# Logic Programming (PLP 11, CTM 9.3)

## Prolog Imperative Control Flow: Backtracking, Cut, Fail, Not Lists, Append

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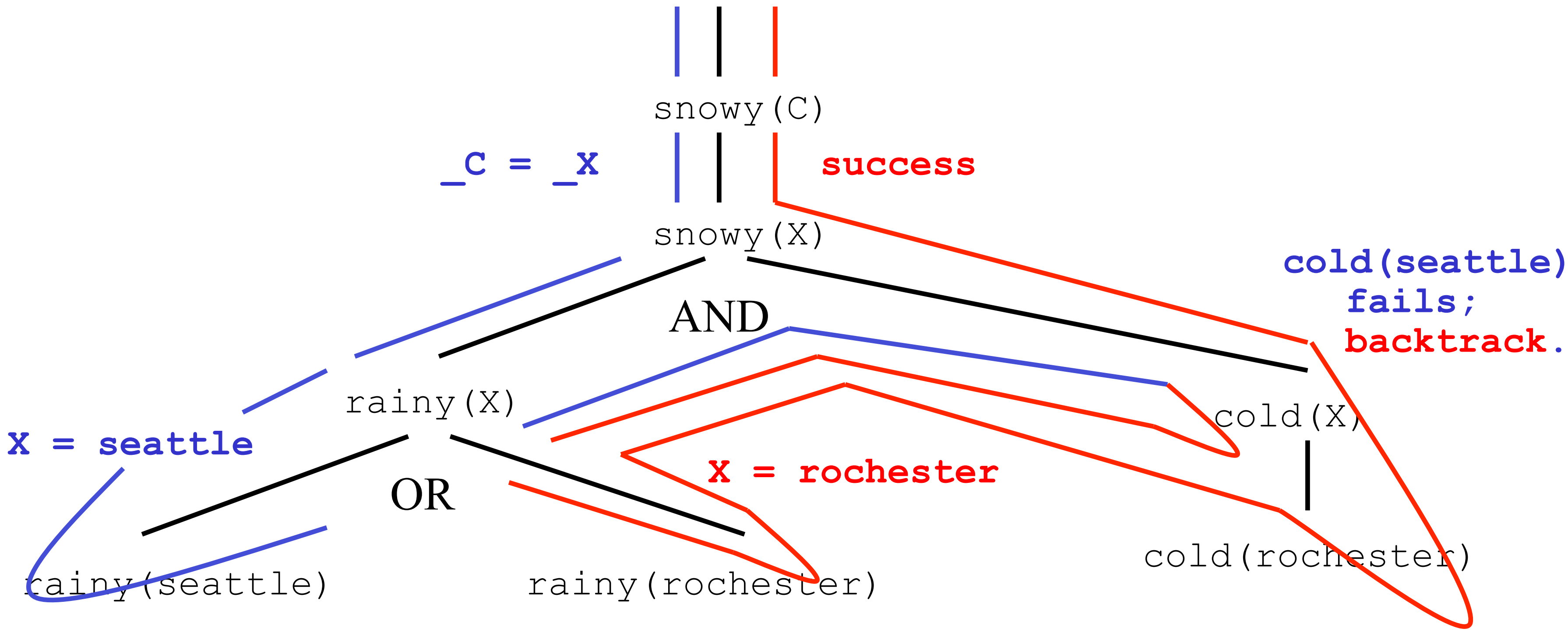
# Backtracking

- *Forward chaining* goes from axioms forward into goals.
- *Backward chaining* starts from goals and works backwards to prove them with existing axioms.

# Backtracking example

```
rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), cold(X).
```



# Imperative Control Flow

- Programmer has *explicit control* on backtracking process.

