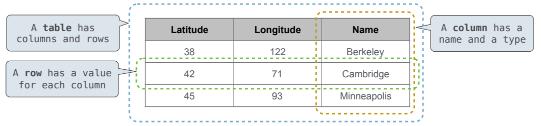
## Declarative Languages

## Database Management Systems

Database management systems (DBMS) are important, heavily used, and interesting!

A table is a collection of records, which are rows that have a value for each column


A **table** has columns and rows
A **row** has a value for each column
A **column** has a name and a type

| Latitude | Longitude | Name |
|---|---|---|
| 38 | 122 | Berkeley |
| 42 | 71 | Cambridge |
| 45 | 93 | Minneapolis |

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

SQL is a *declarative* programming language

## Declarative Programming

In **declarative languages** such as SQL & Prolog:
- A "program" is a description of the desired result
- The interpreter figures out how to generate the result

In **imperative languages** such as Python & Scheme:
- A "program" is a description of computational processes
- The interpreter carries out execution/evaluation rules

**Cities:**

| latitude | longitude | name |
|---|---|---|
| 38 | 122 | Berkeley |
| 42 | 71 | Cambridge |
| 45 | 93 | Minneapolis |

```
create table cities as
  select 38 as latitude, 122 as longitude, "Berkeley" as name union
  select 42,             71,               "Cambridge"        union
  select 45,             93,               "Minneapolis";
```

| region | name |
|---|---|
| west coast | Berkeley |
| other | Minneapolis |
| other | Cambridge |

```
select "west coast" as region, name from cities where longitude >= 115 union
select "other",                name from cities where longitude <  115;
```

## Structured Query Language (SQL)

## SQL Overview

The SQL language is an ANSI and ISO standard, but DBMS's implement custom variants
- A **select** statement creates a new table, either from scratch or by projecting a table
- A **create table** statement gives a global name to a table
- Lots of other statements exist: **analyze**, **delete**, **explain**, **insert**, **replace**, **update**, etc.
- Most of the important action is in the **select** statement

*Today's theme:*

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

## Getting Started with SQL

Install sqlite (version 3.8.3 or later): http://sqlite.org/download.html

Use sqlite online: code.cs61a.org/sql

## Selecting Value Literals

A **select** statement always includes a comma-separated list of column descriptions

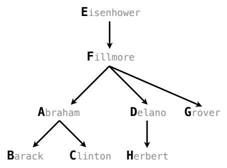
A column description is an expression, optionally followed by **as** and a column name

```
        select [expression] as [name], [expression] as [name]; ...
```

Selecting literals creates a one-row table

The union of two select statements is a table containing the rows of both of their results

```
select "delano" as parent, "herbert" as child;union
select "abraham"         , "barack"           union
select "abraham"         , "clinton"          union
select "fillmore"        , "abraham"          union
select "fillmore"        , "delano"           union
select "fillmore"        , "grover"           union
select "eisenhower"      , "fillmore";
```



## Naming Tables

SQL is often used as an interactive language

The result of a **select** statement is displayed to the user, but not stored

A **create table** statement gives the result a name

```
     create table [name] as [select statement];
```

```
create table parents as
select "delano" as parent, "herbert" as child union
select "abraham"         , "barack"           union
select "abraham"         , "clinton"          union
select "fillmore"        , "abraham"          union
select "fillmore"        , "delano"           union
select "fillmore"        , "grover"           union
select "eisenhower"      , "fillmore";
```

**Parents:**

| Parent | Child |
|---|---|
| abraham | barack |
| abraham | clinton |
| delano | herbert |
| fillmore | abraham |
| fillmore | delano |
| fillmore | grover |
| eisenhower | fillmore |

