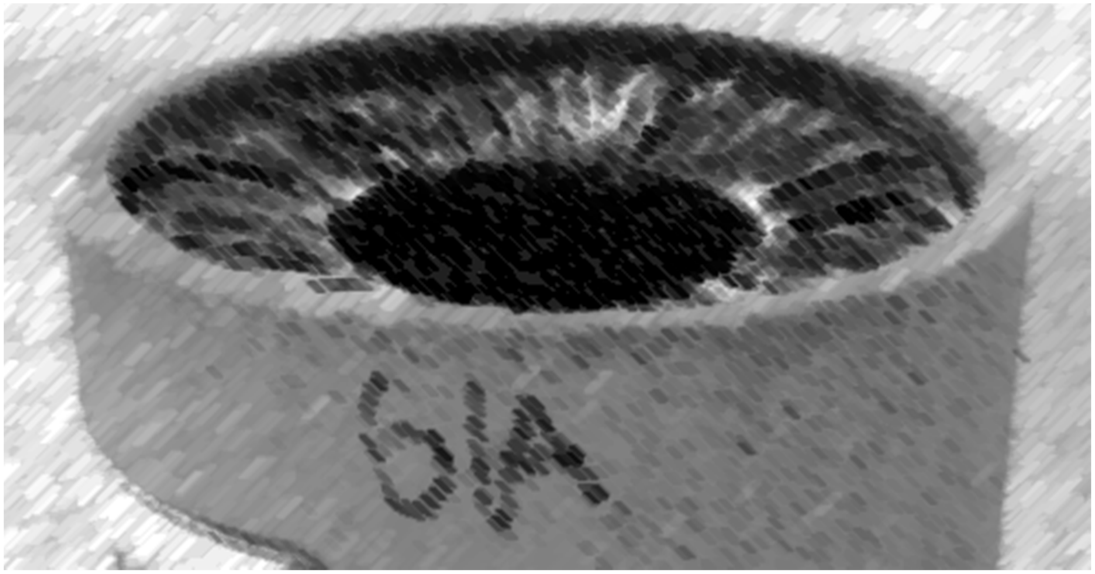


CS61A Lecture 39

Amir Kamil

UC Berkeley

April 22, 2013

Announcements

- HW12 due Wednesday
- Scheme project, contest due next Monday

Databases

Databases

A database is a collection of records (tuples) and an interface for adding, editing, and retrieving records

Databases

A database is a collection of records (tuples) and an interface for adding, editing, and retrieving records

The Structured Query Language (SQL) is perhaps the most widely used programming language on Earth

Databases

A database is a collection of records (tuples) and an interface for adding, editing, and retrieving records

The Structured Query Language (SQL) is perhaps the most widely used programming language on Earth

```
SELECT * FROM toy_info WHERE color='yellow';
```

Databases

A database is a collection of records (tuples) and an interface for adding, editing, and retrieving records

The Structured Query Language (SQL) is perhaps the most widely used programming language on Earth

```
SELECT * FROM toy_info WHERE color='yellow';
```

toy_id	toy	color	cost	weight
2	whiffleball	yellow	2.20	0.40
5	frisbee	yellow	1.50	0.20
10	yoyo	yellow	1.50	0.20

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

Databases

A database is a collection of records (tuples) and an interface for adding, editing, and retrieving records

The Structured Query Language (SQL) is perhaps the most widely used programming language on Earth

```
SELECT * FROM toy_info WHERE color='yellow';
```

toy_id	toy	color	cost	weight
2	whiffleball	yellow	2.20	0.40
5	frisbee	yellow	1.50	0.20
10	yoyo	yellow	1.50	0.20

SQL is an example of a declarative programming language.

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

Databases

A database is a collection of records (tuples) and an interface for adding, editing, and retrieving records

The Structured Query Language (SQL) is perhaps the most widely used programming language on Earth

```
SELECT * FROM toy_info WHERE color='yellow';
```

toy_id	toy	color	cost	weight
2	whiffleball	yellow	2.20	0.40
5	frisbee	yellow	1.50	0.20
10	yoyo	yellow	1.50	0.20

SQL is an example of a declarative programming language.

It separates *what* to compute from *how* it is computed

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

Databases

A database is a collection of records (tuples) and an interface for adding, editing, and retrieving records

The Structured Query Language (SQL) is perhaps the most widely used programming language on Earth

```
SELECT * FROM toy_info WHERE color='yellow';
```

toy_id	toy	color	cost	weight
2	whiffleball	yellow	2.20	0.40
5	frisbee	yellow	1.50	0.20
10	yoyo	yellow	1.50	0.20

SQL is an example of a declarative programming language.

It separates *what* to compute from *how* it is computed

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

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

Declarative Programming

Declarative Programming

The main characteristics of declarative languages:

Declarative Programming

The main characteristics of declarative languages:

- A "program" is a description of the desired solution

Declarative Programming

The main characteristics of declarative languages:

- A "program" is a description of the desired solution
- The interpreter figures out how to generate such a solution

Declarative Programming

The main characteristics of declarative languages:

- A "program" is a description of the desired solution
- The interpreter figures out how to generate such a solution

By contrast, in procedural languages such as Python & Scheme:

Declarative Programming

The main characteristics of declarative languages:

- A "program" is a description of the desired solution
- The interpreter figures out how to generate such a solution

By contrast, in procedural languages such as Python & Scheme:

- A "program" is a description of procedures

Declarative Programming

The main characteristics of declarative languages:

- A "program" is a description of the desired solution
- The interpreter figures out how to generate such a solution

By contrast, in procedural languages such as Python & Scheme:

- A "program" is a description of procedures
- The interpreter carries out execution/evaluation rules

Declarative Programming

The main characteristics of declarative languages:

- A "program" is a description of the desired solution
- The interpreter figures out how to generate such a solution

By contrast, in procedural languages such as Python & Scheme:

- A "program" is a description of procedures
- The interpreter carries out execution/evaluation rules

Building a universal problem solver is a difficult task

Declarative Programming

The main characteristics of declarative languages:

- A "program" is a description of the desired solution
- The interpreter figures out how to generate such a solution

By contrast, in procedural languages such as Python & Scheme:

- A "program" is a description of procedures
- The interpreter carries out execution/evaluation rules

Building a universal problem solver is a difficult task

Declarative programming languages compromise by solving only a subset of all problems

Declarative Programming

The main characteristics of declarative languages:

- A "program" is a description of the desired solution
- The interpreter figures out how to generate such a solution

By contrast, in procedural languages such as Python & Scheme:

- A "program" is a description of procedures
- The interpreter carries out execution/evaluation rules

Building a universal problem solver is a difficult task

Declarative programming languages compromise by solving only a subset of all problems

They typically trade off data scale for problem complexity

The Logic Language

The Logic Language

The *Logic* language is invented for this course

The Logic Language

The *Logic* language is invented for this course

- Based on the Scheme project & ideas from Prolog

The Logic Language

The *Logic* language is invented for this course

- Based on the Scheme project & ideas from Prolog
- Expressions are facts or queries, which contain relations

The Logic Language

The *Logic* language is invented for this course

- Based on the Scheme project & ideas from Prolog
- Expressions are facts or queries, which contain relations
- Expressions and relations are both Scheme lists

The Logic Language

The *Logic* language is invented for this course

- Based on the Scheme project & ideas from Prolog
- Expressions are facts or queries, which contain relations
- Expressions and relations are both Scheme lists
- For example, `(likes Amir dogs)` is a relation

The Logic Language

The *Logic* language is invented for this course

- Based on the Scheme project & ideas from Prolog
- Expressions are facts or queries, which contain relations
- Expressions and relations are both Scheme lists
- For example, `(likes Amir dogs)` is a relation
- Implementation fits on a single sheet of paper (next lecture)

The Logic Language

The *Logic* language is invented for this course

- Based on the Scheme project & ideas from Prolog
- Expressions are facts or queries, which contain relations
- Expressions and relations are both Scheme lists
- For example, `(likes Amir dogs)` is a relation
- Implementation fits on a single sheet of paper (next lecture)

Today's theme:

The Logic Language

The *Logic* language is invented for this course

- Based on the Scheme project & ideas from Prolog
- Expressions are facts or queries, which contain relations
- Expressions and relations are both Scheme lists
- For example, **`(likes Amir dogs)`** is a relation
- Implementation fits on a single sheet of paper (next lecture)

Today's theme:

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

Simple Facts

Simple Facts

A simple fact expression in the *Logic* language declares a relation to be true

Simple Facts

A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Simple Facts

A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

Simple Facts

A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

- A relation is a Scheme list

Simple Facts

A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

- A relation is a Scheme list
- A fact expression is a Scheme list containing **`fact`** followed by one or more relations

Simple Facts

A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

- A relation is a Scheme list
- A fact expression is a Scheme list containing **`fact`** followed by one or more relations

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

Simple Facts

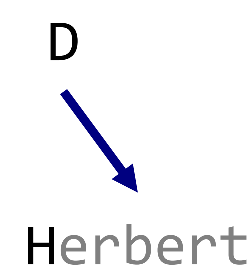
A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

- A relation is a Scheme list
- A fact expression is a Scheme list containing **`fact`** followed by one or more relations

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



Simple Facts

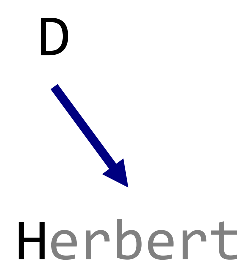
A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

- A relation is a Scheme list
- A fact expression is a Scheme list containing **`fact`** followed by one or more relations

```
logic> (fact (parent delano herbert))
logic> (fact (parent abraham barack))
```



Simple Facts

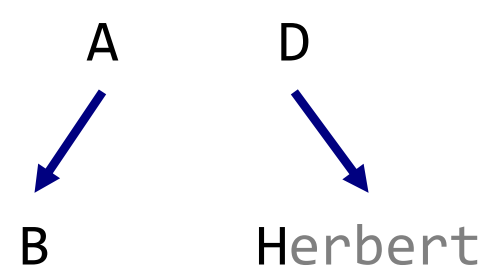
A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

- A relation is a Scheme list
- A fact expression is a Scheme list containing **`fact`** followed by one or more relations

```
logic> (fact (parent delano herbert))
logic> (fact (parent abraham barack))
```



Simple Facts

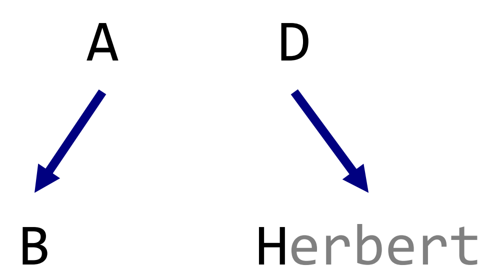
A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

- A relation is a Scheme list
- A fact expression is a Scheme list containing **`fact`** followed by one or more relations

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



Simple Facts

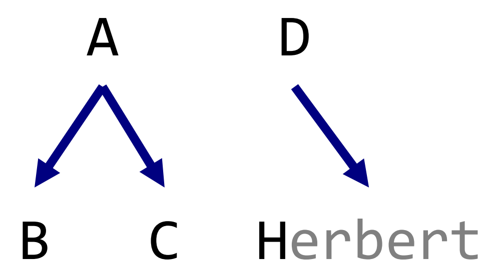
A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

- A relation is a Scheme list
- A fact expression is a Scheme list containing **`fact`** followed by one or more relations

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



Simple Facts

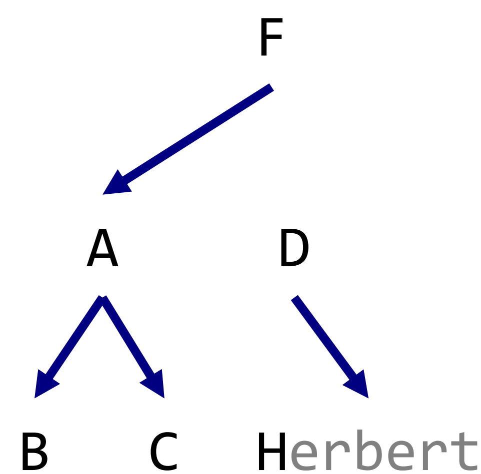
A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

- A relation is a Scheme list
- A fact expression is a Scheme list containing **`fact`** followed by one or more relations

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



Simple Facts

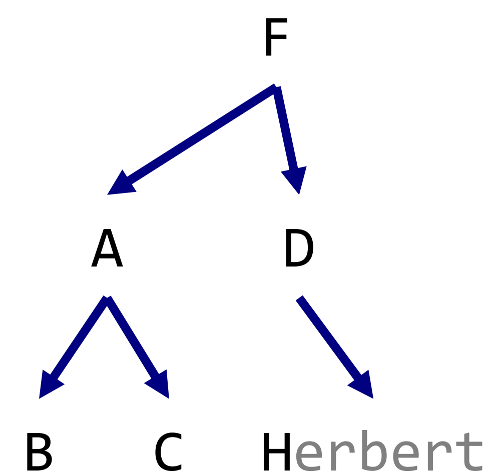
A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

- A relation is a Scheme list
- A fact expression is a Scheme list containing **fact** followed by one or more relations

```
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))
```



Simple Facts

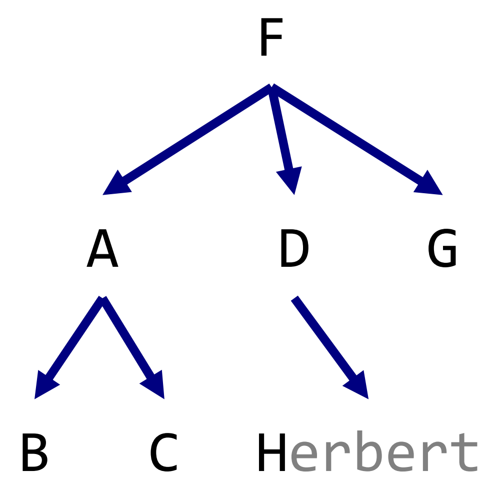
A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

- A relation is a Scheme list
- A fact expression is a Scheme list containing **`fact`** followed by one or more relations

```
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))
```



Simple Facts

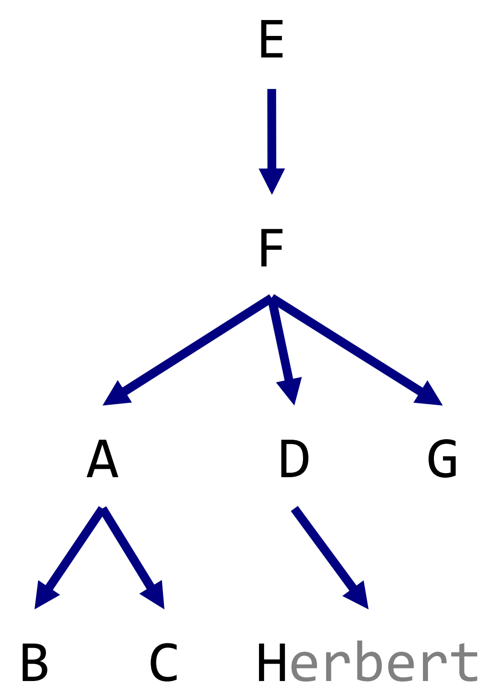
A simple fact expression in the *Logic* language declares a relation to be true

Let's say I want to track my many dogs' ancestry

Language Syntax:

- A relation is a Scheme list
- A fact expression is a Scheme list containing **`fact`** followed by one or more relations

```
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))
```



Relations are Not Procedure Calls

Relations are Not Procedure Calls

In *Logic*, a relation is not a call expression

Relations are Not Procedure Calls

In *Logic*, a relation is not a call expression

- In Scheme, we write **`(abs -3)`** to call **`abs`** on **`-3`**

Relations are Not Procedure Calls

In *Logic*, a relation is not a call expression

- In Scheme, we write **`(abs -3)`** to call **`abs`** on **`-3`**
- In *Logic*, **`(abs -3 3)`** asserts that the **`abs`** of **`-3`** is **`3`**

Relations are Not Procedure Calls

In *Logic*, a relation is not a call expression

- In Scheme, we write **`(abs -3)`** to call **`abs`** on **`-3`**
- In *Logic*, **`(abs -3 3)`** asserts that the **`abs`** of **`-3`** is **`3`**

For example, if we wanted to assert that **`1 + 2 = 3`**:

Relations are Not Procedure Calls

In *Logic*, a relation is not a call expression

- In Scheme, we write **`(abs -3)`** to call **`abs`** on **`-3`**
- In *Logic*, **`(abs -3 3)`** asserts that the **`abs`** of **`-3`** is **`3`**

