61A Lecture 33

Friday, November 16

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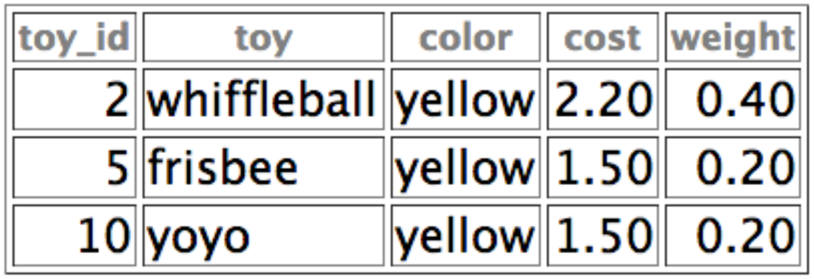

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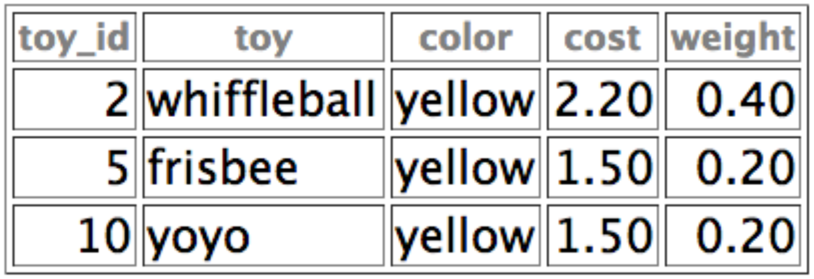

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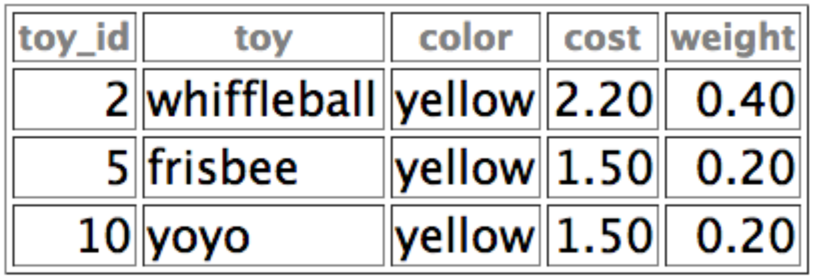

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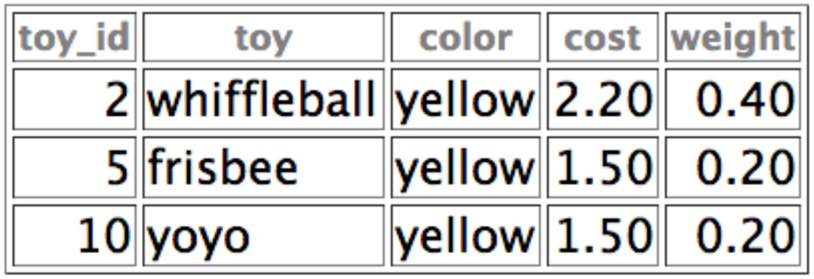

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The language interpreter is free to compute the result in any way it deems appropriate.

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They typically trade off data scale for problem complexity.

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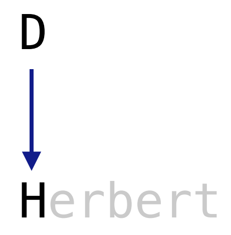

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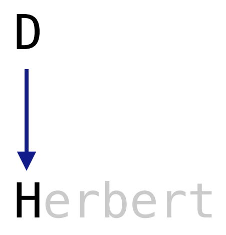

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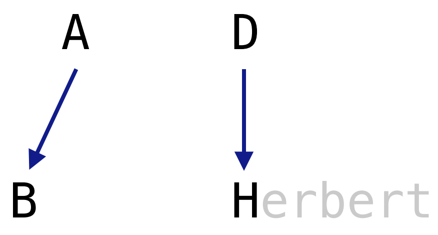

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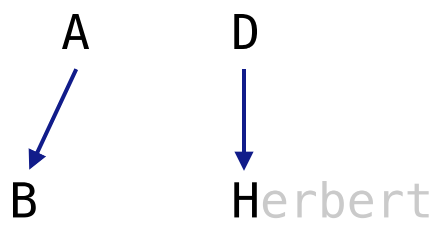

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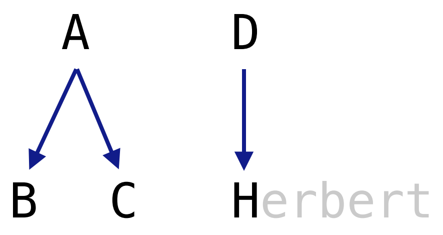

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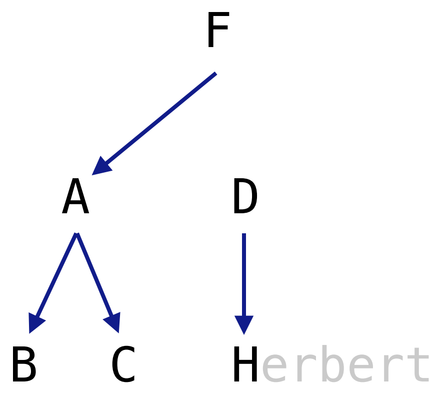

