61A Lecture 31

Wednesday, November 20

Announcements

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- Project 4 due Thursday 11/21 @ 11:59pm.

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- Recursive art contest entries will be due Monday 12/2 @ 11:59pm (After Thanksgiving).

Declarative Languages

Databases

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Databases store tables and have have methods for adding, editing, and retrieving records.

http://www.headfirstlabs.com/sql_hands_on/

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toy_id	toy	color	cost	weight
2	whiffleball	yellow	2.20	0.40
5	frisbee	yellow	1.50	0.20
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The language interpreter is free to compute the result in any way it wants.

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Solve cool problems *Limited problem solving*

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http://awhimsicalbohemian.typepad.com/.a/6a00e5538b84f3883301538dfa8f19970b-800wi

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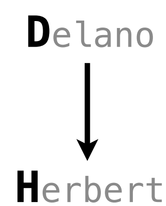

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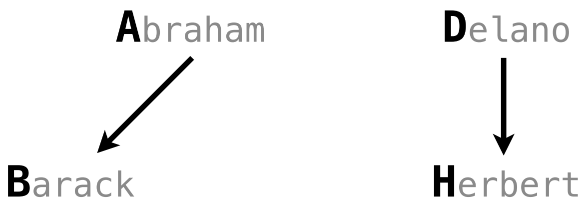

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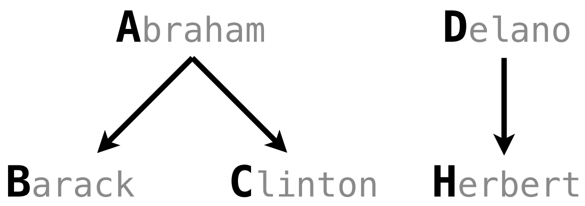

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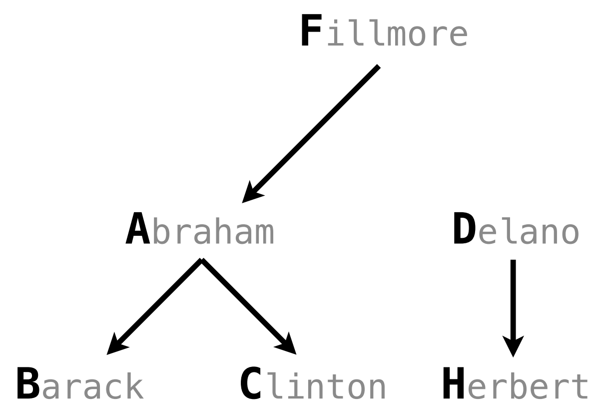

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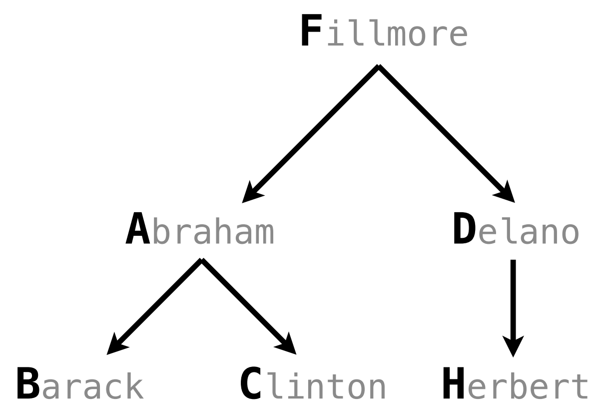

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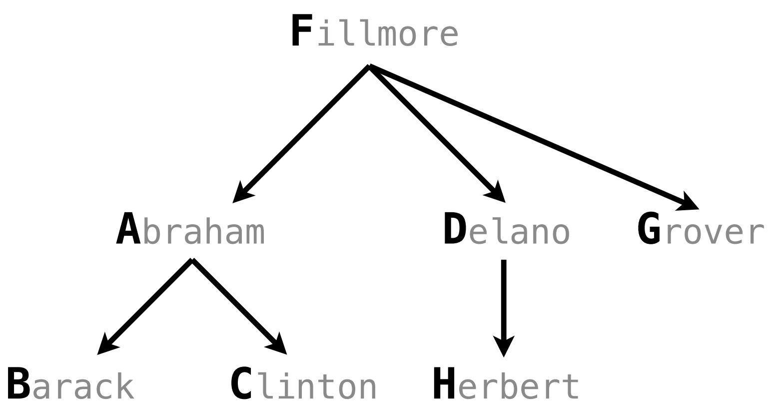

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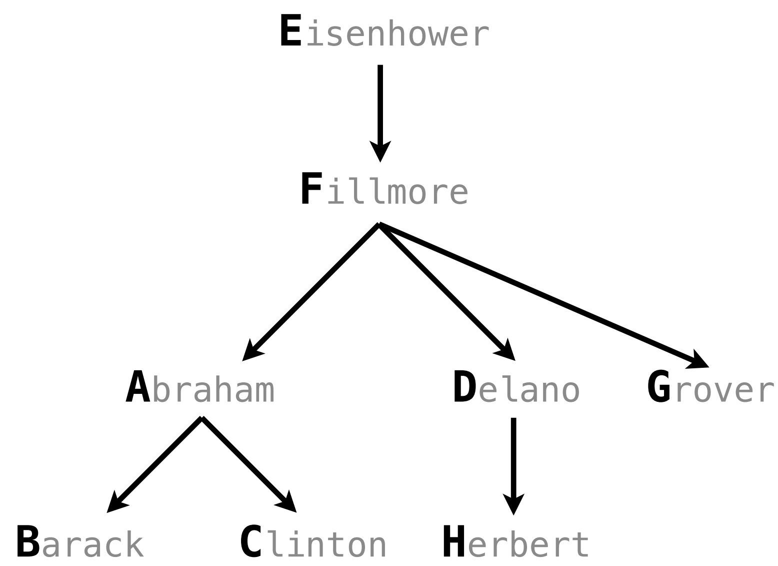

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(add _?_ 2 3)	**1**
(add 1 _?_ 3)	**2**
(add 1 2 _?_)	**3**
(_?_ 1 2 3)	**add**

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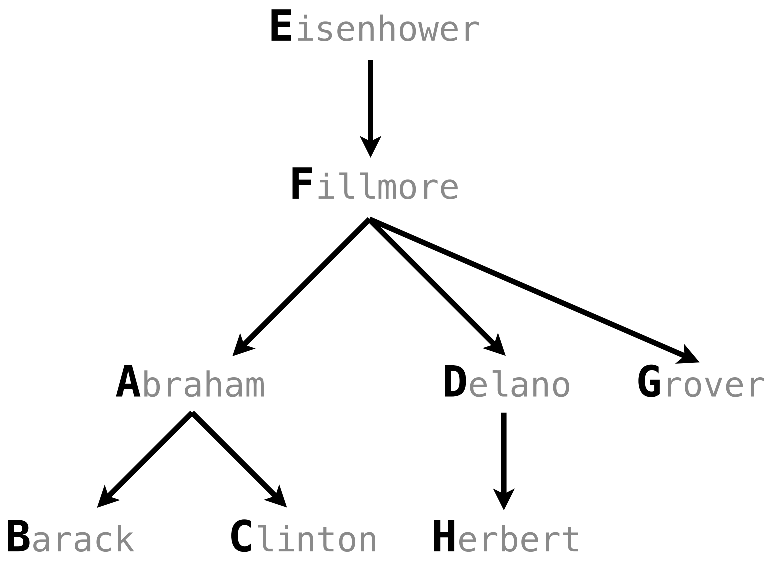

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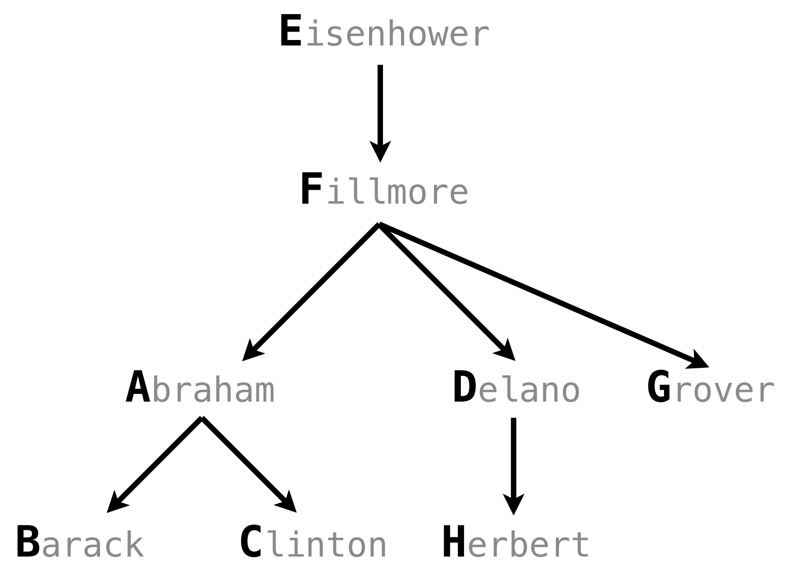
logic> (fact (parent eisenhower fillmore))

logic> (query (parent abraham ?puppy))
```



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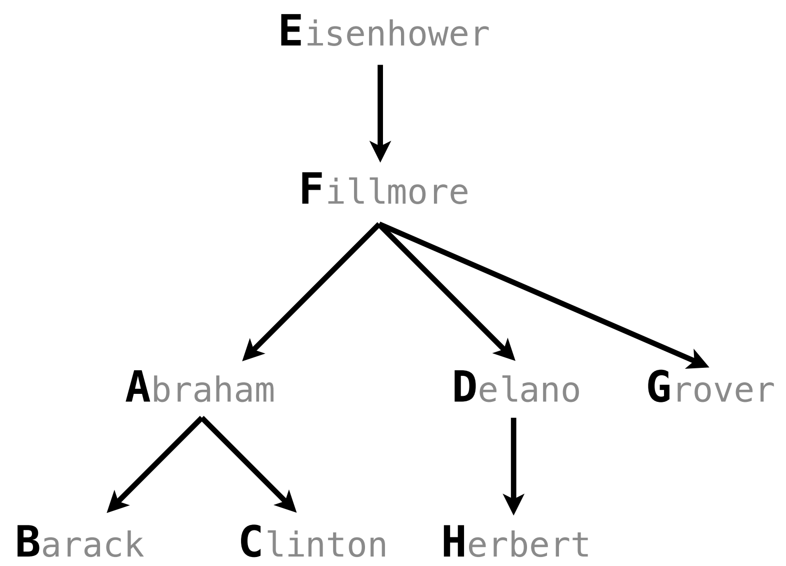
A variable can have any name



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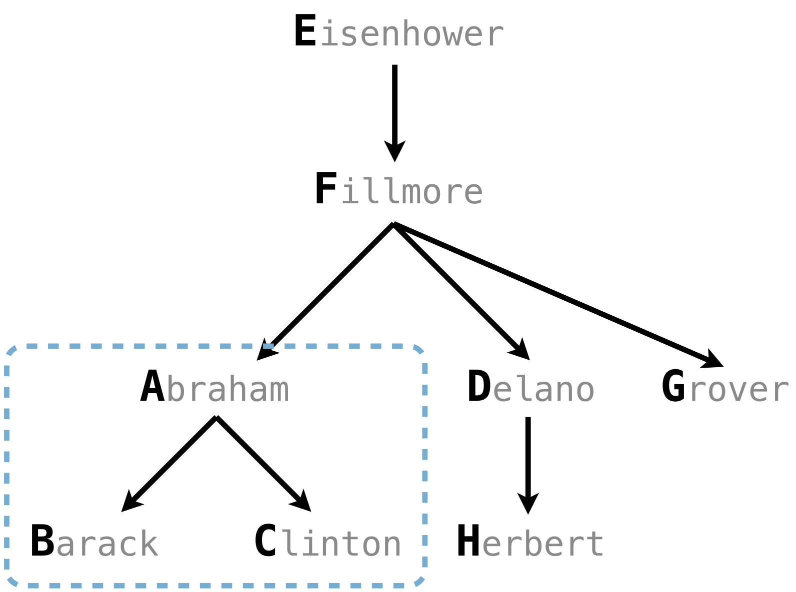

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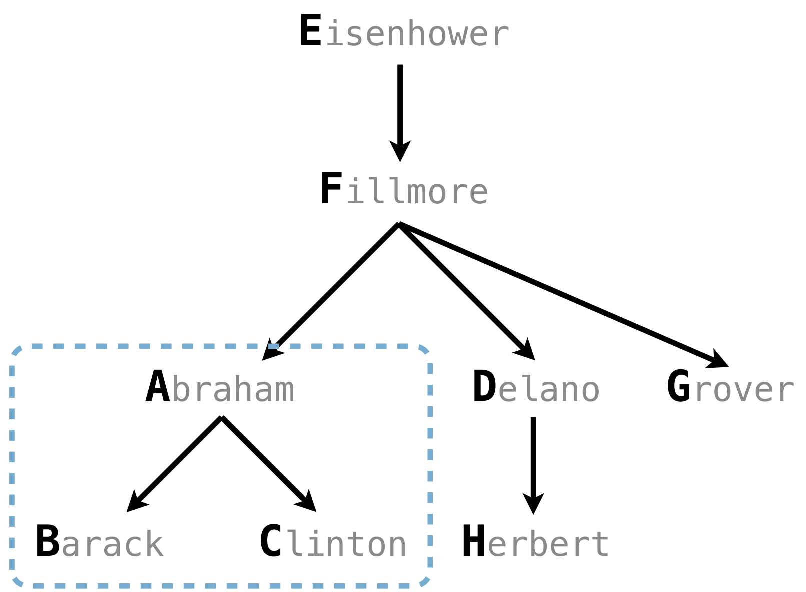
logic> (query (parent abraham ?puppy))
Success!
```

A variable can have any name



Queries

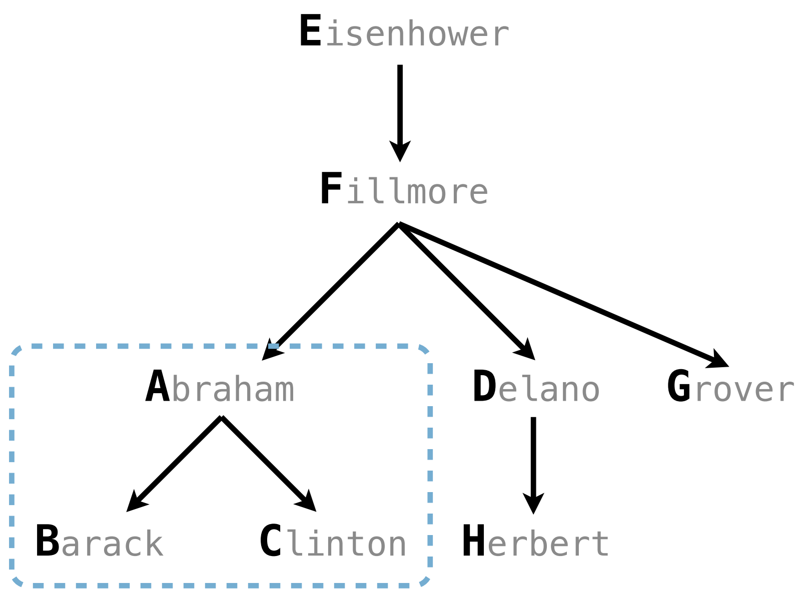
A *query* contains one or more relations that may contain variables.

