CSE 412 Database Management

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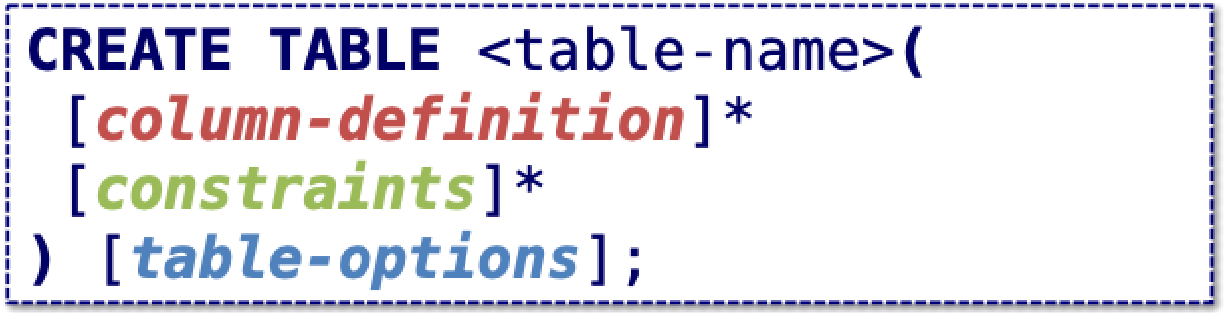
Review of SQL Basics

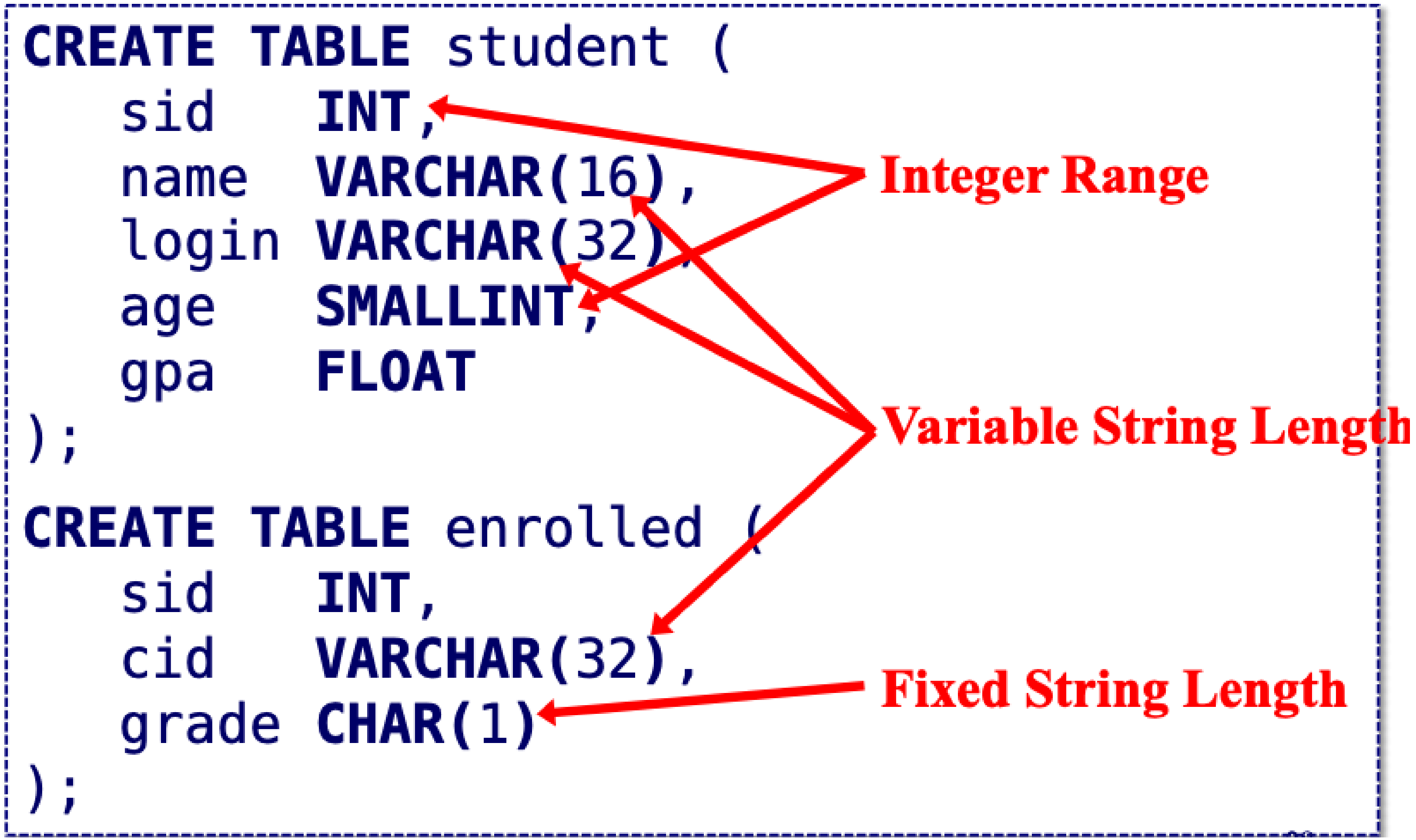
Review of Data Definition Language



```
CREATE TABLE <table-name>(
 [column-definition]*
 [constraints]*
) [table-options];
```

- **Column-Definition:** Comma separated list of column names with types.
- **Constraints:** Primary key, foreign key, and other meta-data attributes of columns.
- **Table-Options:** DBMS-specific options for the table (not SQL-92).

