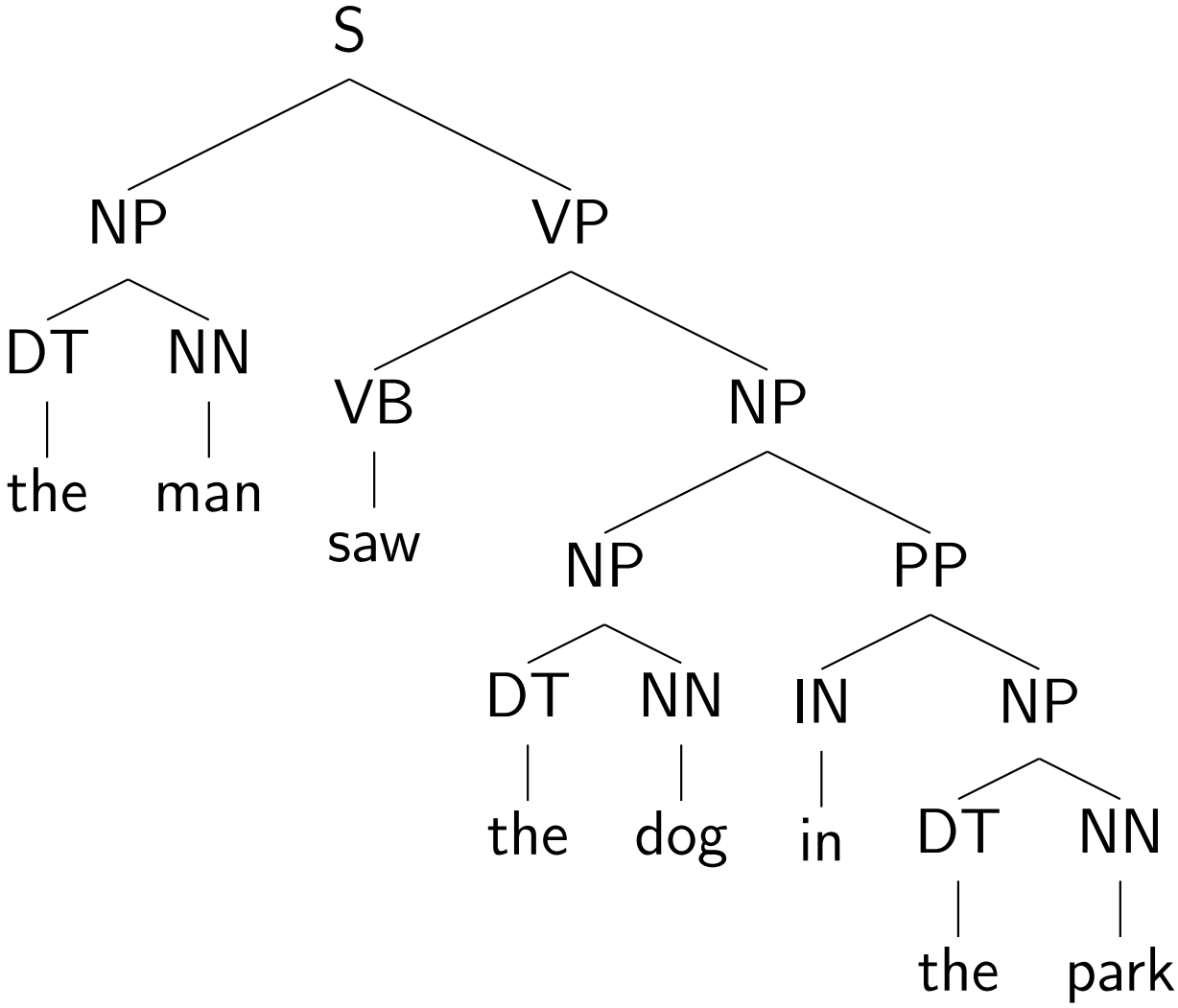