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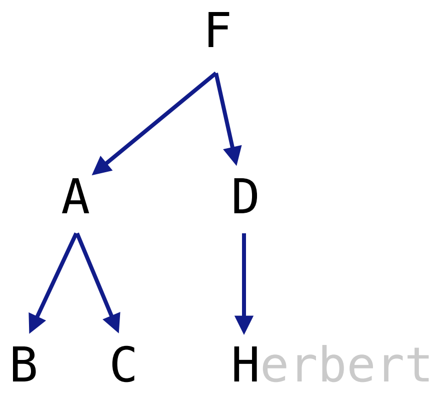

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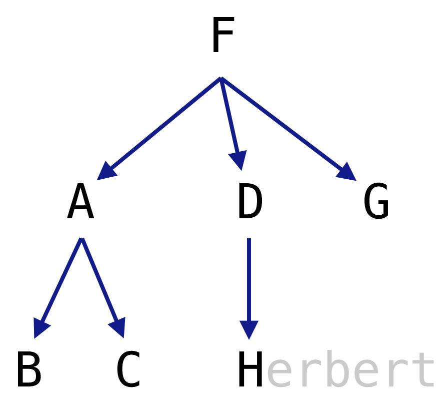

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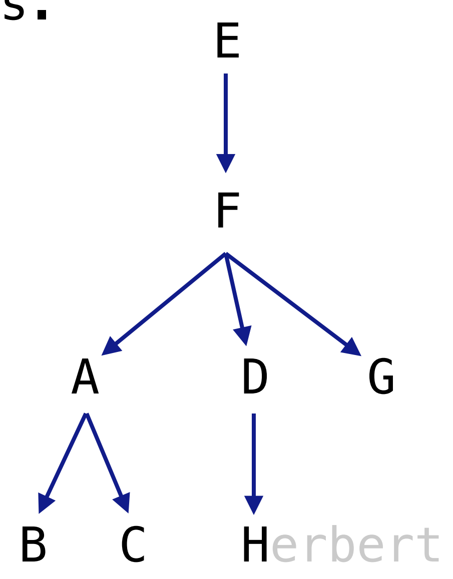

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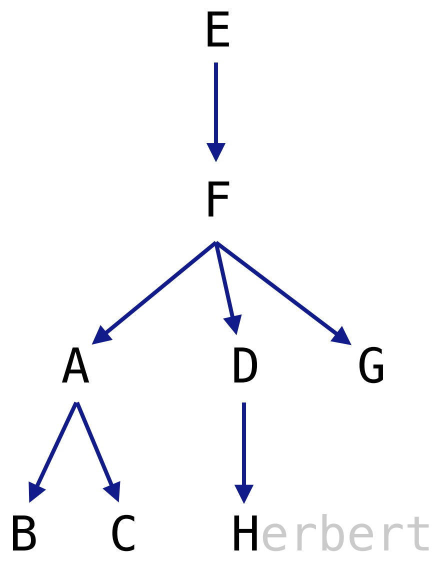
$$\begin{tikzcd}
 & E \arrow[d] & \\
 & F \arrow[dl] \arrow[d] \arrow[dr] & \\
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B & C \quad H\text{erbert} &
\end{tikzcd}$$

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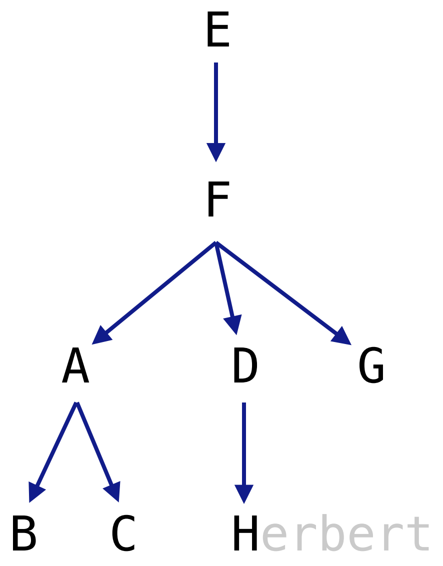
A query contains one or more relations. The *Logic* interpreter returns whether (& how) they are all simultaneously satisfied.



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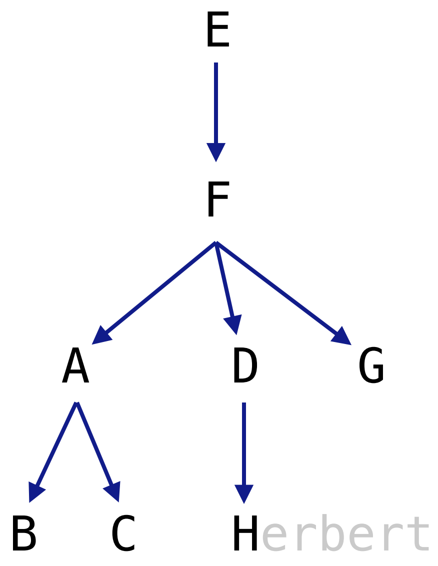

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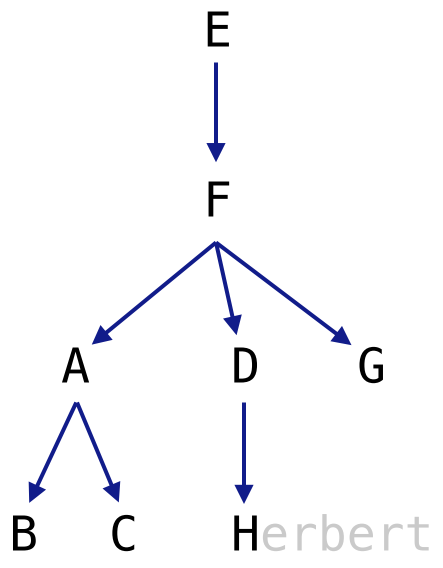