Variables are symbols starting with **?**

```
logic> (fact (parent delano herbert))
logic> (fact (parent abraham barack))
logic> (fact (parent abraham clinton))
logic> (fact (parent fillmore abraham))
logic> (fact (parent fillmore delano))
logic> (fact (parent fillmore grover))
logic> (fact (parent eisenhower fillmore))

logic> (query (parent abraham ?puppy))
Success!
puppy: barack
```

A variable can have any name



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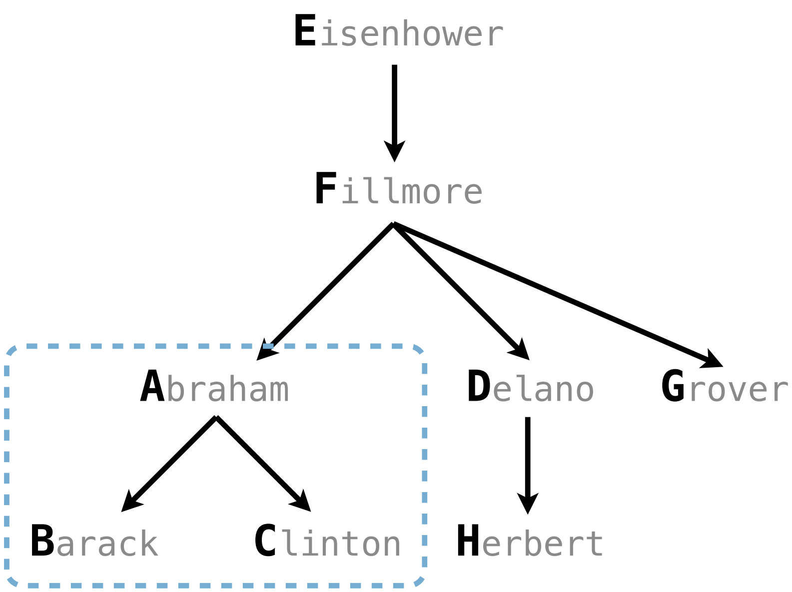
logic> (fact (parent eisenhower fillmore))

logic> (query (parent abraham ?puppy))
Success!
puppy: barack
puppy: clinton
```

A variable can have any name



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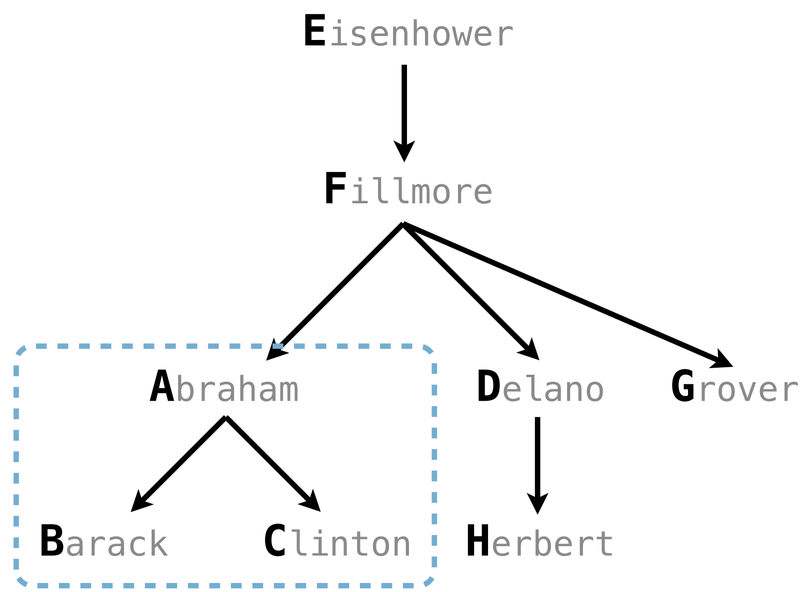
logic> (query (parent abraham ?puppy))
Success!
puppy: barack
puppy: clinton
```

A variable can have any name

Each line is an assignment of variables to values



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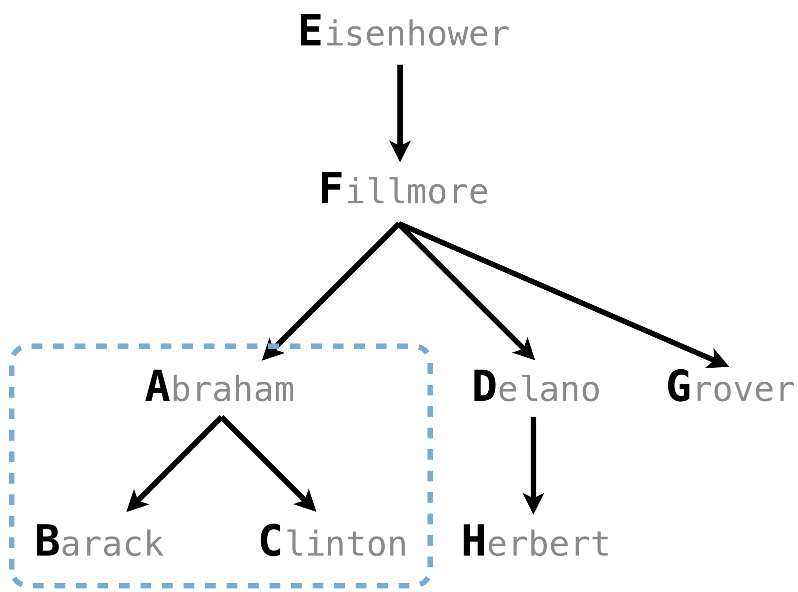
logic> (fact (parent eisenhower fillmore))

logic> (query (parent abraham ?puppy))
Success!
puppy: barack
puppy: clinton
```

A variable can have any name

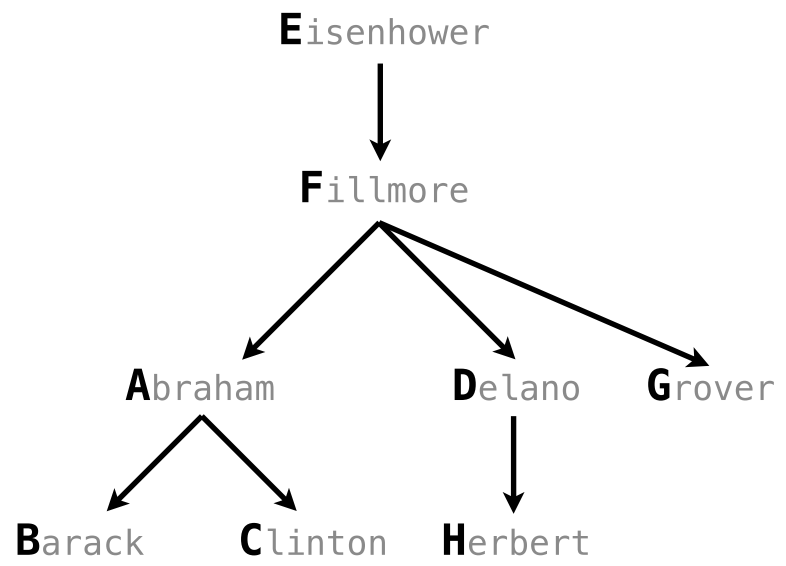
Each line is an assignment of variables to values



(Demo)

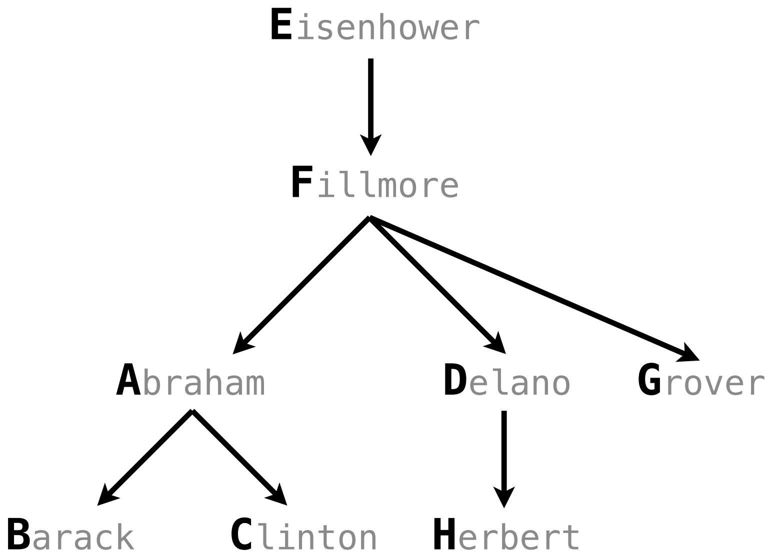
Compound Facts and Queries

Compound Facts



Compound Facts

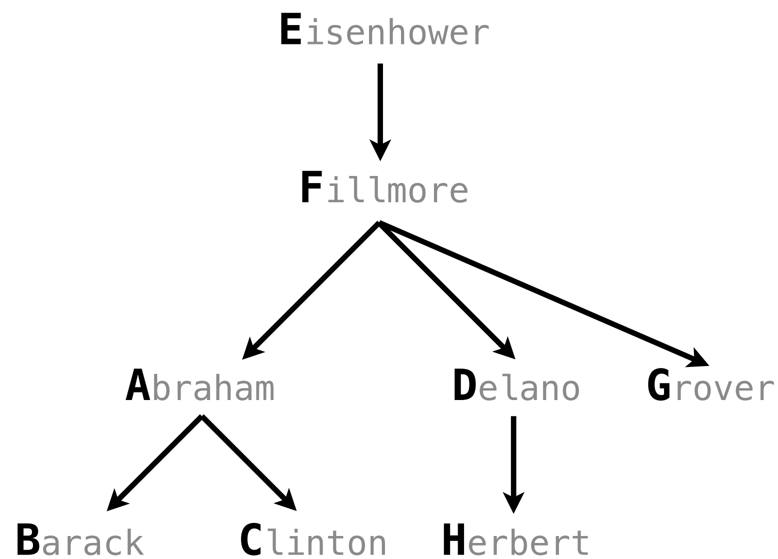
A fact can include multiple relations and variables as well.



Compound Facts

A fact can include multiple relations and variables as well.

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



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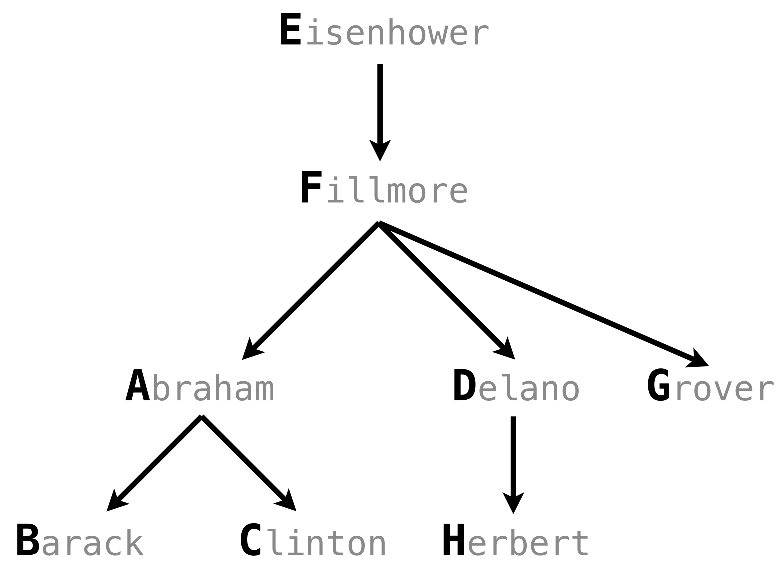
A fact can include multiple relations and variables as well.

(fact <conclusion> <hypothesis$_0$> <hypothesis$_1$> ... <hypothesis$_N$>)

Means <conclusion> is true if all the <hypothesis$_K$> are true.



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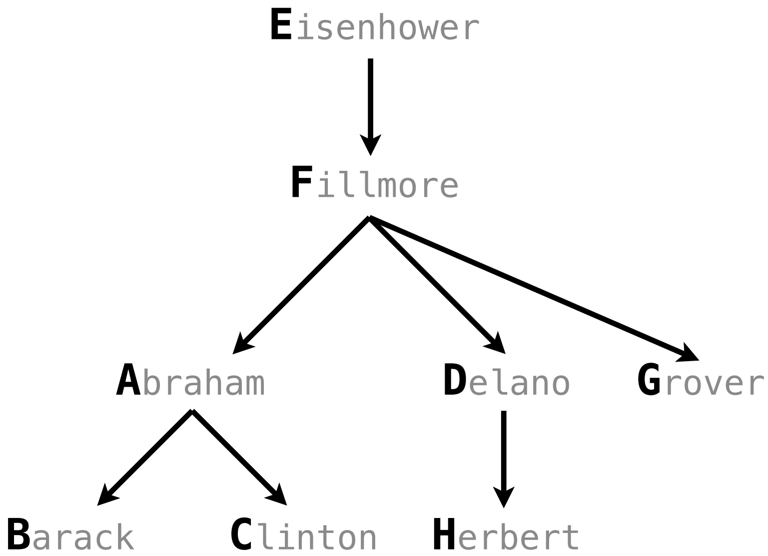
```
logic> (fact (child ?c ?p) (parent ?p ?c))
```



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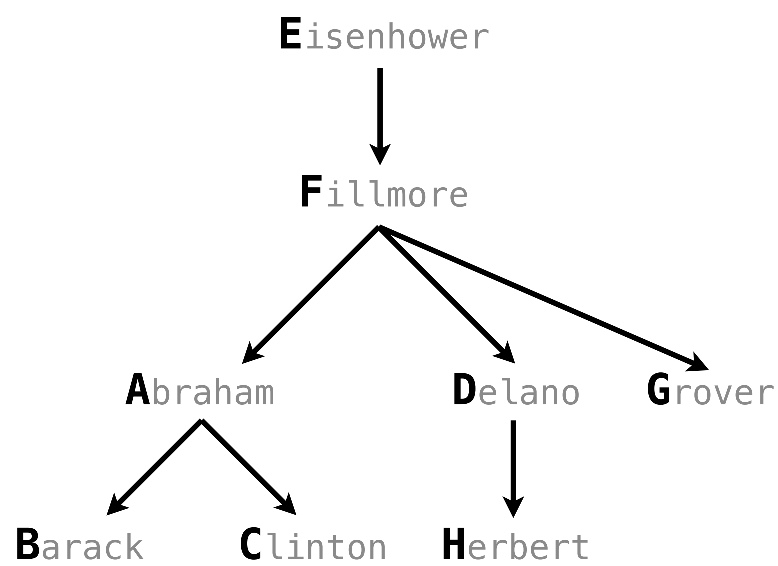
```
logic> (fact (child ?c ?p) (parent ?p ?c))