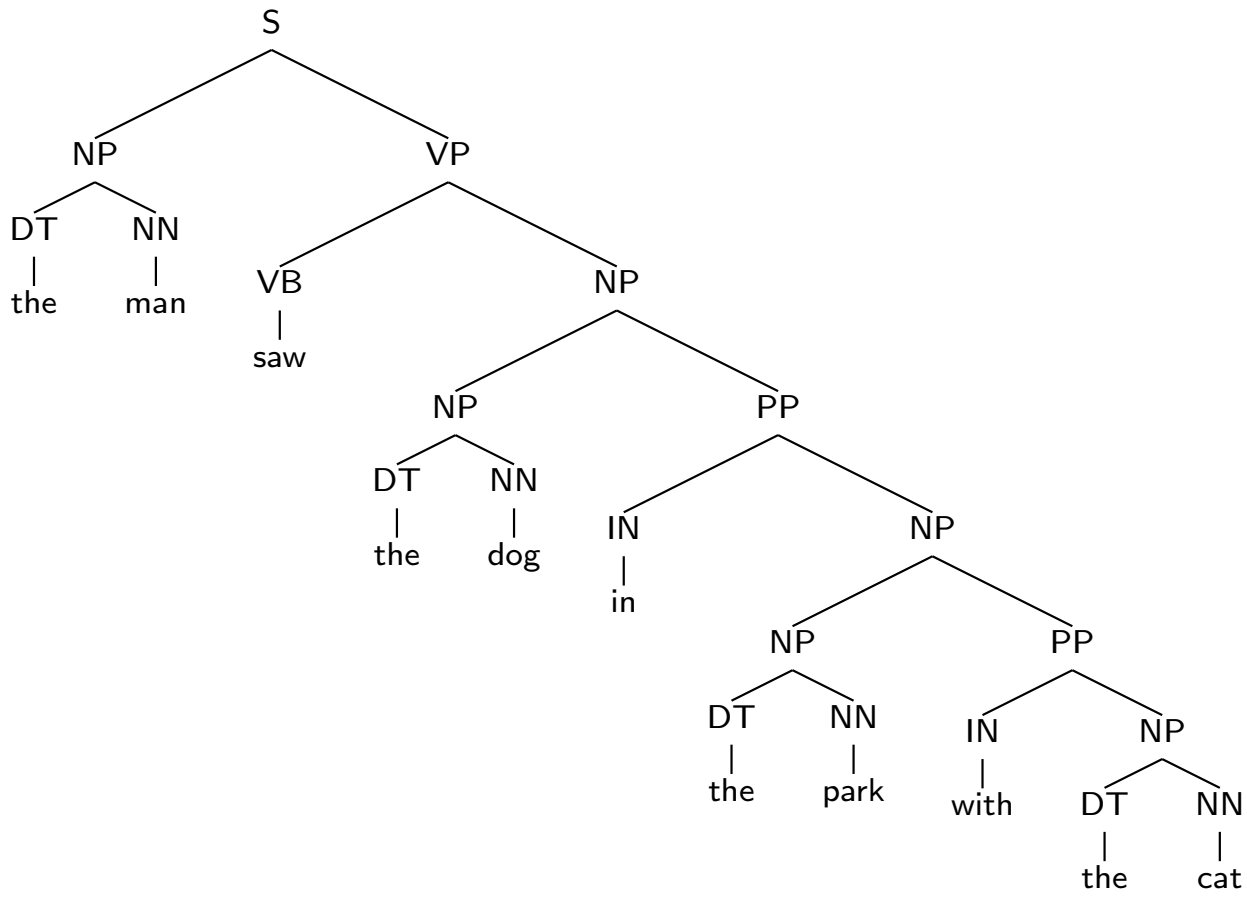
Question 1a