For example, if we wanted to assert that **`1 + 2 = 3`**:

```
(add 1 2 3)
```

Relations are Not Procedure Calls

In *Logic*, a relation is not a call expression

- In Scheme, we write **`(abs -3)`** to call **`abs`** on **`-3`**
- In *Logic*, **`(abs -3 3)`** asserts that the **`abs`** of **`-3`** is **`3`**

For example, if we wanted to assert that **`1 + 2 = 3`**:

```
(add 1 2 3)
```

Why declare knowledge in this way? It will allow us to solve problems in two directions:

Relations are Not Procedure Calls

In *Logic*, a relation is not a call expression

- In Scheme, we write **`(abs -3)`** to call **`abs`** on **`-3`**
- In *Logic*, **`(abs -3 3)`** asserts that the **`abs`** of **`-3`** is **`3`**

For example, if we wanted to assert that **`1 + 2 = 3`**:

```
(add 1 2 3)
```

Why declare knowledge in this way? It will allow us to solve problems in two directions:

```
(add 1 2 _)
```

Relations are Not Procedure Calls

In *Logic*, a relation is not a call expression

- In Scheme, we write **`(abs -3)`** to call **`abs`** on **`-3`**
- In *Logic*, **`(abs -3 3)`** asserts that the **`abs`** of **`-3`** is **`3`**

For example, if we wanted to assert that **`1 + 2 = 3`**:

```
(add 1 2 3)
```

Why declare knowledge in this way? It will allow us to solve problems in two directions:

```
(add 1 2 _)
(add _ 2 3)
```

Relations are Not Procedure Calls

In *Logic*, a relation is not a call expression

- In Scheme, we write **`(abs -3)`** to call **`abs`** on **`-3`**
- In *Logic*, **`(abs -3 3)`** asserts that the **`abs`** of **`-3`** is **`3`**

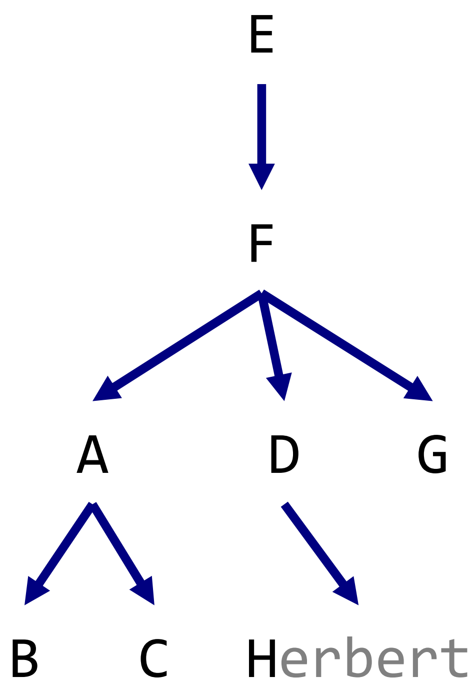
For example, if we wanted to assert that **`1 + 2 = 3`**:

```
(add 1 2 3)
```

Why declare knowledge in this way? It will allow us to solve problems in two directions:

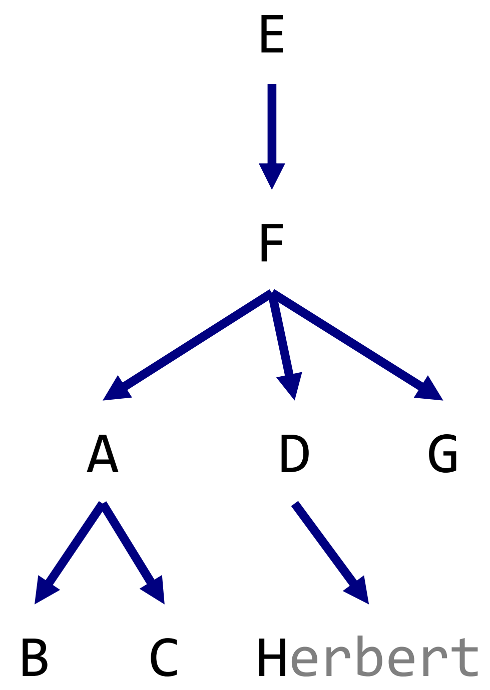
```
(add 1 2 _)
(add _ 2 3)
(add 1 _ 3)
```

Queries



Queries

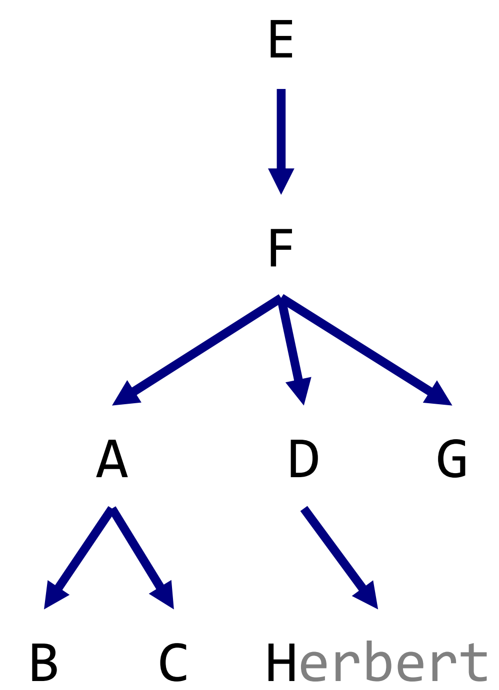
A query contains one or more relations. The *Logic* interpreter returns whether (and how) they are all simultaneously satisfied



Queries

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

Queries may contain variables: symbols starting with **?**

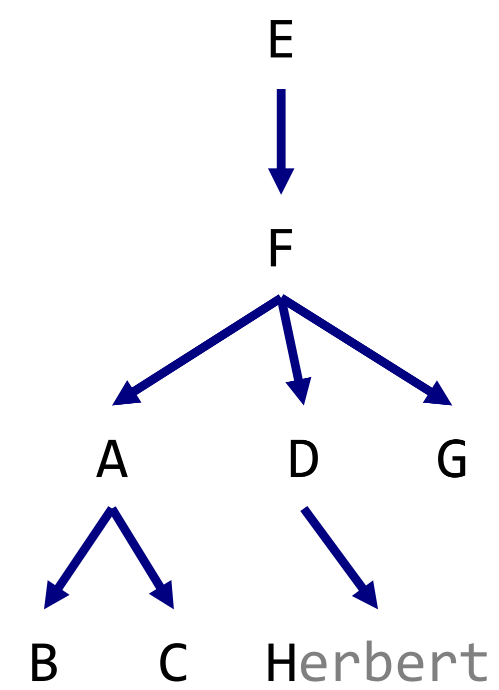


Queries

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

Queries may contain variables: 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))
```

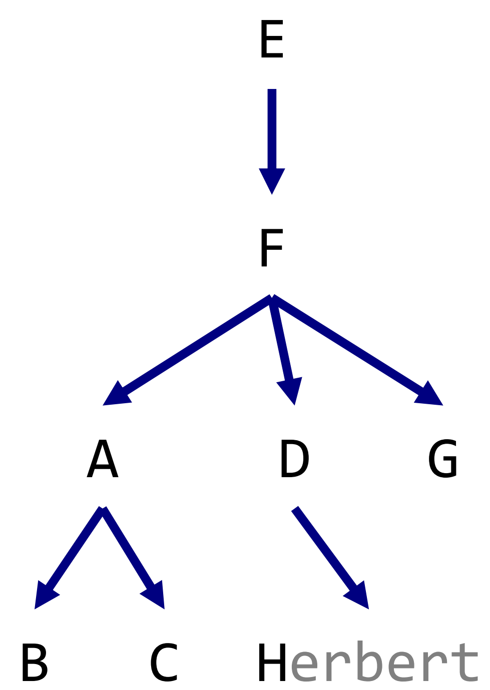


Queries

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

Queries may contain variables: 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 ?child))
```