**`Cut (!)`**

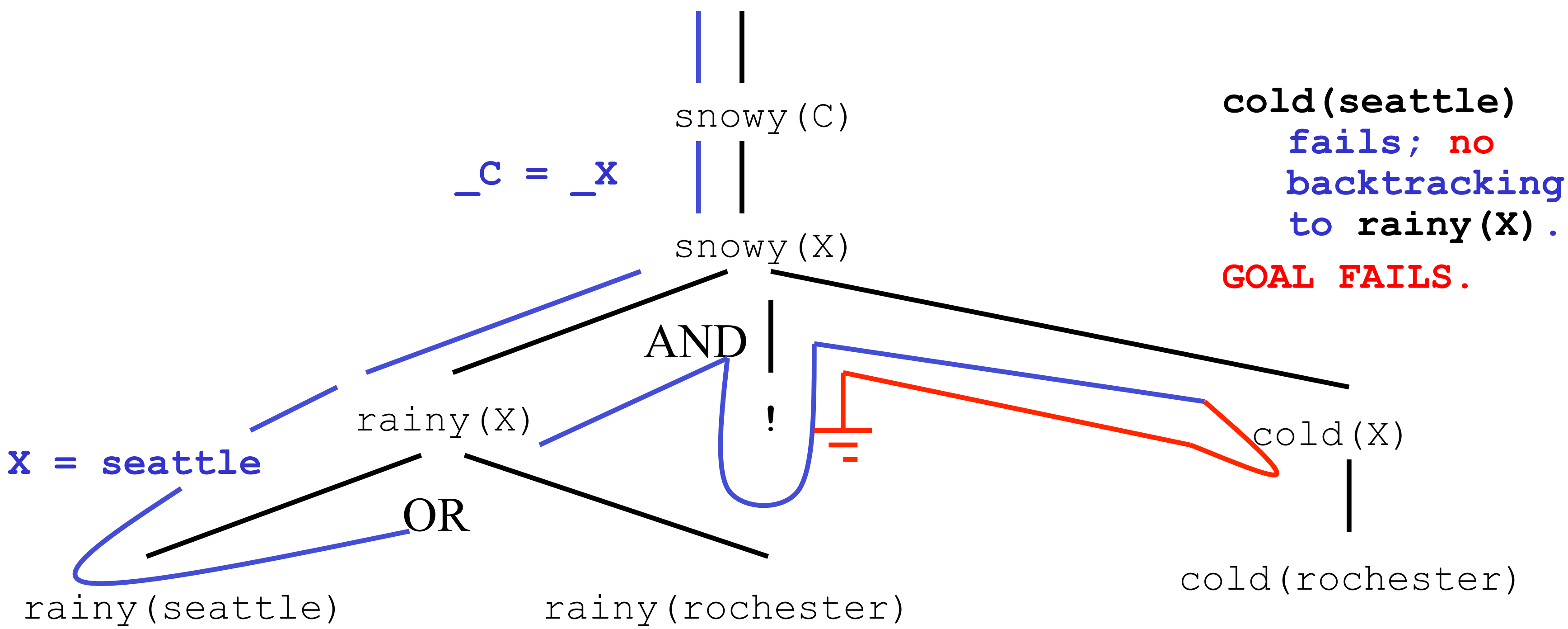
- As a goal it succeeds, but with a side effect:
  - Commits interpreter to choices made since unifying parent goal with left-hand side of current rule. Choices include variable unifications and rule to satisfy the parent goal.

