A (very) basic introduction to Prolog
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2. Steps of Programming

- 1. step: create a database

  - facts ~ object properties and relations to other objects
    - girl(jane). beer(heineken). likes(jane,heineken).
    - likes(jane,beer(heineken).
    - HIERARCHICAL STRUCTURES
  - rules ~ relations between facts
    - head :- body.
    - IF body – THEN head
    - Will talk on it later … hope today ;-)

- DB contains the true information, i.e. information not in DB are false... closed world assumption

2. Steps of Programming

- 2. step: dialogue with the system
  - We are asking questions, Prolog answers
  - e.g.
    ```
    ?- 3>2.
    yes
    ?- likes(jane,heineken).
    yes
    ?- likes(jane,beer).
    no
    ?- girl(jane), beer(heineken)    // compound question, "," == " &"
    yes
    ```

Variables

- who is a girl? what is a beer?

    ?- girl(X).

    X = jane

- enter after the answer ~ thanks

- ";" after the answer ~ thanks and want more

    ?- girl(X).

    X = jane → enter

    yes

    ?- girl(X).

    X = jane → ;

    no

More sophisticated asking

- asking have 2 uses:
  - is something true?
    - yes or no
  - give me some values.
    - need variables

Variables

- bounded … input

- free … output

- special, 'don't care' variable: "_"

- how to write a proposition "peter loves women who like beer." ?
  - be careful to use just the facts in the table!

more sophisticated questions

- "peter loves women who like beer"

- "if there is a women and this woman likes beer then peter loves this woman"

- "if X is a woman and X likes beer then peter loves X"

  ?- loves(peter,X) :- woman(X), likes(X,beer).

  X = jane → enter

  yes

Unification

- when searching for answers Prolog tries to unify two objects (variables or constants)

  - unifying a variable and constant is basically a bounding of a variable to a concrete object.

  - strict rules for unification!

    - constants ~ if are the same

    - variable can be unified with an arbitrary object (two variables became associated after unification

    - structures ~ same functor and number of arguments and all arguments are unifiable

    - **goals** are unifiable with facts if are represented with unifiable structures

    - goals are unifiable with rules if the goal and the head of the rule are unifiable

Unification

- "=" is an operator for syntactical unification

  ?- 5 = 2+3

  no

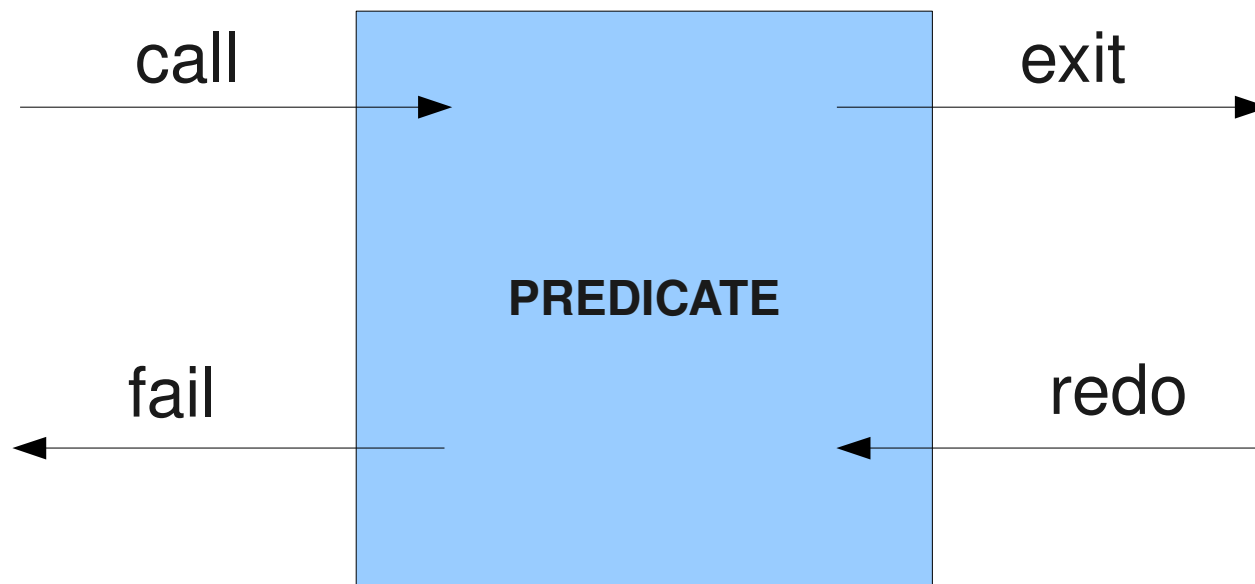- "is" is an operator for semantical unification

  ?- X is 2+3

  X = 5 → enter

  yes

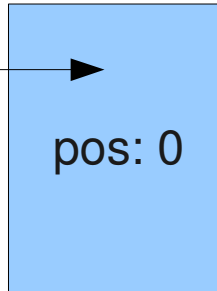- arithmetical comparison "=:=", "=\="

How does Prolog answering?

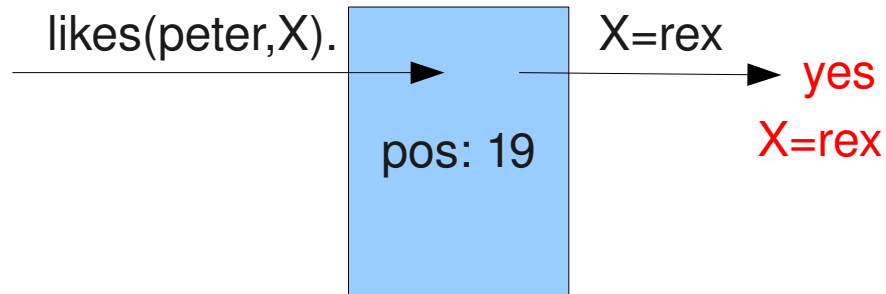- 4 actions
  - Call, Exit, Redo, Fail

```
1.   beer(beck).
2.   beer(urquell).
3.   girl(eva).
4.   girl(janka).
5.   girl(anna).
6.   boy(tomas).
7.   boy(zeno).
8.   boy(andre).
9.   dog(rex).
10.  cat(reggy).
11.  likes(eva,urquell).
12.  likes(eva,tomas).
13.  likes(eva,janka).
14.  likes(janka,andre).
15.  likes(janka,eva).
16.  likes(janka,beck).
17.  likes(anna,zeno).
18.  likes(anna,reggy).
19.  likes(peter,rex).
20.  likes(peter,beck).
21.  likes(peter,urquell).
22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).
```
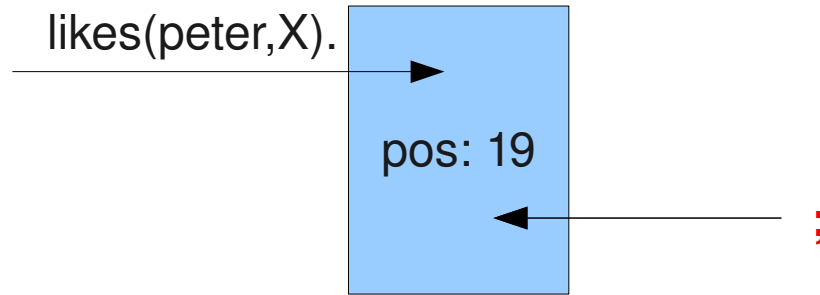
likes(peter,X). → pos: 0

?- likes(peter,X).

```
1.   beer(beck).
2.   beer(urquell).
3.   girl(eva).
4.   girl(janka).
5.   girl(anna).
6.   boy(tomas).
7.    boy(zeno).
8.   boy(andre).
9.   dog(rex).
10. cat(reggy).
11.  likes(eva,urquell).
12.  likes(eva,tomas).
13.  likes(eva,janka).
14.  likes(janka,andre).
15.  likes(janka,eva).
16.  likes(janka,beck).
17.  likes(anna,zeno).
18.  likes(anna,reggy).
19.  likes(peter,rex).
20.  likes(peter,beck).
21.  likes(peter,urquell).
22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).
```
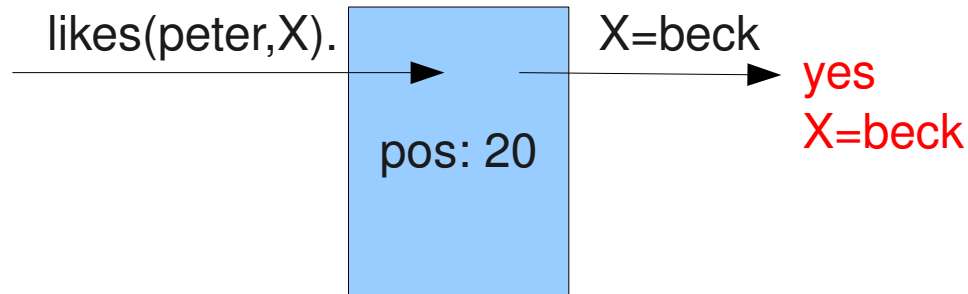
likes(peter,X). → pos: 19 → X=rex → yes
X=rex

?- likes(peter,X).

```
1.   beer(beck).
2.   beer(urquell).
3.   girl(eva).
4.   girl(janka).
5.   girl(anna).
6.   boy(tomas).
7.   boy(zeno).
8.   boy(andre).
9.   dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,andre).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).
```
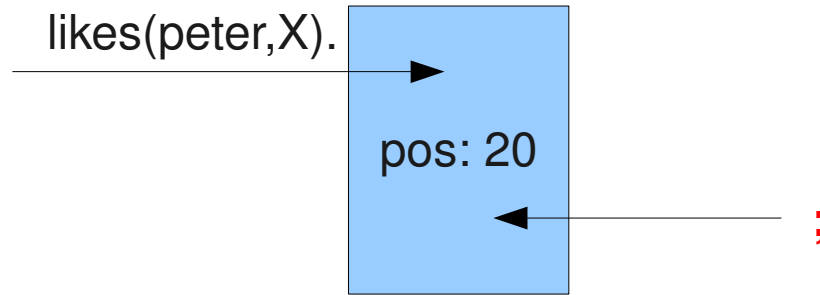
likes(peter,X).

pos: 19

;

?- likes(peter,X).

```
1.   beer(beck).
2.   beer(urquell).
3.   girl(eva).
4.   girl(janka).
5.   girl(anna).
6.   boy(tomas).
7.    boy(zeno).
8.   boy(andre).
9.   dog(rex).
10. cat(reggy).
11.  likes(eva,urquell).
12.  likes(eva,tomas).
13.  likes(eva,janka).
14.  likes(janka,andre).
15.  likes(janka,eva).
16.  likes(janka,beck).
17.  likes(anna,zeno).
18.  likes(anna,reggy).
19.  likes(peter,rex).
20.  likes(peter,beck).
21.  likes(peter,urquell).
22. likes(X,Y) :- boy(X),
   girl(Y), likes(Y,Z), beer(Z).
```
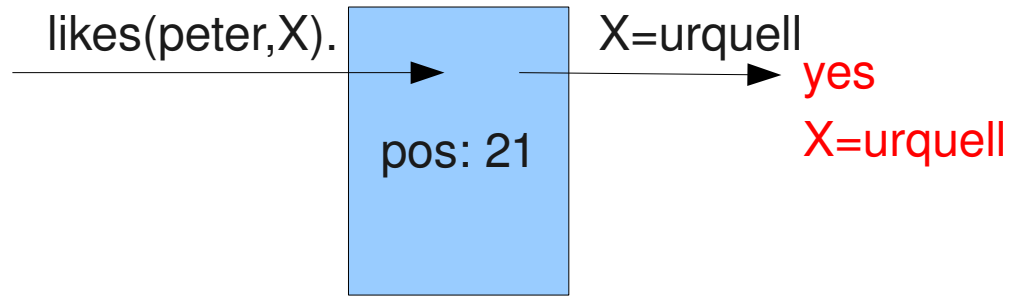
likes(peter,X).   pos: 20   X=beck   yes
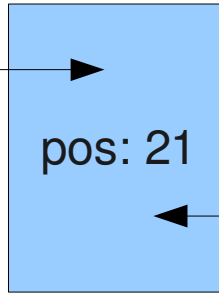X=beck

?- likes(peter,X).

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(andre).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,andre).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).