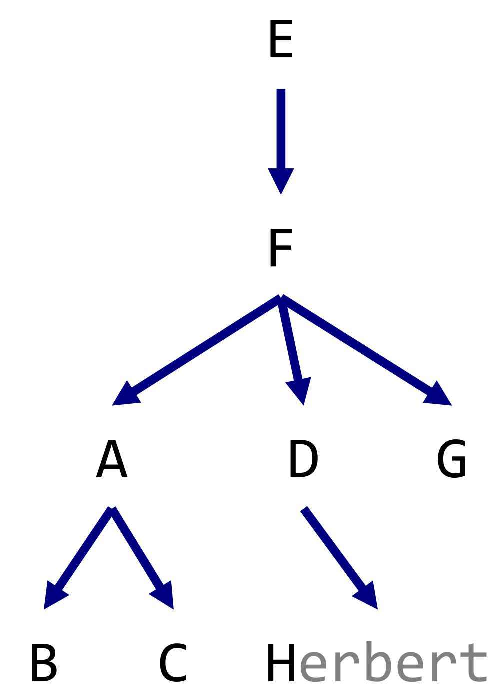


Queries

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

Queries may contain variables: 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 ?child))
Success!
```

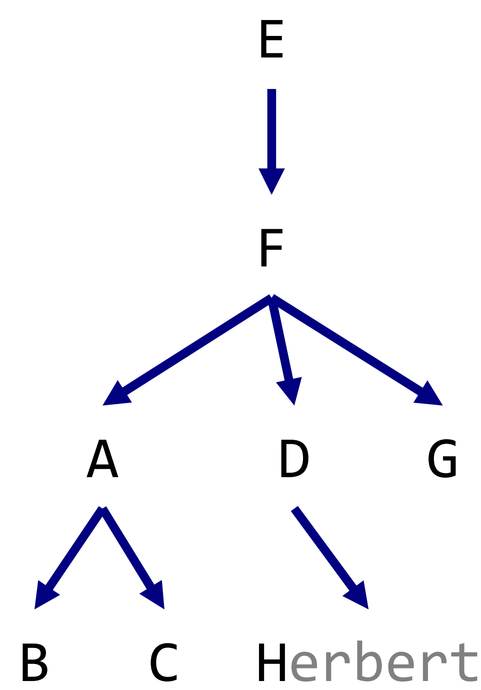


Queries

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

Queries may contain variables: 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 ?child))
Success!
child: barack
```

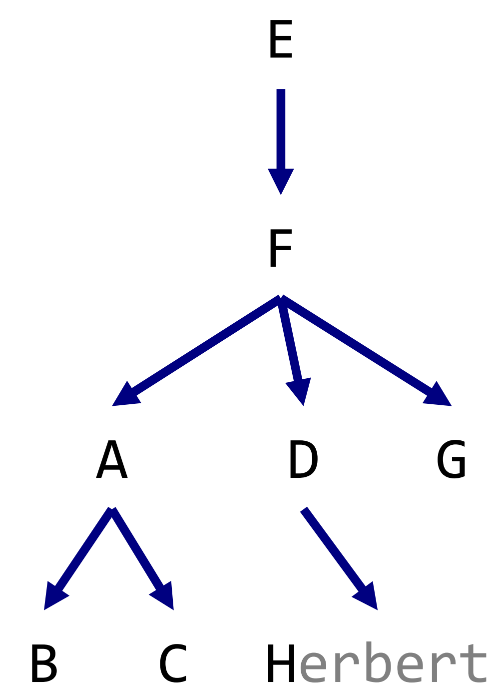


Queries

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

Queries may contain variables: 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 ?child))
Success!
child: barack
child: clinton
```

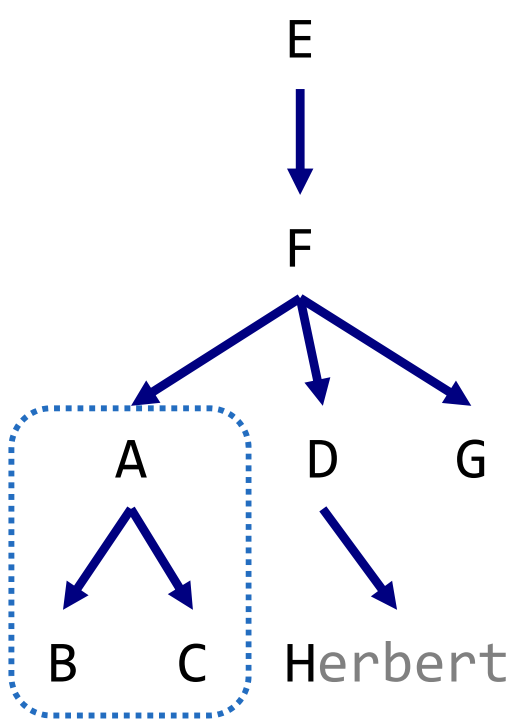


Queries

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

Queries may contain variables: 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 ?child))
Success!
child: barack
child: clinton
```

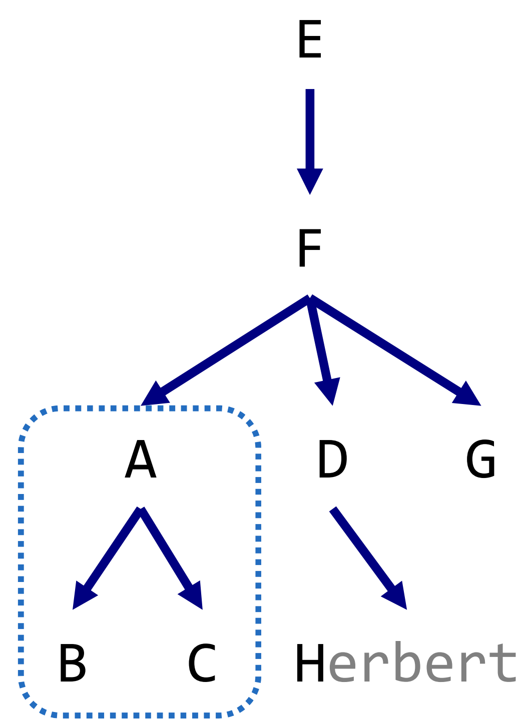


Queries

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

Queries may contain variables: 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))
```

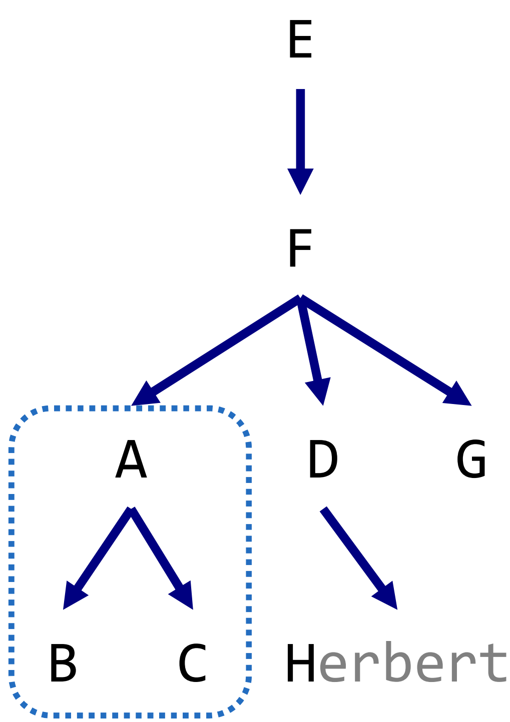


Queries

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

Queries may contain variables: 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 ?who barack))
```

