problems whenever there is a cycle of categories that can be repeated without popping any words. For instance, with left-to-right expansion, a two step cycle like the rules below gives exactly the same problem. (Where these rules are designed to parse NP's like *the boy 's father 's job* – we're separating the *'s* off because it behaves like a *phrasal clitic* in (conversational) English – cf. *the person I talked to yesterday's approach was to move through the material more slowly*.)

NP	$\rightarrow$	Det N	Det	$\rightarrow$	NP *'s*
			Det	$\rightarrow$	the

4. Here are the corresponding moves for a left-corner parser. This time we have to regard the left end of any lists as the top of the stack. (It's common to need to change this convention, so that we can use grammar rules to match sequences in different orders without having to reverse them, which makes them hard to read.)

Begin Place the predicted start symbol on the stack.

- (Shift) Put the next input symbol on top of the stack
- (Pop) If $\overline{a}$ is on top of the stack, and a is the next input symbol, remove both.
- (Leftcorner attach) If $X\overline{A}$ is on top of the stack and $A \rightarrow X\gamma$, replace $X\overline{A}$ by $\overline{\gamma}$
- (Leftcorner) If X is on top of the stack and $A \rightarrow X\gamma$, replace X by $\overline{\gamma}A$

Halt Halt with success if the stack is empty and there is no more input

The idea of a left-corner parser is it mixes top-down and bottom-up processing: it both works predictively down from a goal, and up from an identified left-corner of a phrase.

(a) Trace the moves of one successful parse of the sentence *cats scratch people that bite* using the grammar at the beginning.

(b) Through the "Leftcorner attach" operation, this parser does what is sometimes referred to as "composition". Namely, if it has found a Det, and the goal is an $\overline{NP}$, and there is a rule NP $\rightarrow$ Det Adj N, then it will in one step remove the Det and the $\overline{NP}$ goal, and put goals of an $\overline{Adj}$ and $\overline{N}$ on the stack. A completed NP never actually appears on the stack. Change the above parser so that it doesn't do composition. That is, the "Left-corner attach" operation would be removed, and the completed NP would be placed on the stack using the existing Leftcorner operation. Modify the parser as needed so as to still have a sound and complete parser.

Answers:

(a) [1 pt] The parse:

Stack	Input	Operation
$\overline{S}$	*cats scratch people that bite*	Begin
$cats\,\overline{S}$	*scratch people that bite*	Shift
$N\ \overline{S}$	*scratch people that bite*	Leftcorner
$NP\ \overline{S}$	*scratch people that bite*	Leftcorner
$\overline{VP}$	*scratch people that bite*	Leftcorner Attach
$scratch\ \overline{VP}$	*people that bite*	Shift
$V\ \overline{VP}$	*people that bite*	Leftcorner
$\overline{NP}$	*people that bite*	Leftcorner Attach
$people\ \overline{NP}$	*that bite*	Shift
$N\ \overline{NP}$	*that bite*	Leftcorner
$NP\ \overline{NP}$	*that bite*	Leftcorner
$\overline{RelCl}$	*that bite*	Leftcorner Attach
$that\ \overline{RelCl}$	*bite*	Shift
$Comp\ \overline{RelCl}$	*bite*	Leftcorner
$\overline{V}$	*bite*	Leftcorner Attach
$bite\ \overline{V}$		Shift
		Leftcorner Attach
		Halt

Note that at the end of this parse you cannot change $\overline{V}$ to $\overline{bite}$ and then execute the (Pop) operation, and you cannot reduce $bite$ to V and then take the sequence $V\overline{V}$ off the stack. Neither of these is correct; $\overline{V}$ cannot go to $\overline{bite}$ because (Leftcorner attach) requires a non-empty category X before $\overline{A}$ on top of the stack, and $V\overline{V}$ can't come off the stack because (Pop) as defined can operate only on terminals. In fact, the only time that (Pop) would ever be used in this parser is if there were a production of the form $X->\ \ \beta\ \ a\,\gamma$ for non-empty β or γ–that is, if there were a rule whose RHS included both a terminal and some other content.

(b) [2 pt] Delete the "Leftcorner attach" operation, and add an Attach operation:

   (Attach) If $X\overline{X}$ is on top of the stack, remove both.

   If you changed X to α in either of the parsers, then you would allow the leftcorner parser to handle empties, but it could also then proceed to parse like a topdown parser.

5. All of the methods we have looked at above can be regarded as instances of "Generalized Left Corner Parsing" (A. J. Demers, Generalized left corner parsing, *Proceedings of the Fourth Annual ACM Symposium on Principles of Programming Languages*, pp. 170–181, 1977). Here's the algorithm:

Begin Place the predicted start symbol on the stack (i.e., with a bar over it).

- (Shift) Put the next input symbol on top of the stack
- (LeftPart) If β is on top of the stack and condition Φ holds and $A \rightarrow \beta\gamma$, replace β by $\overline{\gamma}A$
- (Attach) If $X\overline{X}$ is on top of the stack, remove both.

Halt Halt with success if the stack is empty and there is no more input

All of top-down (LL), bottom-up (LR), and left-corner (LC) parsing can be realized by the above algorithm, by appropriately defining the condition Φ (which might depend on β, γ, etc.). Define what Φ should be to give each of these strategies.