?- likes(peter,X).

likes(peter,X).

pos: 20

;

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(andre).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,andre).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
   girl(Y), likes(Y,Z), beer(Z).

likes(peter,X). → pos: 21 → X=urquell

yes

X=urquell

?- likes(peter,X).

```
1.   beer(beck).
2.   beer(urquell).
3.   girl(eva).
4.   girl(janka).
5.   girl(anna).
6.   boy(tomas).
7.    boy(zeno).
8.   boy(andre).
9.   dog(rex).
10. cat(reggy).
11.  likes(eva,urquell).
12.  likes(eva,tomas).
13.  likes(eva,janka).
14.  likes(janka,andre).
15.  likes(janka,eva).
16.  likes(janka,beck).
17.  likes(anna,zeno).
18.  likes(anna,reggy).
19.  likes(peter,rex).
20.  likes(peter,beck).
21.  likes(peter,urquell).
22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).
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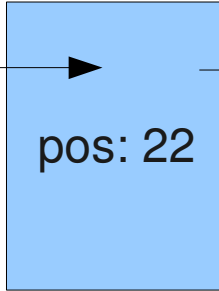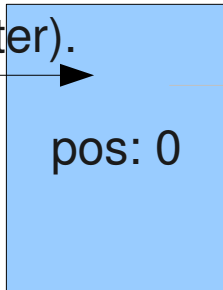
likes(peter,X).

pos: 21

;

?- likes(peter,X).
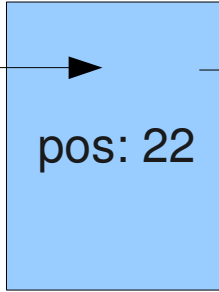
1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).

likes(peter,X). → pos: 22 X22=peter, Y22=X

?- likes(peter,X).

boy(peter). → pos: 0   girl(Y22). → pos: 0   likes(Y22,Z22). → pos: 0   beer(Z22). → pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7.   boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
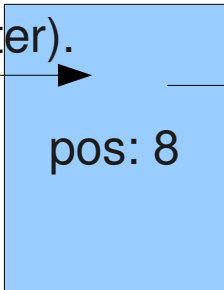22. likes(X,Y) :- boy(X), girl(Y), likes(Y,Z), beer(Z).

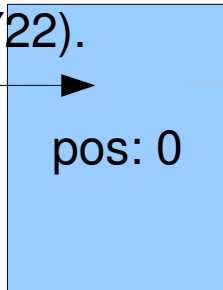likes(peter,X).   →   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   →   girl(Y22).   →   likes(Y22,Z22).   →   beer(Z22).

pos: 8   pos: 0   pos: 0   pos: 0
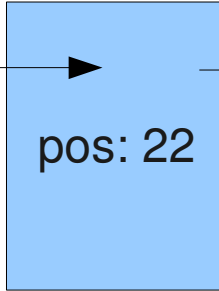
1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
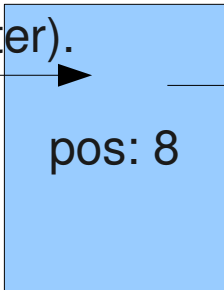   girl(Y), likes(Y,Z), beer(Z).
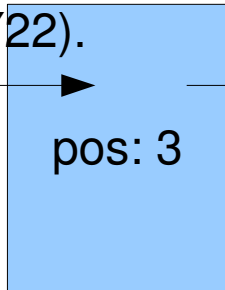
likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(eva,Z22).   beer(Z22).

pos: 8   pos: 3   Y22=eva   pos: 0   pos: 0