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



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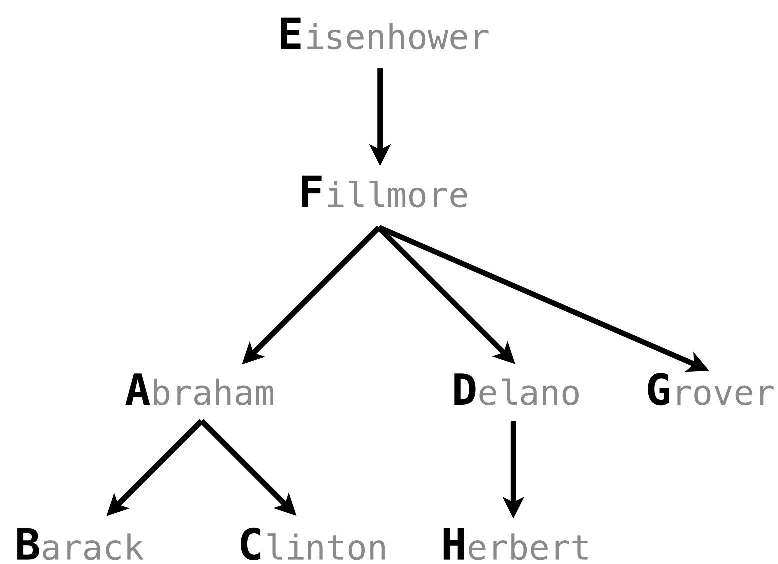
logic> (fact (child ?c ?p) (parent ?p ?c))

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



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

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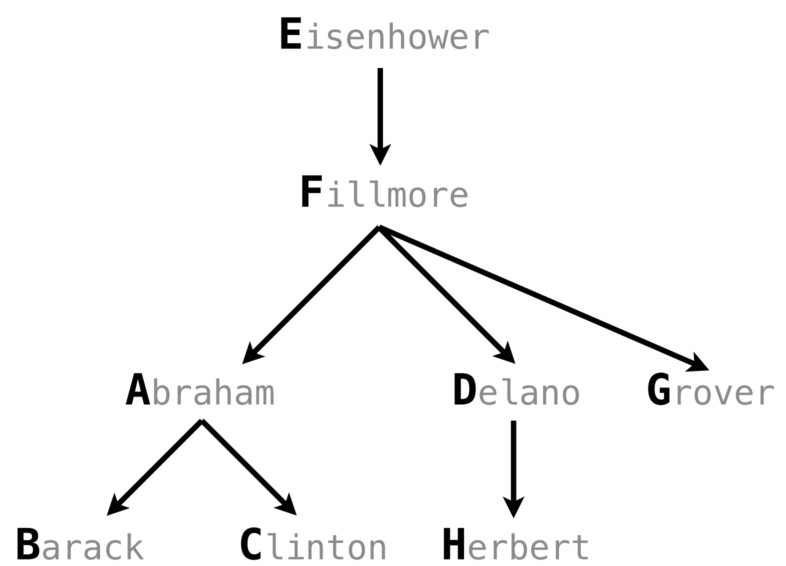
```
logic> (fact (child ?c ?p) (parent ?p ?c))

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

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



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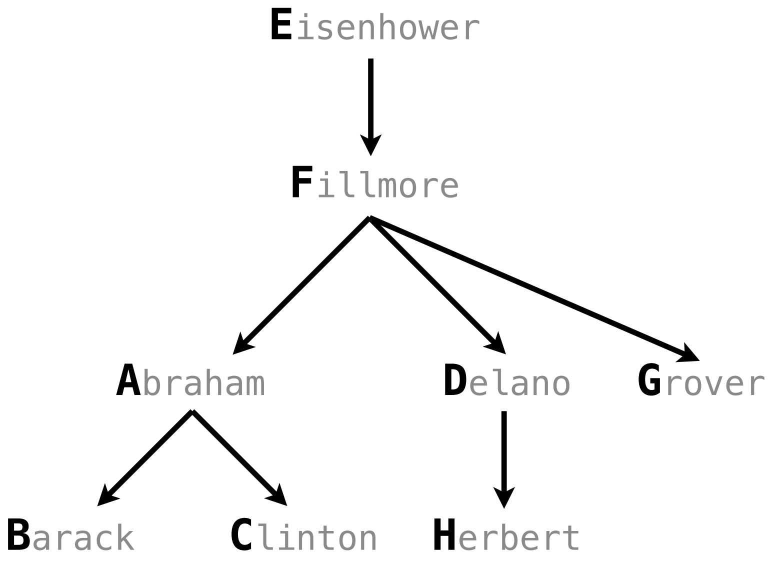
```
logic> (fact (child ?c ?p) (parent ?p ?c))

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

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



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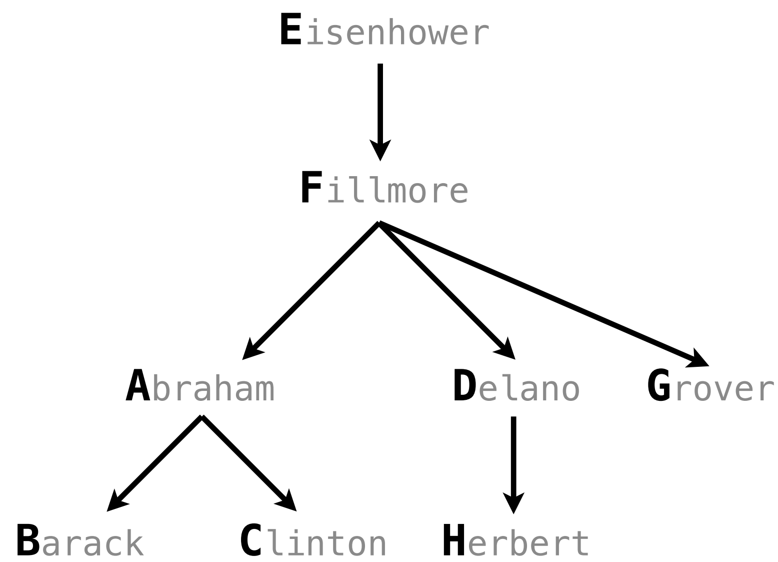
```
logic> (fact (child ?c ?p) (parent ?p ?c))

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

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

logic> (query (child ?kid fillmore))
```



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Failure.

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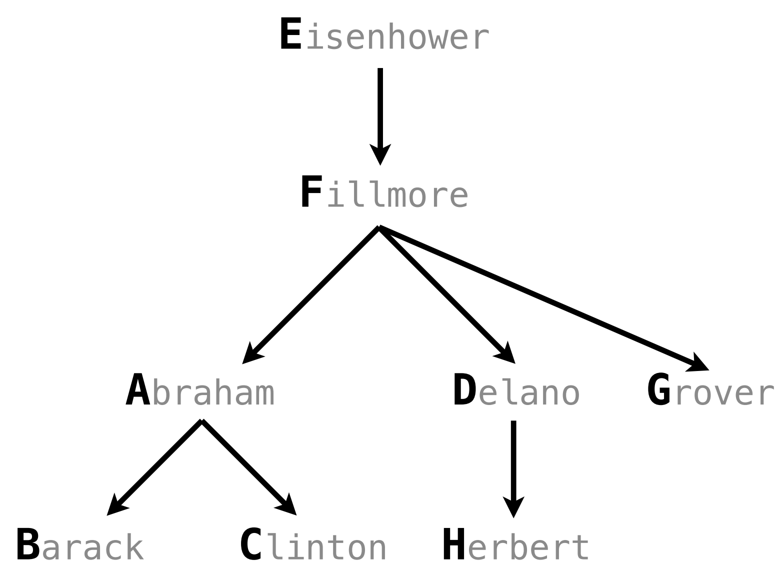
Success!
```



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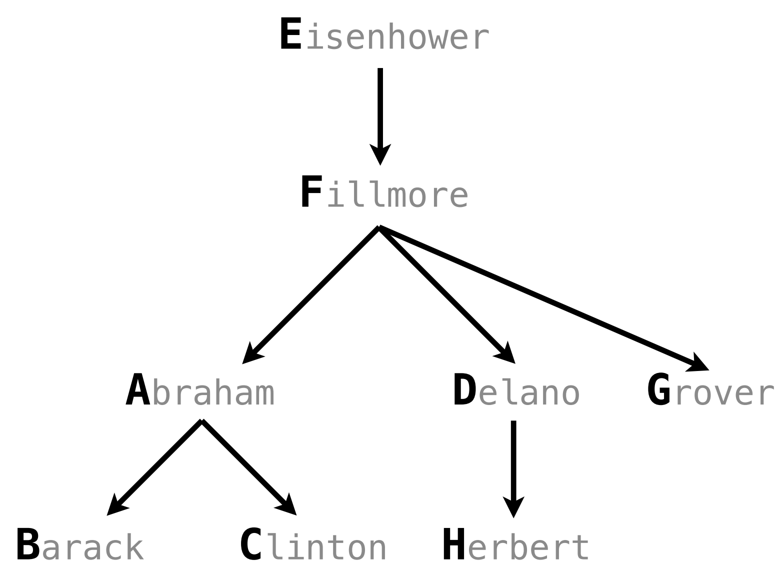
logic> (fact (child ?c ?p) (parent ?p ?c))

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

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

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



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Success!

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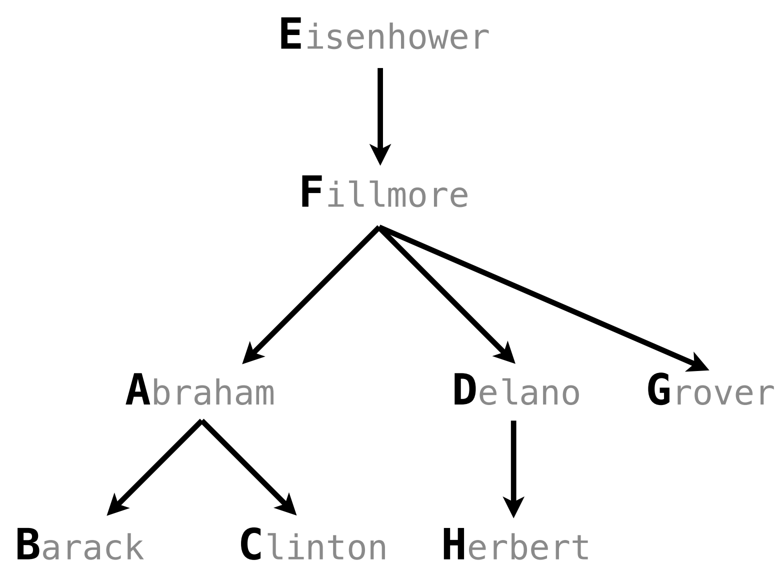
Failure.

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



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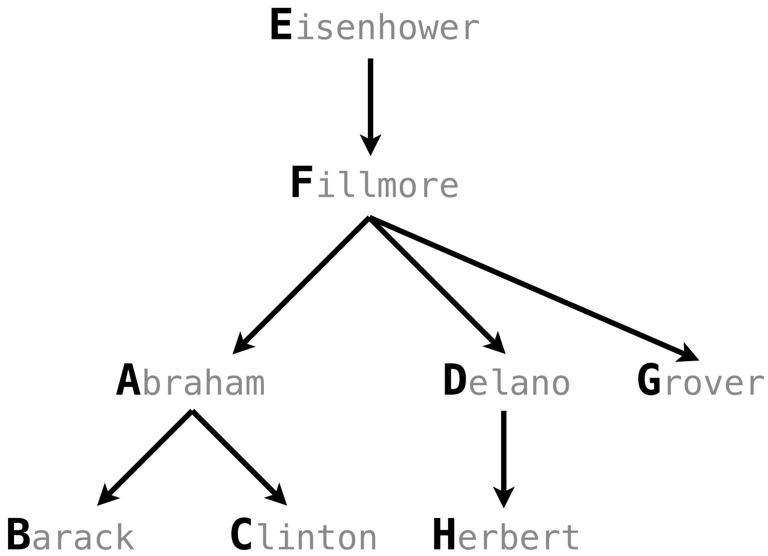
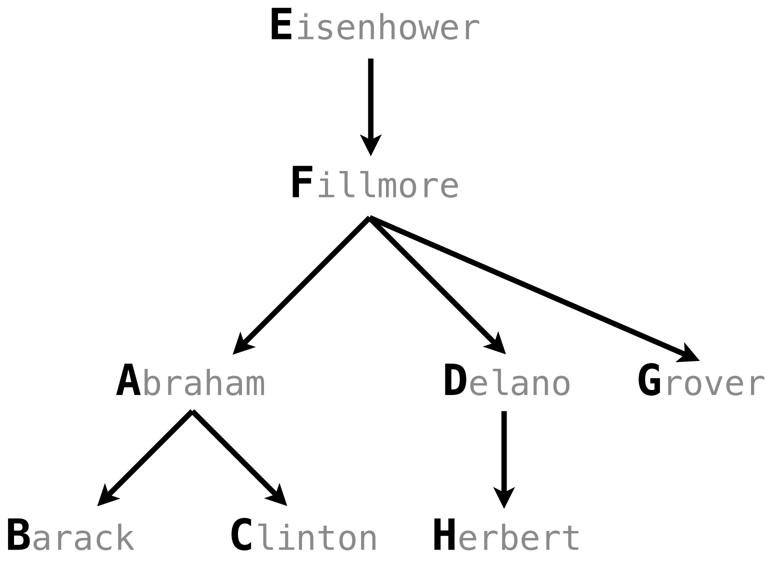
Success!

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

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

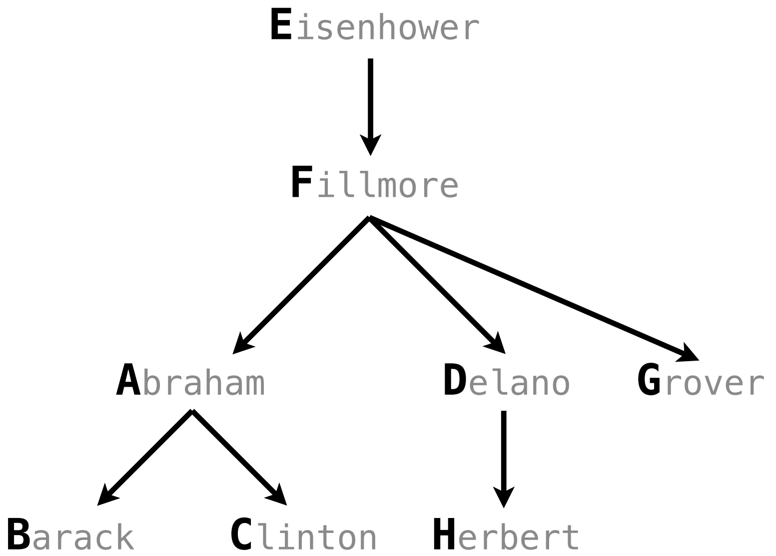


Compound Queries



Compound Queries

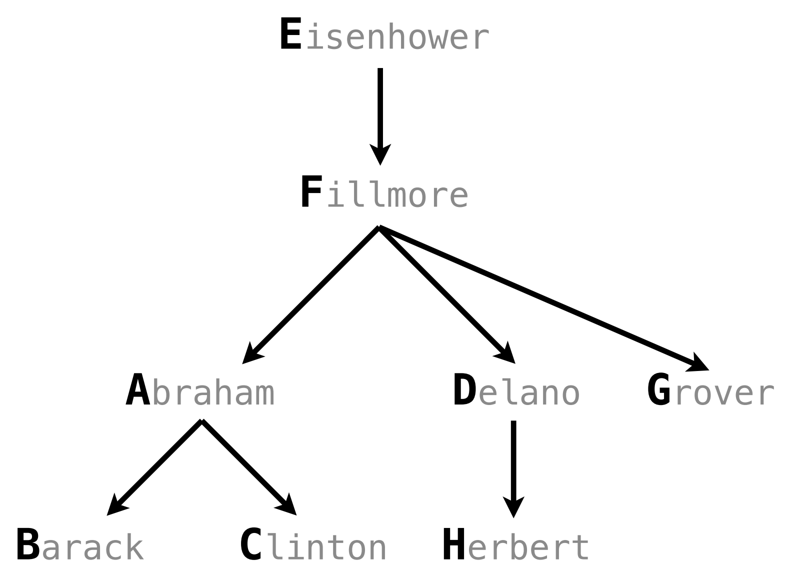
An assignment must satisfy all relations in a query.



Compound Queries

An assignment must satisfy all relations in a query.