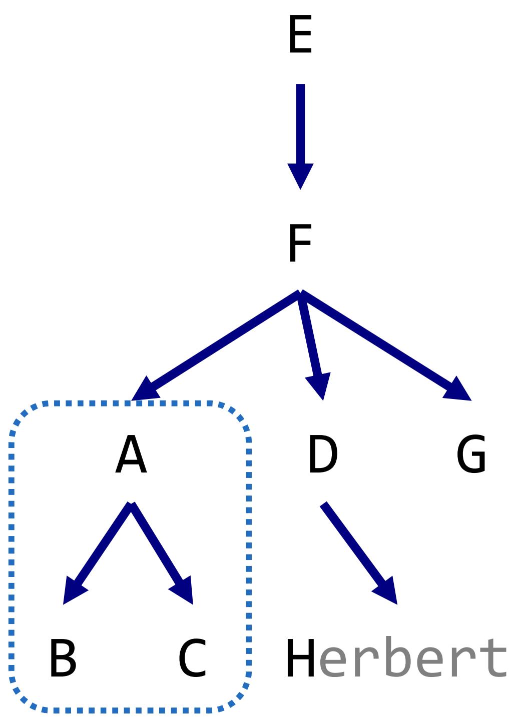


Queries

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

Queries may contain variables: 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 ?who barack)
              (parent ?who clinton))
```

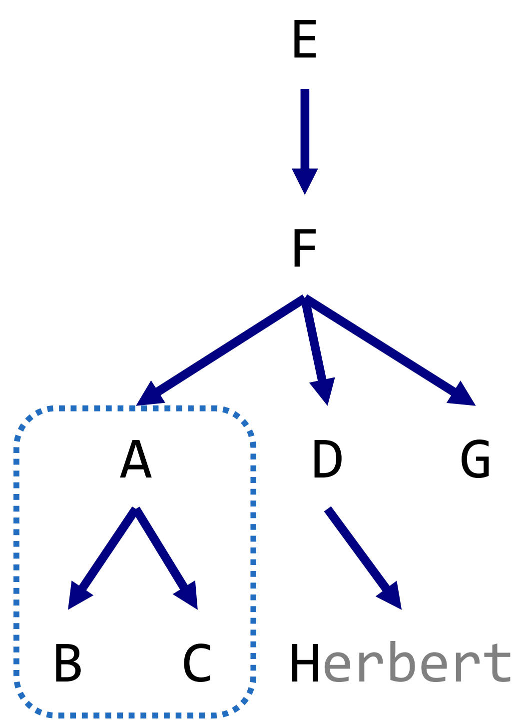


Queries

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

Queries may contain variables: 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 ?who barack)
              (parent ?who clinton))
Success!
```

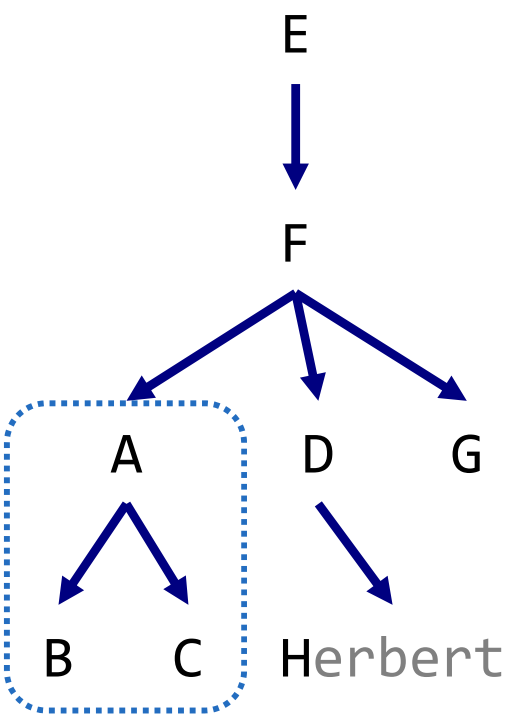


Queries

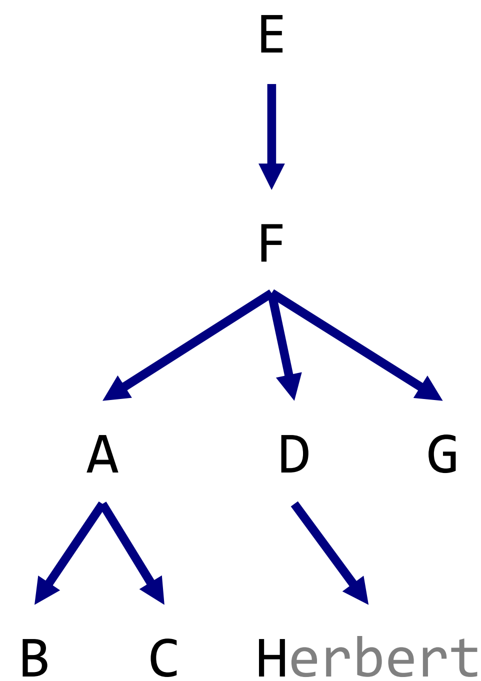
A query contains one or more relations. The *Logic* interpreter returns whether (and how) they are all simultaneously satisfied

Queries may contain variables: 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 ?who barack)
              (parent ?who clinton))
Success!
who: abraham
```

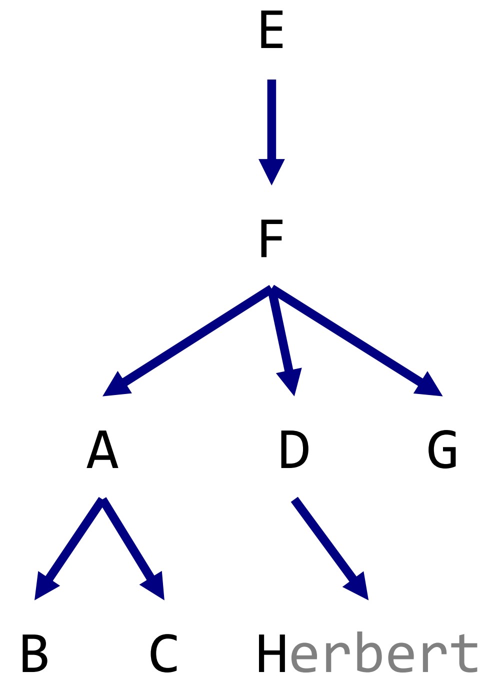


Compound Facts



Compound Facts

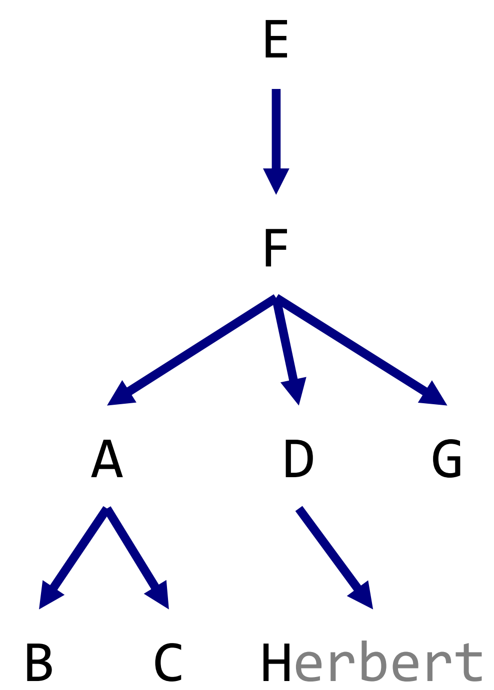
A fact can include multiple relations and variables as well



Compound Facts

A fact can include multiple relations and variables as well

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



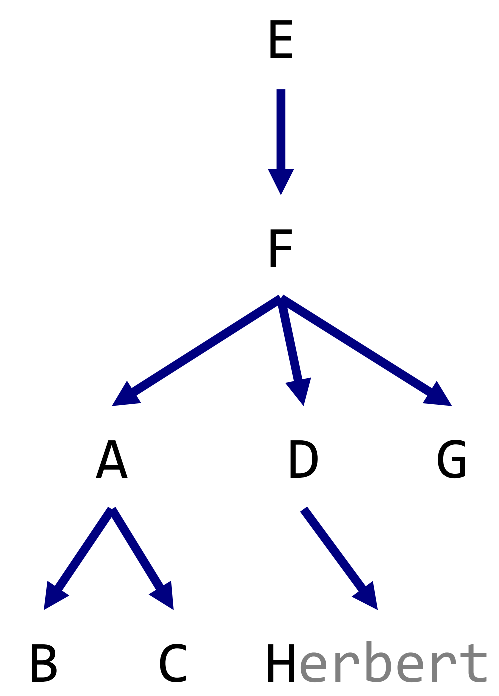
Compound Facts

A fact can include multiple relations and variables as well

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

Means **<conclusion>** is true if all **<hypothesi$_s$K>** are true

hesis$_N$>)



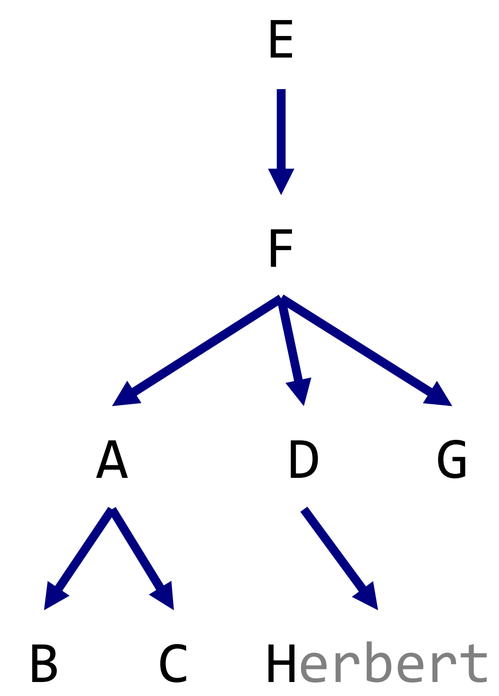
Compound Facts

A fact can include multiple relations and variables as well

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

Means **<conclusion>** is true if all **<hypothesisK>** are true

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



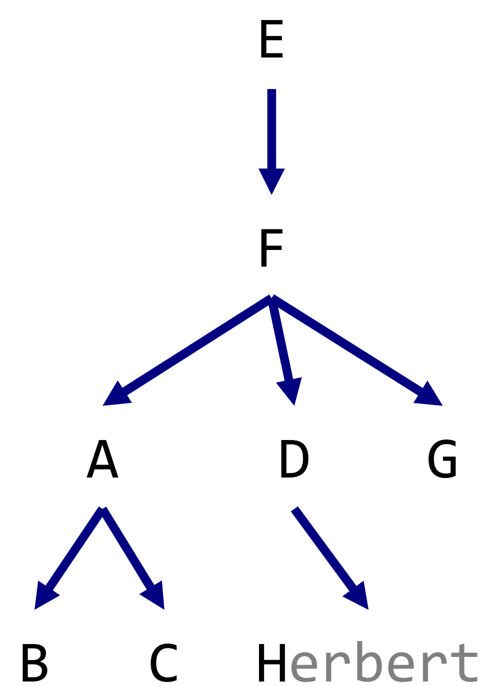
Compound Facts

A fact can include multiple relations and variables as well

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

Means **<conclusion>** is true if all **<hypothesisK>** are true