```
1.   beer(beck).
2.   beer(urquell).
3.   girl(eva).
4.   girl(janka).
5.   girl(anna).
6.   boy(tomas).
7.    boy(zeno).
8.   boy(peter).
9.   dog(rex).
10.  cat(reggy).
11.  likes(eva,urquell).
12.  likes(eva,tomas).
13.  likes(eva,janka).
14.  likes(janka,peter).
15.  likes(janka,eva).
16.  likes(janka,beck).
17.  likes(anna,zeno).
18.  likes(anna,reggy).
19.  likes(peter,rex).
20.  likes(peter,beck).
21.  likes(peter,urquell).
22. likes(X,Y) :- boy(X),
   girl(Y), likes(Y,Z), beer(Z).
```

likes(peter,X).   X22=peter, Y22=X
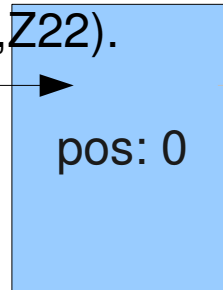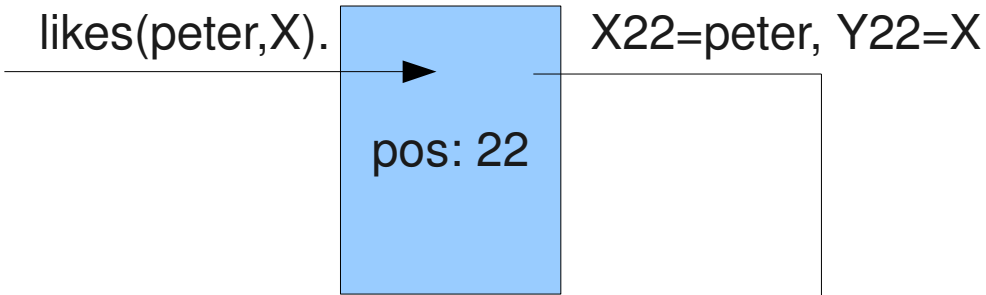
pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(eva,Z22).   beer(urquel).

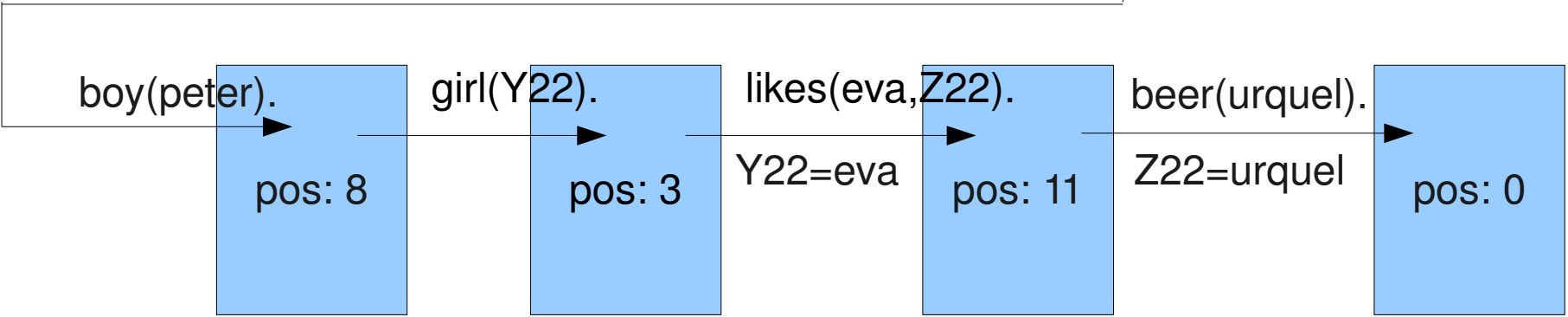pos: 8   pos: 3   Y22=eva   pos: 11   Z22=urquel   pos: 0
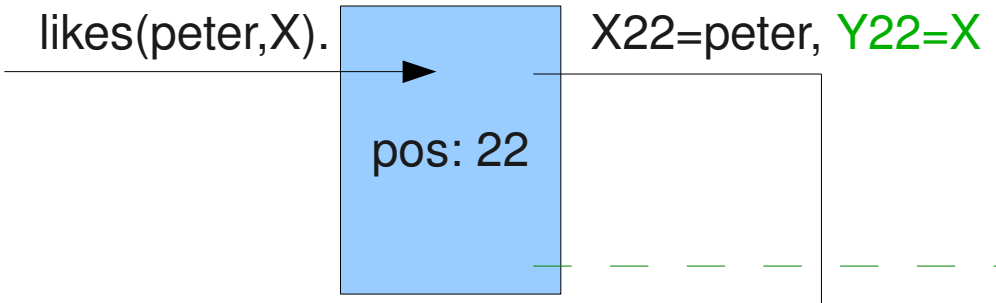
1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
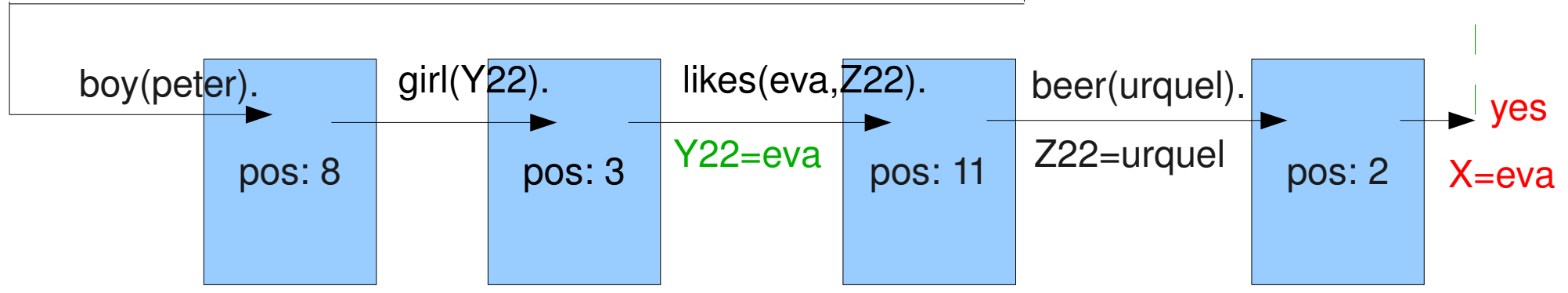22. likes(X,Y) :- boy(X), girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   → pos: 22   X22=peter, Y22=X

?- likes(peter,X).

boy(peter).   → pos: 8   girl(Y22).   → pos: 3   likes(eva,Z22).   → pos: 11   beer(urquel).   → pos: 2   yes

Y22=eva   Z22=urquel   X=eva
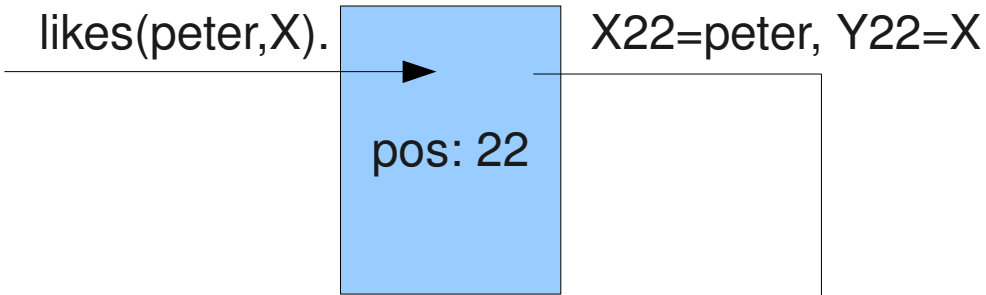
1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
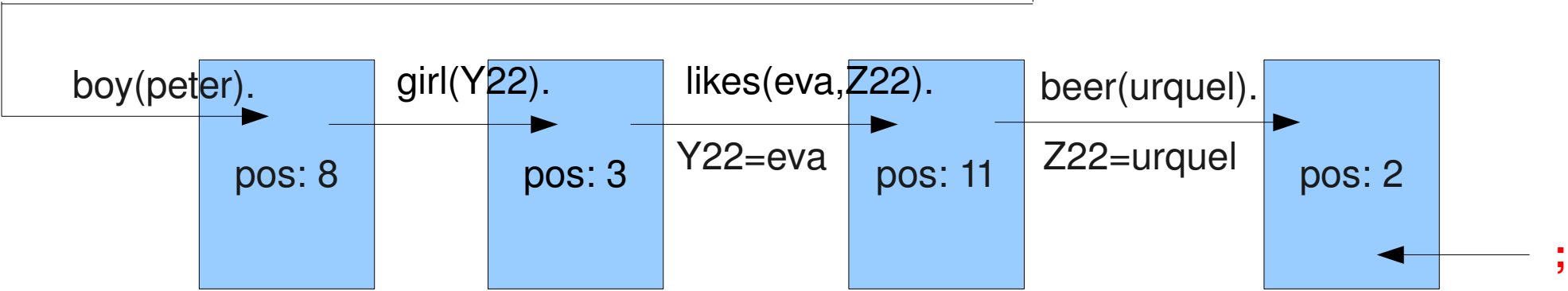   girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(eva,Z22).   beer(urquel).

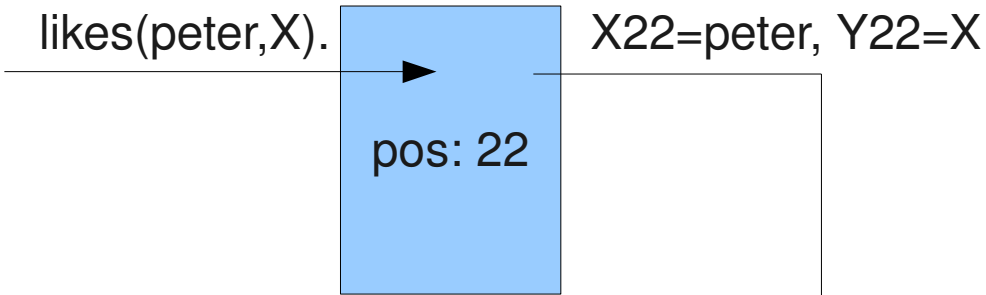pos: 8   pos: 3   Y22=eva   pos: 11   Z22=urquel   pos: 2

;

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
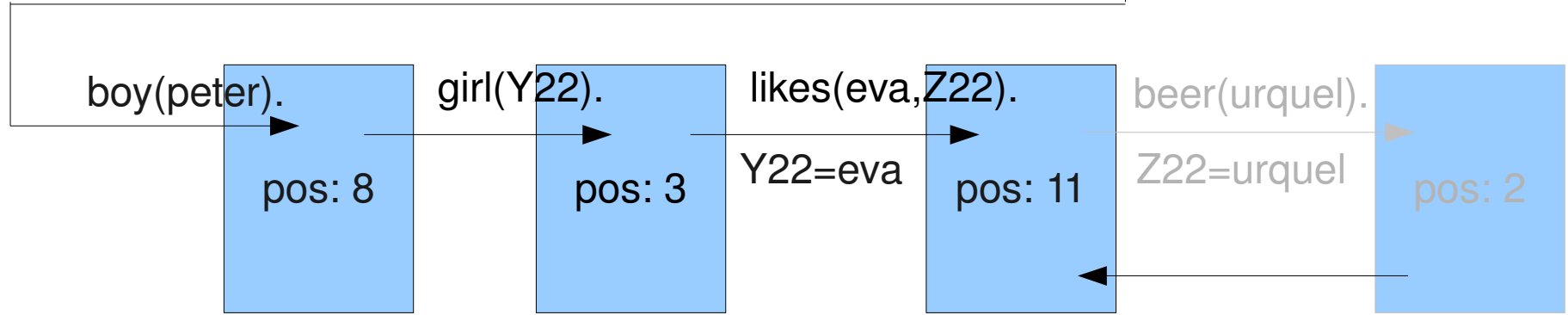   girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(eva,Z22).   beer(urquel).

pos: 8   pos: 3   Y22=eva   pos: 11   Z22=urquel   pos: 2
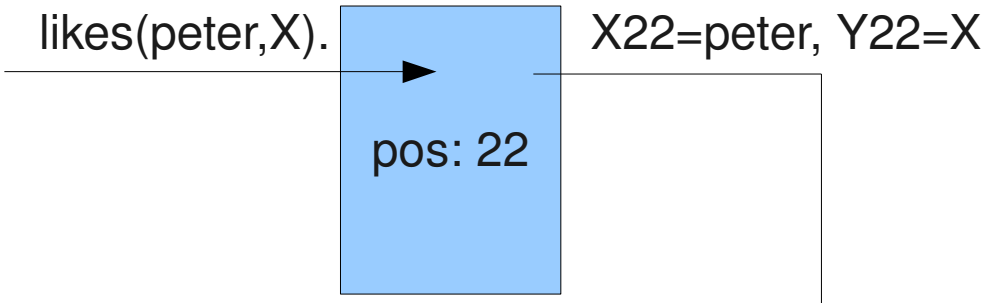
1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
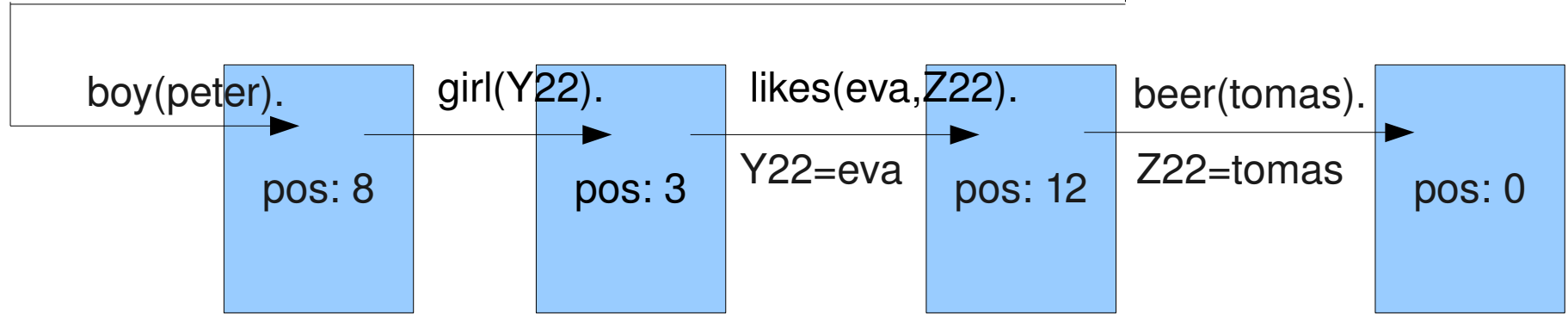   girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   →   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   →   girl(Y22).   →   likes(eva,Z22).   →   beer(tomas).