```
(query <relation₀> <relation₁> ... <relationN>)
```



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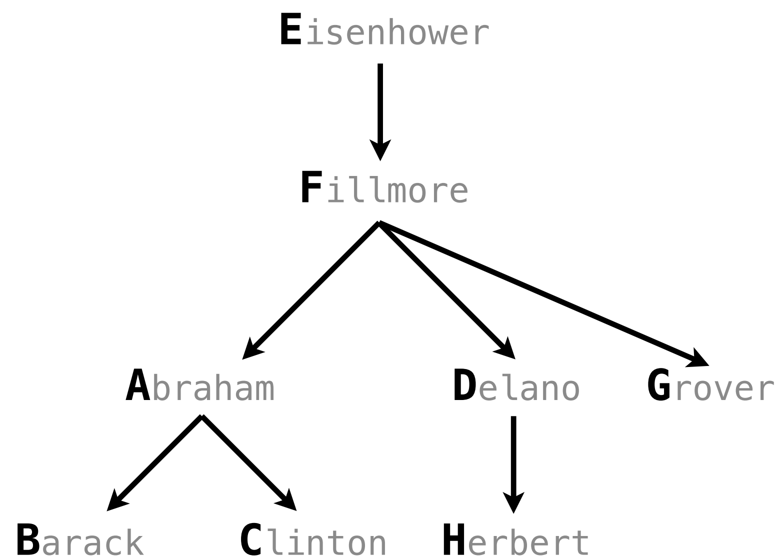

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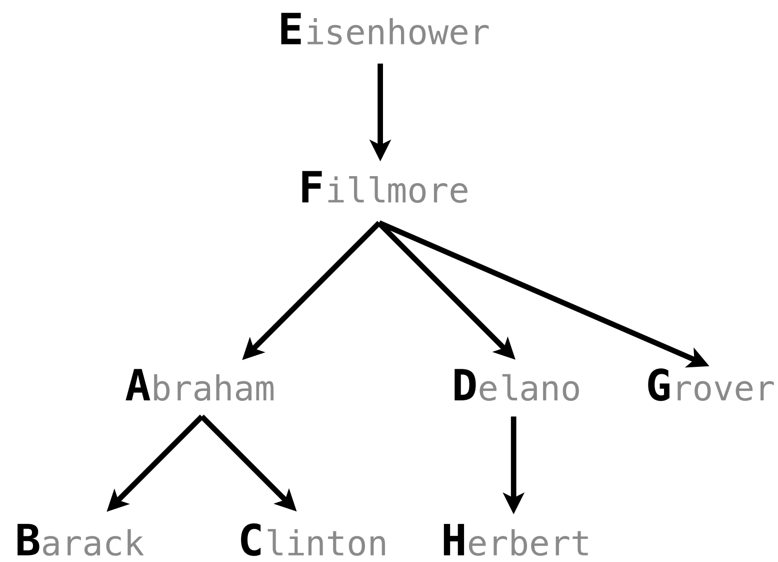


Compound Queries

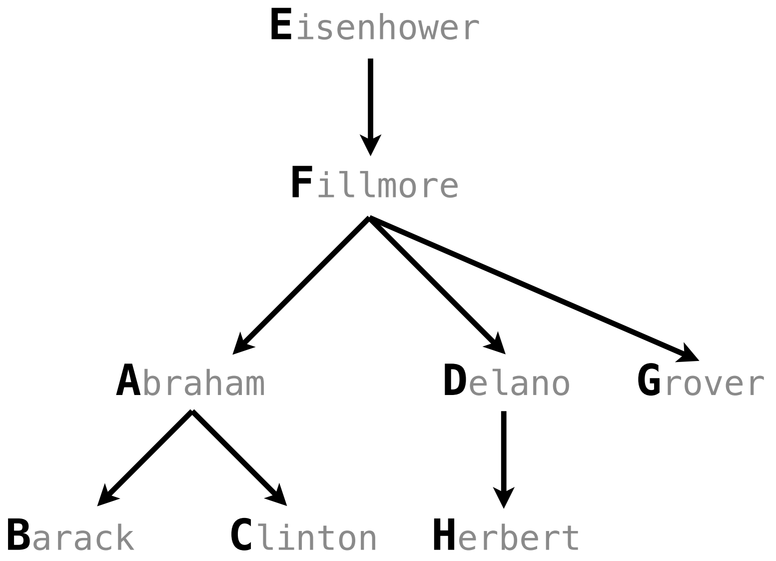
An assignment must satisfy all relations in a query.

```
(query <relation_0> <relation_1> ... <relation_N>)
```

is satisfied if all the `<relation_K>` are true.

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

logic> (query (parent ?grampa ?kid)
```



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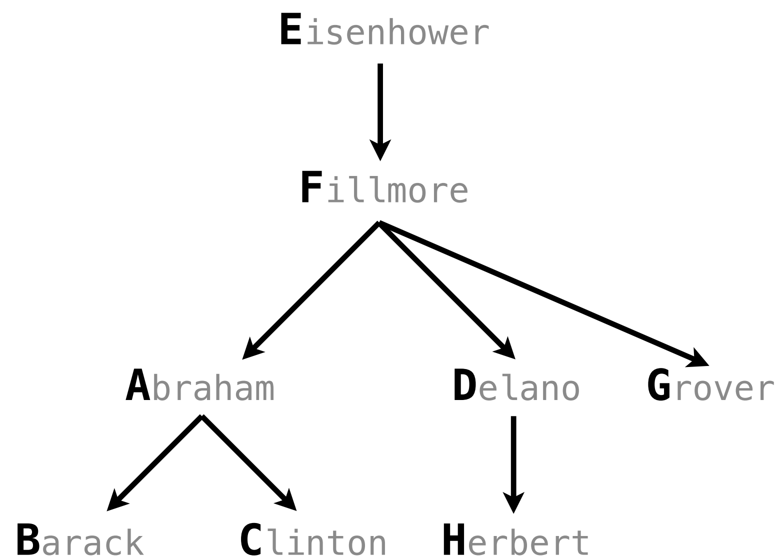
logic> (fact (child ?c ?p) (parent ?p ?c))

logic> (query (parent ?grampa ?kid)
              (child clinton ?kid))
```



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

logic> (query (parent ?grampa ?kid)
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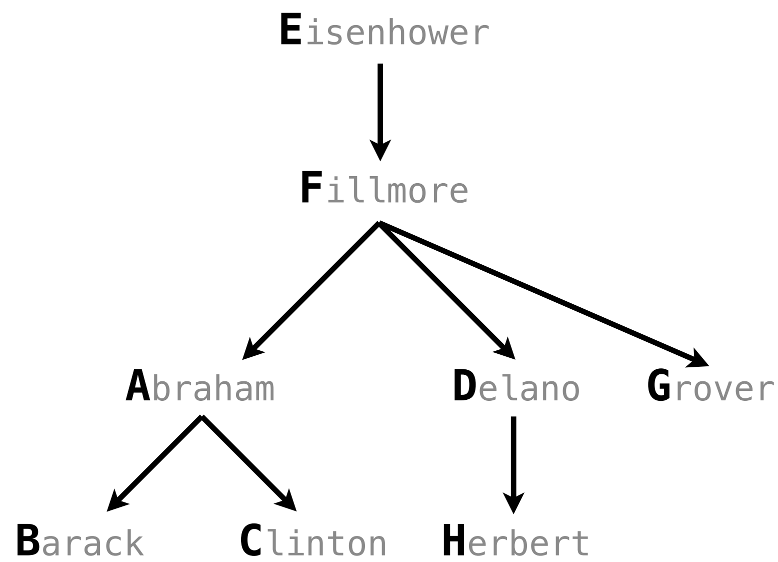
Success!
```



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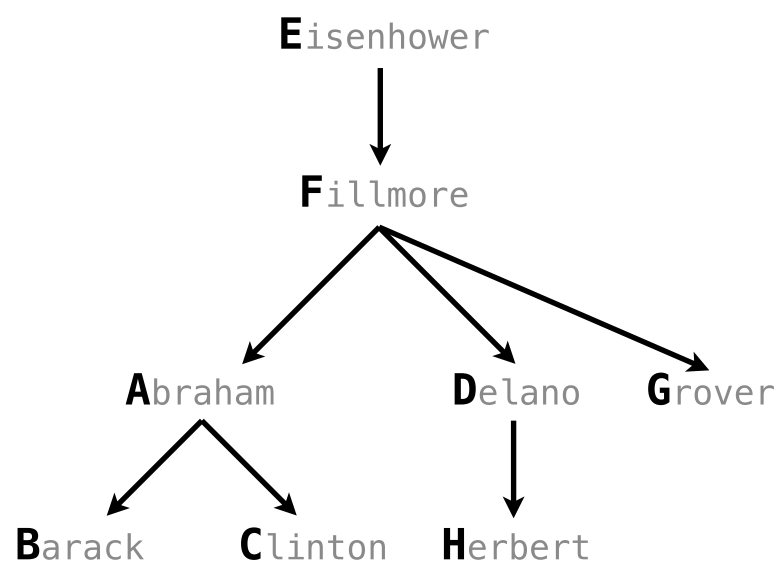
logic> (fact (child ?c ?p) (parent ?p ?c))

logic> (query (parent ?grampa ?kid)
              (child clinton ?kid))
Success!
grampa: fillmore    kid: abraham
```



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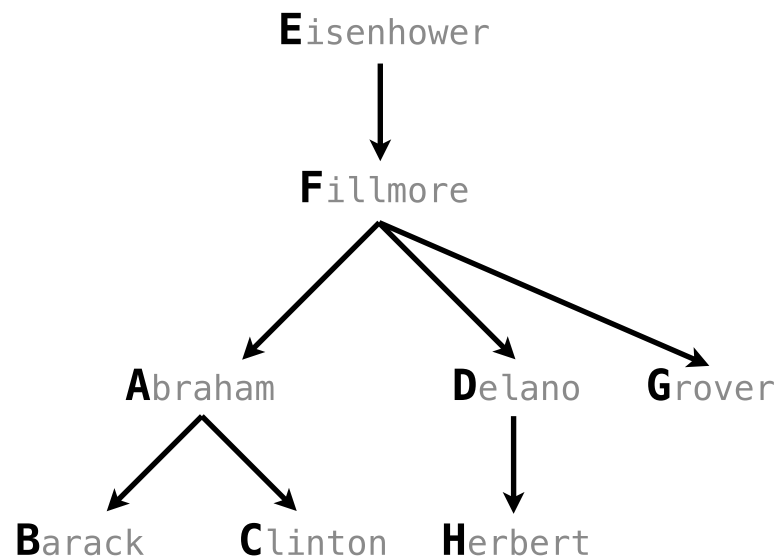
logic> (fact (child ?c ?p) (parent ?p ?c))

logic> (query (parent ?grampa ?kid)
              (child clinton ?kid))
Success!
grampa: fillmore    kid: abraham

logic> (query (child ?y ?x)
```



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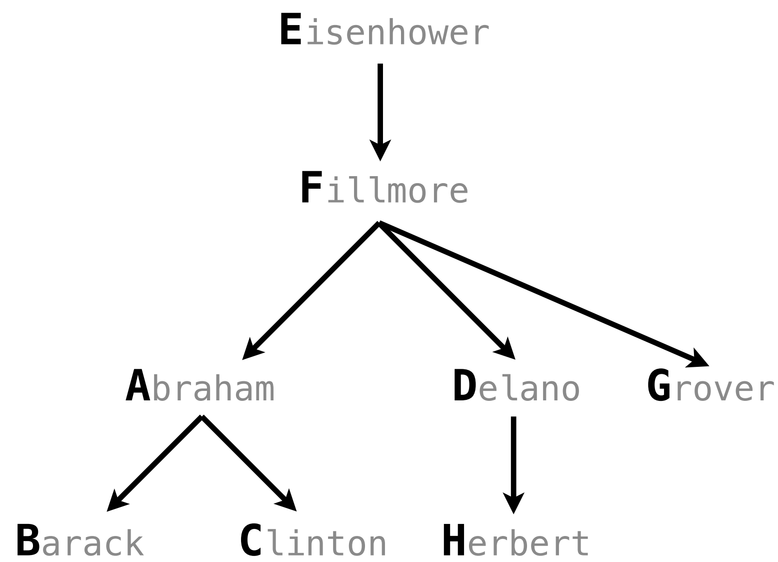
```
logic> (fact (child ?c ?p) (parent ?p ?c))

logic> (query (parent ?grampa ?kid)
              (child clinton ?kid))
Success!
grampa: fillmore    kid: abraham

logic> (query (child ?y ?x)
              (child ?x eisenhower))
```