Answers:

- [1 pt] Top-down: β is empty. If you want any efficiency at all, you should also specify that $\overline{A}$ is on top of the stack, but one could just rely on Attach to check that downstream.
- [1 pt] Bottom-up: γ is empty.
- [1 pt] Leftcorner: β consists of a single category, or $\beta\gamma$ is empty (to allow our parser to deal with empty rewrite rules).

Essentially, for top-down, we can hypothesize expansions freely, without having seen any found components yet. In bottom-up, we may only act on or record completely found categories, and we cannot postulate sought categories along the way from partial evidence. For left-corner, we must act either immediately or after seeing the first element of an expansion. Many people said that the above rules with no condition Φ gives left-corner, but left-corner is *not* generalized left-corner. Nor does left-corner allow you to do *either* top-down *or* bottom-up, as a few people said; in left-corner parsing you always consume exactly *one* category when hypothesizing a mother.

There were ways to make the rules for Φ more complex than this, but it's important to remember that we have Attach to do cleanup for our matching sought and found categories.

C. (Practical)

1. One way to explore the Penn treebank is with the program tgrep. This only runs on SUN machines (elaine, myth, epic, saga). It requires the following setup:

   ```
   setenv TGREP_CORPUS /afs/ir/data/linguistic-data/Treebank/tgrepabl/wsj_mrg.crp
   setenv PATH /afs/ir/data/linguistic-data/bin/sun4x_57:$PATH
   setenv MANPATH /afs/ir/data/linguistic-data/man:$MANPATH
   ```

   or if you don't have a defined MANPATH, just:

   ```
   setenv MANPATH /afs/ir/data/linguistic-data/man:
   ```

   You can then give queries like `tgrep 'VP < (NP . NP)'` to find ditransitive verb phrases in the Penn treebank. See `man tgrepdoc` for information on the syntax of tgrep patterns. Patterns almost always have to be quoted so that they are not misinterpreted by the shell.

   (a) Use a tgrep query to find three adjectives that take an SBAR complement in the WSJ Penn Treebank (the basic tag for adjectives is JJ, and complex adjective constructions appear in adjectival phrases labeled ADJP. Give the query and the adjectives (there are more than 3 in total; but listing 3 is sufficient).

   (b) Which adjective is the (unique) one that occurs commonly with SBAR complements in the Penn treebank?

   (c) In English prepositional phrases normally follow the noun phrase object, giving a structure like:

   [[NP She] [VP opened [NP the door] [PP with a crowbar]]]

   whereas the reverse sounds somewhat weird:

[[NP She] [VP opened [PP with a crowbar] [NP the door]]]

However, in many circumstances, this ordering can be reversed. This is referred to in the linguistics literature as *Heavy NP Shift* (since one of the reasons for it is the 'heaviness' of the NP, though there are also other causes such as the informational content of the sentence). Find an instance of Heavy NP Shift in the Penn Treebank. Give the instance, and the tgrep query you used to find it.

Answers:[3 pts]

(a) There were many adjectives that you could have listed here. One tgrep command to find the adjectives was "tgrep 'ADJP < (JJ $ SBAR)'". Some adjectives were "angry", "sure", and "afraid".

(b) The one adjective that showed up repeatedly with an SBAR complement was "sure".

(c) Use the query "tgrep 'VP < (PP $. NP)"' - if you look at the sentences produced, it should be clear that such a shift seems to occur when the NP is relatively long (or "heavy").

2. We've put in /afs/ir/class/cs224n/parser a context-free grammar chart parser. It was actually written for probabilistic parsing and so has a couple of hold-overs from that (which I should really clean up!): rules and lexical entries have to have scores specified, even if one is just using it as a nonprobabilistic parser, and it doesn't handle empty nodes. But we can live with these limitations. You can invoke it as follows:

```
cd /afs/ir/class/cs224n/parser
./parse simple-test.grammar simple-test.lexicon s simple-test.sentences
```

The parse file is just a simple shell script that invokes a Java parser. For files in your own directory you can invoke it as:

/afs/ir/class/cs224n/parser/parse *arguments*

The parser takes four arguments: a grammar file, a lexicon file, the start category for parsing, and a file of sentences to parse, one per line. The format of the grammar and lexicon is:

```
# lines beginning with a hash are ignored
cat -> cat+ %% score
# A rule may not have an empty righthand side.
# It must have a score, even if this is going to be
# ignored later.  This can be any number -- e.g., always 1.0
```

Write a grammar and lexicon that can parse the two sentences and all the noun phrases in part A with this parser, and include the grammar and lexicon in your homework. The grammar and lexicon only have to cover the words and constructions in this sentence, but they should use "sensible" rules reflecting reasonably the nature of English grammar. E.g., you should *not* submit a finite state grammar that generates those words. (Given the limitation mentioned above, the grammar can't have empty categories, and so you need to remove those from any rules where one might be tempted to postulate them.)

Answers:[2 pts] The grammars varied depending on how the sentences in Q1 were parsed. We were looking for linguistically plausible rules and a reasonable parse of the sentence. (You did not have to make the grammar unambiguous!)