Logic Programming

Lecture 5:
Nonlogical features, continued:
negation-as-failure, collecting solutions, assert/retract

Outline for today

- Nonlogical features continued
  - Negation-as-failure
  - Collecting solutions (findall, setof, bagof)
  - Assert/retract

Negation-as-failure

- We can use cut to define *negation-as-failure*
  - recall Tutorial #1

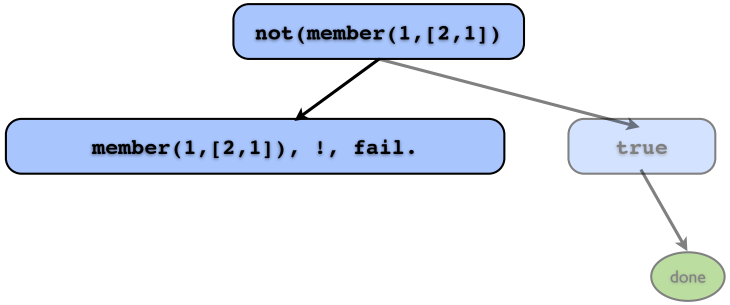
```
not(G) :- G, !, fail ; true.
```

- This tries to solve G
  - If successful, fail
  - Otherwise, succeed

How it works

```
not(member(1,[2,1]))
```

How it works



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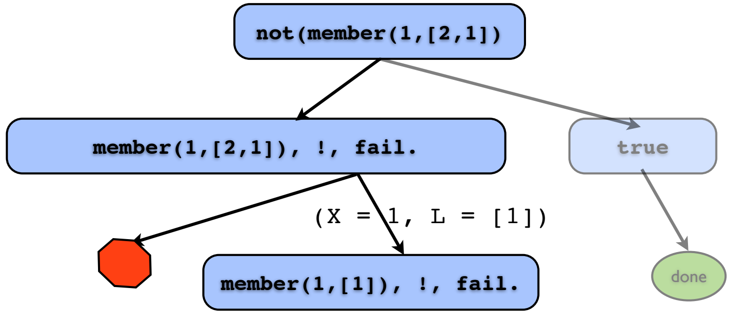

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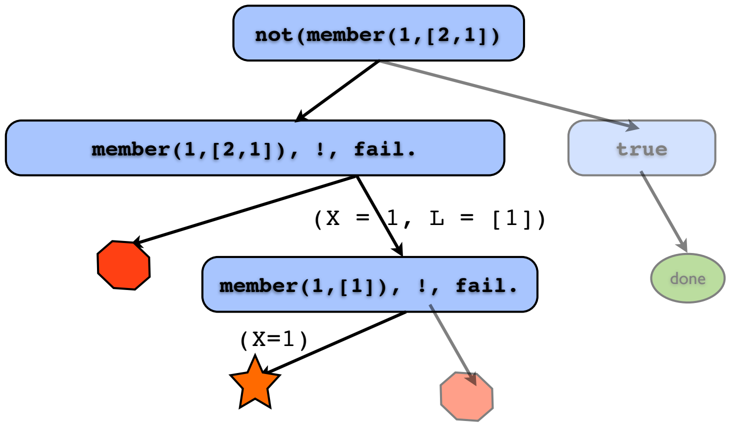

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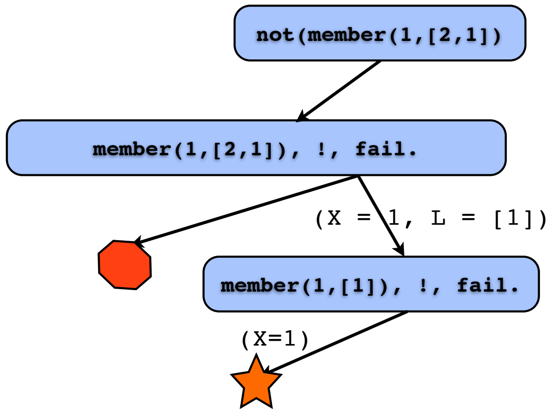