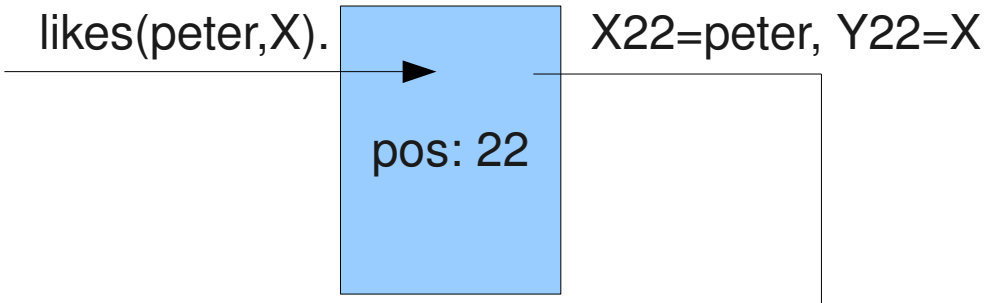pos: 8   pos: 3   Y22=eva   pos: 12   Z22=tomas   pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
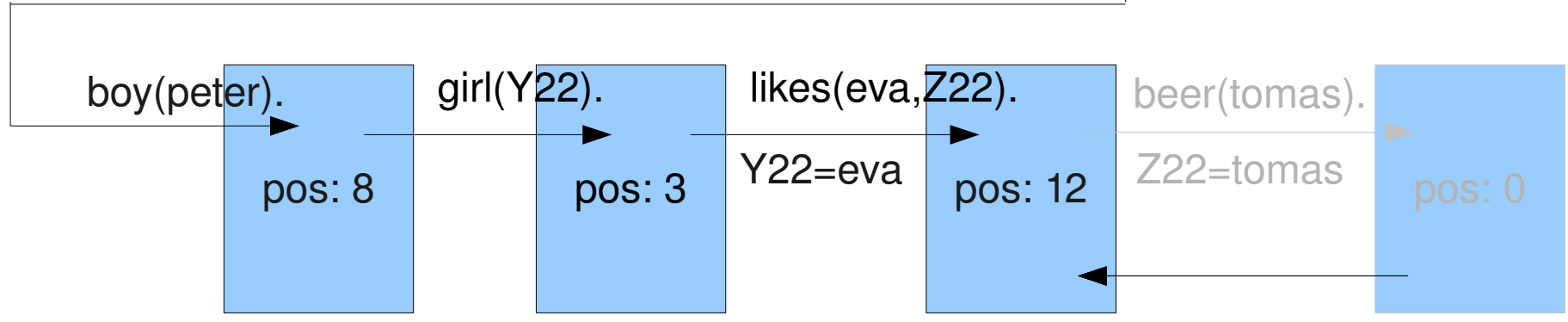22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(eva,Z22).   beer(tomas).

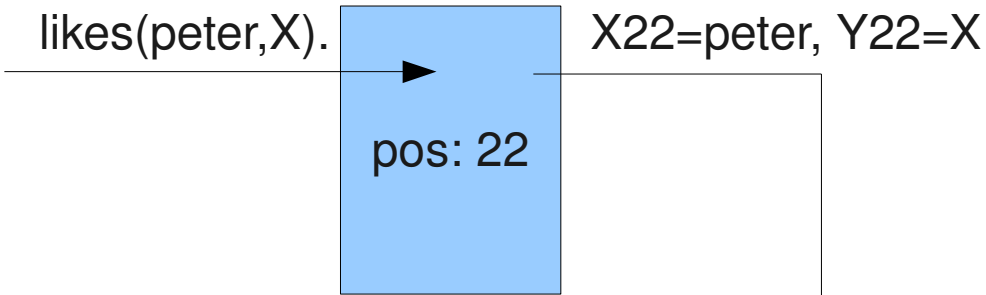pos: 8   Y22=eva   pos: 3   pos: 12   Z22=tomas   pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
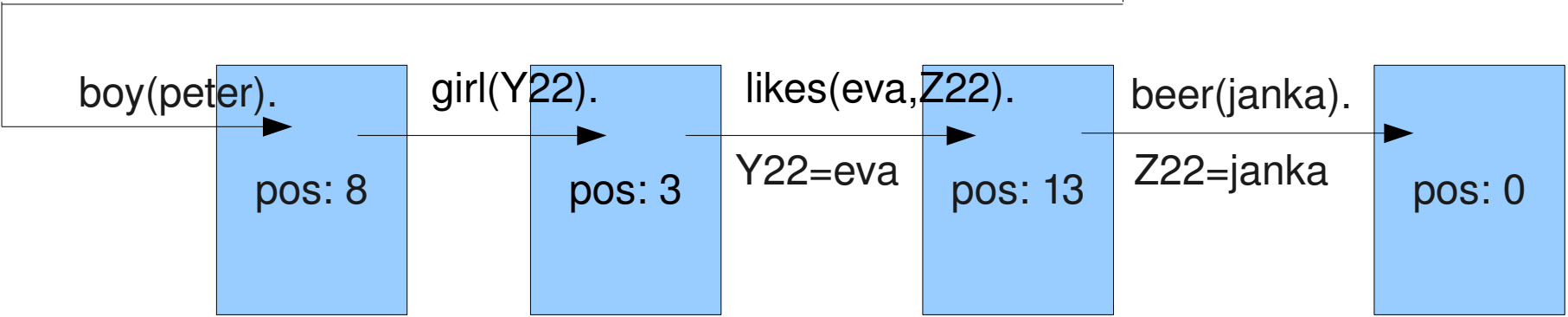22. likes(X,Y) :- boy(X),
     girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(eva,Z22).   beer(janka).

pos: 8   pos: 3   Y22=eva   pos: 13   Z22=janka   pos: 0
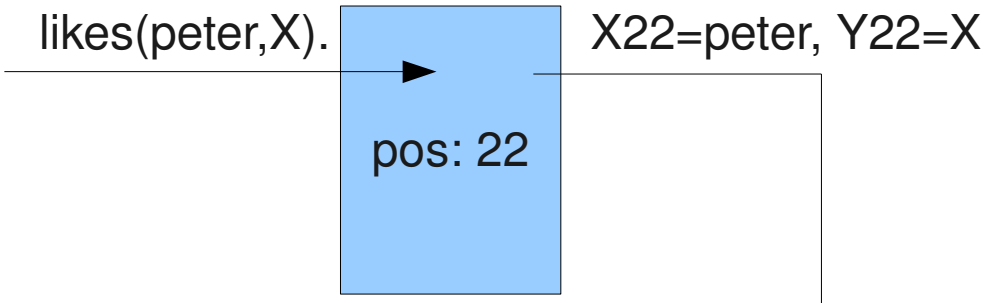
```
1.   beer(beck).
2.   beer(urquell).
3.   girl(eva).
4.   girl(janka).
5.   girl(anna).
6.   boy(tomas).
7.   boy(zeno).
8.   boy(peter).
9.   dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
   girl(Y), likes(Y,Z), beer(Z).
```
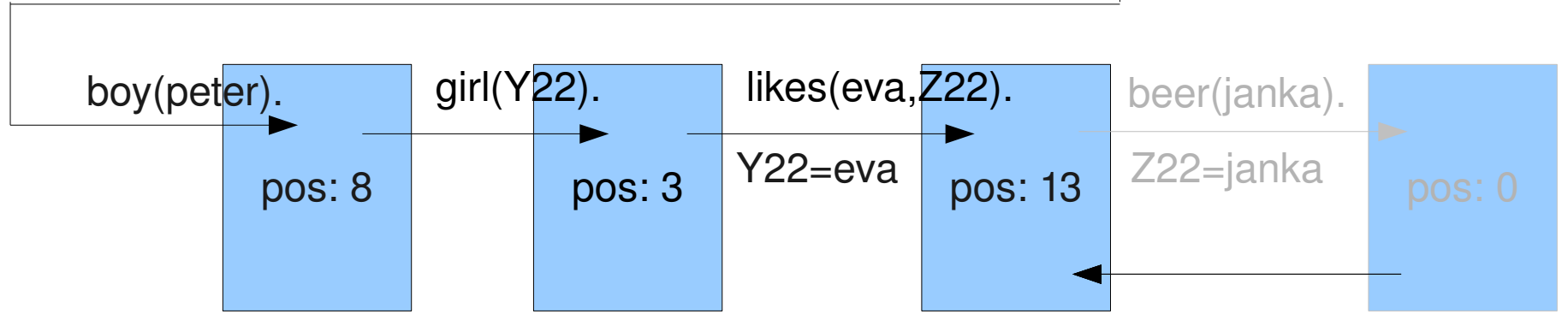
likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(eva,Z22).   beer(janka).

Y22=eva   Z22=janka

pos: 8   pos: 3   pos: 13   pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
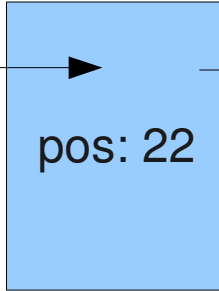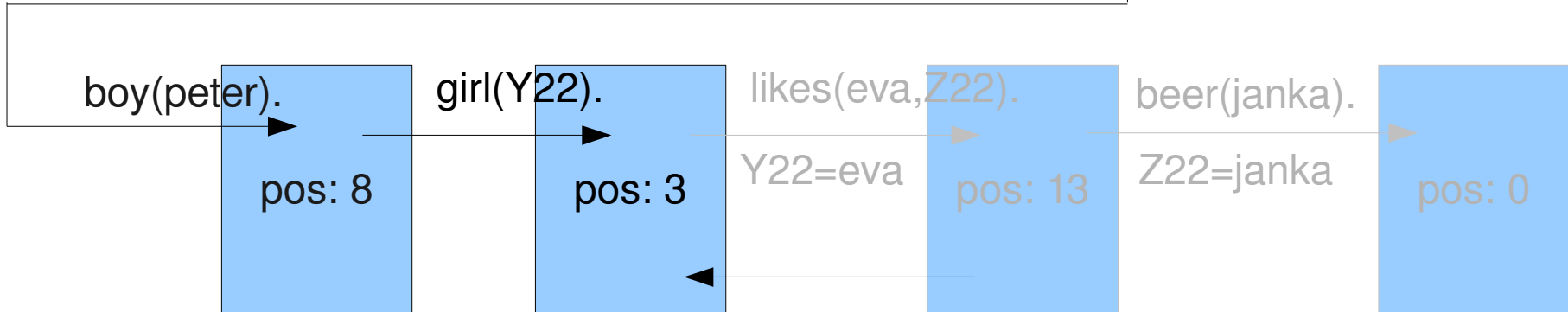   girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(eva,Z22).   beer(janka).

pos: 8   pos: 3   Y22=eva   Z22=janka

pos: 13   pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X), girl(Y), likes(Y,Z), beer(Z).
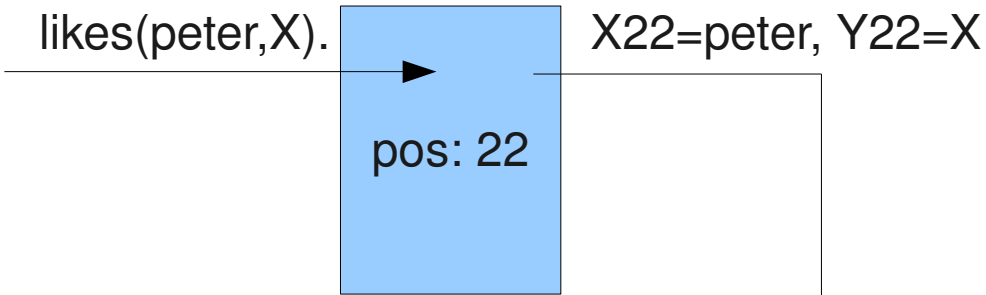
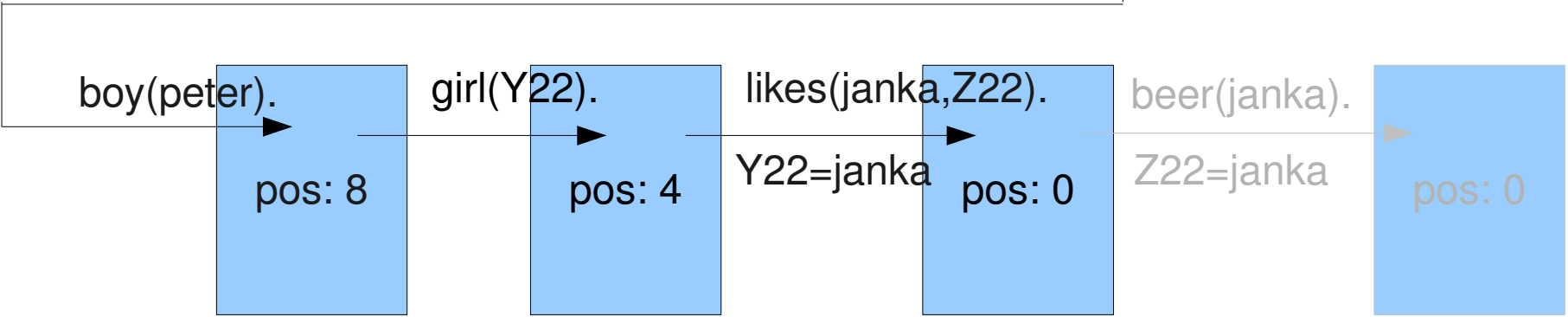likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(janka,Z22).   beer(janka).

pos: 8   pos: 4   Y22=janka   pos: 0   Z22=janka   pos: 0
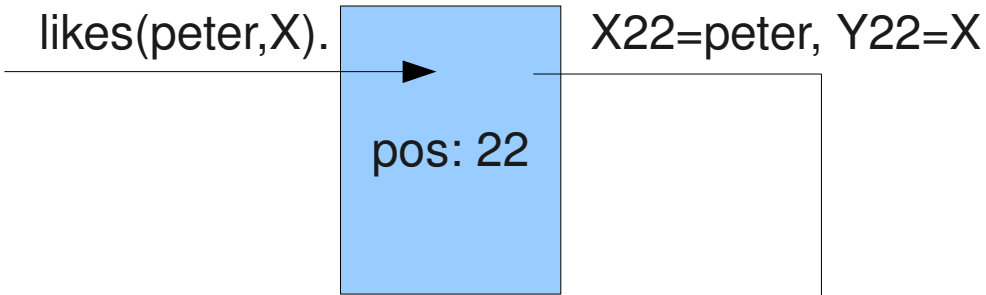
```
1.   beer(beck).
2.   beer(urquell).
3.   girl(eva).
4.   girl(janka).
5.   girl(anna).
6.   boy(tomas).
7.   boy(zeno).
8.   boy(peter).
9.   dog(rex).
10.  cat(reggy).
11.  likes(eva,urquell).
12.  likes(eva,tomas).
13.  likes(eva,janka).