```
logic> (fact (child ?c ?p) (parent ?p ?c))
logic> (query (child herbert delano))
Success!
```



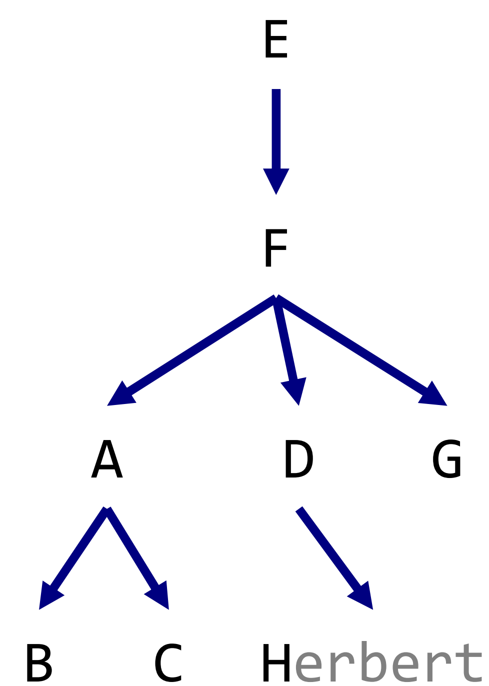
Compound Facts

A fact can include multiple relations and variables as well

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

Means **<conclusion>** is true if all **<hypothesisK>** are true

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

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

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



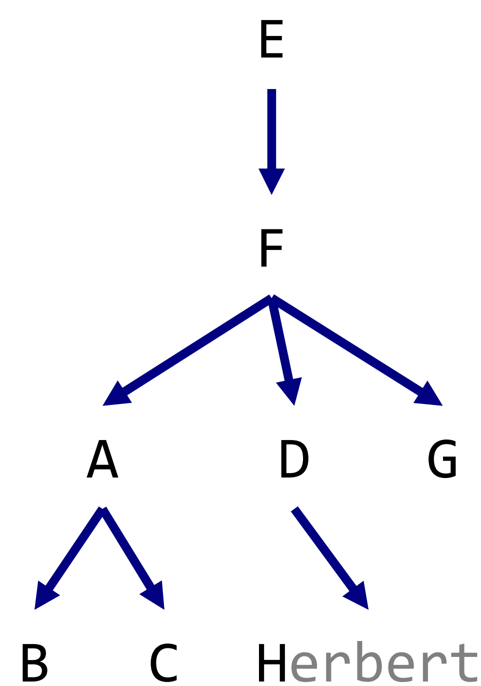
Compound Facts

A fact can include multiple relations and variables as well

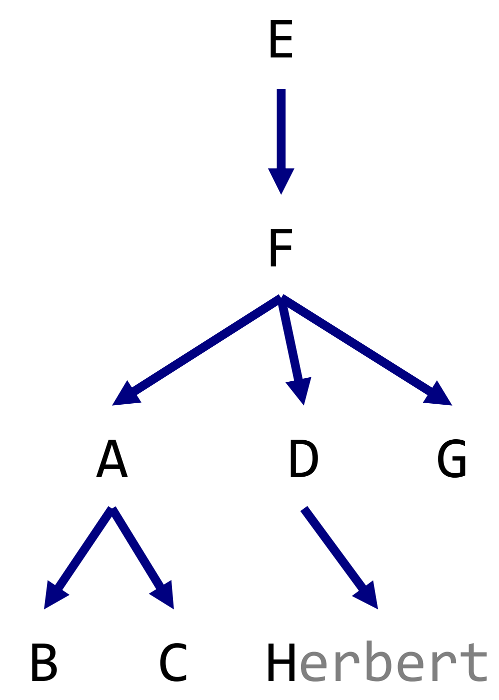
```
(fact <conclusion> <hypothesis0> <hypothesis1> ... <hypothesisN>)
```

Means **<conclusion>** is true if all **<hypothesisK>** 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
```

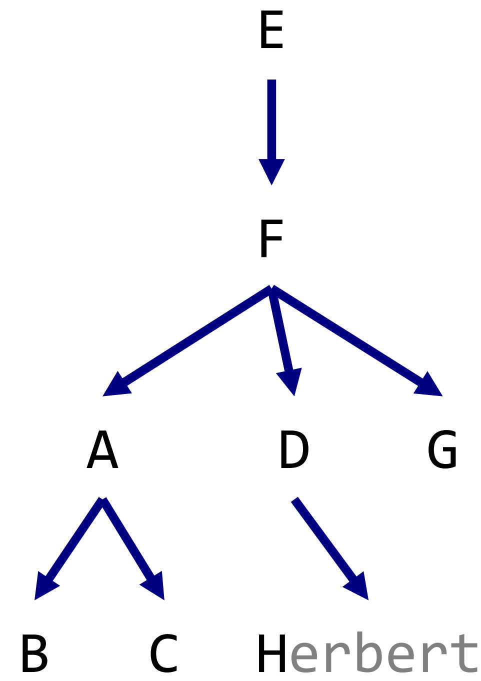


Recursive Facts



Recursive Facts

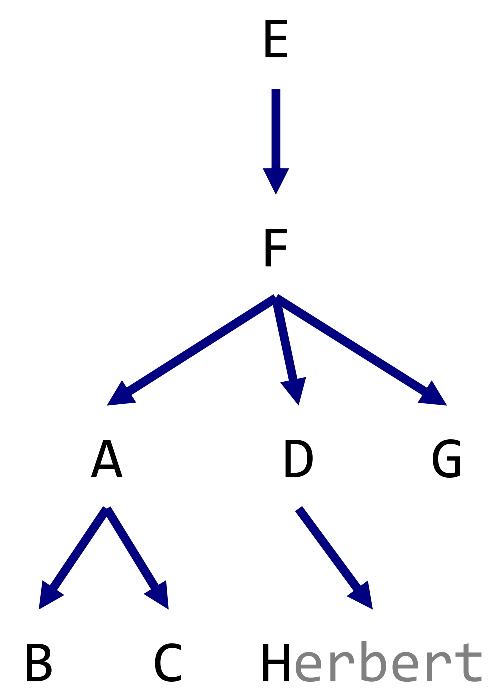
A fact is recursive if the same relation is mentioned in a hypothesis and the conclusion