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logic> (query (parent ?grampa ?kid)
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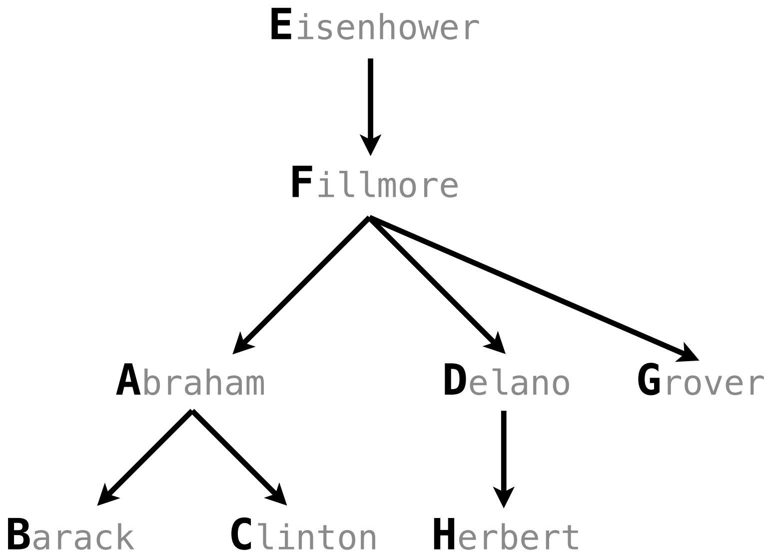
Success!
grampa: fillmore    kid: abraham

logic> (query (child ?y ?x)
              (child ?x eisenhower))
Success!
```



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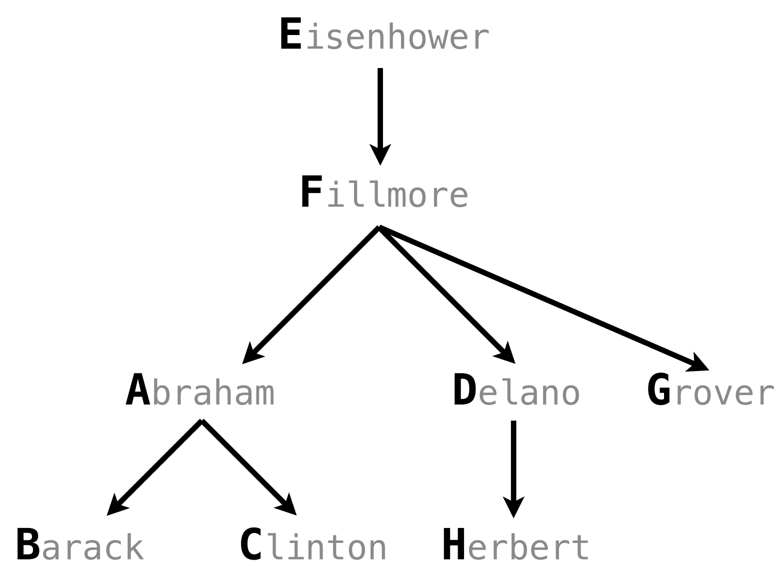
logic> (query (parent ?grampa ?kid)
              (child clinton ?kid))
Success!
grampa: fillmore    kid: abraham

logic> (query (child ?y ?x)
              (child ?x eisenhower))
Success!
y: abraham    x: fillmore
```



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An assignment must satisfy all relations in a query.

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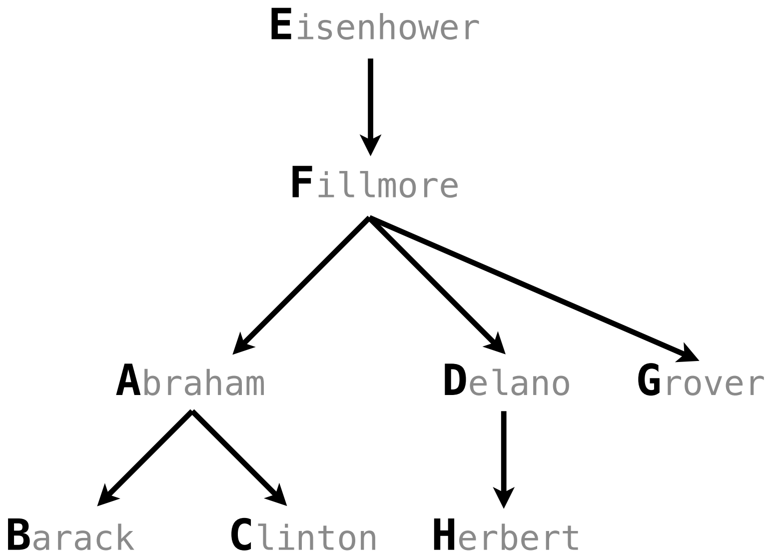
logic> (fact (child ?c ?p) (parent ?p ?c))

logic> (query (parent ?grampa ?kid)
              (child clinton ?kid))
Success!
grampa: fillmore    kid: abraham

logic> (query (child ?y ?x)
              (child ?x eisenhower))
Success!
y: abraham    x: fillmore
y: delano     x: fillmore
```



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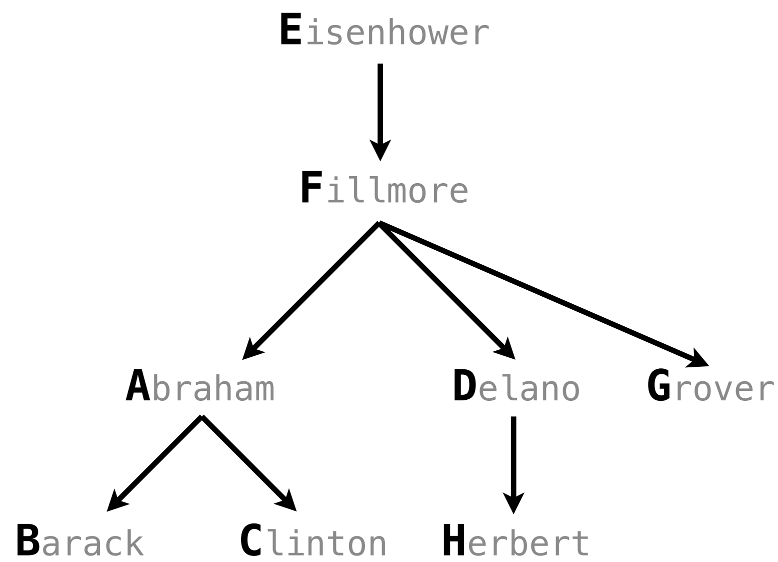
```
logic> (fact (child ?c ?p) (parent ?p ?c))

logic> (query (parent ?grampa ?kid)
              (child clinton ?kid))
Success!
grampa: fillmore    kid: abraham

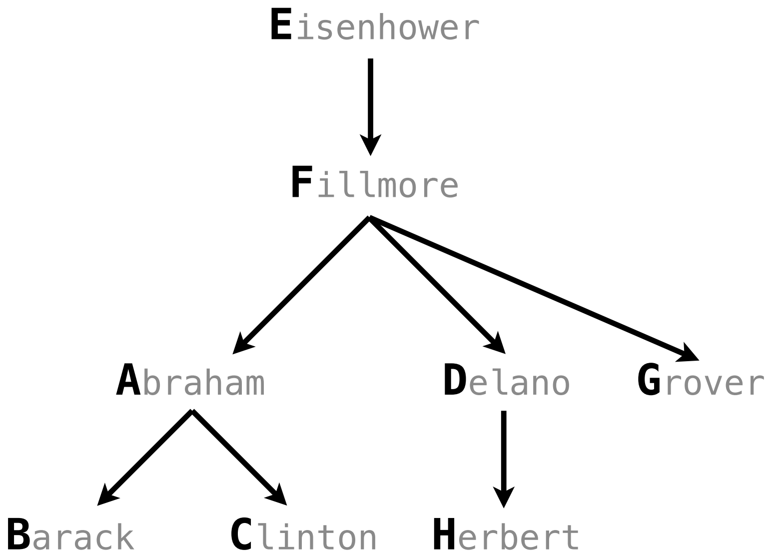
logic> (query (child ?y ?x)
              (child ?x eisenhower))
Success!
y: abraham    x: fillmore
y: delano     x: fillmore
y: grover     x: fillmore
```



Recursive Facts

Recursive Facts

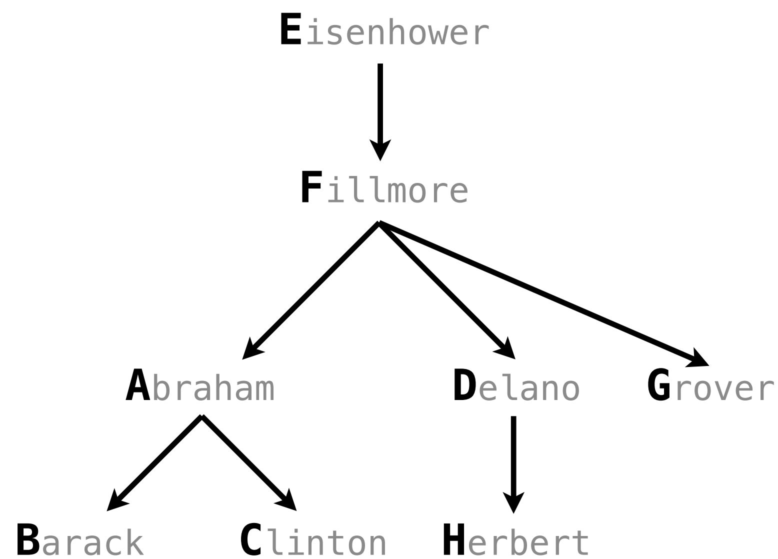
A fact is recursive if the same relation is mentioned in a hypothesis and the conclusion.



Recursive Facts

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

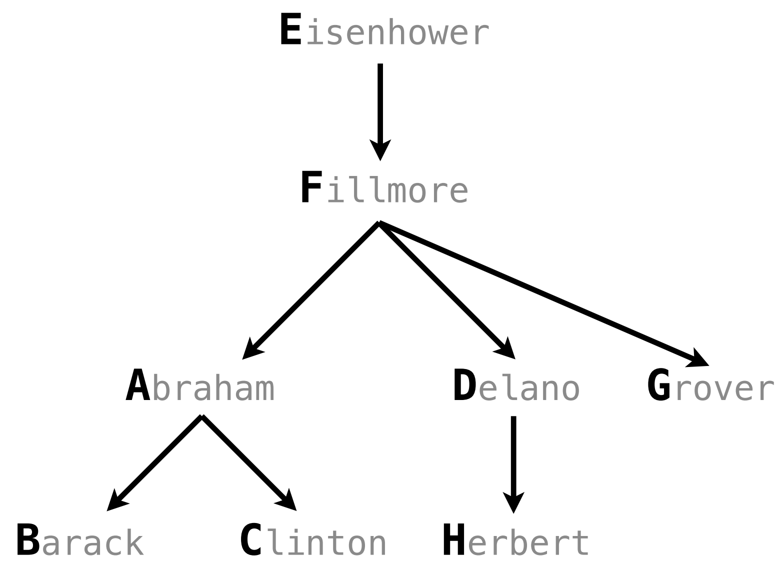
```
logic> (fact (ancestor ?a ?y) (parent ?a ?y))
```



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))
```

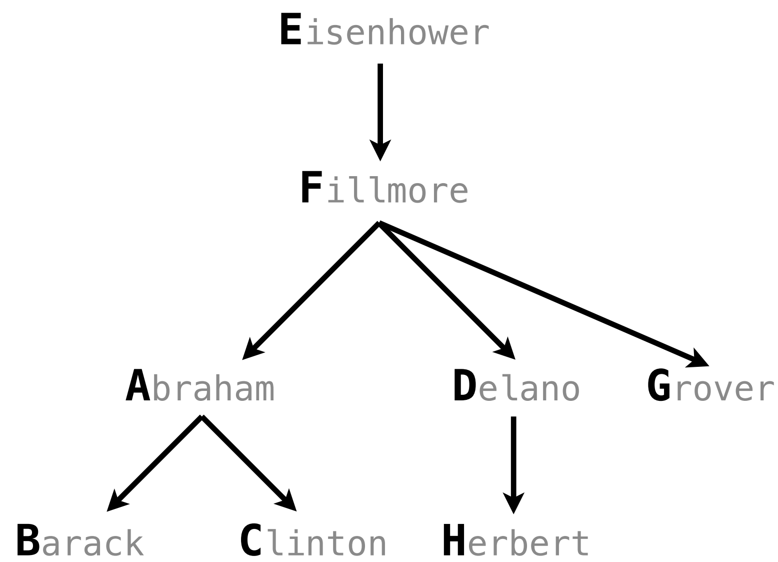


Recursive Facts

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))
```



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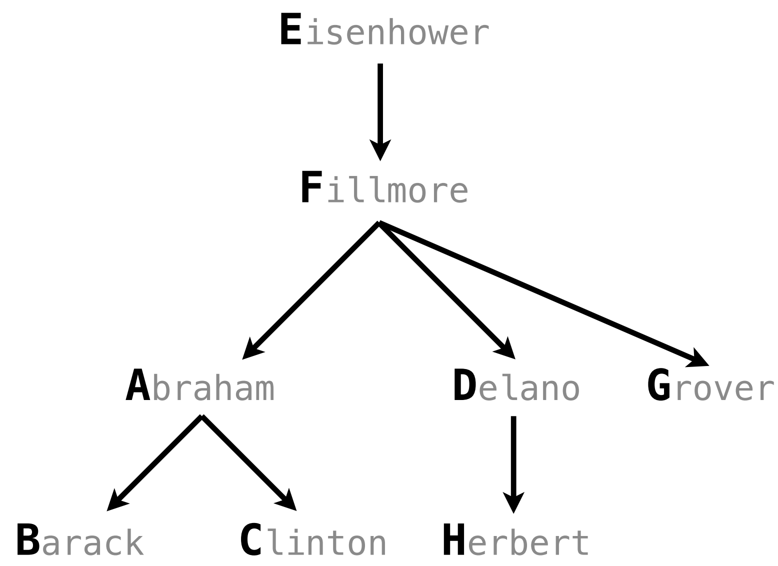
A fact is recursive if the same relation is mentioned in a hypothesis and the conclusion.