14.  likes(janka,peter).
15.  likes(janka,eva).
16.  likes(janka,beck).
17.  likes(anna,zeno).
18.  likes(anna,reggy).
19.  likes(peter,rex).
20.  likes(peter,beck).
21.  likes(peter,urquell).
22.  likes(X,Y) :- boy(X),
     girl(Y), likes(Y,Z), beer(Z).
```
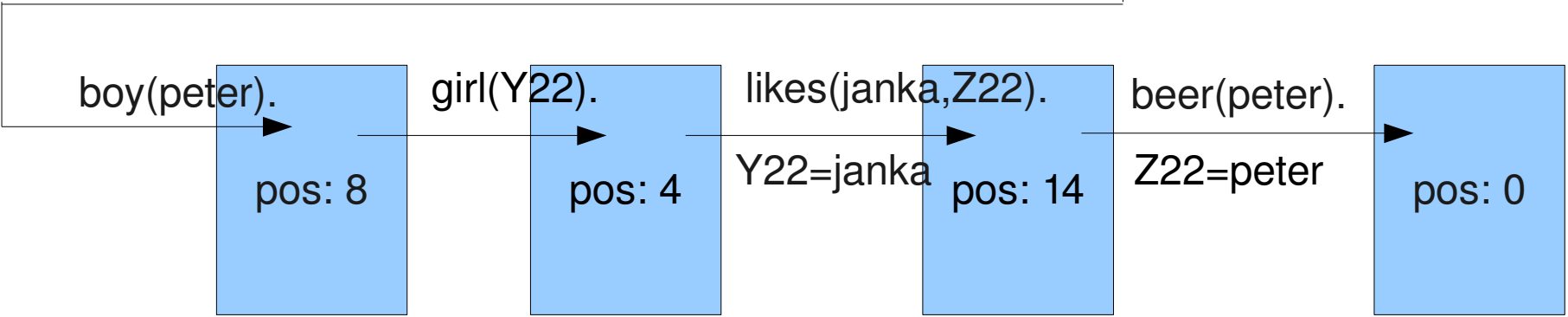
likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(janka,Z22).   beer(peter).

pos: 8   pos: 4   Y22=janka   pos: 14   Z22=peter   pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).
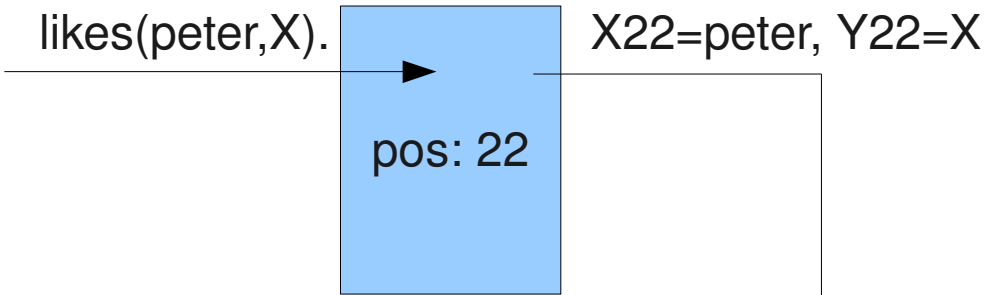
boy(peter).   girl(Y22).   likes(janka,Z22).   beer(peter).

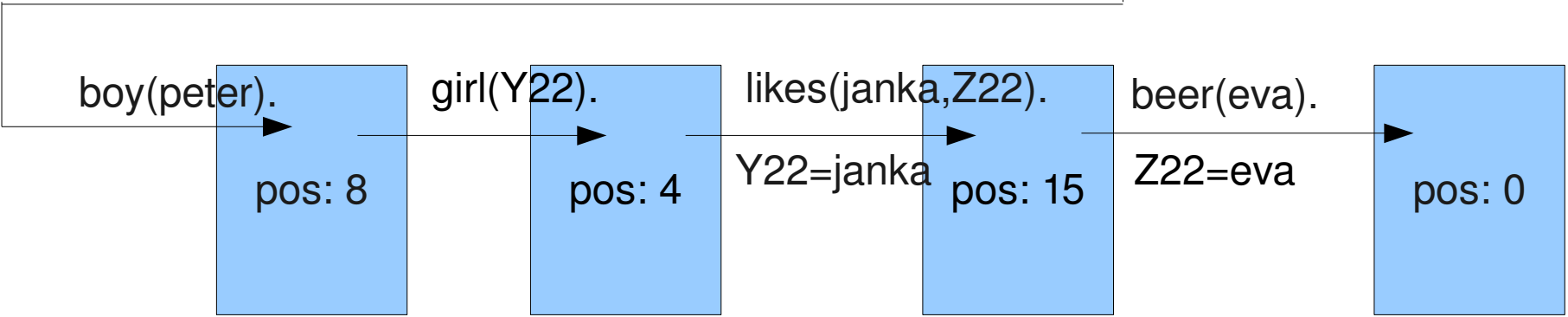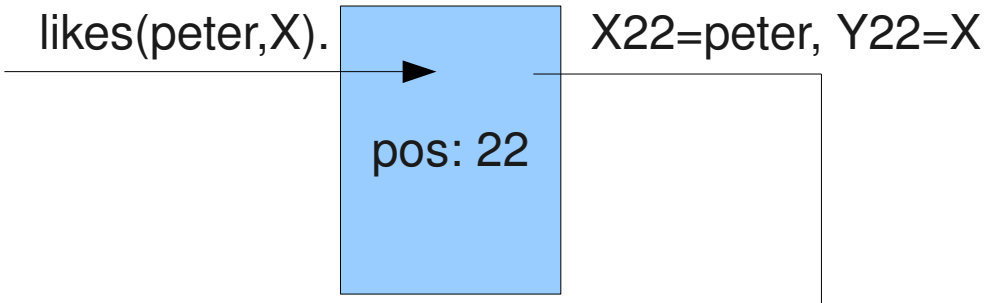pos: 8   pos: 4   Y22=janka   pos: 14   Z22=peter   pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X), girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(janka,Z22).   beer(eva).

pos: 8   pos: 4   Y22=janka   pos: 15   Z22=eva   pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7.   boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
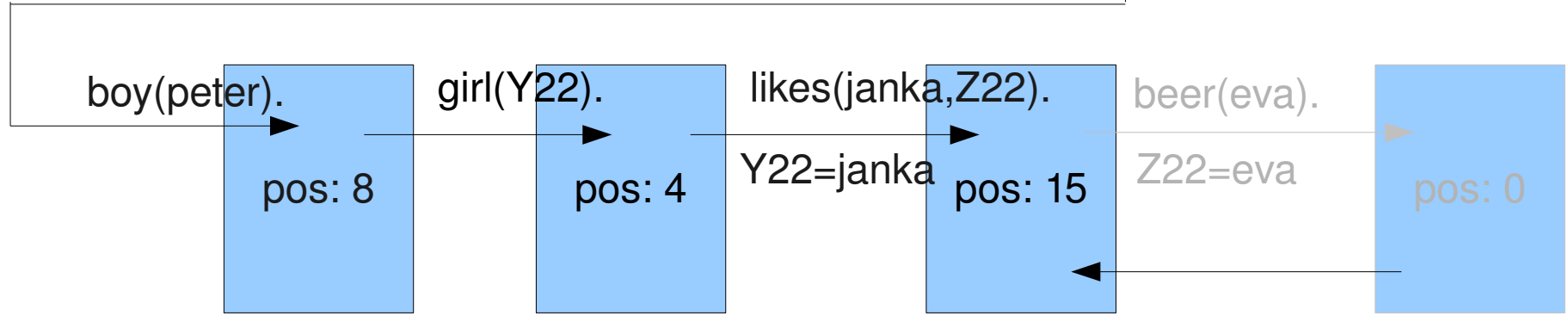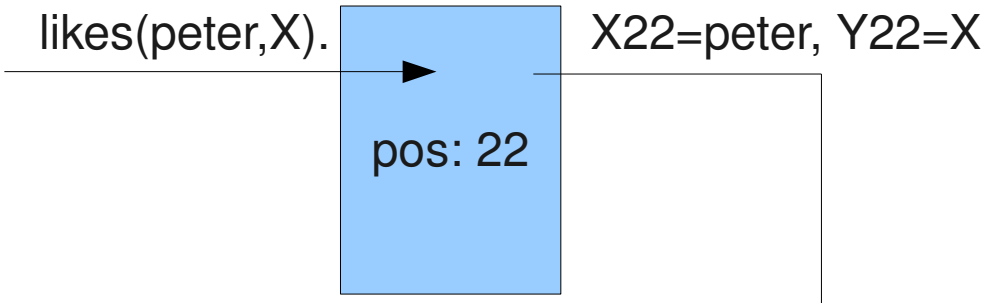   girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   pos: 22   X22=peter, Y22=X

?- likes(peter,X).

boy(peter).   pos: 8   girl(Y22).   pos: 4   likes(janka,Z22).   pos: 15   beer(eva).   pos: 0

Y22=janka   Z22=eva

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
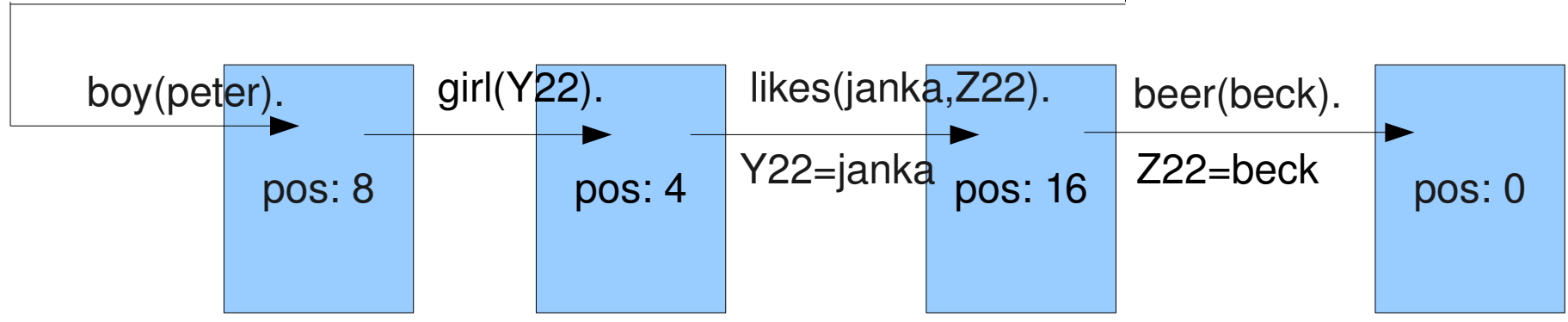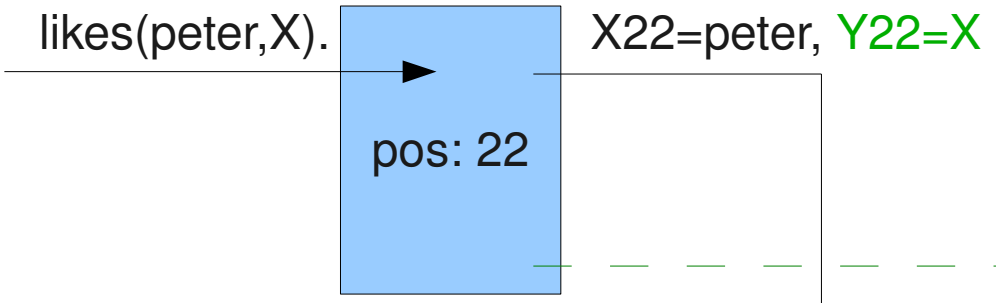22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(janka,Z22).   beer(beck).

pos: 8   pos: 4   Y22=janka   pos: 16   Z22=beck   pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
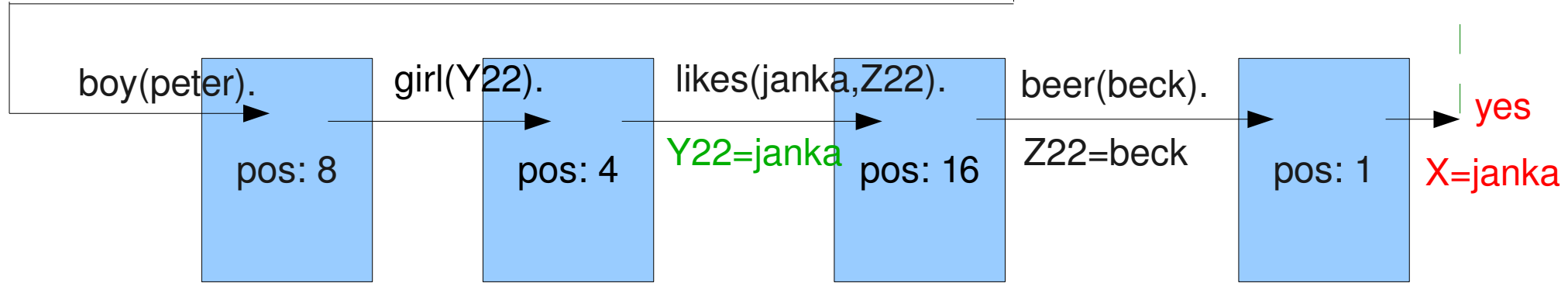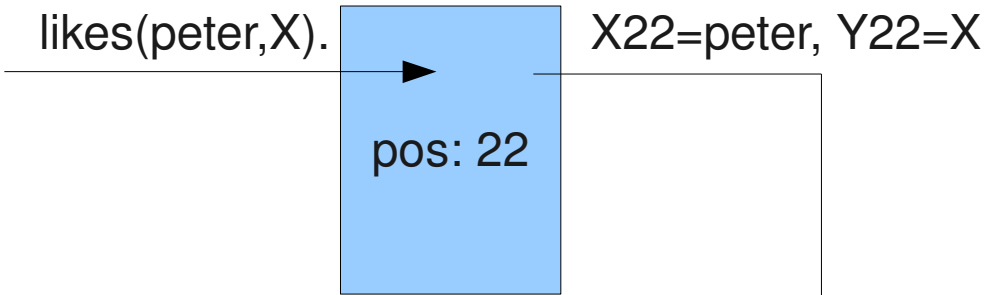22. likes(X,Y) :- boy(X), girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   pos: 22   X22=peter, Y22=X

?- likes(peter,X).

boy(peter).   pos: 8   girl(Y22).   pos: 4   likes(janka,Z22).   pos: 16   beer(beck).   pos: 1   yes

Y22=janka   Z22=beck   X=janka