## Projecting Tables

## Select Statements Project Existing Tables

A **select** statement can specify an input table using a **from** clause

A subset of the rows of the input table can be selected using a **where** clause

An ordering over the remaining rows can be declared using an **order by** clause

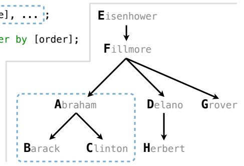
Column descriptions determine how each input row is projected to a result row

```
select [expression] as [name], [expression] as [name], ... ;

select [columns] from [table] where [condition] order by [order];

select child from parents where parent = "abraham";

select parent from parents where parent > child;
```

| Child |
|---|
| barack |
| clinton |

| Parent |
|---|
| fillmore |
| fillmore |

(Demo)



## Arithmetic

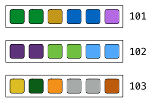
## Arithmetic in Select Expressions

In a select expression, column names evaluate to row values

Arithmetic expressions can combine row values and constants

```
create table lift as
  select 101 as chair, 2 as single, 2 as couple union
  select 102         , 0          , 3           union
  select 103         , 4          , 1;

select chair, single + 2 * couple as total from lift;
```

| chair | total |
|---|---|
| 101 | 6 |
| 102 | 6 |
| 103 | 6 |



## Discussion Question

Given the table **ints** that describes how to sum powers of 2 to form various integers

```
create table ints as
  select "zero" as word, 0 as one, 0 as two, 0 as four, 0 as eight union
  select "one"         , 1       , 0       , 0        , 0          union
  select "two"         , 0       , 2       , 0        , 0          union
  select "three"       , 1       , 2       , 0        , 0          union
  select "four"        , 0       , 0       , 4        , 0          union
  select "five"        , 1       , 0       , 4        , 0          union
  select "six"         , 0       , 2       , 4        , 0          union
  select "seven"       , 1       , 2       , 4        , 0          union
  select "eight"       , 0       , 0       , 0        , 8          union
  select "nine"        , 1       , 0       , 0        , 8;
```

(A) Write a select statement for a two-column table of the **word** and **value** for each integer

| word | value |
|---|---|
| zero | 0 |
| one | 1 |
| two | 2 |
| three | 3 |
| ... | ... |

(Demo)

(B) Write a select statement for the **word** names of the powers of two

| word |
|---|
| one |
| two |
| four |
| eight |

## Joining Tables

## Reminder: John the Patriotic Dog Breeder

```
CREATE TABLE parents AS
SELECT "abraham" AS parent, "barack" AS child UNION
SELECT "abraham"          , "clinton"         UNION
SELECT "delano"           , "herbert"         UNION
SELECT "fillmore"         , "abraham"         UNION
SELECT "fillmore"         , "delano"          UNION
SELECT "fillmore"         , "grover"          UNION
SELECT "eisenhower"       , "fillmore";
```

**Parents:**

| Parent | Child |
|---|---|
| abraham | barack |
| abraham | clinton |
| delano | herbert |
| fillmore | abraham |
| fillmore | delano |
| fillmore | grover |
| eisenhower | fillmore |

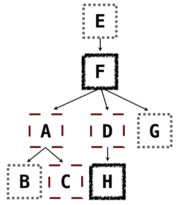
## Joining Two Tables

Two tables **A** & **B** are joined by a comma to yield all combos of a row from **A** & a row from **B**

```
  CREATE TABLE dogs AS
    SELECT "abraham" AS name, "long" AS fur UNION
    SELECT "barack"         , "short"       UNION
    SELECT "clinton"        , "long"        UNION
    SELECT "delano"         , "long"        UNION
    SELECT "eisenhower"     , "short"       UNION
    SELECT "fillmore"       , "curly"       UNION
    SELECT "grover"         , "short"       UNION
    SELECT "herbert"        , "curly";

  CREATE TABLE parents AS
    SELECT "abraham" AS parent, "barack" AS child UNION
    SELECT "abraham"          , "clinton"         UNION
    ...;
```

Select the parents of curly-furred dogs

```
  SELECT parent FROM parents, dogs
                WHERE child = name AND fur = "curly";
```



(Demo)