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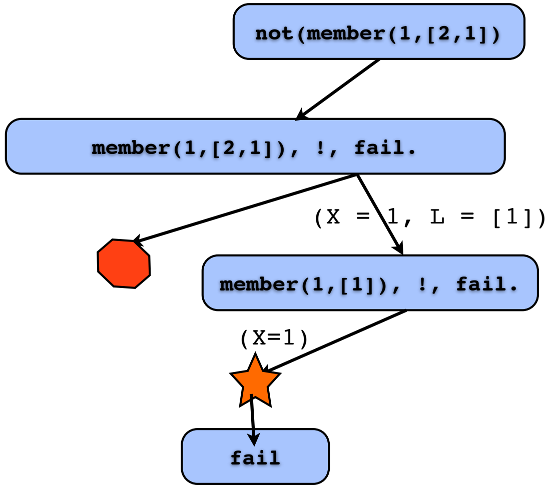

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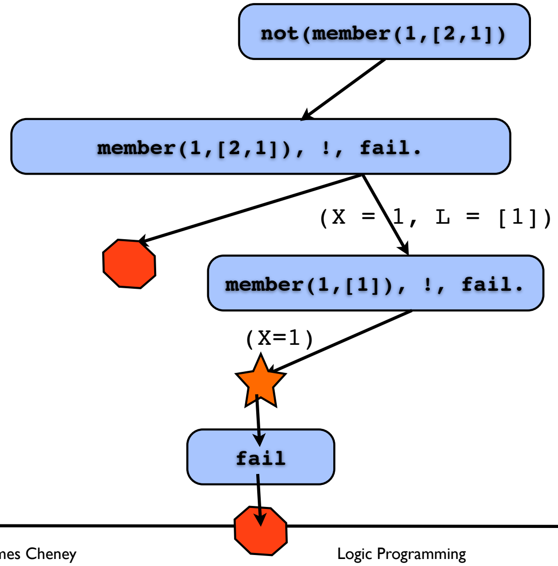

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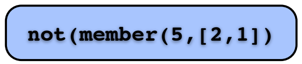

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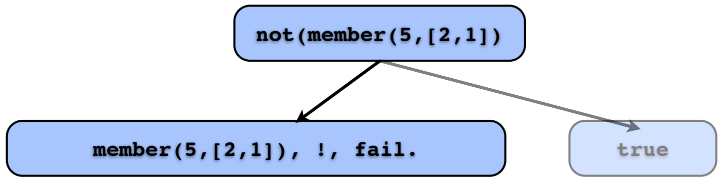

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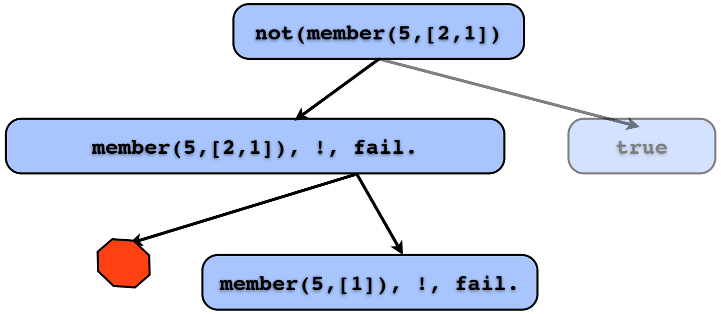

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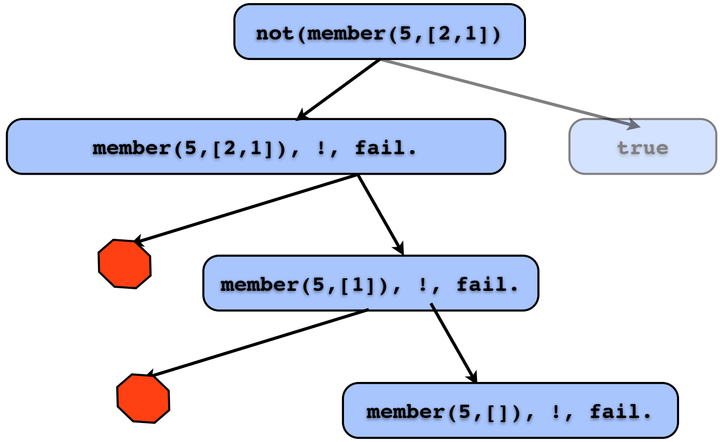