One parse tree:



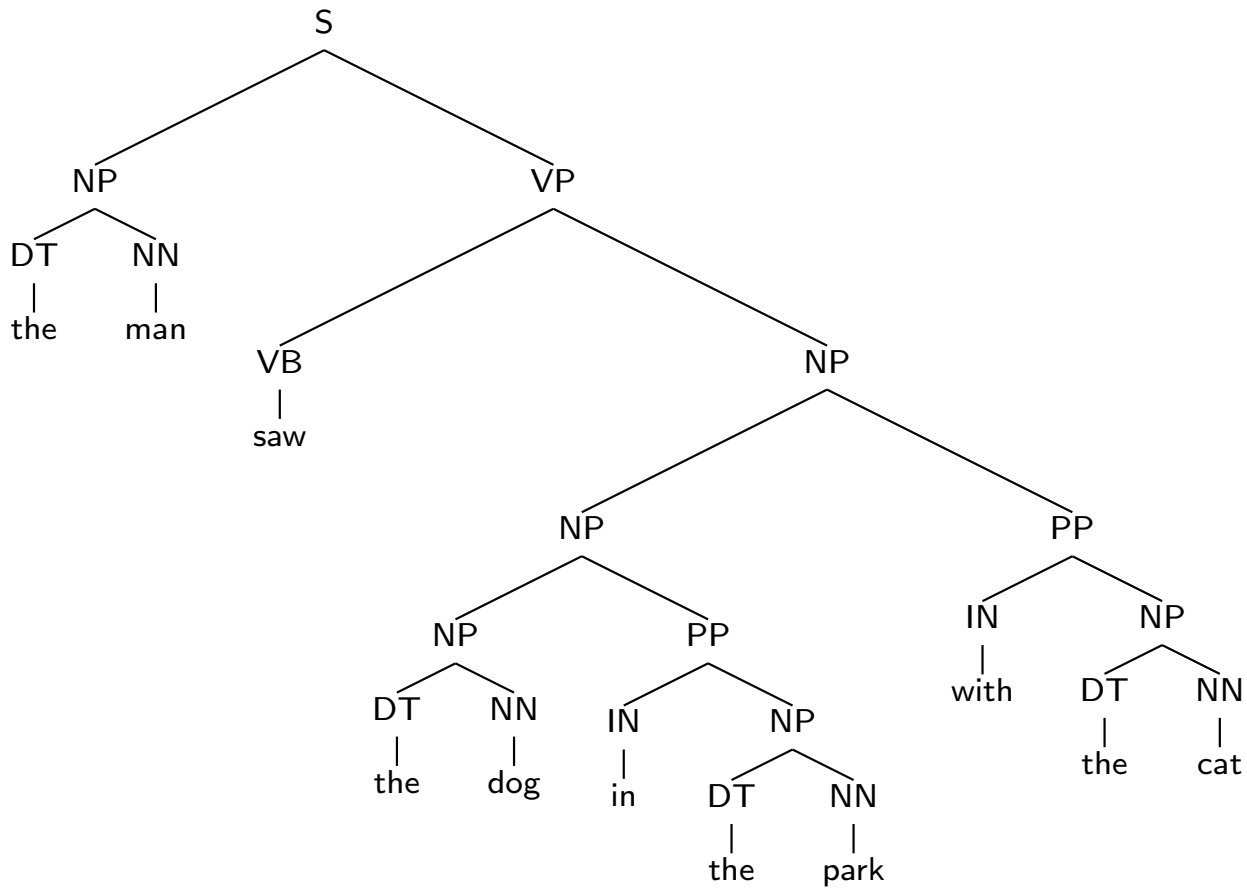
Question 1b

Two parse trees, parse tree 1:



Question 1b

Two parse trees, parse tree 2:



Question 1c

k prepositions after the verb leads to an NP after the verb that is equivalent to a binary branching tree with $k + 1$ leaves. So we have C_k parse trees.