Recursive Facts

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

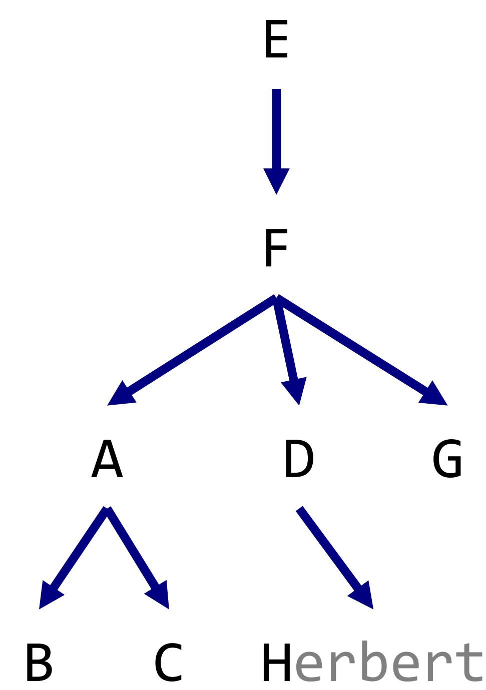
```
logic> (fact (ancestor ?a ?y) (parent ?a ?y))
logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))
```



Recursive Facts

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

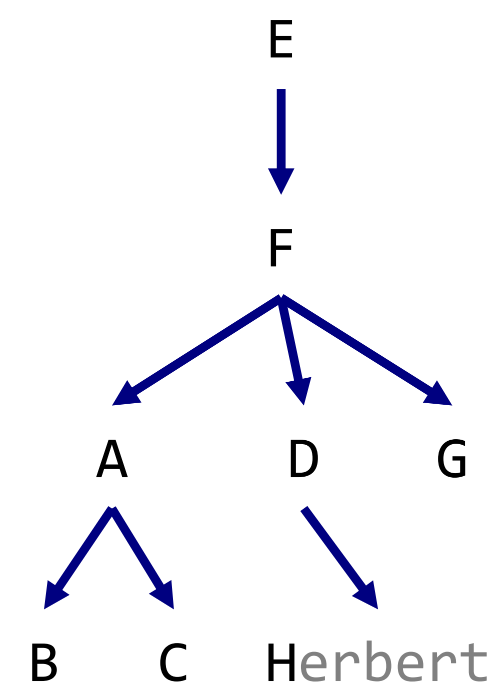
```
logic> (fact (ancestor ?a ?y) (parent ?a ?y))
logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))

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



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
a: eisenhower
```



Searching to Satisfy Queries

Searching to Satisfy Queries

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

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
```

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
```

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))
```

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))
```

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
```

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

Hierarchical Facts

Relations can contain relations in addition to atoms

Hierarchical Facts

Relations can contain relations in addition to atoms

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

Hierarchical Facts

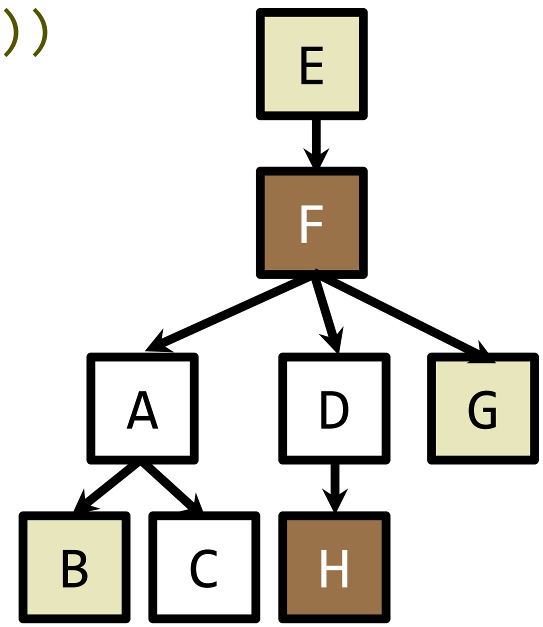
Relations can contain relations in addition to atoms

```
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)))
```

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)))
```

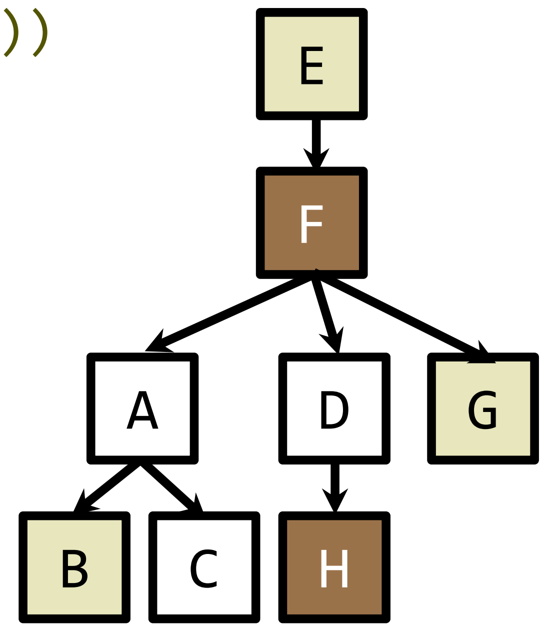


Hierarchical Facts

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)))
```

Variables can refer to atoms or relations



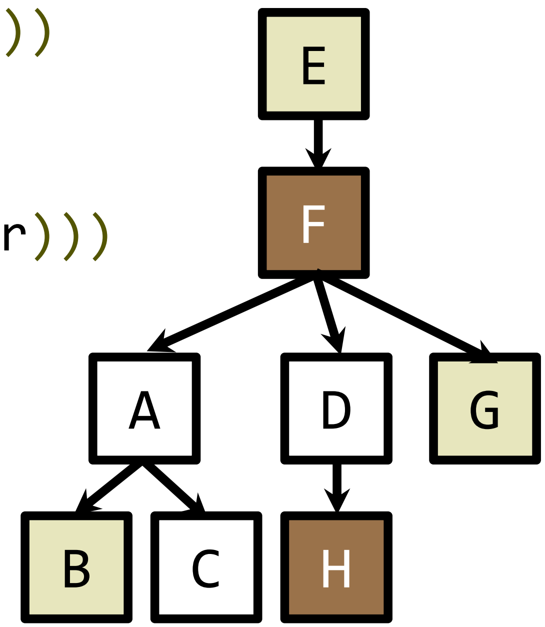
Hierarchical Facts

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)))
```

Variables can refer to atoms or relations

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



Hierarchical Facts

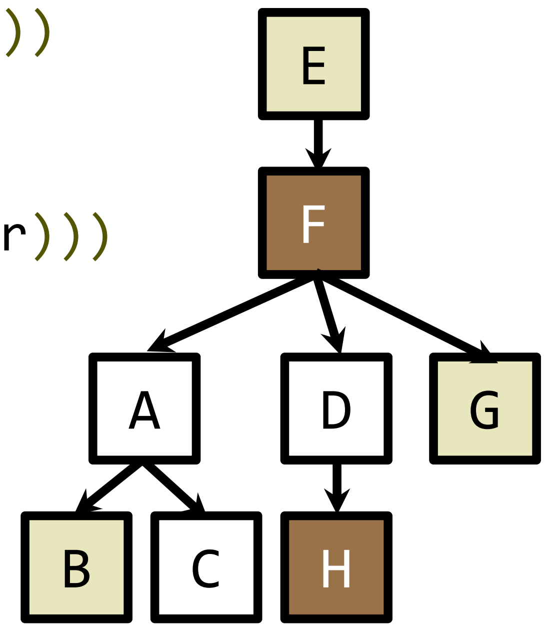
Relations can contain relations in addition to atoms

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

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)
```



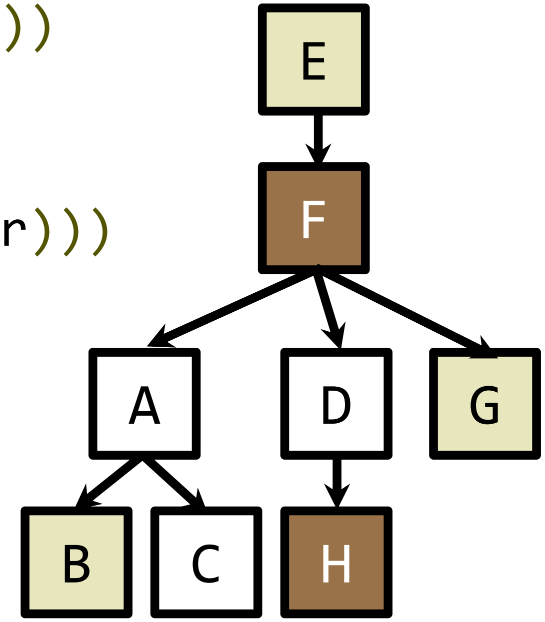
Hierarchical Facts

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)))
```