```
1.   beer(beck).
2.   beer(urquell).
3.   girl(eva).
4.   girl(janka).
5.   girl(anna).
6.   boy(tomas).
7.    boy(zeno).
8.   boy(peter).
9.   dog(rex).
10.  cat(reggy).
11.  likes(eva,urquell).
12.  likes(eva,tomas).
13.  likes(eva,janka).
14.  likes(janka,peter).
15.  likes(janka,eva).
16.  likes(janka,beck).
17.  likes(anna,zeno).
18.  likes(anna,reggy).
19.  likes(peter,rex).
20.  likes(peter,beck).
21.  likes(peter,urquell).
22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).
```
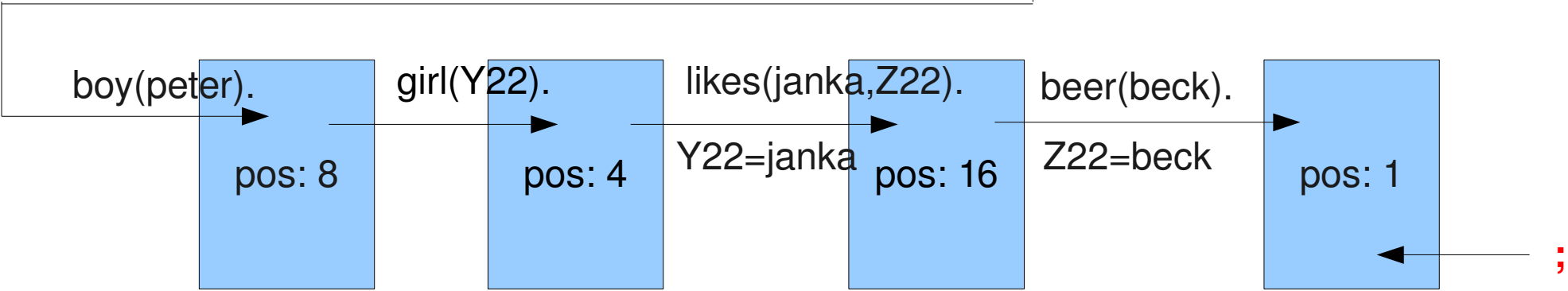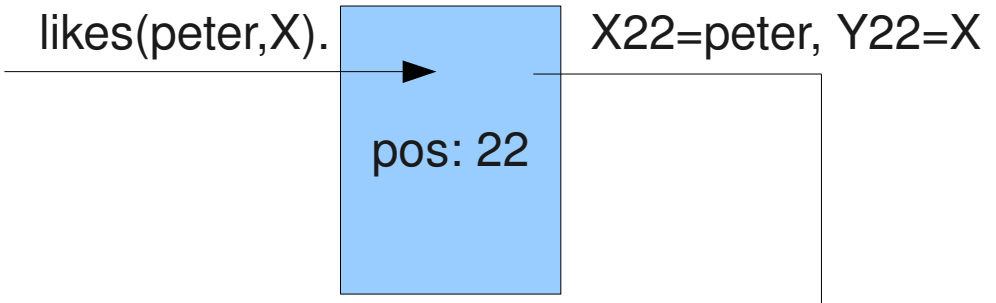
likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(janka,Z22).   beer(beck).

pos: 8   pos: 4   Y22=janka   pos: 16   Z22=beck   pos: 1

;

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
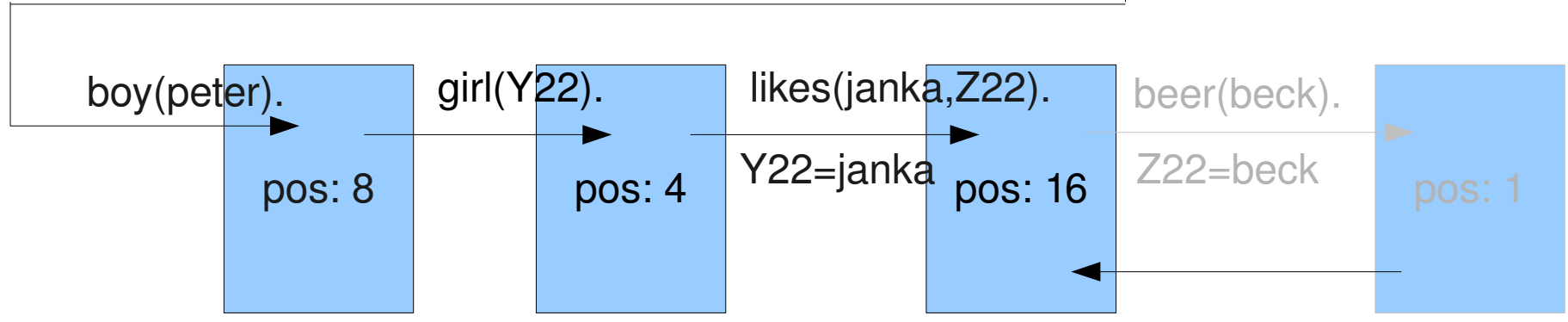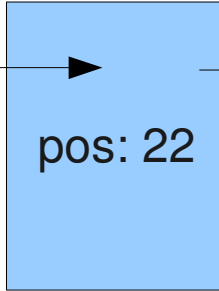22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(janka,Z22).   beer(beck).

pos: 8   pos: 4   Y22=janka   pos: 16   Z22=beck   pos: 1

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
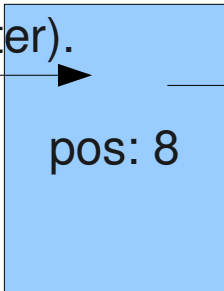   girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X
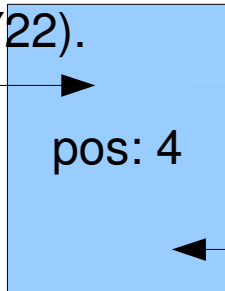
pos: 22

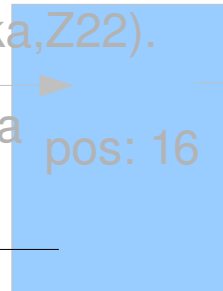?- likes(peter,X).

boy(peter).   girl(Y22).   likes(janka,Z22).   beer(beck).

Y22=janka   Z22=beck

pos: 8   pos: 4   pos: 16   pos: 1

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(anna,Z22).   beer(beck).
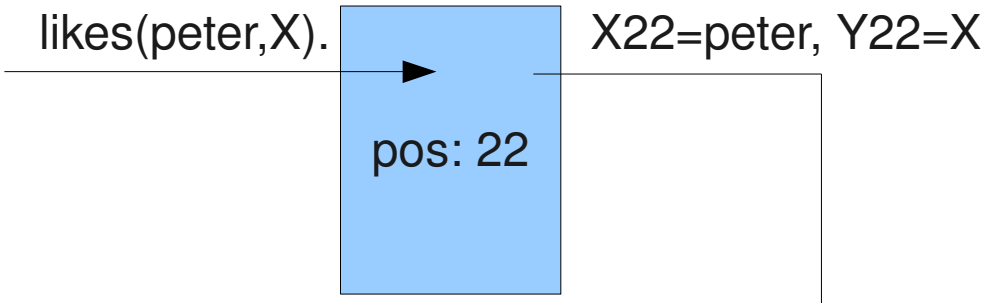
pos: 8   pos: 5   Y22=anna   pos: 0   Z22=beck   pos: 1
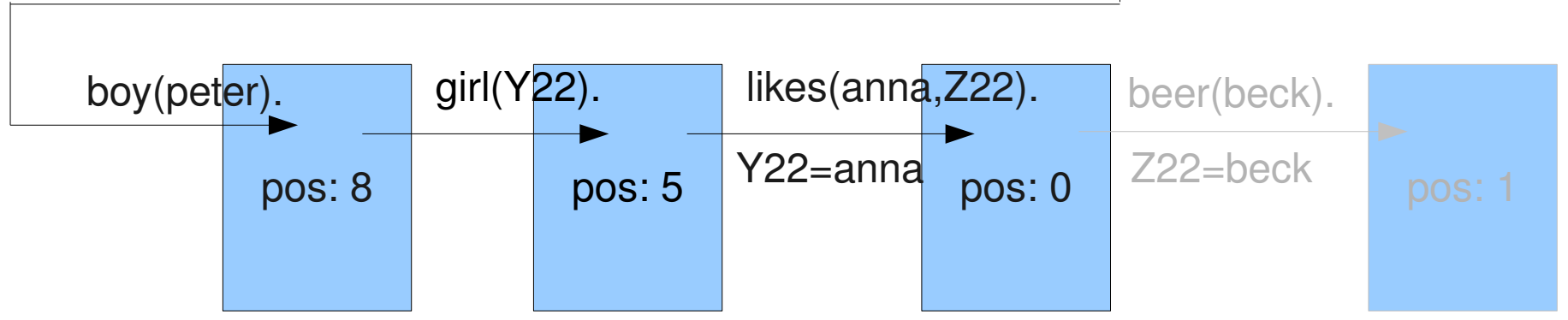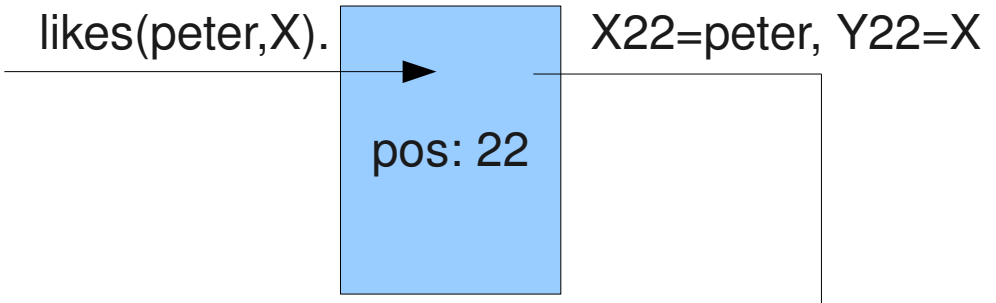
1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
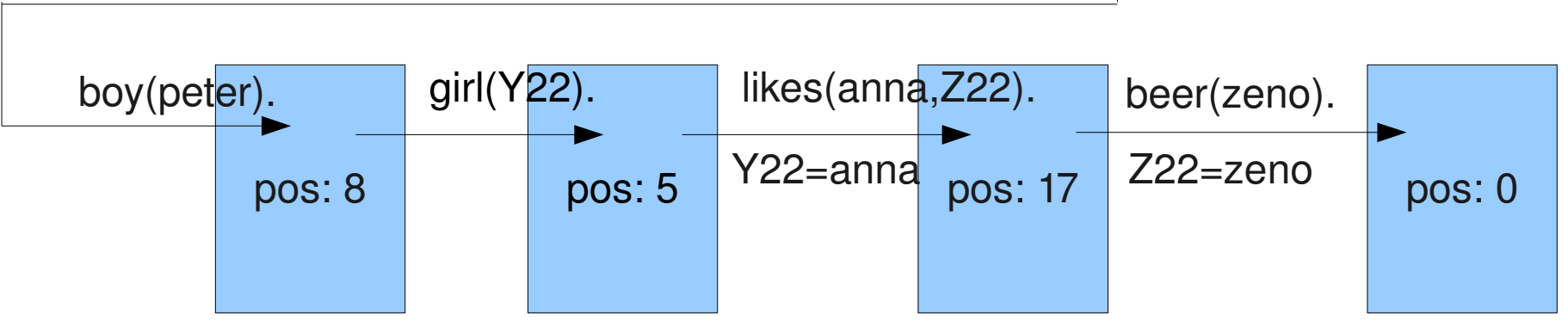22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(anna,Z22).   beer(zeno).

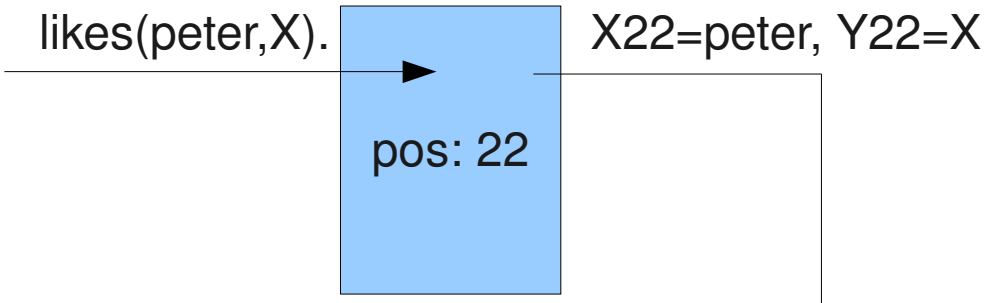pos: 8   pos: 5   Y22=anna   pos: 17   Z22=zeno   pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
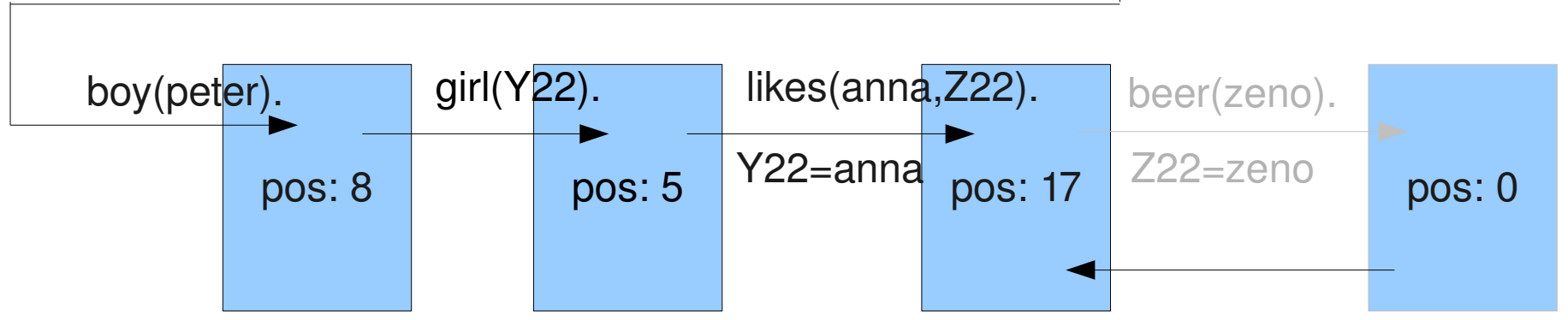22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(anna,Z22).   beer(zeno).

pos: 8   pos: 5   Y22=anna   pos: 17   Z22=zeno   pos: 0
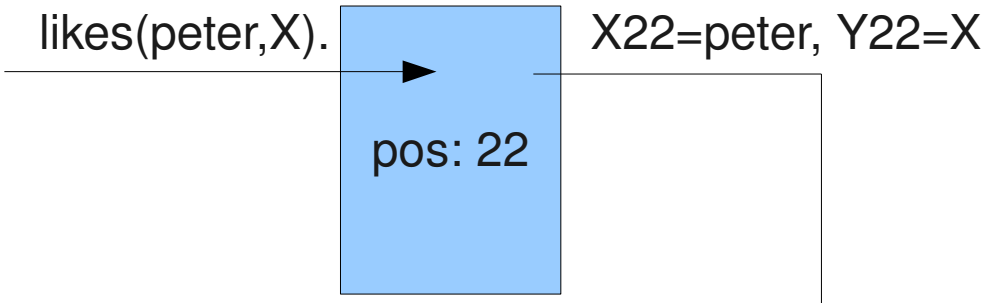
```
1.   beer(beck).
2.   beer(urquell).
3.   girl(eva).
4.   girl(janka).
5.   girl(anna).
6.   boy(tomas).
7.   boy(zeno).
8.   boy(peter).
9.   dog(rex).
10.  cat(reggy).
11.  likes(eva,urquell).
12.  likes(eva,tomas).
13.  likes(eva,janka).
14.  likes(janka,peter).
15.  likes(janka,eva).
16.  likes(janka,beck).
17.  likes(anna,zeno).
18.  likes(anna,reggy).
19.  likes(peter,rex).
20.  likes(peter,beck).
21.  likes(peter,urquell).
22.  likes(X,Y) :- boy(X),
     girl(Y), likes(Y,Z), beer(Z).
```
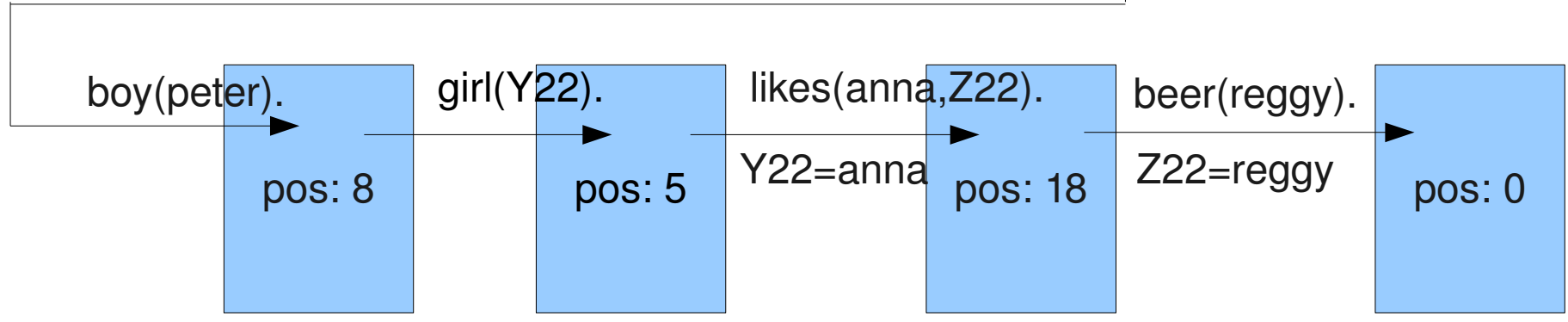
likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(anna,Z22).   beer(reggy).

pos: 8   pos: 5   Y22=anna   pos: 18   Z22=reggy   pos: 0
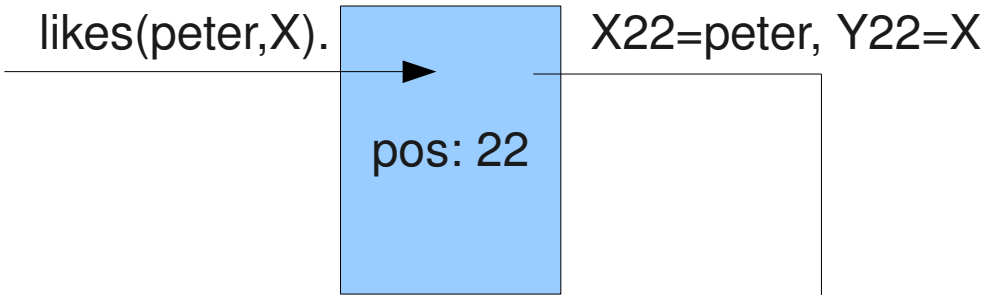
1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
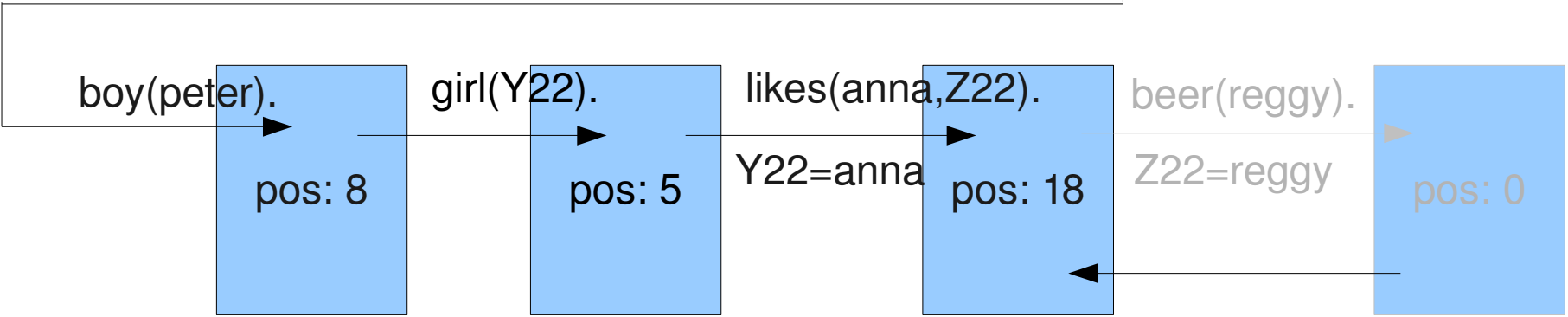   girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(anna,Z22).   beer(reggy).

pos: 8   pos: 5   Y22=anna   pos: 18   Z22=reggy   pos: 0
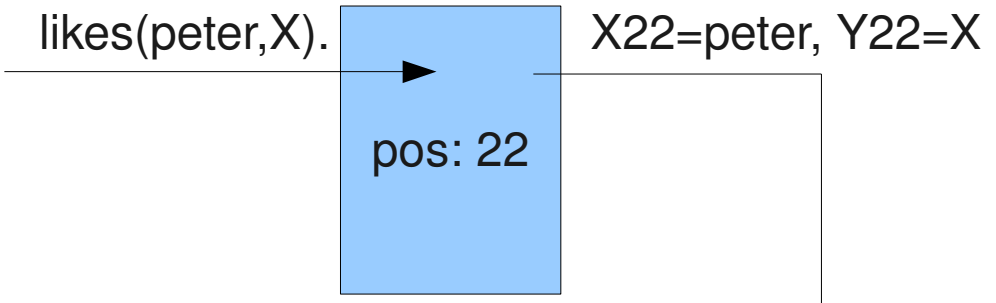
1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
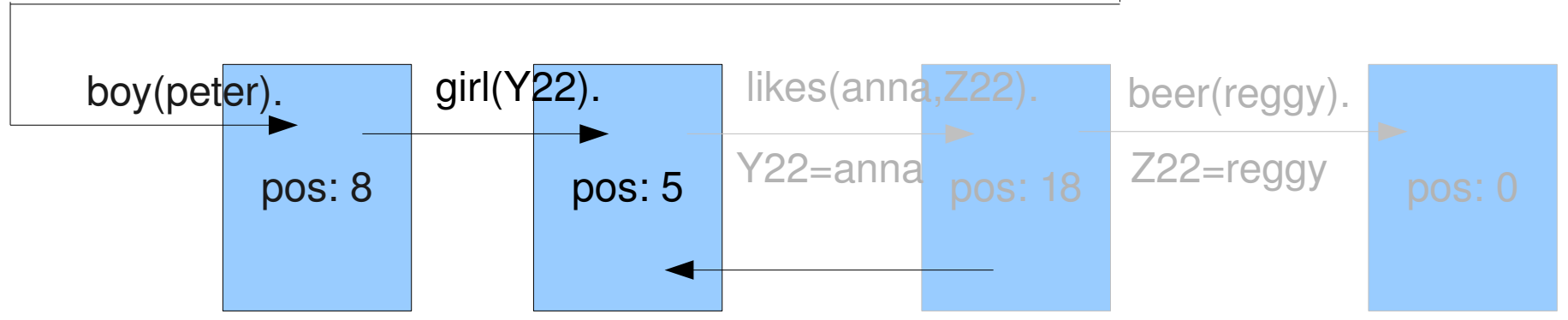   girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   pos: 22   X22=peter, Y22=X

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(anna,Z22).   beer(reggy).

pos: 8   pos: 5   Y22=anna   pos: 18   Z22=reggy   pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
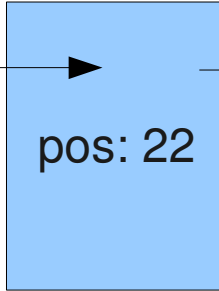22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).

likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(anna,Z22).   beer(reggy).

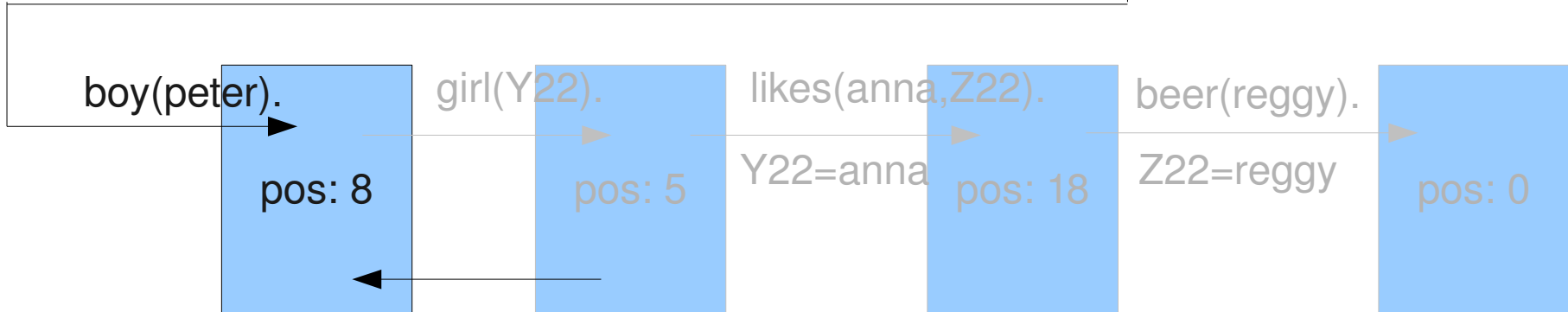pos: 8   pos: 5   Y22=anna   pos: 18   Z22=reggy   pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
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15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
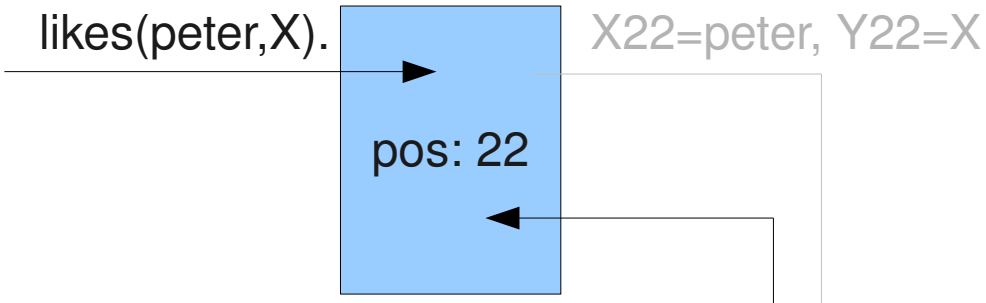   girl(Y), likes(Y,Z), beer(Z).
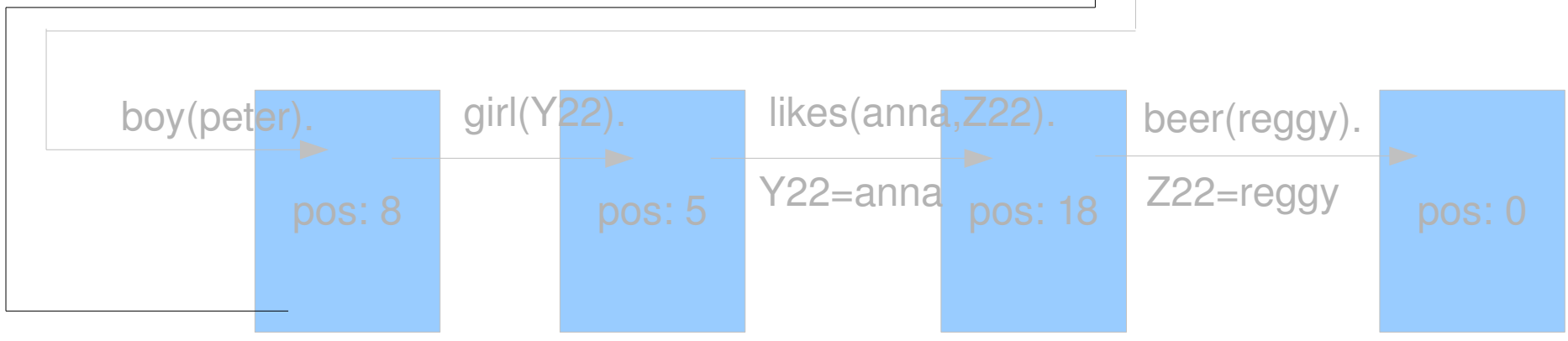
likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(anna,Z22).   beer(reggy).

                           Y22=anna   Z22=reggy

pos: 8   pos: 5   pos: 18   pos: 0