Question 2

Add the singular/plural distinction to the grammar:

S → NP-s VP-s
S → NP-p VP-p
NP-s → DT NN
NP-p → DT NNS
NP-p → NP-p PP
NP-s → NP-s PP
PP → IN NP-s
PP → IN NP-p
VP-s → VB-s NP-s
VP-s → VB-s NP-p
VP-p → VB-p NP-s
VP-p → VB-p NP-p
VP-s → VP-s PP
VP-p → VP-p PP

DT → the
NN → man
NN → dog
NN → cat
NN → park
NNS → dogs
NNS → cats
NNS → parks
VB-p → see
VB-s → sees
IN → in
IN → with
IN → under

Question 3

$$q(\text{DT1}|*) = q(\text{NN1}|\text{DT1}) = q(\text{VB}|\text{NN1}) = q(\text{DT2}|\text{VB}) = q(\text{NN2}|\text{DT2}) = 1$$

$$q(\text{STOP}|\text{NN2}) = q(\text{IN}|\text{NN2}) = 0.5$$

$$q(\text{DT2}|\text{IN}) = 1$$

$$e(\text{the}|\text{DT1}) = e(\text{the}|\text{DT2}) = 1$$

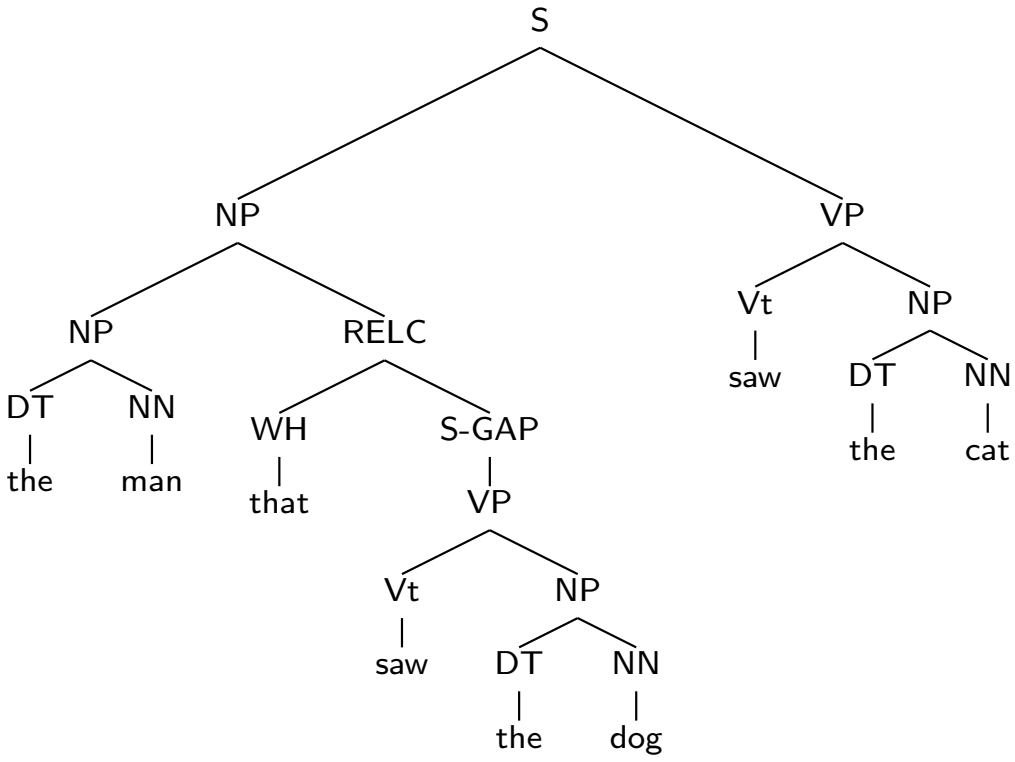
$$e(\text{man}|\text{NN1}) = e(\text{man}|\text{NN2}) = e(\text{dog}|\text{NN1}) = e(\text{dog}|\text{NN2}) = 1/3$$