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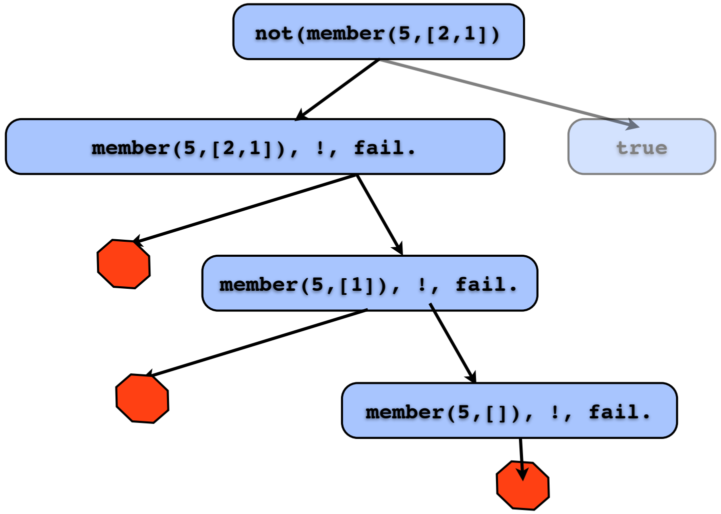

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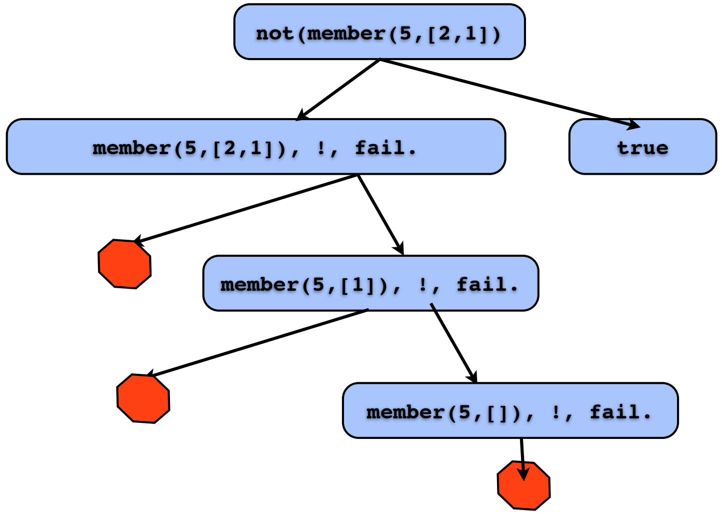

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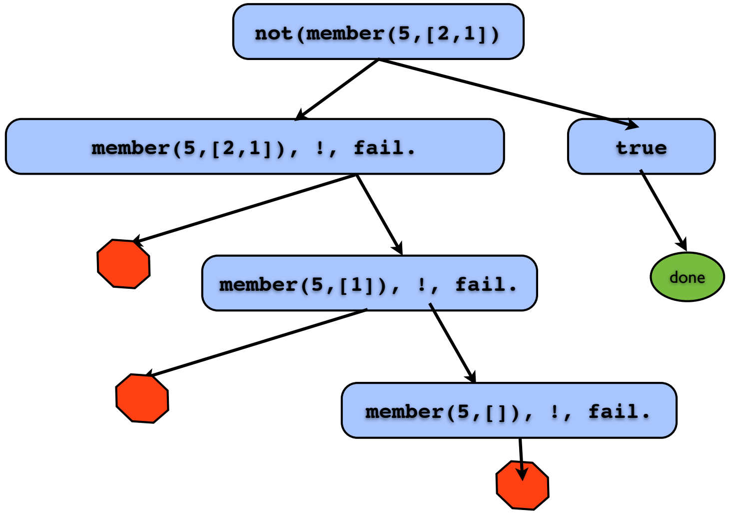
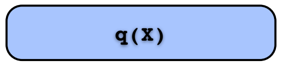


Negation-as-failure

- Built-in syntax: `\+(G)`
- Example: people that are not teachers

```
q(X) :- person(X),
        \+(teaches(X,Y)).
```


Behavior

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  person(b).
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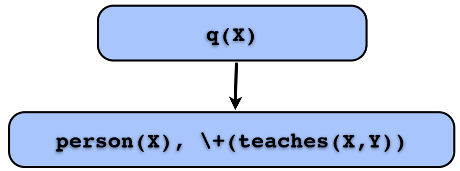