```
1.  beer(beck).
2.  beer(urquell).
3.  girl(eva).
4.  girl(janka).
5.  girl(anna).
6.  boy(tomas).
7.  boy(zeno).
8.  boy(peter).
9.  dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
16. likes(janka,beck).
17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).
```

likes(peter,X).

X22=peter, Y22=X

pos: 22

no

?- likes(peter,X).

boy(peter).

pos: 8

girl(Y22).

pos: 5

likes(anna,Z22).

Y22=anna

pos: 18

beer(reggy).

Z22=reggy

pos: 0

1. beer(beck).
2. beer(urquell).
3. girl(eva).
4. girl(janka).
5. girl(anna).
6. boy(tomas).
7. boy(zeno).
8. boy(peter).
9. dog(rex).
10. cat(reggy).
11. likes(eva,urquell).
12. likes(eva,tomas).
13. likes(eva,janka).
14. likes(janka,peter).
15. likes(janka,eva).
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17. likes(anna,zeno).
18. likes(anna,reggy).
19. likes(peter,rex).
20. likes(peter,beck).
21. likes(peter,urquell).
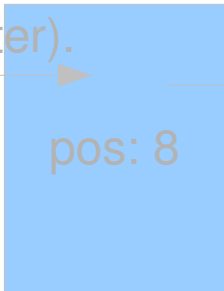22. likes(X,Y) :- boy(X),
    girl(Y), likes(Y,Z), beer(Z).

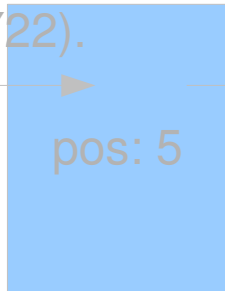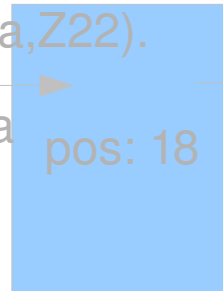likes(peter,X).   X22=peter, Y22=X

pos: 22

?- likes(peter,X).

boy(peter).   girl(Y22).   likes(anna,Z22).   beer(reggy).

                                 Y22=anna   Z22=reggy

pos: 8   pos: 5   pos: 18   pos: 0

Negation vs. closed world

- "not"

  - not (Goal) is true if Goal is not true (i.e. not **derivable** from DB)

  likes(peter, jana). likes(fred,jana). likes(joe,jana). likes(peter,mary). likes(fred,mary). likes(joe,mary). likes(peter,paula). liikes(joe,paula). likes(peter,beer). likes(fred,beer). girl(jana). girl(paula). girl(mary). boy(peter). boy(fred). boy(joe).

- who is not liked by fred? who doesn't likes beer? who doesn't likes any girl? who likes all the girls?

Negation vs. closed world

?- not likes(fred,**W**ho).

?- no

?- not likes(Who, beer).

no

?-boy(B), girl(G), not likes(B,G).

no

4. question needs Universal quantifier but Prolog knows just Existential...

- why are such answers? how to solve it?

Trick is in smart asking ;-)

?- girl(G), not likes(fred,G).

G = paula → enter
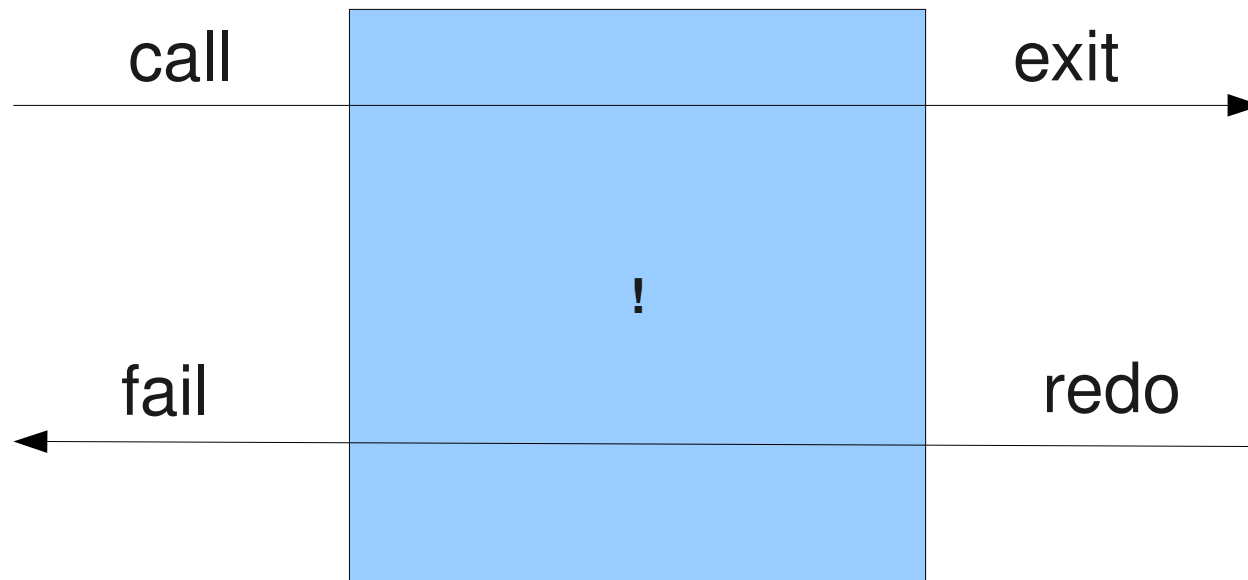
no

?- (boy(Who); girl(Who)), not likes(Who, beer).

?- boy(B), not ((girl(G), likes(B,G))).

- (( )) for right interpretation of "," as a conjunction and not as a parameter separator

?- boy(B), not((girl(G), not likes(B,G))).

The Cut !

- sounds like a title for a new thriller...

- predicate which exits immediately when call and fails immediately when redo

The Cut !