$$e(\text{telescope}|\text{NN1}) = e(\text{telescope}|\text{NN2}) = 1/3$$

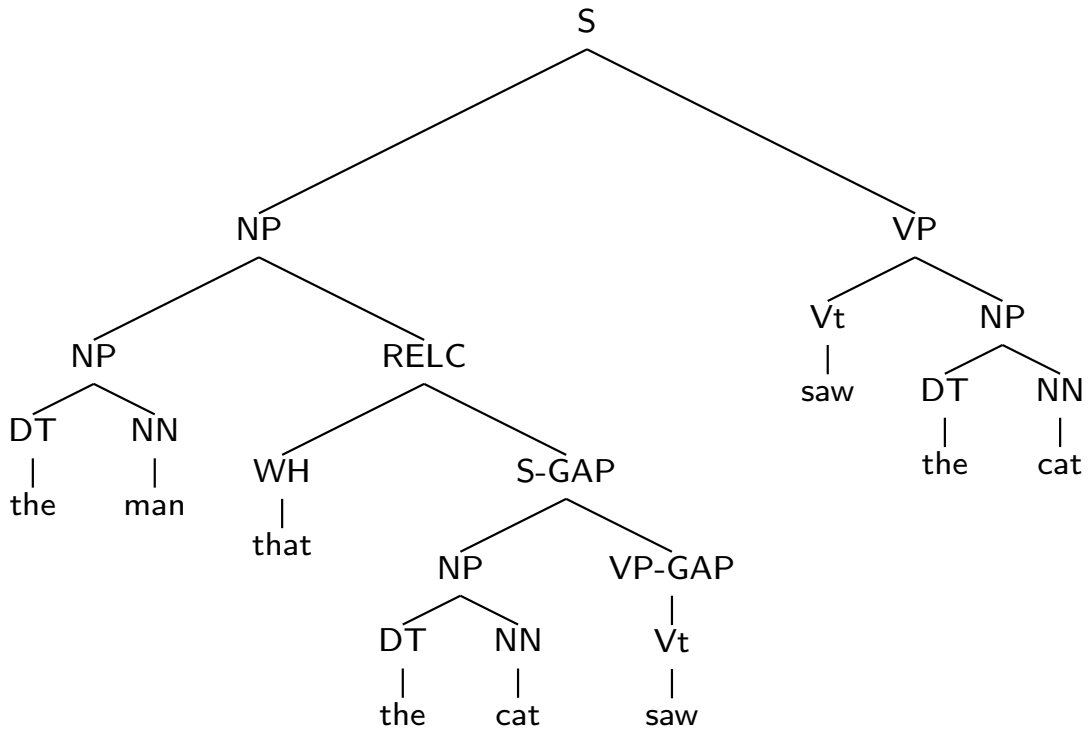
$$e(\text{saw}|\text{VB}) = 1$$

$$e(\text{with}|\text{IN}) = e(\text{under}|\text{IN}) = 0.5$$

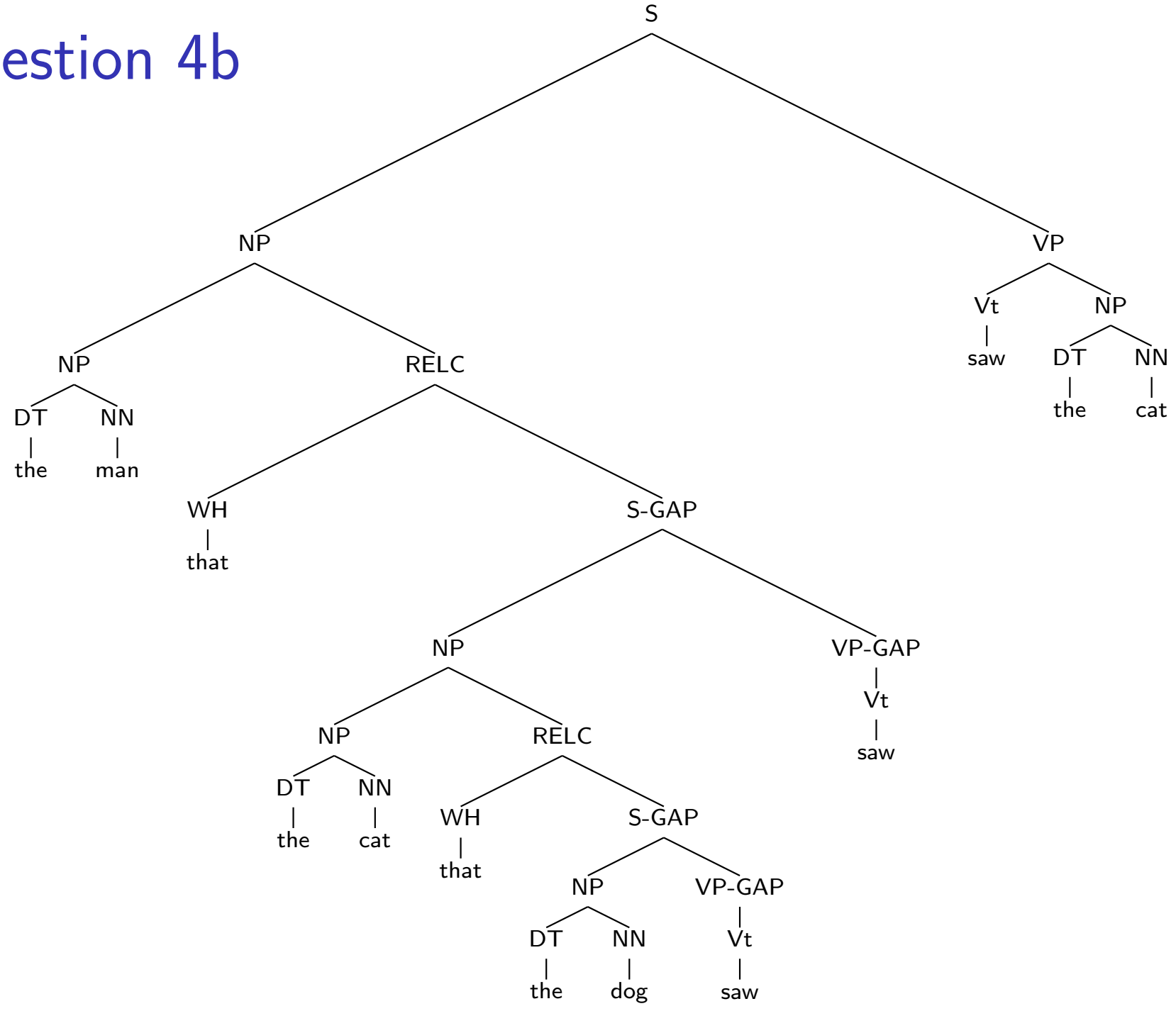
Question 4a


S
NP
VP
NP
RELC
Vt
NP
DT
NN
WH
S-GAP
saw
DT
NN
the
man
that
VP
the
cat
Vt
NP
saw
DT
NN
the
dog

Question 4a


S
NP
VP
NP
RELC
Vt
NP
saw
DT
NN
DT
NN
WH
S-GAP
DT
NN
the
cat
the
man
that
NP
VP-GAP
DT
NN
Vt
the
cat
saw

Question 4b


S
NP
VP
NP
RELC
Vt
NP
DT
NN
saw
DT
NN
the
man
the
cat
WH
S-GAP
that
NP
VP-GAP
Vt
saw
NP
RELC
DT
NN
WH
S-GAP
the
cat
that
NP
VP-GAP
DT
NN
Vt
the
dog
saw

Question 4c

Add the rule

VP-GAP $\rightarrow$ V3 S-GAP