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logic> (query (parent abraham ?child))
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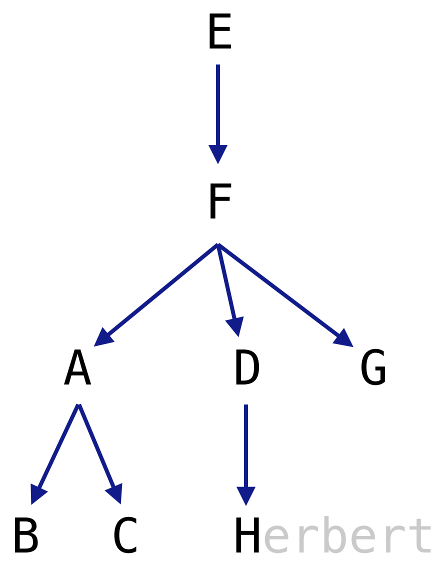

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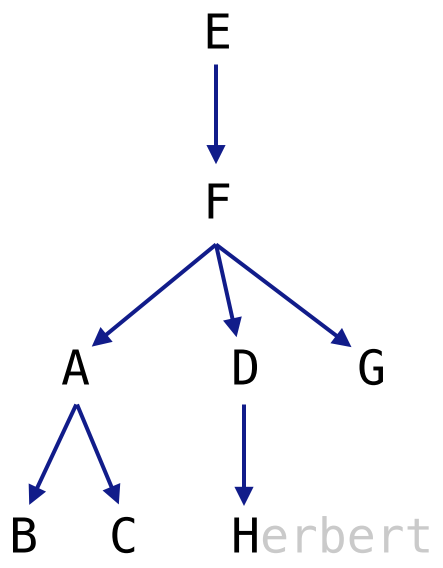

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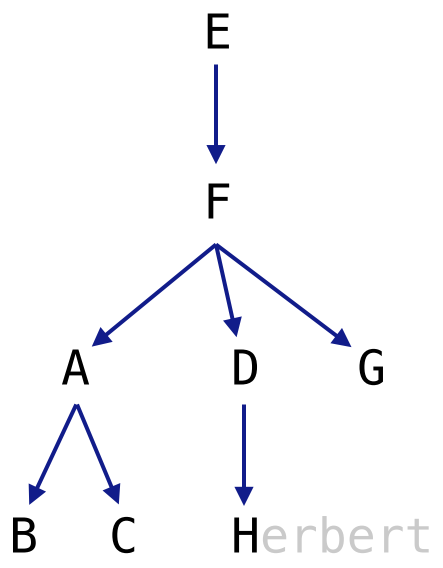

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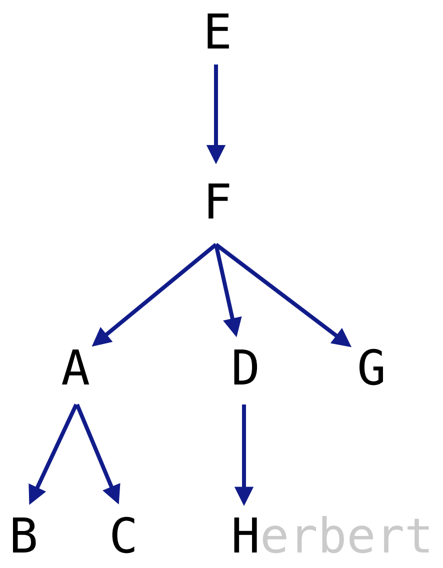

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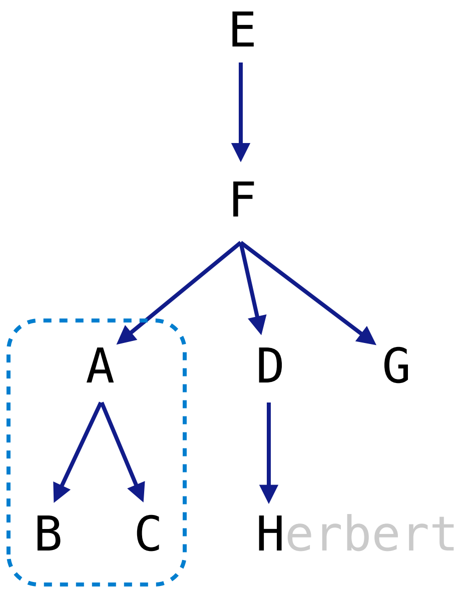

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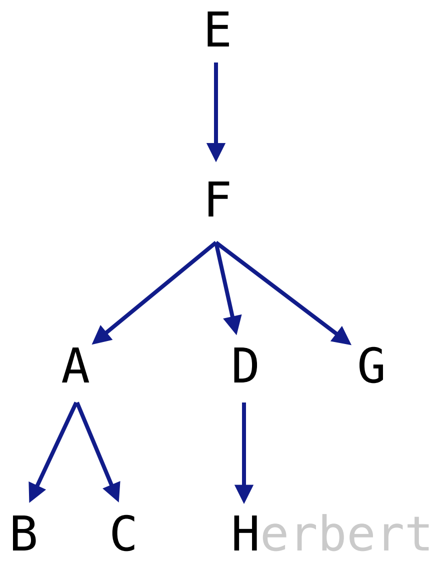