# Cut (!) Example

```
rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), !, cold(X).
```

# Cut (!) Example

```
rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), !, cold(X).
```

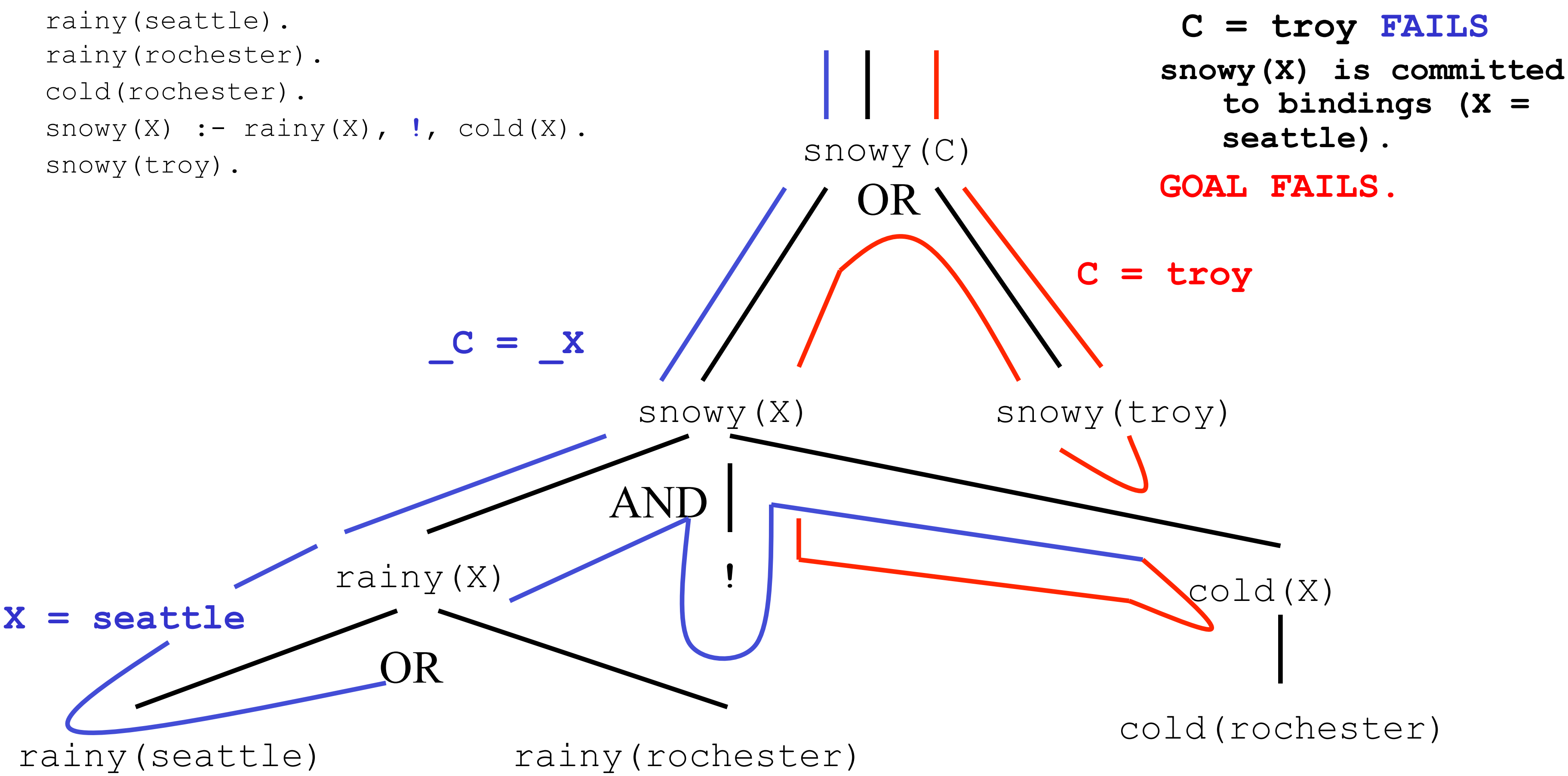


# Cut (!) Example 2

```
rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), !, cold(X).
snowy(troy).
```

# Cut (!) Example 2

```
rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), !, cold(X).
snowy(troy).
```



# Cut (!) Example 3

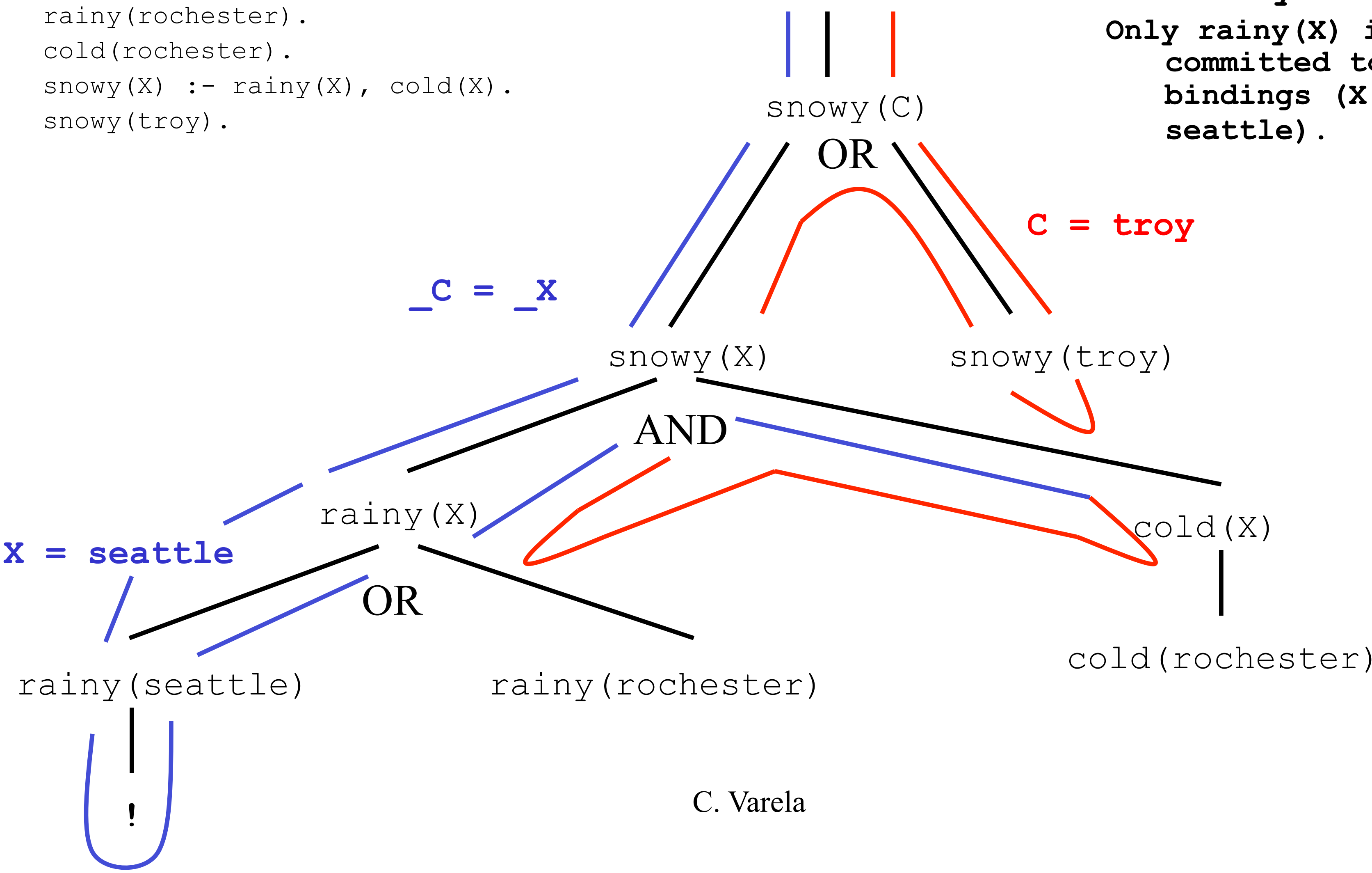
```
rainy(seattle) :- !.
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), cold(X).
snowy(troy).
```

# Cut (!) Example 3

```
rainy(seattle) :- !.
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), cold(X).
snowy(troy).
```