```prolog
x(t).
x(tt).
a(t).
b(t).
b(ttt).
c(w).
c(ww).
d(v).
e(t).
f(t).

hc(X) :- x(X), nc(X), y(X).

nc(X) :- a(X), b(X), !, c(Y), d(Y).
nc(X) :- e(X), f(X).
```

```
[trace]  ?- hc(X).
   Call: (7) hc(_G335) ? creep
   Call: (8) x(_G335) ? creep
   Exit: (8) x(t) ? creep
   Call: (8) nc(t) ? creep
   Call: (9) a(t) ? creep
   Exit: (9) a(t) ? creep
   Call: (9) b(t) ? creep
   Exit: (9) b(t) ? creep
   Call: (9) c(_L212) ? creep
   Exit: (9) c(w) ? creep
   Call: (9) d(w) ? creep
   Fail: (9) d(w) ? creep
   Redo: (9) c(_L212) ? creep
   Exit: (9) c(ww) ? creep
   Call: (9) d(ww) ? creep
   Fail: (9) d(ww) ? creep
   Fail: (8) nc(t) ? creep
   Redo: (8) x(_G335) ? creep
   Exit: (8) x(tt) ? creep
   Call: (8) nc(tt) ? creep
   Call: (9) a(tt) ? creep
   Fail: (9) a(tt) ? creep
   Redo: (8) nc(tt) ? creep
   Call: (9) e(tt) ? creep
   Fail: (9) e(tt) ? creep
   Fail: (7) hc(_G335) ? creep
false.
```

- moreover, when fails all the predicates on her left are unable to redo

  - the parent goal (or the head of the rule) fails immediately, too

The Cut !

```
bigger(X,Y,Z) :- X < Y, Z is Y.
bigger(X,Y,Z) :- X > Y, Z is X.
```
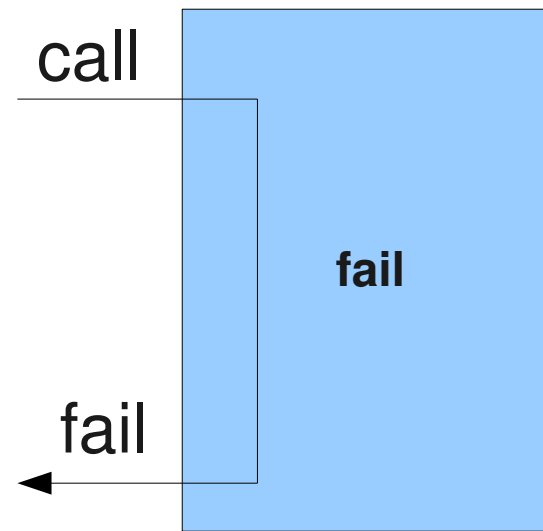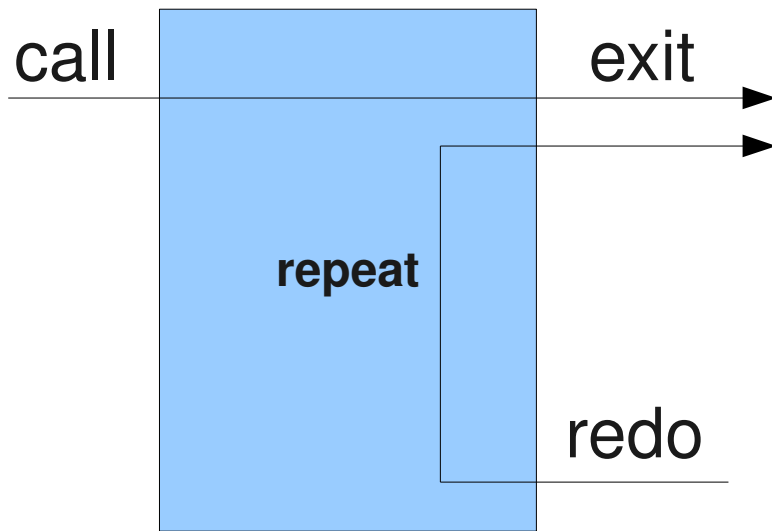
- Green cut (no impact on semantics)

```
bigger1(X,Y,Y) :- X < Y, !.
bigger1(X,Y,X).
```

- Red cut (influences the semantics)

  - the real horror for computer scientists

```
bigger2(X,Y,Y) :- !, X < Y.
bigger2(X,Y,X).
```
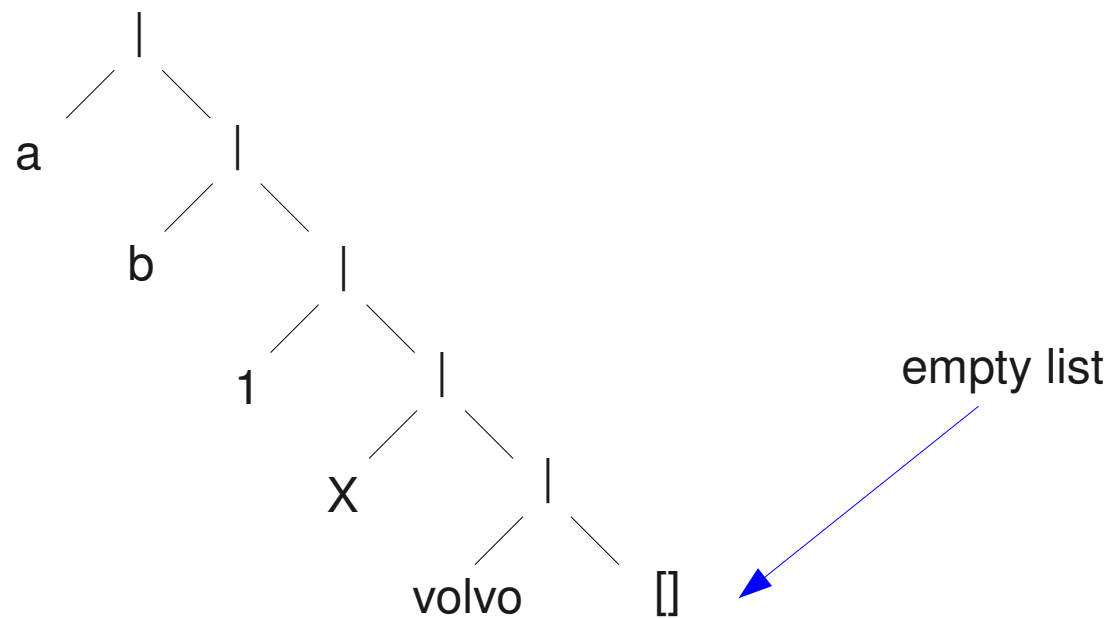
Other interesting built-in predicates


```
:- dynamic(man/1).

man(tomas). man(zeno).

write_men :- man(M), write(M), nl, fail.
write_men :- write('No other man in the database').
read_men :- repeat, write('Name: '), read(M), man(M), !.
add_man_first(M) :- asserta(man(M)).
add_man_last(M) :- assertz(man(M)).
delete_man(M) :- retract(man(M)).
```

changes the DB just implicitly

Lists

- [a,b,1,X,volvo]

  - in fact, it is a binary structure [Head | Body]

  - [a | [b | [1 | [X | [volvo | []]]]]]

    – direct access ONLY from the Head

    – can be represented as a tree

```
          |
         / \
        a   |
           / \
          b   |
             / \
            1   |
               / \
              X   |
                 / \
              volvo []          empty list
```

Lists

results(p1,[1,1,3,2,5,3]).
results(p2,[2,2,3,1,1,4]).

member(X,[X|_]).
member(X,[H|B]) :- member(X,B).

append([],L,L).
append([H|B1],L2,[H|B]) :- append(B1,L2,B).

reverse([],[]).
reverse([H|B],L) :- reverse(B,X), append(X,[H],L).

sum([],0).
sum([H|B],S) :- sum(B,S1), S is S1 + H.

compute_res1(Prog,Res) :- results(Prog,Results), sum(Results,Res).

References

- Lloyd, J. W. 1984 Foundations of Logic Programming. Springer-Verlag New York, Inc.

- this presentation was inspired by the following study materials:

  - Július Csontó: Umelá inteligencia v príkladoch. Elfa s.r.o, Košice, Slovakia, 1995.