## Aliases and Dot Expressions

## Joining a Table with Itself

Two tables may share a column name; dot expressions and aliases disambiguate column values

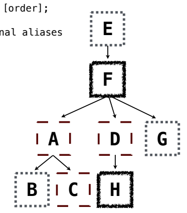
```
   SELECT [columns] FROM [table] WHERE [condition] ORDER BY [order];
```

[table] is a comma-separated list of table names with optional aliases

Select all pairs of siblings

```
  SELECT a.child AS first, b.child AS second
    FROM parents AS a, parents AS b
    WHERE a.parent = b.parent AND a.child < b.child;
```

| First | Second |
|---|---|
| barack | clinton |
| abraham | delano |
| abraham | grover |
| delano | grover |



## Example: Grandparents

Which select statement evaluates to all grandparent, grandchild pairs?

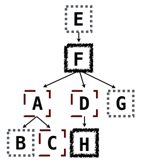
1 `SELECT a.grandparent, b.child FROM parents AS a, parents AS b WHERE b.parent = a.child;`

2 `SELECT a.parent, b.child FROM parents AS a, parents AS b WHERE a.parent = b.child;`

3 `SELECT a.parent, b.child FROM parents AS a, parents AS b WHERE b.parent = a.child;`

4 `SELECT a.grandparent, b.child FROM parents AS a, parents AS b WHERE a.parent = b.child;`

5 None of the above



## Joining Multiple Tables

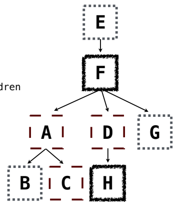
Multiple tables can be joined to yield all combinations of rows from each

```
CREATE TABLE grandparents AS
  SELECT a.parent AS grandog, b.child AS granpup
    FROM parents AS a, parents AS b
    WHERE b.parent = a.child;
```

Select all grandparents with the same fur as their grandchildren

Which tables need to be joined together?

```
SELECT grandog FROM grandparents, dogs AS c, dogs AS d
               WHERE grandog = c.name AND
                     granpup = d.name AND
                     c.fur = d.fur;
```



## Example: Dog Triples

## Fall 2014 Quiz Question (Slightly Modified)

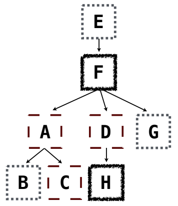
Write a SQL query that selects all possible combinations of three different dogs
with the same fur and lists each triple in *inverse* alphabetical order

```
CREATE TABLE dogs AS
  SELECT "abraham" AS name, "long" AS fur UNION
  SELECT "barack"         , "short"       UNION
  ...;

CREATE TABLE parents AS
  SELECT "abraham" AS parent, "barack" AS child UNION
  SELECT "abraham"          , "clinton"         UNION
  ...;
```

Expected output:

```
delano|clinton|abraham
grover|eisenhower|barack
```

(Demo)



## Numerical Expressions

## Numerical Expressions

Expressions can contain function calls and arithmetic operators

```
          [expression] AS [name], [expression] AS [name], ...
SELECT [columns] FROM [table] WHERE [expression] ORDER BY [expression];
```

Combine values: +, −, ∗, /, %, and, or

Transform values: abs, round, not, −

Compare values: <, <=, >, >=, <>, !=, =

(Demo)

## String Expressions

## String Expressions

String values can be combined to form longer strings

```
sqlite> SELECT "hello," || " world";
hello, world
```

Basic string manipulation is built into SQL, but differs from Python

```
sqlite> CREATE TABLE phrase AS SELECT "hello, world" AS s;
sqlite> SELECT substr(s, 4, 2) || substr(s, instr(s, " ")+1, 1) FROM phrase;
low
```

Strings can be used to represent structured values, but doing so is rarely a good idea

```
sqlite> CREATE TABLE lists AS SELECT "one" AS car, "two,three,four" AS cdr;
sqlite> SELECT substr(cdr, 1, instr(cdr, ",")-1) AS cadr FROM lists;
two
```

(Demo)