```
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!
```

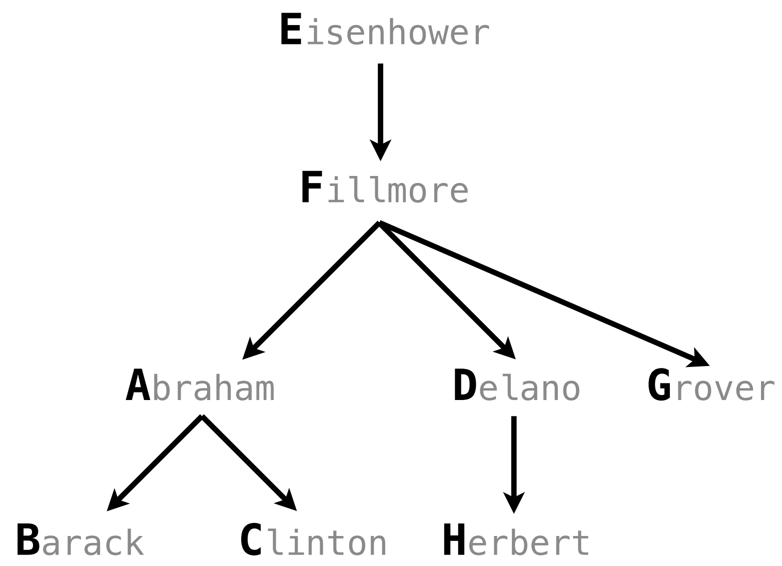


Recursive Facts

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
```

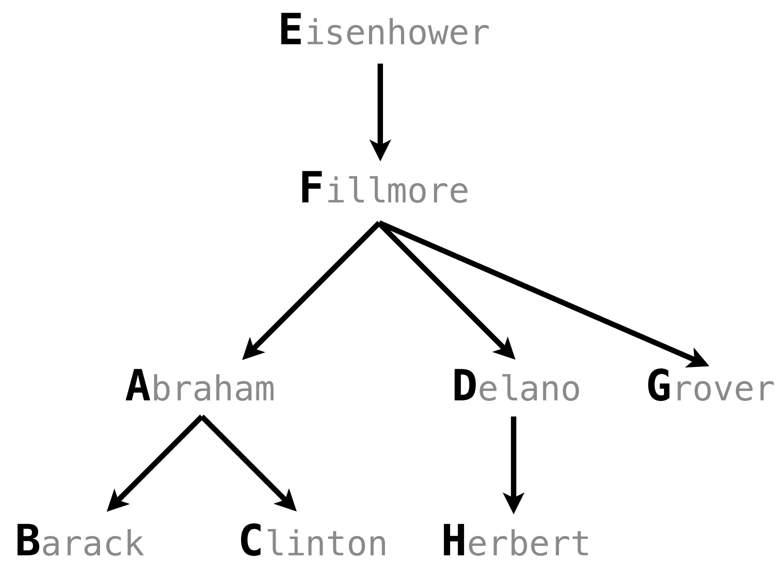


Recursive Facts

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
```

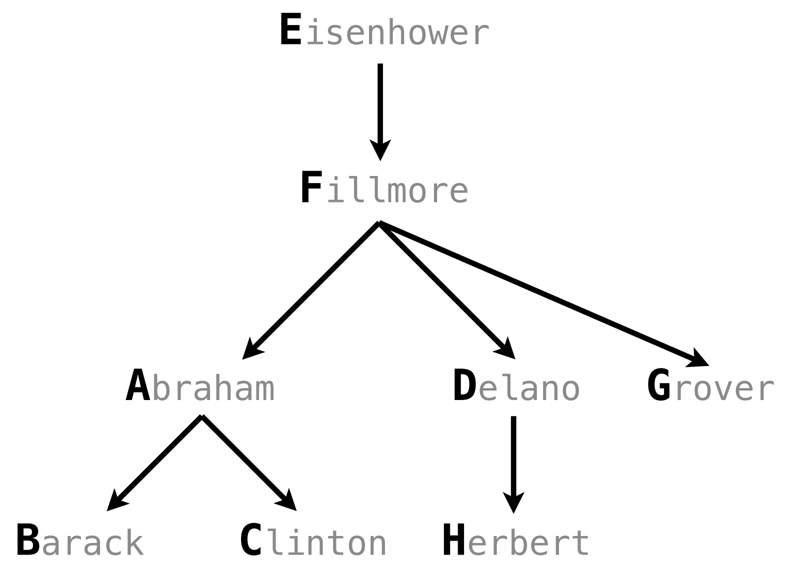


Recursive Facts

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
```



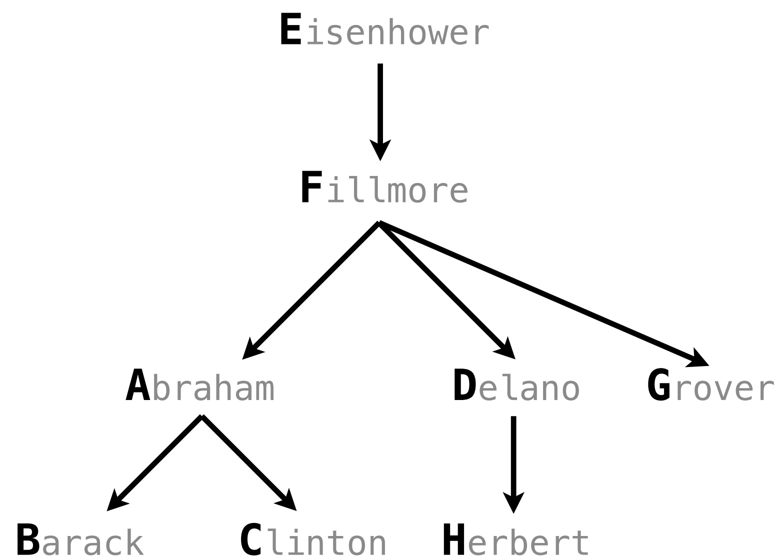
Recursive Facts

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

logic> (query (ancestor ?a barack)
```



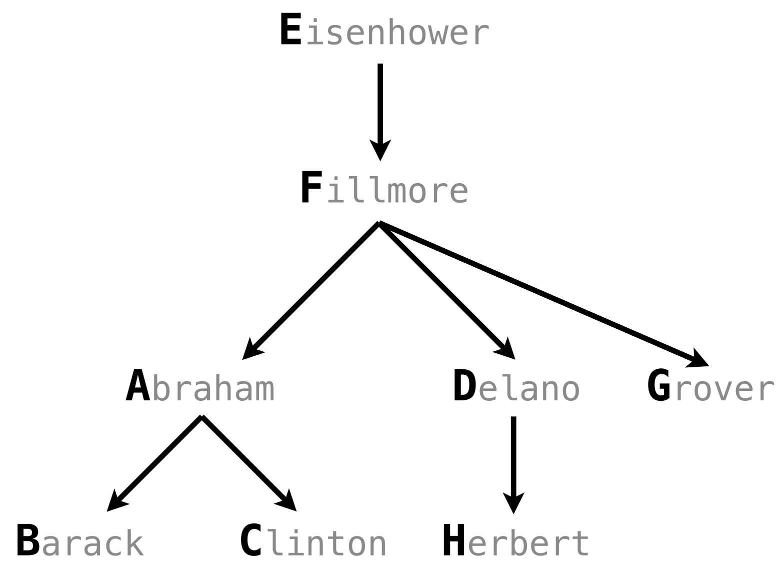
Recursive Facts

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

logic> (query (ancestor ?a barack)
              (ancestor ?a herbert))
```



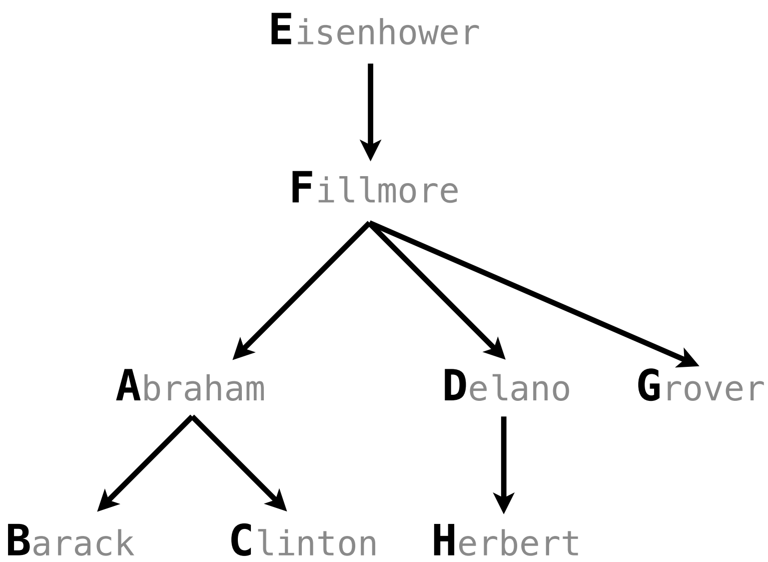
Recursive Facts

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

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



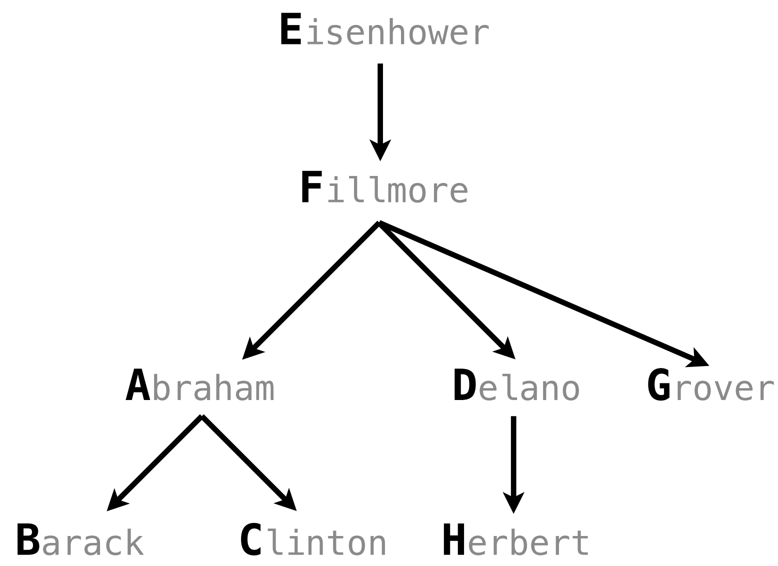
Recursive Facts

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

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



Recursive Facts

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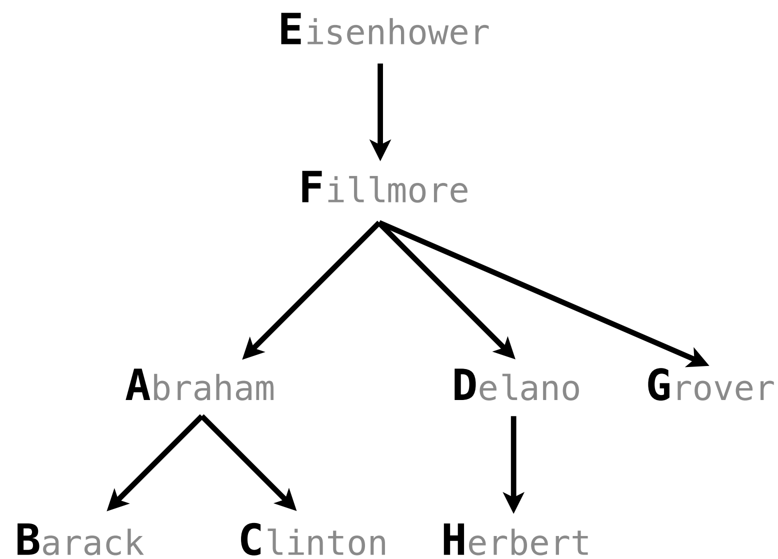
```
logic> (fact (ancestor ?a ?y) (parent ?a ?y))
logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))

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
```



Searching to Satisfy Queries

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

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```
logic> (query (ancestor ?a herbert))
```

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logic> (query (ancestor ?a herbert))
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```

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Success!
a: delano
```

Searching to Satisfy Queries

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

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

Searching to Satisfy Queries

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

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

Searching to Satisfy Queries

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

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

Searching to Satisfy Queries

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

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

Searching to Satisfy Queries

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

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

Searching to Satisfy Queries

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

```
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))
```

Searching to Satisfy Queries

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

```
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))
```

Searching to Satisfy Queries

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

```
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 satisfying assignments.

```
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 satisfying assignments.

```
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 satisfying assignments.

```
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

Hierarchical Facts

Hierarchical Facts

Relations can contain relations in addition to symbols.

Hierarchical Facts

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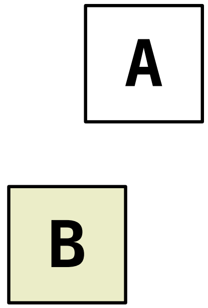
```
logic> (fact (dog (name abraham) (color white)))
```

A

Hierarchical Facts

Relations can contain relations in addition to symbols.

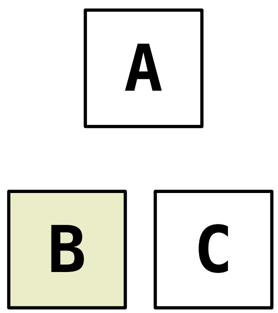
```
logic> (fact (dog (name abraham) (color white)))
logic> (fact (dog (name barack) (color tan)))
```



Hierarchical Facts

Relations can contain relations in addition to symbols.

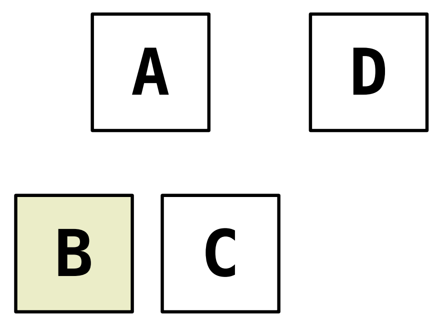
```
logic> (fact (dog (name abraham) (color white)))
logic> (fact (dog (name barack) (color tan)))
logic> (fact (dog (name clinton) (color white)))
```



Hierarchical Facts

Relations can contain relations in addition to symbols.

```
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)))
```



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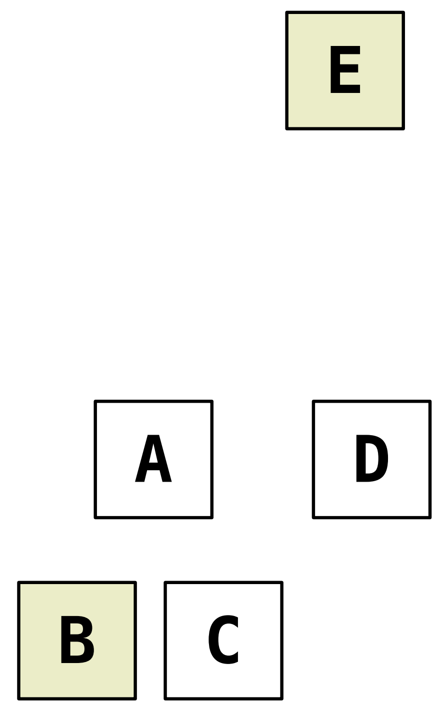
Relations can contain relations in addition to symbols.

```
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)))
```