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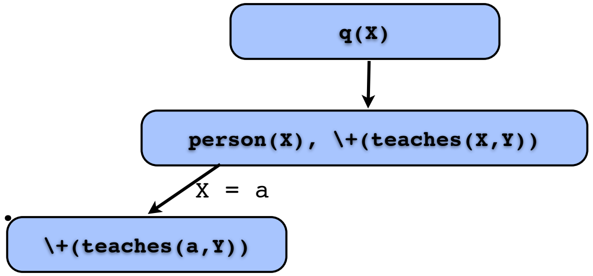


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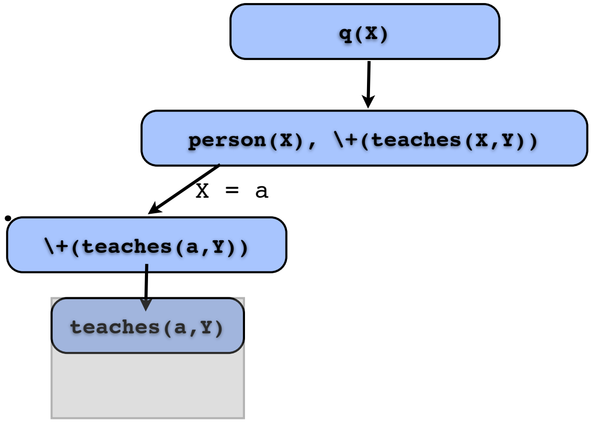


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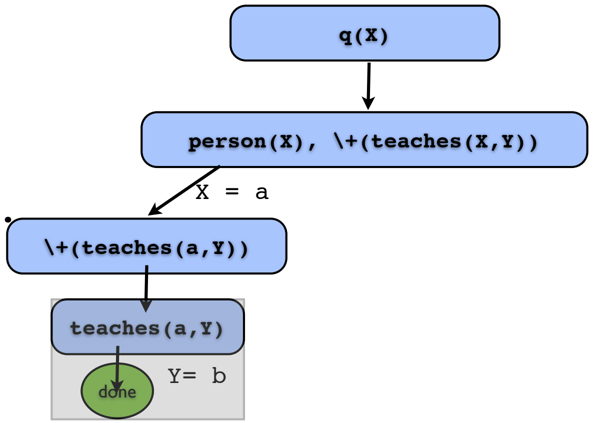


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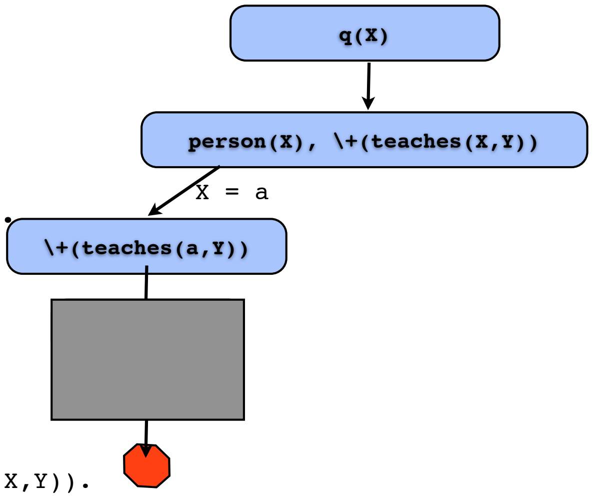


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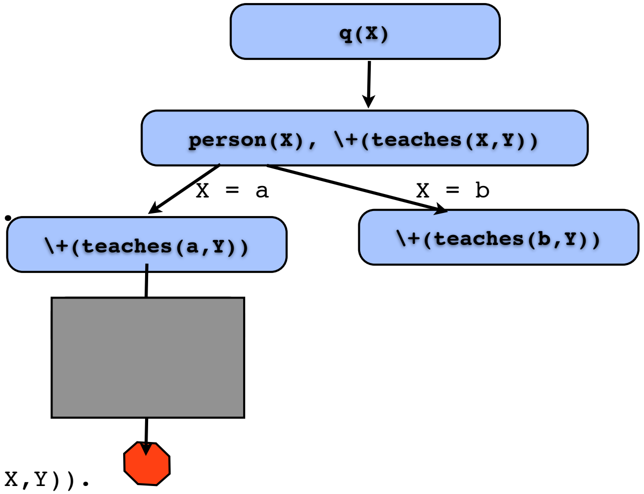