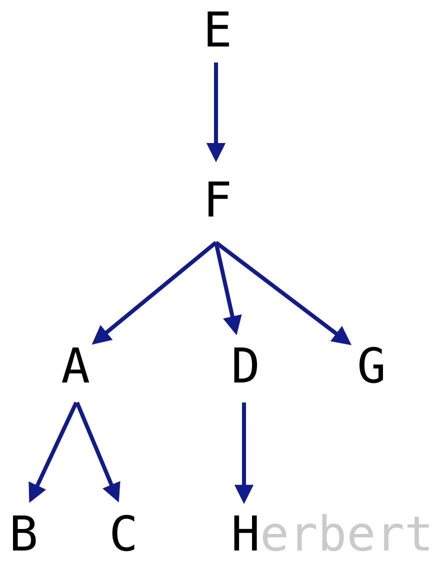
Compound Facts

A fact can include multiple relations and variables as well.

```
(fact <conclusion> <hypothesis0> <hypothesis1> ... <hypothesisN>)
```

Means `<conclusion>` is true if all `<hypothesisI>` are true.

```
logic> (fact (child ?c ?p) (parent ?p ?c))
```



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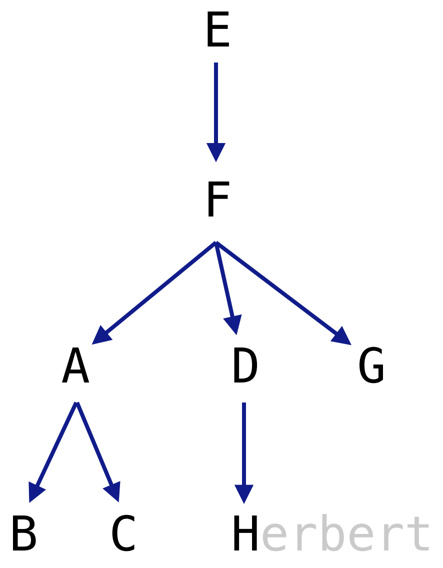
```

Means `<conclusion>` is true if all `<hypothesisI>` are true.

```
logic> (fact (child ?c ?p) (parent ?p ?c))

logic> (query (child herbert delano))
Success!
```



Compound Facts

A fact can include multiple relations and variables as well.

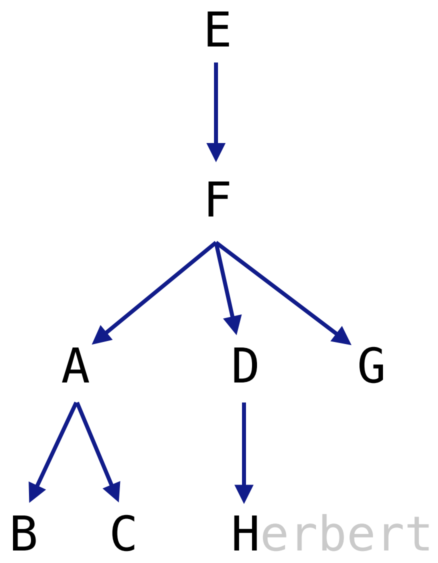
```
(fact <conclusion> <hypothesis₀> <hypothesis₁> ... <hypothesisN>)
```

Means `<conclusion>` is true if all `<hypothesisI>` are true.

```
logic> (fact (child ?c ?p) (parent ?p ?c))

logic> (query (child herbert delano))
Success!

logic> (query (child eisenhower clinton))
Failure.
```



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(fact <conclusion> <hypothesis₀> <hypothesis₁> ... <hypothesisN>)
```
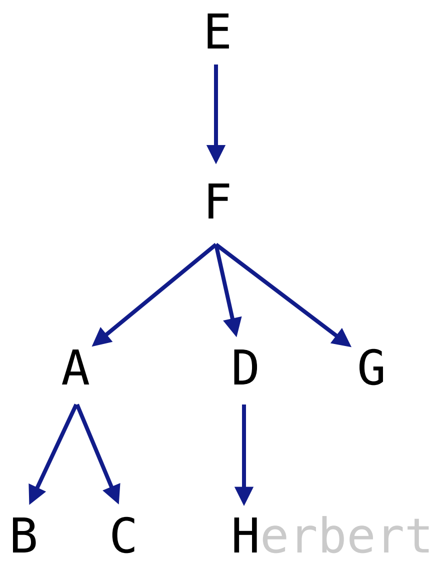
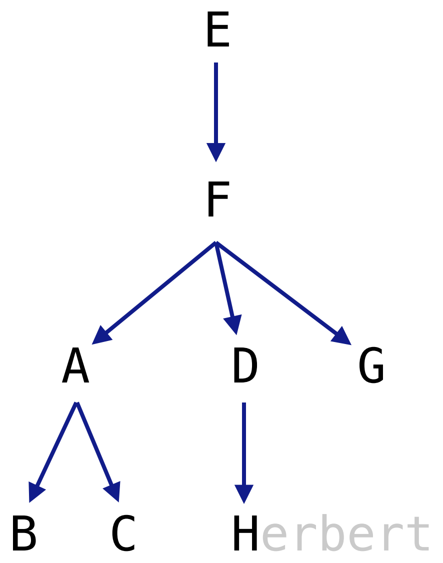