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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)))
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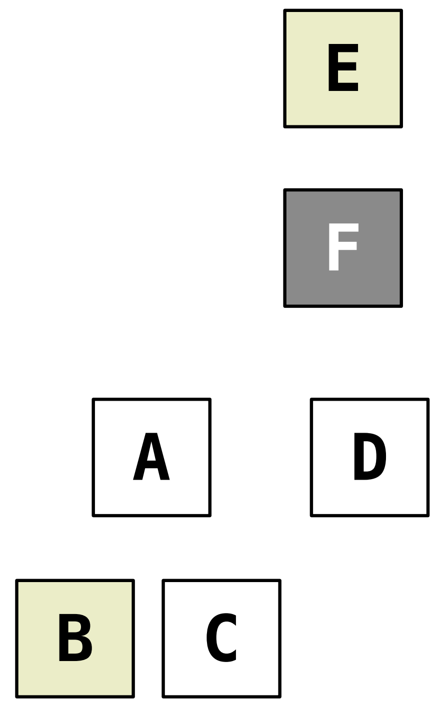
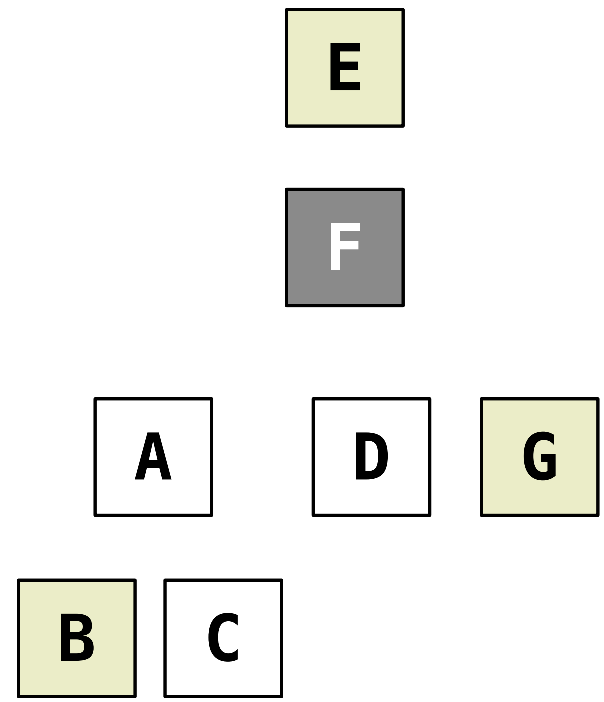
logic> (fact (dog (name fillmore) (color gray)))
```



Hierarchical Facts

Relations can contain relations in addition to symbols.

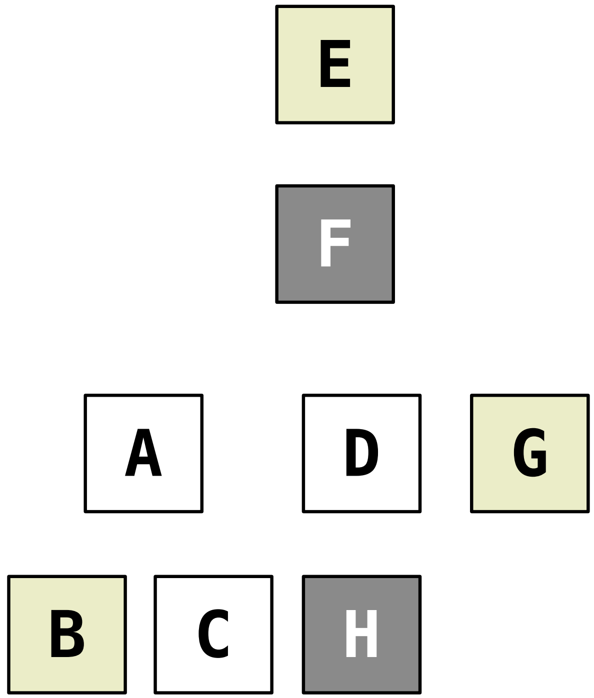
```
logic> (fact (dog (name abraham) (color white)))
logic> (fact (dog (name barack) (color tan)))
logic> (fact (dog (name clinton) (color white)))
logic> (fact (dog (name delano) (color white)))
logic> (fact (dog (name eisenhower) (color tan)))
logic> (fact (dog (name fillmore) (color gray)))
logic>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



Hierarchical Facts

Relations can contain relations in addition to symbols.

```
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 gray)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color gray)))
```



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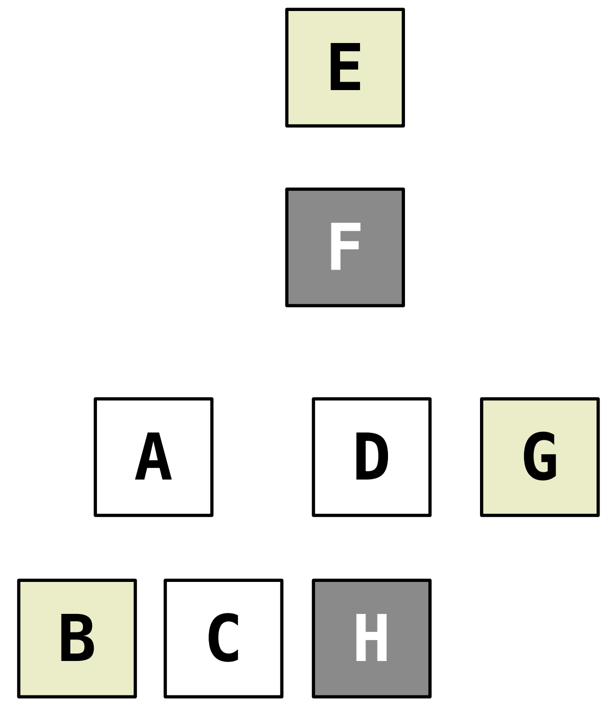
```
logic> (fact (dog (name abraham) (color white)))
logic> (fact (dog (name barack) (color tan)))
logic> (fact (dog (name clinton) (color white)))
logic> (fact (dog (name delano) (color white)))
logic> (fact (dog (name eisenhower) (color tan)))
logic> (fact (dog (name fillmore) (color gray)))
logic>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

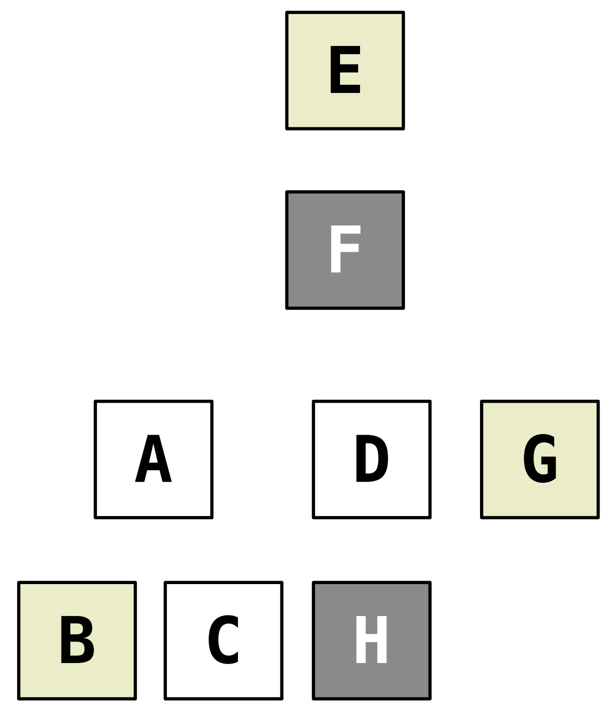
Variables can refer to symbols or whole relations.



Hierarchical Facts

Relations can contain relations in addition to symbols.

```
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 gray)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color gray)))
```



Variables can refer to symbols or whole relations.

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

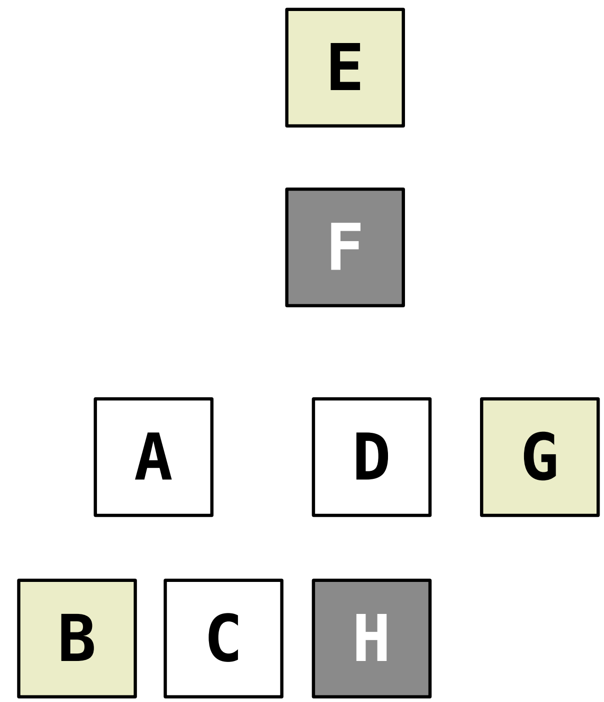
Hierarchical Facts

Relations can contain relations in addition to symbols.

```
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 gray)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color gray)))
```

Variables can refer to symbols or whole relations.

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



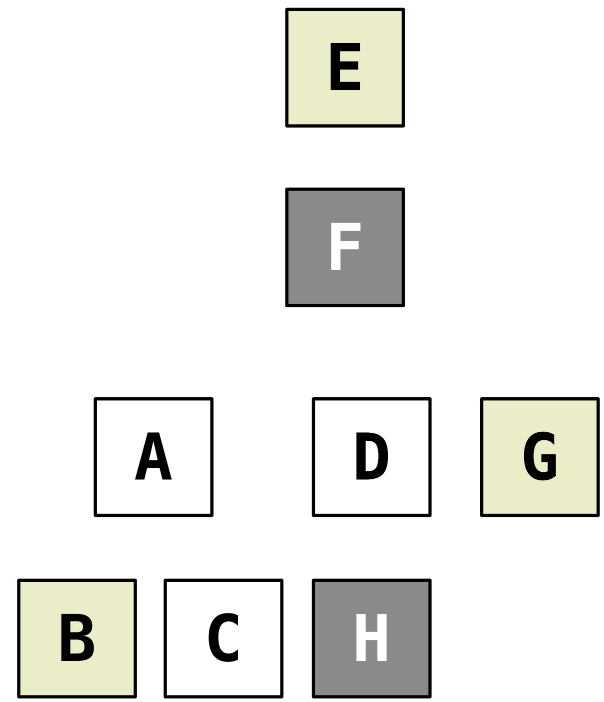
Hierarchical Facts

Relations can contain relations in addition to symbols.

```
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 gray)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color gray)))
```

Variables can refer to symbols or whole relations.

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



Hierarchical Facts

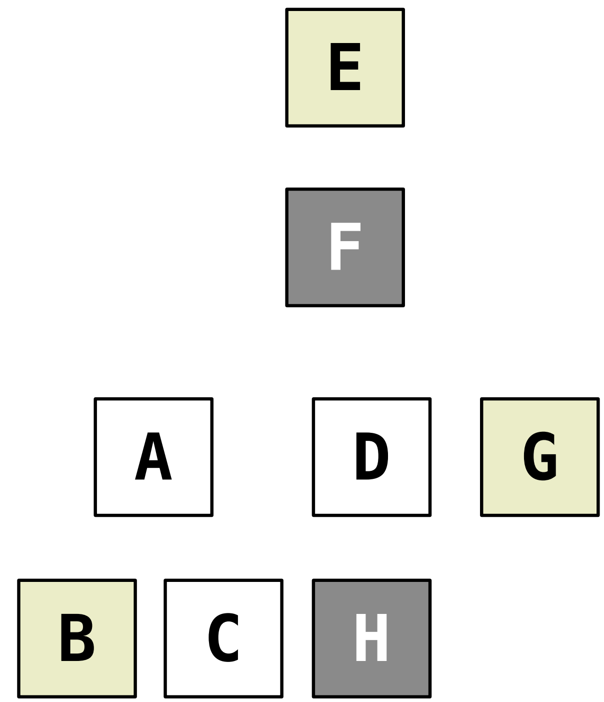
Relations can contain relations in addition to symbols.

```
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 gray)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color gray)))
```

Variables can refer to symbols or whole relations.

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

```
logic> (query (dog (name clinton) ?stats))
```



Hierarchical Facts

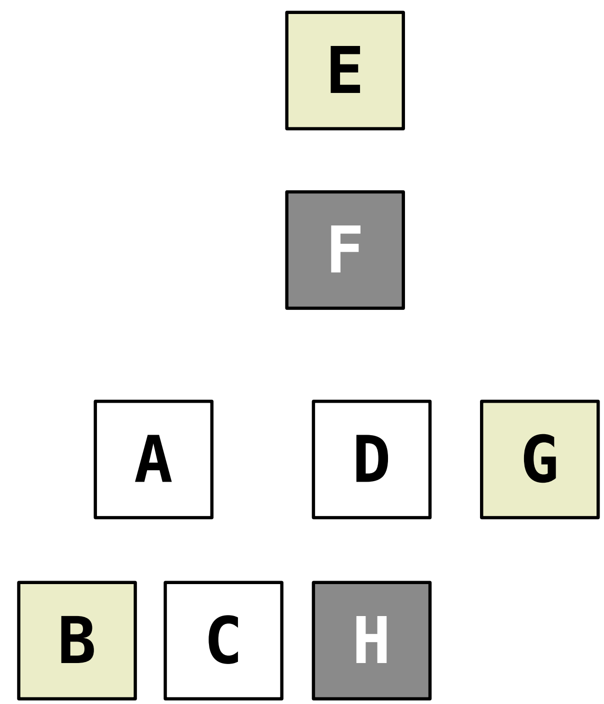
Relations can contain relations in addition to symbols.

```
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 gray)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color gray)))
```

Variables can refer to symbols or whole relations.

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

```
logic> (query (dog (name clinton) ?stats))
Success!
```



Hierarchical Facts

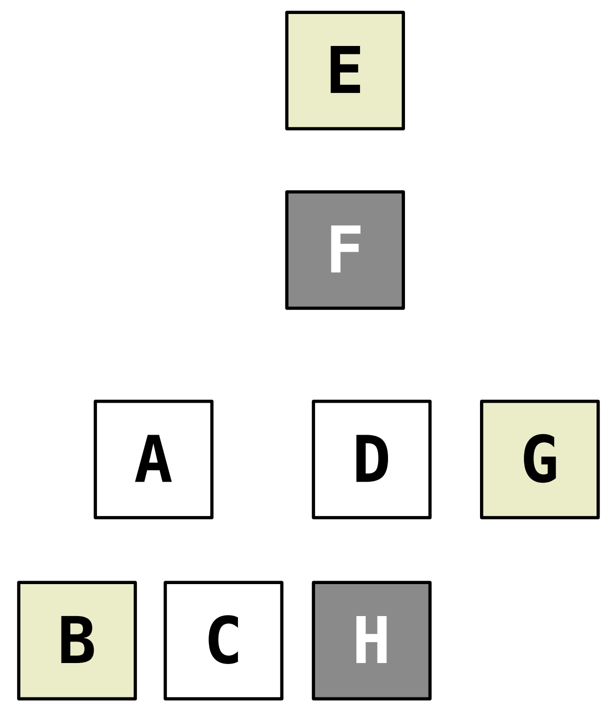
Relations can contain relations in addition to symbols.

