Definite-Clause Grammars
[Covington, 1994]

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BOTTOM-UP vs. TOP-DOWN

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S → NP VP

s(L1, L) :- np(L1, L2), vp(L2, L).
S → NP VP

s(L1, L) :- np(L1, L2), vp(L2, L).

L1-[the, dog, saw, the, cat] - the input string (IS)
L2-[saw, the, cat] - the IS without the initial NP
L-[ ] - the IS without the NP or the VP
s(L1,L) :- np(L1,L2), vp(L2,L).
np(L1,L) :- d(L1,L2), n(L2,L).
v(L1,L) :- v(L1,L2), np(L2,L).
d([the|L],L).
d([a|L],L).
n([dog|L],L).
n([cat|L],L).
n([gardener|L],L).
n([policeman|L],L).
n([butler|L],L).
v([chased|L],L).
v([saw|L],L).

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What are DCG Rules?
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```plaintext
nonterminal symbol - -&gt; expansion
```
What are DCG Rules?

*nonterminal symbol* $\rightarrow$ *expansion*, where *expansion* is:

- A nonterminal symbol such as *np*
- A list of terminal symbols
- A null constituent represented by `[ ]`
- A plain Prolog goal enclosed in braces
  ```prolog
  {write ('Found NP')}
  ```
- A series of any of these expansions joined by commas
s --> np, vp.
np --> d, n.
vp --> v, np.
d --> [the]; [a].
n --> [dog]; [cat]; [gardner]; [policeman]; [butler].
v --> [chased]; [saw].
A → A B
A → A B

NP → NP Conj NP
NP → D N

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A → A B

NP → NP Conj NP
NP → D N
NP → NPX Conj NP
NP → NPX
NPX → D N

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s(np(d(the), n(cat)), vp(v(chased), np(d(the), n(dog))))
before translation

\[ s(a, b) \rightarrow np(c, d), \ vp(e, f). \]

after translation

\[ s(a, b, L1, L2) \rightarrow np(c, d, L1, L2), \ vp(e, f, L2, L). \]
s(s(NP, VP)) \rightarrow np(NP), vp(VP).
np(np(D, N)) \rightarrow d(D), n(N).
vp(vp(V, NP)) \rightarrow v(V), np(NP).
d(d(the)) \rightarrow [the].
n(n(dog)) \rightarrow [dog].
n(n(cat)) \rightarrow [cat].
v(v(chased)) \rightarrow [chased].
v(v(saw)) \rightarrow [saw].

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Definite-Clause Grammars [Covington, 1994]
The dog chases the cats. (Singular subject, singular verb)
The dogs chase the cats. (Plural subject, plural verb)
*The dog chase the cats. (Singular subject, plural verb)
*The dogs chases the cats. (Plural subject, singular verb)
n(singular) --> [dog]; [cat]; [mouse].
n(plural) --> [dogs]; [cats]; [mice].

v(singular) --> [chases]; [sees].
v(plural) --> [chase]; [see].

np(Number) --> d, n(Number).
vp(Number) --> v(Number), np(_).

s --> np(Number), vp(Number).
He sees him. *Him sees he.
She sees her. *Her sees she.
They see them. *Them see they.
pronoun(singular, nominative) --> [he]; [she].
pronoun(singular, accusative) --> [him]; [her].
pronoun(plural, nominative) --> [they].
pronoun(plural, accusative) --> [them].

np(Number, Case) --> pronoun(Number, Case).
np(Number, _) --> d, n(Number).

s --> np(Number, nominative), vp(Number).
vp(Number) --> v(Number), np(_, accusative).
<table>
<thead>
<tr>
<th>VERB</th>
<th>COMPLEMENT</th>
<th>EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>sleep, bark</td>
<td>None</td>
<td><em>(The cat) slept.</em></td>
</tr>
<tr>
<td>chase, see</td>
<td>One NP</td>
<td><em>(The dog) chased the cat.</em></td>
</tr>
<tr>
<td>give, sell</td>
<td>Two NPs</td>
<td><em>(Max) sold Bill his car.</em></td>
</tr>
<tr>
<td>say, claim</td>
<td>Sentence</td>
<td><em>(Max) claimed the cat barked.</em></td>
</tr>
</tbody>
</table>

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Definite-Clause Grammars [Covington, 1994]
VP → V
VP → V NP
VP → V NP NP
VP → V S

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VP → V1
VP → V2 NP
VP → V3 NP NP
VP → V4 S
vp --> v(1).
vp --> v(2), np.
vp --> v(3), np, np.
vp --> v(4), s.

v(1) --> [barked]; [slept].
v(2) --> [chased]; [saw].
v(3) --> [gave]; [sold].
v(4) --> [said]; [thought].
Max said Bill thought Joe believed Fido barked.

Who said Bill thought Joe believed Fido barked? (Max.)
Who did Max say □ thought Joe believed Fido barked? (Bill.)
Who did Max say Bill thought □ believed Fido barked? (Joe.)
Who did Max say Bill thought Joe believed □ barked? (Fido.)
s(In,Out) --＞ [who,did], np([who|In]), Out1), vp(Out1, Out).

np([who|Out], Out) --＞ [ ].
\[ s(\text{In}, \text{Out}) \rightarrow \text{np}(\text{In}, \text{Out1}), \text{vp}(\text{Out1}, \text{Out}). \]

\[ \text{np}(X, X) \rightarrow \text{[max]}; \text{[joe]}; \text{[bill]}; \text{[frido]}. \]

\[ \text{vp}(X, X) \rightarrow v. \]
\[ \text{vp}(\text{In}, \text{Out}) \rightarrow v, \text{np}(\text{In}, \text{Out}). \]
\[ \text{vp}(\text{In}, \text{Out}) \rightarrow v, s(\text{In}, \text{Out}). \]

\[ v \rightarrow \text{[saw]}; \text{[said]}; \text{[thought]}; \text{[believed]}; \text{[barked]}. \]
\[ v \rightarrow \text{[see]}; \text{[say]}; \text{[think]}; \text{[believe]}; \text{[bark]}. \]
n --> [X], (noun (X)).
noun(dog).
noun(cat).
noun(gardener).

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