Means `<conclusion>` is true if all `<hypothesisI>` are true.

```
logic> (fact (child ?c ?p) (parent ?p ?c))

logic> (query (child herbert delano))
Success!

logic> (query (child eisenhower clinton))
Failure.

logic> (query (child ?child fillmore))
Success!
child: abraham
child: delano
child: grover
```

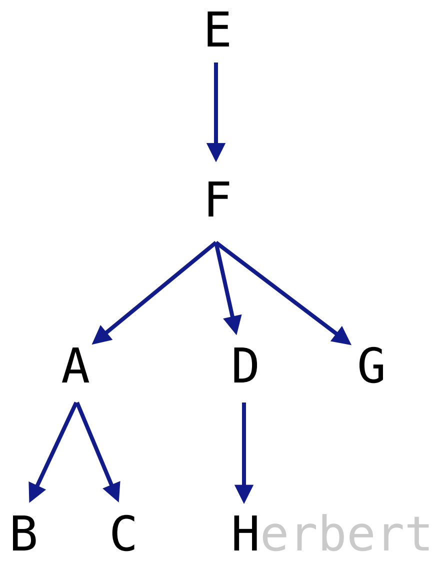


Recursive Facts



Recursive Facts

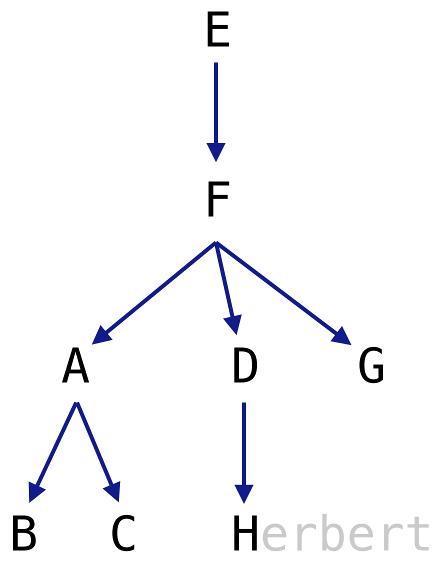
A fact is recursive if the same relation is mentioned in a hypothesis and the conclusion.



Recursive Facts

A fact is recursive if the same relation is mentioned in a hypothesis and the conclusion.

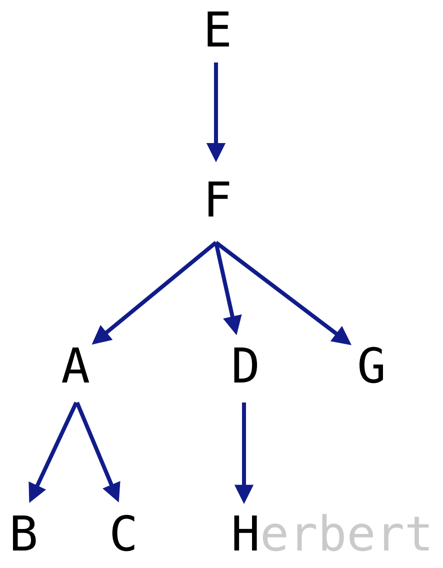
```
logic> (fact (ancestor ?a ?y) (parent ?a ?y))
logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))
```



Recursive Facts

A fact is recursive if the same relation is mentioned in a hypothesis and the conclusion.

```
logic> (fact (ancestor ?a ?y) (parent ?a ?y))

logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))

logic> (query (ancestor ?a herbert))
Success!
a: delano
a: fillmore
a: eisenhower
```



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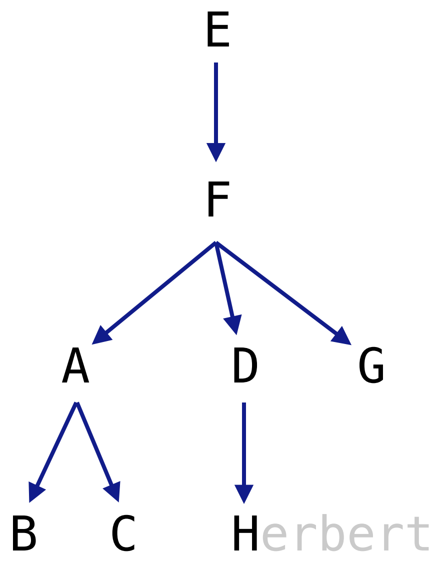
logic> (fact (ancestor ?a ?y) (parent ?a ?y))
logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))
logic> (query (ancestor ?a herbert))
Success!
a: delano
a: fillmore
a: eisenhower

logic> (query (ancestor ?a barack)
              (ancestor ?a herbert))
Success!
a: fillmore
a: eisenhower
```



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logic> (fact (ancestor ?a ?y) (parent ?a ?y))

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Success!
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logic> (query (ancestor ?a barack)
              (ancestor ?a herbert))
Success!
a: fillmore
a: eisenhower
```

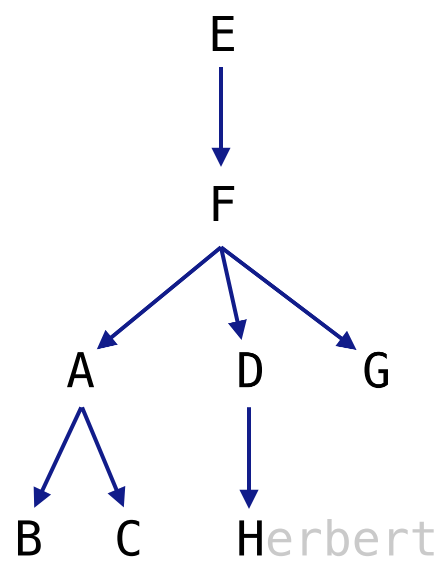

Demo

Searching to Satisfy Queries

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The *Logic* interpreter performs a search in the space of relations for each query to find a satisfying assignment.