**C = troy SUCCEEDS**

**Only rainy(X) is committed to bindings (X = seattle).**

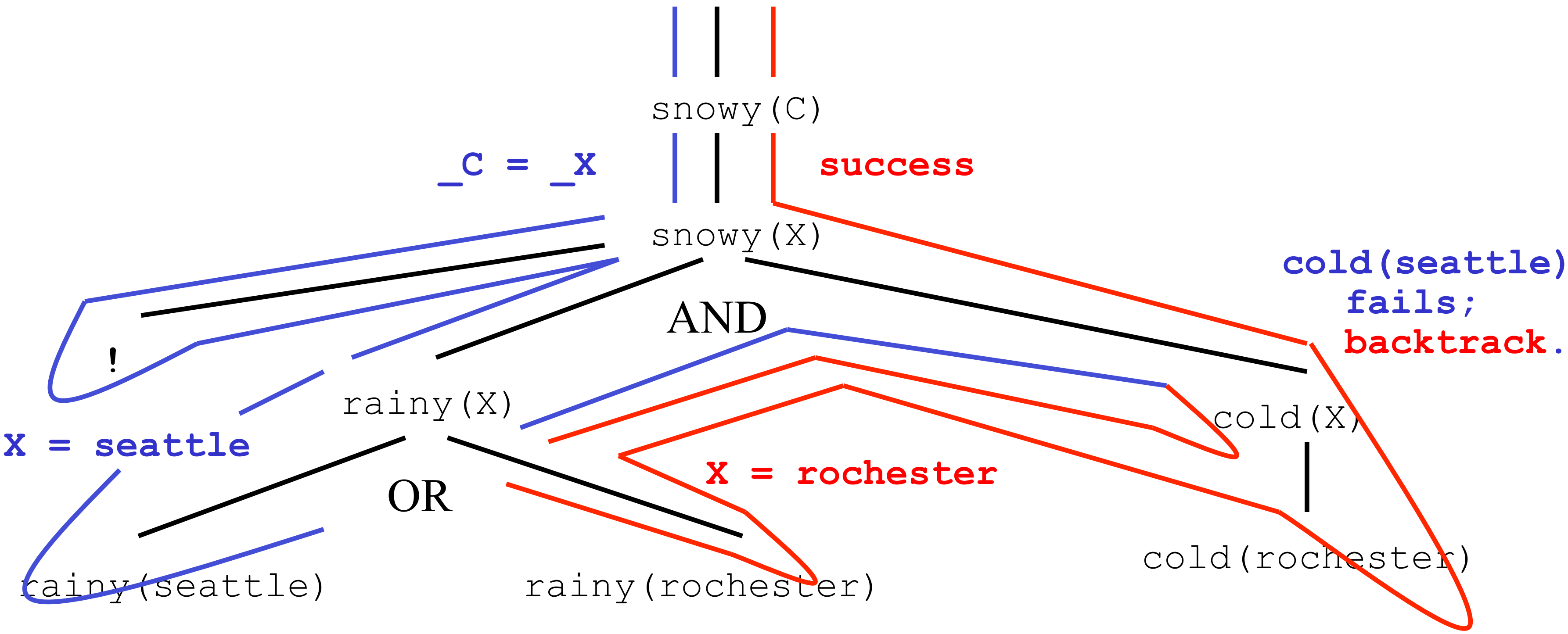


# Cut (!) Example 4

```
rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- !, rainy(X), cold(X).
```

# Cut (!) Example 4

```
rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- !, rainy(X), cold(X).
```

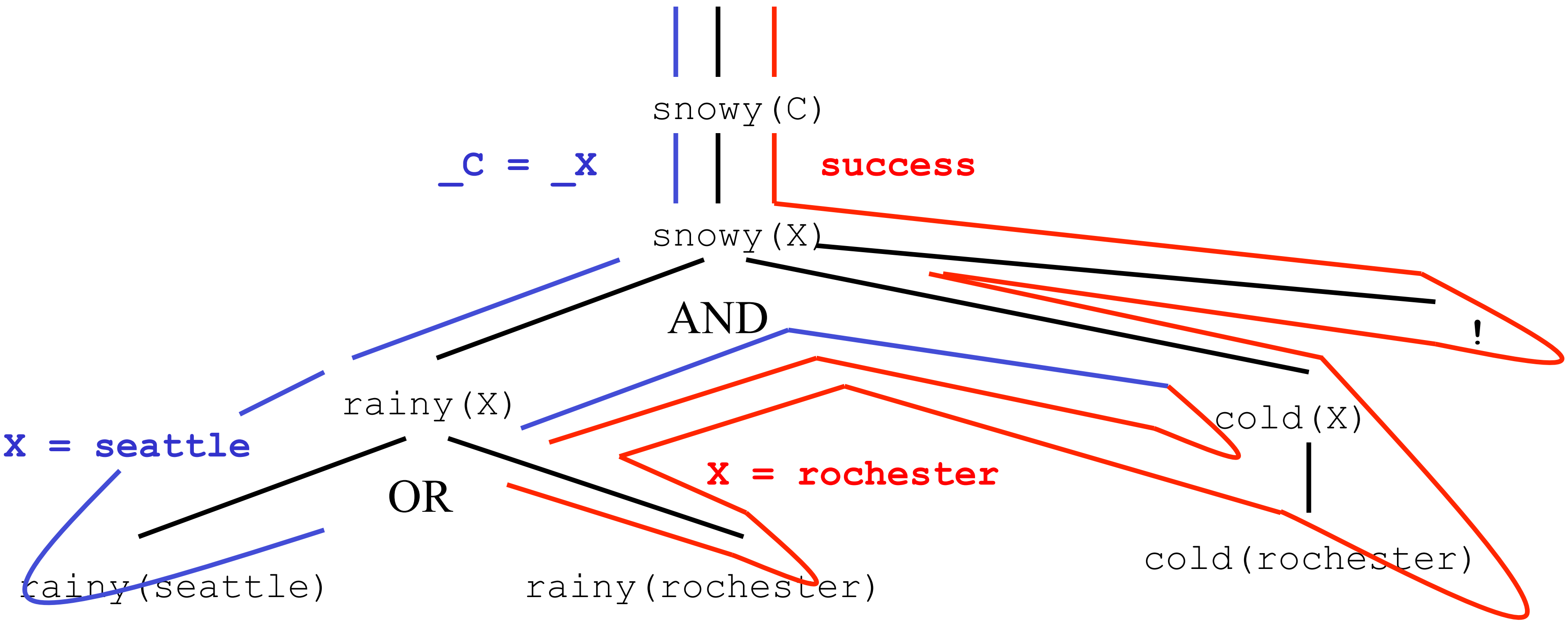


# Cut (!) Example 5

```
rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), cold(X), !.
```

# Cut (!) Example 5

```
rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), cold(X), !.
```



# First-Class Terms

| | |
|---|---|
| `call(P)` | Invoke predicate as a goal. |
| `assert(P)` | Adds predicate to database. |
| `retract(P)` | Removes predicate from database. |
| `functor(T,F,A)` | Succeeds if `T` is a *term* with *functor* `F` and *arity* `A`. |
| `findall(F,P,L)` | Returns a list L with elements F satisfying predicate P |

# `not P` is not `¬P`

- In Prolog, the database of facts and rules includes a list of things assumed to be **true**.
- It does not include anything assumed to be **false**.
- Unless our database contains everything that is **true** (the *closed-world assumption*), the goal `not P` (or `\+ P` in some Prolog implementations) can succeed simply because our current knowledge is insufficient to prove `P`.