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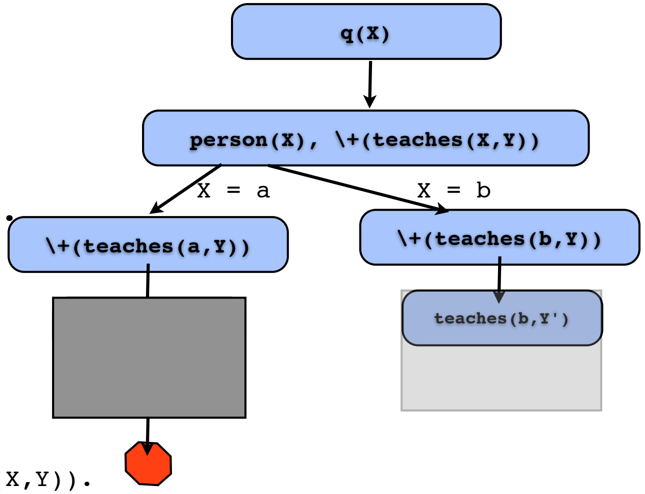

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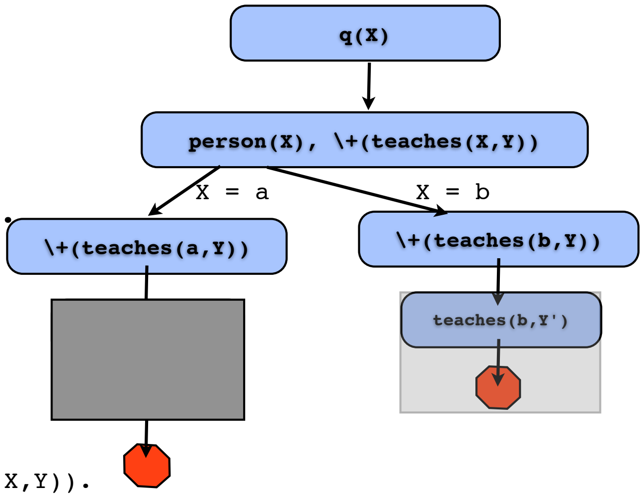

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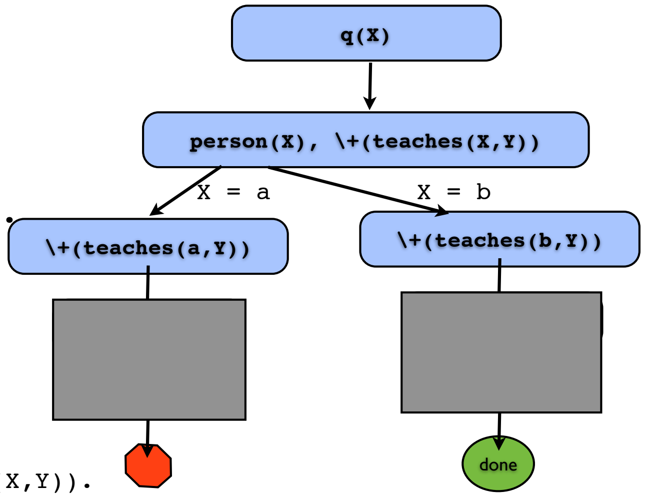

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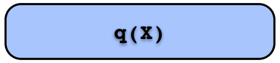


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```
q(X) :- \+(teaches(X,Y)),
        person(X).
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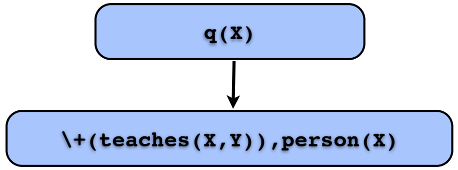