```
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 gray)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color gray)))
```

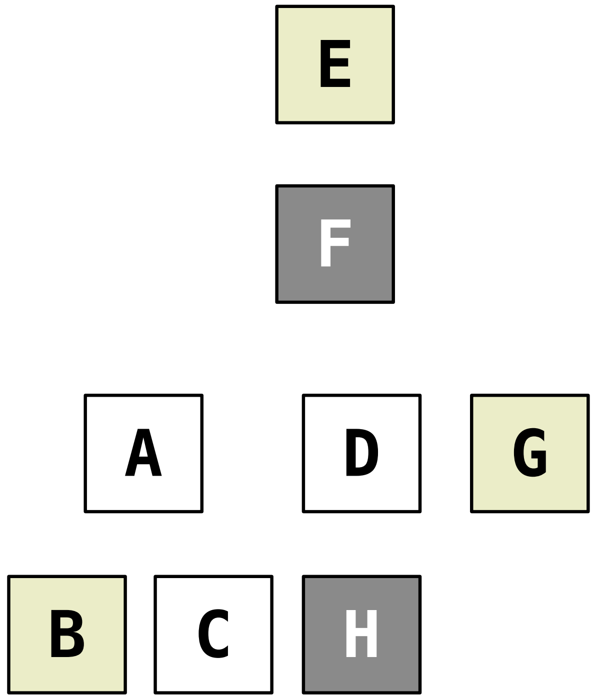
Variables can refer to symbols or whole relations.

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

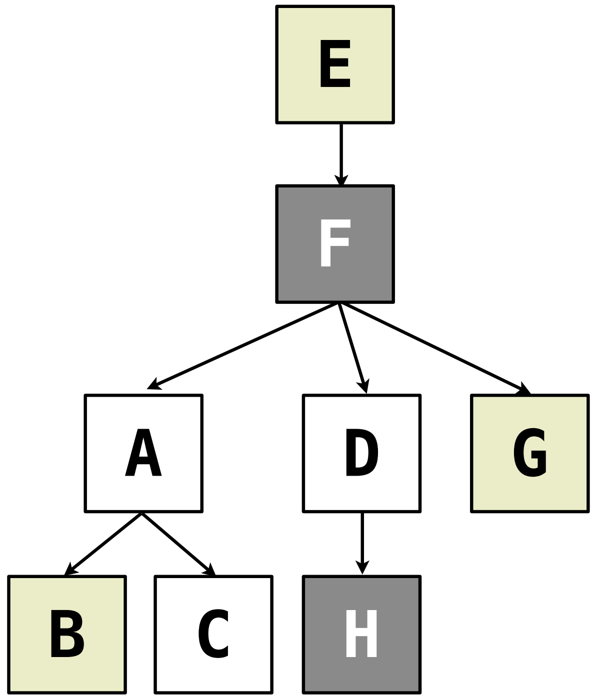
```
logic> (query (dog (name clinton) ?stats))
Success!
stats: (color white)
```



Combining Multiple Data Sources

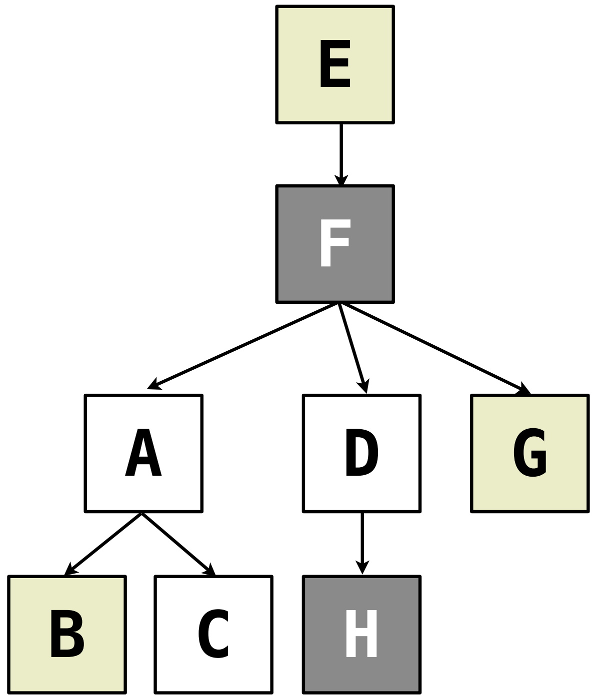


Combining Multiple Data Sources



Combining Multiple Data Sources

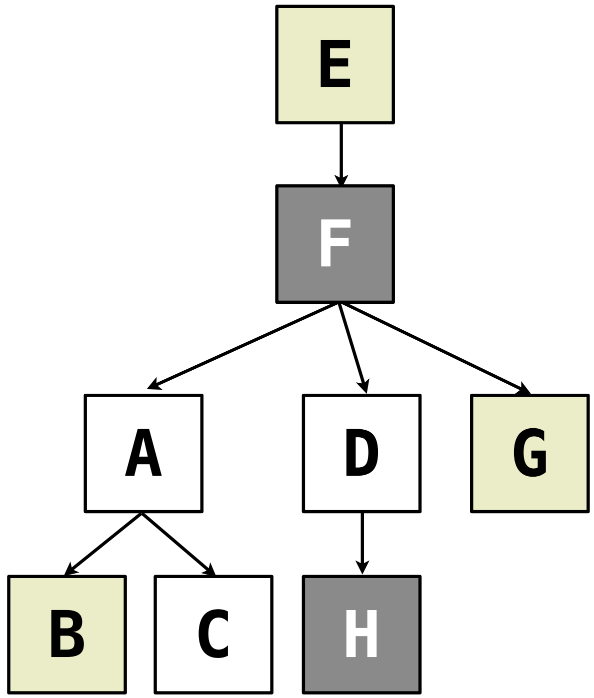
`Which dogs have an ancestor of the same color?`



Combining Multiple Data Sources

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

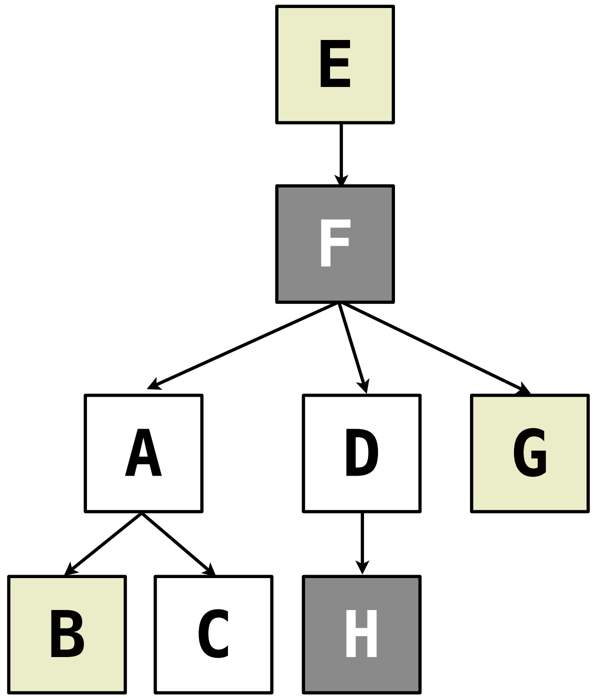
```
logic> (query (dog (name ?x) (color ?fur))
```



Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

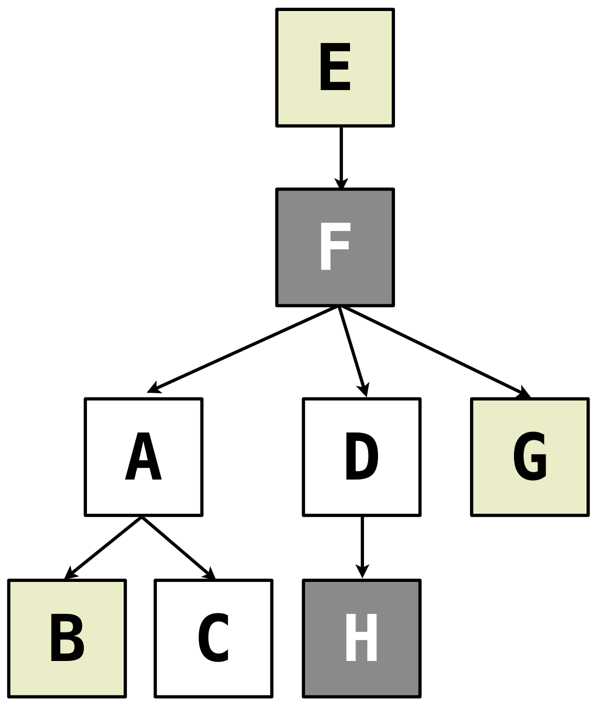
```
logic> (query (dog (name ?x) (color ?fur))
              (ancestor ?y ?x)
```



Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

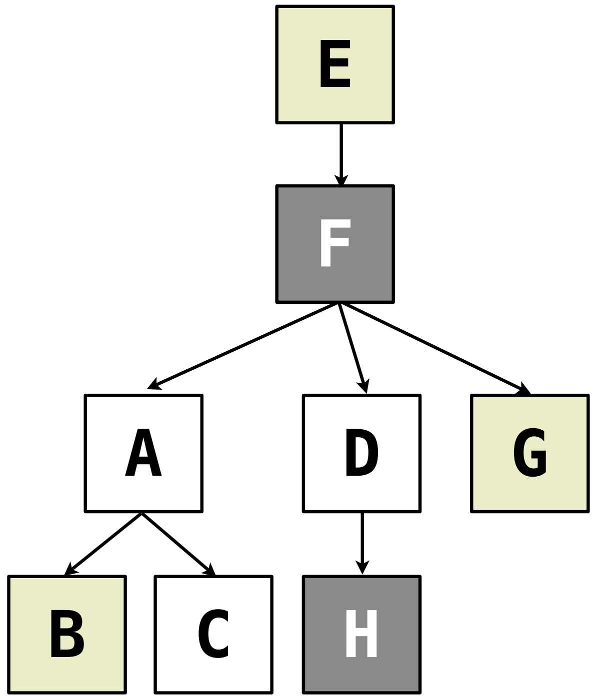
```
logic> (query (dog (name ?x) (color ?fur))
              (ancestor ?y ?x)
              (dog (name ?y) (color ?fur)))
```



Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

```
logic> (query (dog (name ?x) (color ?fur))
              (ancestor ?y ?x)
              (dog (name ?y) (color ?fur)))
Success!
```



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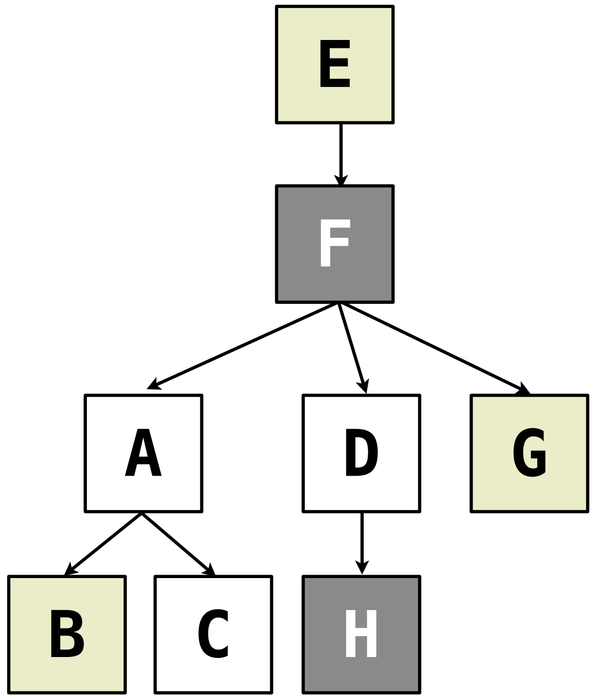
Which dogs have an ancestor of the same color?

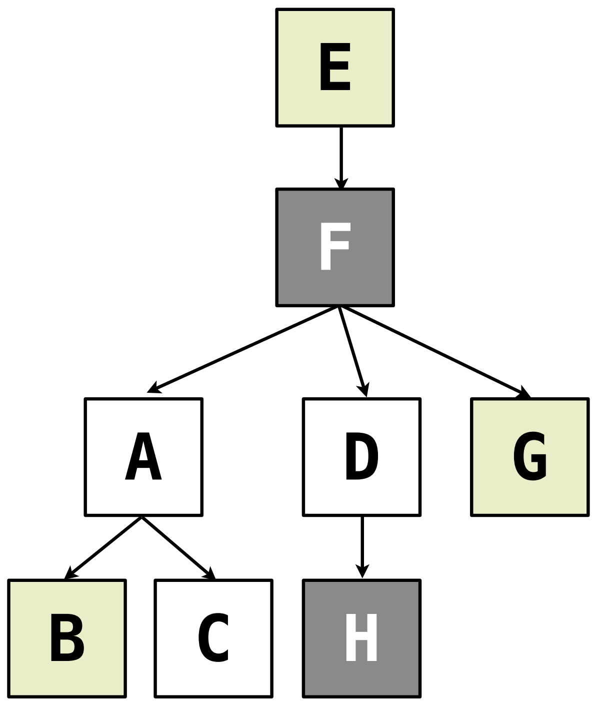
```
logic> (query (dog (name ?x) (color ?fur))
              (ancestor ?y ?x)
              (dog (name ?y) (color ?fur)))
Success!
x: barack    fur: tan     y: eisenhower
```



Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

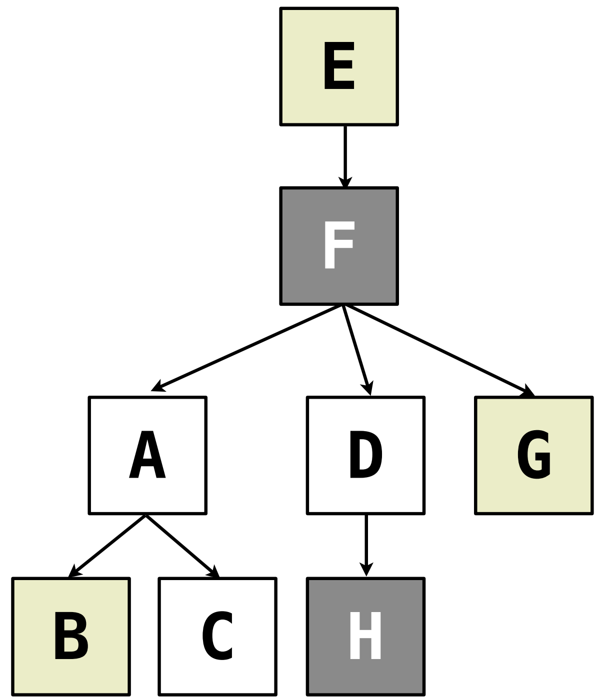
```
logic> (query (dog (name ?x) (color ?fur))
              (ancestor ?y ?x)
              (dog (name ?y) (color ?fur)))
Success!
x: barack    fur: tan     y: eisenhower
x: clinton   fur: white   y: abraham
```



Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

```
logic> (query (dog (name ?x) (color ?fur))
              (ancestor ?y ?x)
              (dog (name ?y) (color ?fur)))
Success!
x: barack    fur: tan     y: eisenhower
x: clinton   fur: white   y: abraham
x: grover    fur: tan     y: eisenhower
```



Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

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