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logic> (query (ancestor ?a herbert))
Success!
a: delano
a: fillmore
a: eisenhower

logic> (fact (parent delano herbert))
logic> (fact (parent fillmore delano))
```

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logic> (fact (parent fillmore delano))

logic> (fact (ancestor ?a ?y) (parent ?a ?y))
logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))
```

Searching to Satisfy Queries

The *Logic* interpreter performs a search in the space of relations for each query to find a satisfying assignment.

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logic> (query (ancestor ?a herbert))
Success!
a: delano
a: fillmore
a: eisenhower

logic> (fact (parent delano herbert))
logic> (fact (parent fillmore delano))

logic> (fact (ancestor ?a ?y) (parent ?a ?y))
logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))

(parent delano herbert)        ; (1), a simple fact
```

Searching to Satisfy Queries

The *Logic* interpreter performs a search in the space of relations for each query to find a satisfying assignment.

```
logic> (query (ancestor ?a herbert))
Success!
a: delano
a: fillmore     ⇦
a: eisenhower
```

```
logic> (fact (parent delano herbert))
logic> (fact (parent fillmore delano))
```

```
logic> (fact (ancestor ?a ?y) (parent ?a ?y))
logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))
```

```
(parent delano herbert)         ; (1), a simple fact

(ancestor delano herbert)       ; (2), from (1) and the 1st ancestor fact
```

Searching to Satisfy Queries

The *Logic* interpreter performs a search in the space of relations for each query to find a satisfying assignment.

```
logic> (query (ancestor ?a herbert))
Success!
a: delano
a: fillmore
a: eisenhower
```

```
logic> (fact (parent delano herbert))
logic> (fact (parent fillmore delano))
```

```
logic> (fact (ancestor ?a ?y) (parent ?a ?y))
logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))
```

```
(parent delano herbert)       ; (1), a simple fact
(ancestor delano herbert)     ; (2), from (1) and the 1st ancestor fact
(parent fillmore delano)      ; (3), a simple fact
```

Searching to Satisfy Queries

The *Logic* interpreter performs a search in the space of relations for each query to find a satisfying assignment.

```
logic> (query (ancestor ?a herbert))
Success!
a: delano
a: fillmore
a: eisenhower
```

```
logic> (fact (parent delano herbert))
logic> (fact (parent fillmore delano))
```

```
logic> (fact (ancestor ?a ?y) (parent ?a ?y))
logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))
```

```
(parent delano herbert)        ; (1), a simple fact

(ancestor delano herbert)      ; (2), from (1) and the 1st ancestor fact

(parent fillmore delano)       ; (3), a simple fact

(ancestor fillmore herbert)    ; (4), from (2), (3), & the 2nd ancestor fact
```

Hierarchical Facts

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Relations can contain relations in addition to atoms.

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```
logic> (fact (dog (name abraham) (color white)))
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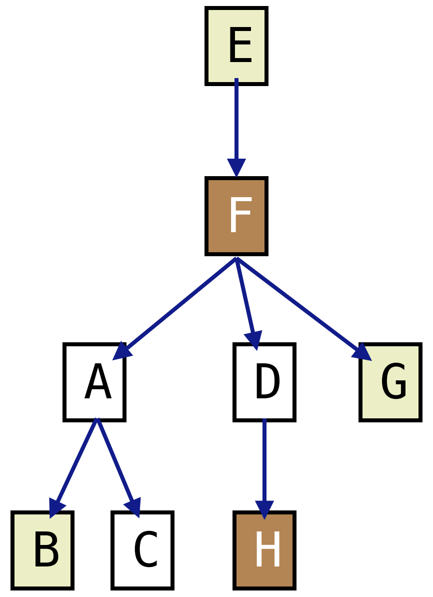
```
logic> (fact (dog (name abraham) (color white)))
logic> (fact (dog (name barack) (color tan)))
logic> (fact (dog (name clinton) (color white)))
logic> (fact (dog (name delano) (color white)))
logic> (fact (dog (name eisenhower) (color tan)))
logic> (fact (dog (name fillmore) (color brown)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color brown)))
```

Hierarchical Facts

Relations can contain relations in addition to atoms.

```
logic> (fact (dog (name abraham) (color white)))
logic> (fact (dog (name barack) (color tan)))
logic> (fact (dog (name clinton) (color white)))
logic> (fact (dog (name delano) (color white)))
logic> (fact (dog (name eisenhower) (color tan)))
logic> (fact (dog (name fillmore) (color brown)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color brown)))
```



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Relations can contain relations in addition to atoms.