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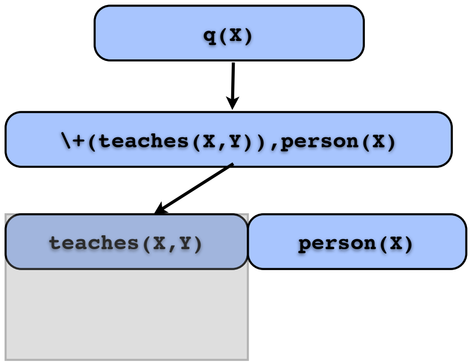


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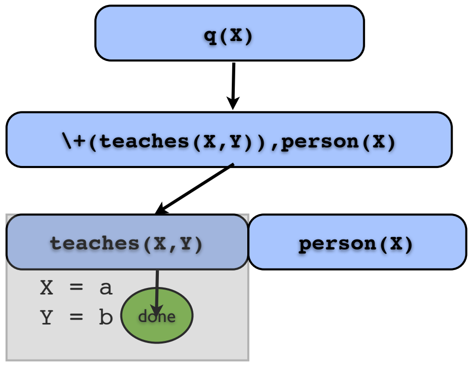


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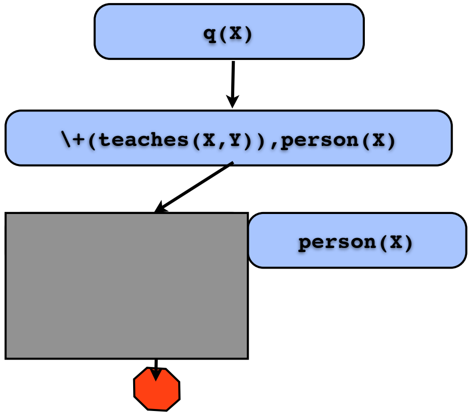


```
q(X) :- \+(teaches(X,Y)),
        person(X).
```


Searching a graph

```
find(X,X).
find(X,Z) :- edge(X,Y),
             find(Y,Z).
```

- **Problem:** Loops easily if graph is cyclic:

```
edge(a,b).
edge(b,c).
edge(c,a).
```


Searching a graph (2)

- To avoid looping:
  1. Remember where we have been
  2. Stop if we try to visit a node we've already seen.

```
find2(X,X,_).
find2(X,Z,P) :- \+(member(X,P)),
                edge(X,Y),
                find2(Y,Z,[X|P]).
```

Note: Needs mode `(+,?,+)`.

Safe use of negation-as-failure

- As with cut, negation-as-failure can have non-logical behavior
  - **Goal order matters**
- `\+(X = Y), X = a, Y = b`
  - fails
- `X = a, Y = b, \+(X = Y)`
  - succeeds

Safe use of negation as failure (2)

- Can read `\+(G)` as "not `G`" only if `G` is **ground when we start solving it**
- Any free variables "existentially quantified"
  - `\+(1=2) == 1 ≠ 2`
  - `\+(X=Y) == ∃ X, Y. X ≠ Y`
- General heuristic: delay negation after other goals to make negated goals ground

Collecting solutions

- We'd like to find **all solutions**
  - collected as an explicit list
- `alist(bart,X)` = "`X` lists the ancestors of `bart`"
- Can't do this in pure Prolog
  - cut doesn't help
- Technically possible (but painful) using assert/ retract

Collecting solutions, declaratively

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- Built-in predicate to do same thing:
  - `findall/3` - list of solutions

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```
?- findall(Y,ancestor(Y,bart),L).
L = [homer,marge,abe,jacqueline]
```


Collecting solutions, declaratively

- Built-in predicate to do same thing:
  - `findall/3` - list of solutions

```
?- findall(Y,ancestor(Y,bart),L).
L = [homer,marge,abe,jacqueline]
?- findall((X,Y),ancestor(X,Y),L).
L = [(abe,homer),(homer,bart),
(homer,lisa),(homer,maggie)|...]
```


`findall/3`

- Usage:

```
findall(?X, ?Goal, ?List)
```

- On success, `List` is list of all substitutions for `X` that make `Goal` succeed.
- Goal can have free variables!
  - `X` treated as "bound" in `G`
- (`X` could also be a "pattern"...)

`bagof/3`

bagof/3

- `bagof/3` - list of solutions

```
?- bagof(Y,ancestor(Y,bart),L).
L = [homer,marge,abe,jacqueline]
```


bagof/3

- `bagof/3` - list of solutions