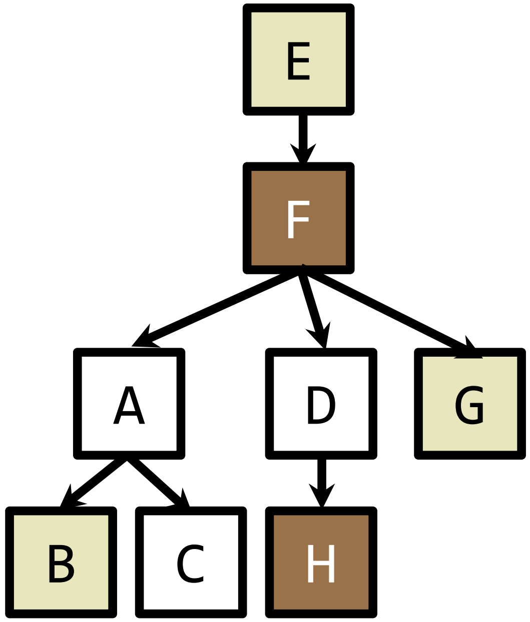
Variables can refer to atoms or relations

```
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

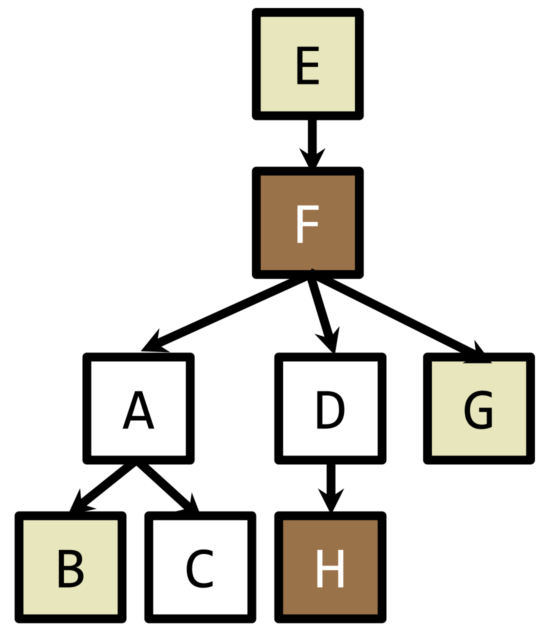
Which dogs have an ancestor of the same color?



Example: Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

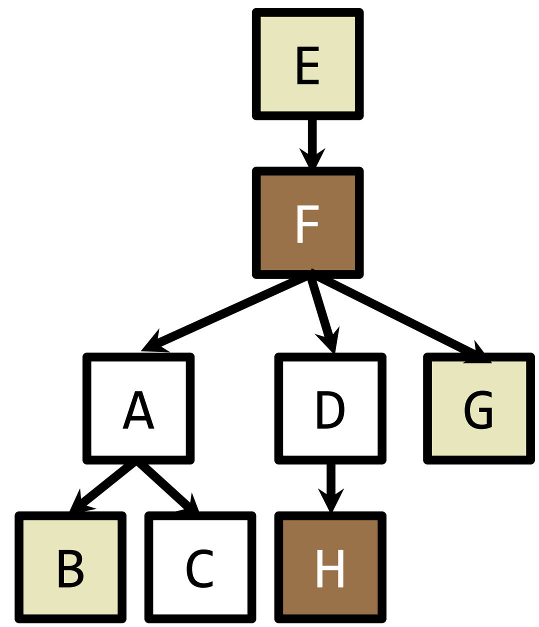
```
logic> (query (dog (name ?name) (color ?color))
```



Example: Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

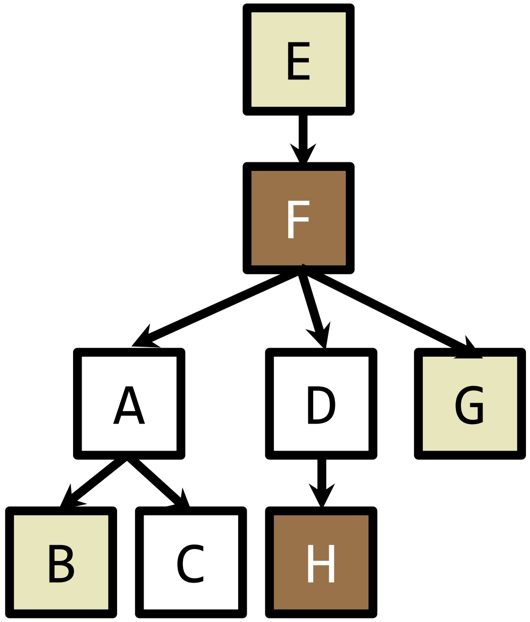
```
logic> (query (dog (name ?name) (color ?color))
              (ancestor ?ancestor ?name)
```



Example: Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

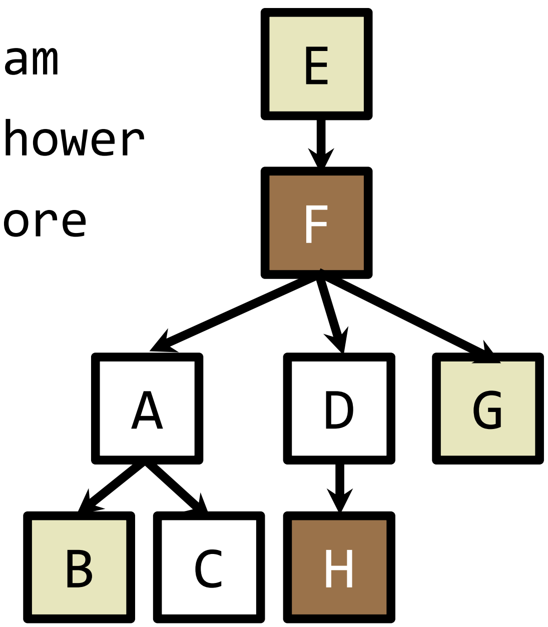
```
logic> (query (dog (name ?name) (color ?color))
              (ancestor ?ancestor ?name)
              (dog (name ?ancestor) (color ?color)))
```



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

Example: Appending Lists

Two lists append to form a third list if:

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

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

```
() (a b c) (a b c)
```

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

```
() (a b c) (a b c)
```

```
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

```
() (a b c) (a b c)
```

- Both of the following hold:

```
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

```
() (a b c) (a b c)
```

- Both of the following hold:
  - List 1 and 3 have the same first element

```
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

```
() (a b c) (a b c)
```

- Both of the following hold:
  - List 1 and 3 have the same first element

```
(a b c) (d e f) (a b c d e f)
```

```
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

```
() (a b c) (a b c)
```

- Both of the following hold:
  - List 1 and 3 have the same first element

```
(a b c) (d e f) (a b c d e f)
```

```
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

```
() (a b c) (a b c)
```

- Both of the following hold:
  - List 1 and 3 have the same first element

```
(a b c) (d e f) (a b c d e f)
```

```
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

```
() (a b c) (a b c)
```

- Both of the following hold:
  - List 1 and 3 have the same first element

```
(a b c) (d e f) (a b c d e f)
```

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

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

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

```
() (a b c) (a b c)
```

- Both of the following hold:
  - List 1 and 3 have the same first element
  - The rest of list 1 and all of list 2 append to form the rest of list 3

```
(a b c) (d e f) (a b c d e f)
```

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

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

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

```
() (a b c) (a b c)
```

- Both of the following hold:
  - List 1 and 3 have the same first element
  - The rest of list 1 and all of list 2 append to form the rest of list 3

```
(a b c) (d e f) (a b c d e f)
```

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

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

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

```
() (a b c) (a b c)
```

- Both of the following hold:
  - List 1 and 3 have the same first element
  - The rest of list 1 and all of list 2 append to form the rest of list 3

```
(a b c) (d e f) (a b c d e f)
```

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

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

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

```
() (a b c) (a b c)
```

- Both of the following hold:
  - List 1 and 3 have the same first element
  - The rest of list 1 and all of list 2 append to form the rest of list 3

```
(a b c) (d e f) (a b c d e f)
```

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

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

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

```
() (a b c) (a b c)
```

- Both of the following hold:
  - List 1 and 3 have the same first element
  - The rest of list 1 and all of list 2 append to form the rest of list 3

```
(a b c) (d e f) (a b c d e f)
```

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

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