```
logic> (fact (dog (name abraham) (color white)))
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logic> (fact (dog (name clinton) (color white)))
logic> (fact (dog (name delano) (color white)))
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logic> (fact (dog (name fillmore) (color brown)))
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```
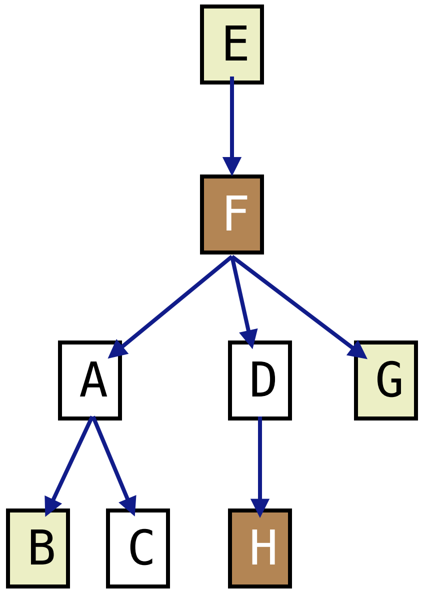

Variables can refer to atoms or relations.



Hierarchical Facts

Relations can contain relations in addition to atoms.

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logic> (fact (dog (name abraham) (color white)))
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logic> (fact (dog (name clinton) (color white)))
logic> (fact (dog (name delano) (color white)))
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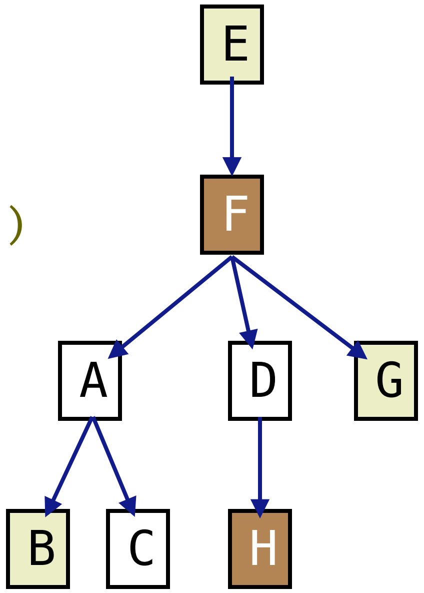
logic> (fact (dog (name fillmore) (color brown)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color brown)))
```

Variables can refer to atoms or relations.

```
logic> (query (dog (name clinton) (color ?color)))
Success!
color: white
```



Hierarchical Facts

Relations can contain relations in addition to atoms.

```
logic> (fact (dog (name abraham) (color white)))
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logic> (fact (dog (name clinton) (color white)))
logic> (fact (dog (name delano) (color white)))
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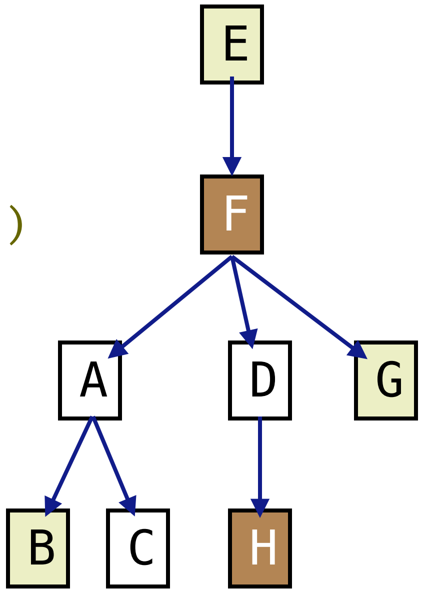
logic> (fact (dog (name fillmore) (color brown)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color brown)))
```

Variables can refer to atoms or relations.

```
logic> (query (dog (name clinton) (color ?color)))
Success!
color: white

logic> (query (dog (name clinton) ?info))
Success!
info: (color white)
```



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Relations can contain relations in addition to atoms.

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logic> (fact (dog (name abraham) (color white)))
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logic> (fact (dog (name clinton) (color white)))
logic> (fact (dog (name delano) (color white)))
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logic> (fact (dog (name fillmore) (color brown)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color brown)))
```
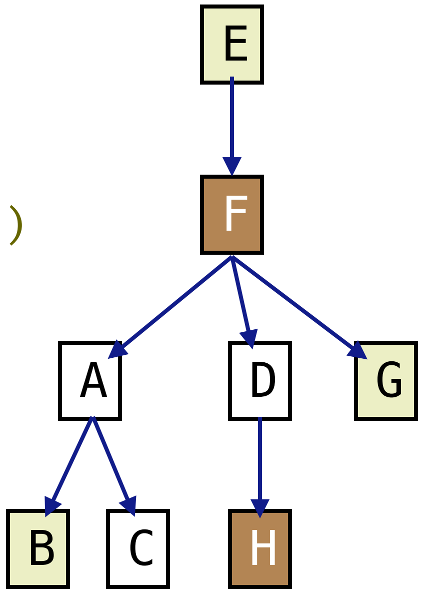
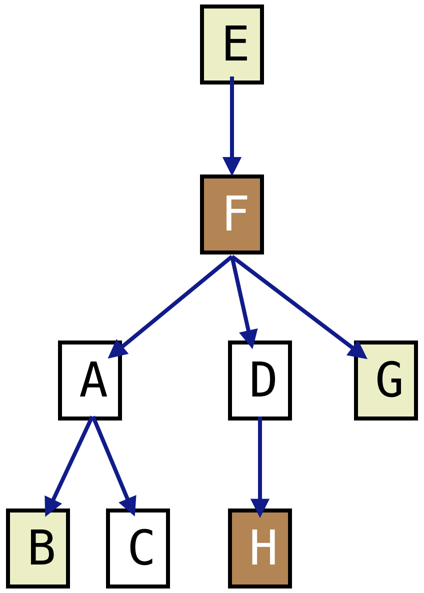