```
?- bagof(Y,ancestor(Y,bart),L).
L = [homer,marge,abe,jacqueline]
```

- different instantiations of free variables lead to different answers

```
| ?- bagof(Y,ancestor(Y,X),L).
L = [homer,marge,abe,jacqueline],
X = bart ? ;
```


bagof/3

- `bagof/3` - list of solutions

```
?- bagof(Y,ancestor(Y,bart),L).
L = [homer,marge,abe,jacqueline]
```

- different instantiations of free variables lead to different answers

```
| ?- bagof(Y,ancestor(Y,X),L).
L = [homer,marge,abe,jacqueline],
X = bart ? ;
L = [abe],
X = homer ? ...
```


Quantification

- In goal part of a `bagof/3`, we can write:

  `X^G(X)`

  to "hide" (existentially quantify) `X`.

```
| ?- bagof(Y,X^ancestor(X,Y),L).
L = [homer,bart,lisa,maggie,rod,
    todd,ralph,bart,lisa,maggie|...]
```

  - This also works for `findall/3`, but is redundant

setof/3

setof/3

- Similar to bagof/3, but **sorts** and **eliminates duplicates**

```
| ?- bagof(Y,X^ancestor(X,Y),L).
L = [homer,bart,lisa,maggie,rod,
     todd,ralph,bart,lisa,maggie|...]
```


setof/3

- Similar to bagof/3, but **sorts** and **eliminates duplicates**

```
| ?- bagof(Y,X^ancestor(X,Y),L).
L = [homer,bart,lisa,maggie,rod,
     todd,ralph,bart,lisa,maggie|...]
| ?- setof(Y,X^ancestor(X,Y),L).
L = [bart,homer,lisa,maggie,marge,
     patty,ralph,rod,selma,todd]
```


Assert and retract

- So far we have **statically** defined facts and rules
  - usually in separate file
- We can also **dynamically** add and remove clauses

assert/1

assert/1

```
?- assert(p).
yes
```


assert/1

```
?- assert(p).
yes
?- p.
yes
```


assert/1

```
?- assert(p).
yes
?- p.
yes
?- assert(q(1)).
yes
```

assert/1

```
?- assert(p).
yes
?- p.
yes
?- assert(q(1)).
yes
?- q(X).
X = 1.
```


Searching a graph using assert/1

```
:- dynamic v/1.
find3(X,X).
find3(X,Z) :- \+(v(X)),
              assert(v(X)),
              edge(X,Y),
              find3(Y,Z).
```

- Mode (+,?).
- **Problem: Need to clean up afterwards.**

Fibonacci

```
fib(0,0).
fib(1,1).
fib(N,K) :- N >= 2,
            M is N-1, fib(M,F),
            P is M-1, fib(P,G),
            K is F+G.
```


Fibonacci, memoized

```
:- dynamic memofib/2.
fib(N,K) :- memofib(N,K), !.
...
fib(N,K) :- N >= 2,
            M is N-1, fib(M,F),
            P is M-1, fib(P,G),
            K is F+G,
            assert(memofib(N,K)).
```

`asserta/1` and `assertz/1`

- Provide limited control over clause order.
- `asserta/1` adds to beginning of KB
- `assertz/1` adds to end of KB

`retract/1`

```
?- retract(p).
yes
?- p.
no
?- retract(q(1)).
yes
?- q(X).
no
```


Warning

- If you assert or retract an unused predicate interactively, Sicstus Prolog **assumes** it is dynamic
- But if you want to use assert/retract in programs, you should **declare** as dynamic in the program
  - for example:

    ```
    :- dynamic memofig/2.
    ```
- Generally wise to avoid assert/retract without good reason

Collecting solutions using assert, retract

- Here's a way to calculate list of all ancestors using assert/retract:

```
:- dynamic p/1.
alist(X,L) :- assert(p([])),
              collect(X);
              p(L),
              retract(p(L)).
collect(X) :- ancestor(Y,X),
              retract(p(L)),
              assert(p([Y|L])),
              fail.
```

- **Kind of a hack! (also need to clean up afterwards).**

- Next time: Definite Clause Grammars
- Further reading: LPN, ch. 10 & 11