# More `not` vs ¬

```
?- snowy(X).
X = rochester
?- not(snowy(X)).
no
```

Prolog does not reply: **`X = seattle.`**

The meaning of `not(snowy(X))` is:

$\neg\exists X\ [snowy(X)]$

rather than:

$\exists X\ [\neg snowy(X)]$

# Fail, true, repeat

| | |
|---|---|
| `fail` | Fails current goal. |
| `true` | Always succeeds. |
| `repeat` | Always succeeds, provides infinite choice points. |

```
repeat.
repeat :- repeat.
```

# `not` Semantics

```
not(P) :- call(P), !, fail.
not(P).
```

Definition of `not` in terms of failure (`fail`) means that variable bindings are lost whenever `not` succeeds, e.g.:

```
?- not(not(snowy(X))).
X=_G147
```

# Conditionals and Loops

```
statement :- condition, !, then.
statement :- else.


natural(1).
natural(N) :-  natural(M), N is M+1.
my_loop(N) :-  N>0,
               natural(I),
               write(I), nl,
               I=N,
               !, fail.
```

Also called *generate-and-test*.

# Prolog lists

- `[a,b,c]` is syntactic sugar for:

```
.(a,.(b,.(c, [])))
```

where `[]` is the empty list, and `.` is a built-in cons-like functor.

- `[a,b,c]` can also be expressed as:

`[a | [b,c]]` , or
`[a, b | [c]]` , or
`[a,b,c | []]`

# Prolog lists append example

```
append([],L,L).
append([H|T], A, [H|L]) :- append(T,A,L).
```

# Oz lists (Review)

- `[a b c]` is syntactic sugar for:

  `'|'(a '|'(b '|'(c nil)))`

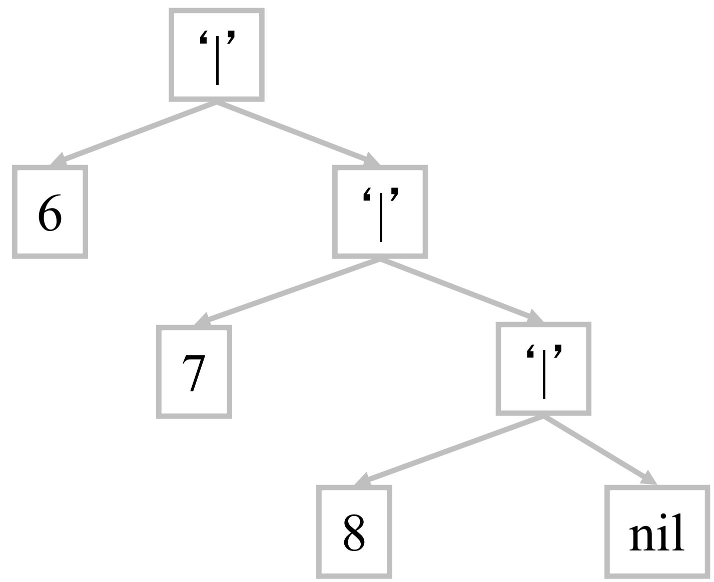
  where `nil` is the empty list, and `'|'` is the tuple's functor.

- A list has two components: a head, and a tail

  declare L = [6 7 8]

  L.1 gives 6

  L.2 give [7 8]



# Oz lists append example

```
proc {Append Xs Ys Zs}
  choice Xs = nil Zs = Ys
  [] X Xr Zr in
    Xs=X|Xr
    Zs=X|Zr
    {Append Xr Ys Zr}
  end
end
```

```
% new search query
proc {P S}
     X Y in
     {Append X Y [1 2 3]} S=X#Y
end

% new search engine
E = {New Search.object script(P)}

% calculate and display one at a time
{Browse {E next($)}}

% calculate all
{Browse {Search.base.all P}}
```

# Exercises

79. What do the following Prolog queries do?

```
?- repeat.

?- repeat, true.

?- repeat, fail.
```

    Corroborate your thinking with a Prolog interpreter.

80. Draw the search tree for the query "`not(not(snowy(City)))`". When are variables bound/unbound in the search/backtracking process?
81. PLP Exercise 11.7 (pg 571).
82. Write the students example in Oz (including the has_taken(Student, Course) inference).