Variables can refer to atoms or relations.

```
logic> (query (dog (name clinton) (color ?color)))
Success!
color: white

logic> (query (dog (name clinton) ?info))
Success!
info: (color white)
```



Example: Combining Multiple Data Sources

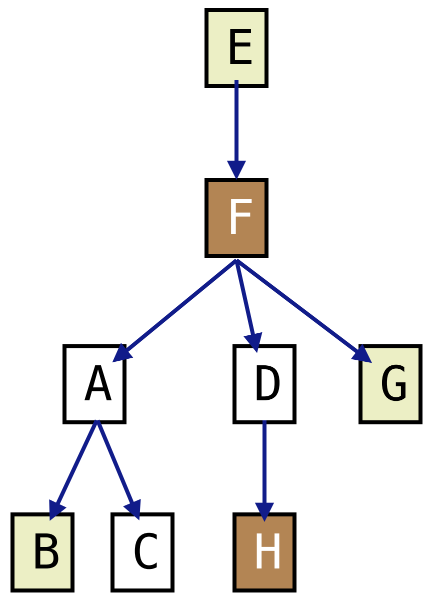
```
Which dogs have an ancestor of the same color?
```



Example: Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

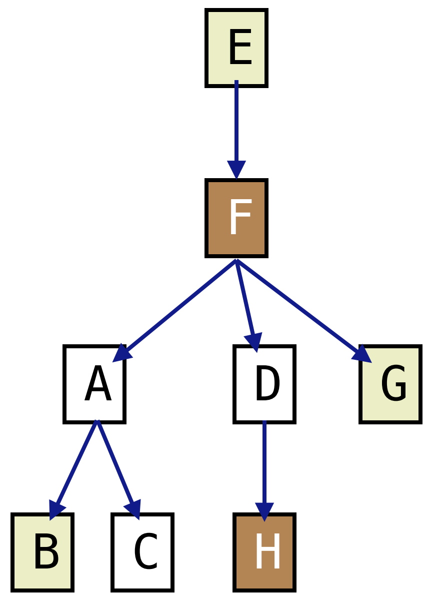
```
logic> (query (dog (name ?name) (color ?color))
```



Example: Combining Multiple Data Sources

```
Which dogs have an ancestor of the same color?
```

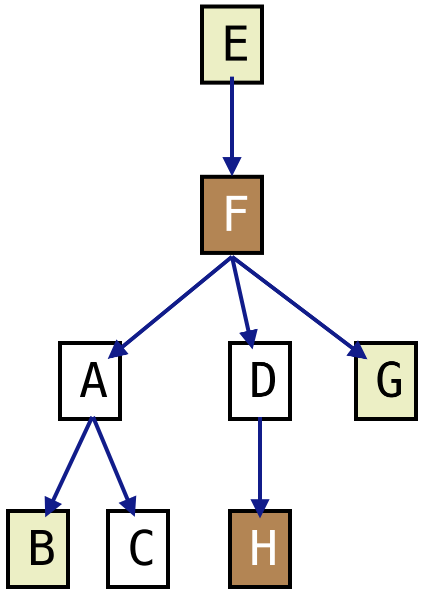
```
logic> (query (dog (name ?name) (color ?color))
              (ancestor ?ancestor ?name)
```



Example: Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

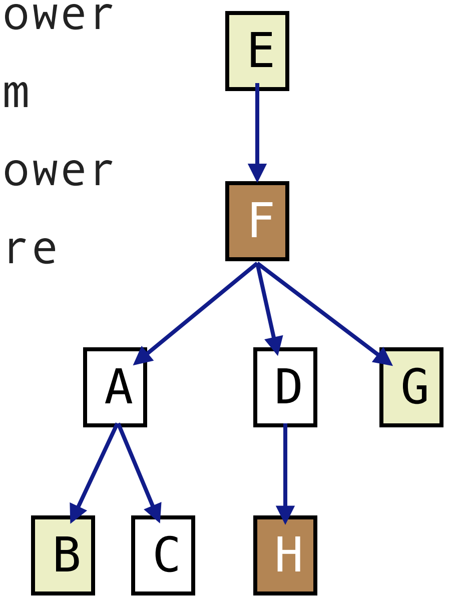
```
logic> (query (dog (name ?name) (color ?color))
              (ancestor ?ancestor ?name)
              (dog (name ?ancestor) (color ?color)))
```



Example: Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

```
logic> (query (dog (name ?name) (color ?color))
              (ancestor ?ancestor ?name)
              (dog (name ?ancestor) (color ?color)))
Success!
name: barack    color: tan      ancestor: eisenhower
name: clinton   color: white    ancestor: abraham
name: grover    color: tan      ancestor: eisenhower
name: herbert   color: brown    ancestor: fillmore
```



Example: Appending Lists

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```
Two lists append to form a third list if:
```

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```
logic> (fact (append-to-form () ?x ?x))
```

Example: Appending Lists

Two lists append to form a third list if:

- The first list is empty and the second and third are the same
- The rest of 1 and 2 append to form the rest of 3

```
logic> (fact (append-to-form () ?x ?x))

logic> (fact (append-to-form (?a . ?r) ?y (?a . ?z))
             (append-to-form ?r ?y ?z))
```

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Two lists append to form a third list if:

- The first list is empty and the second and third are the same
- The rest of 1 and 2 append to form the rest of 3

```
logic> (fact (append-to-form () ?x ?x))

logic> (fact (append-to-form (?a . ?r) ?y (?a . ?z))
             (append-to-form ?r ?y ?z))
```

Demo