Data Definition Language (DDL)



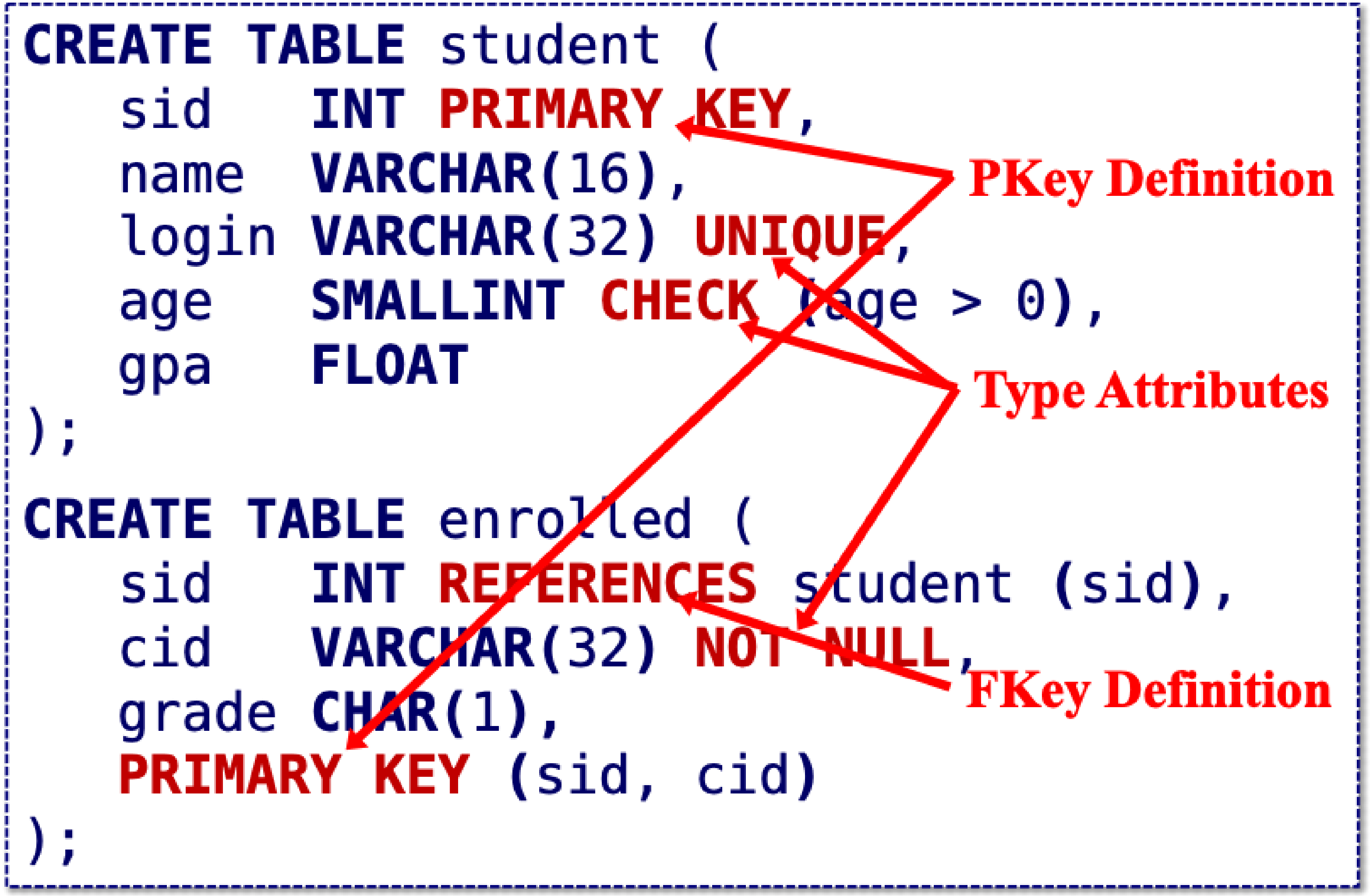
```
CREATE TABLE student (
    sid    INT,
    name   VARCHAR(16),
    login  VARCHAR(32),
    age    SMALLINT,
    gpa    FLOAT
);
CREATE TABLE enrolled (
    sid    INT,
    cid    VARCHAR(32),
    grade  CHAR(1)
);
```

Integer Range

Variable String Length

Fixed String Length

Integrity Constraints



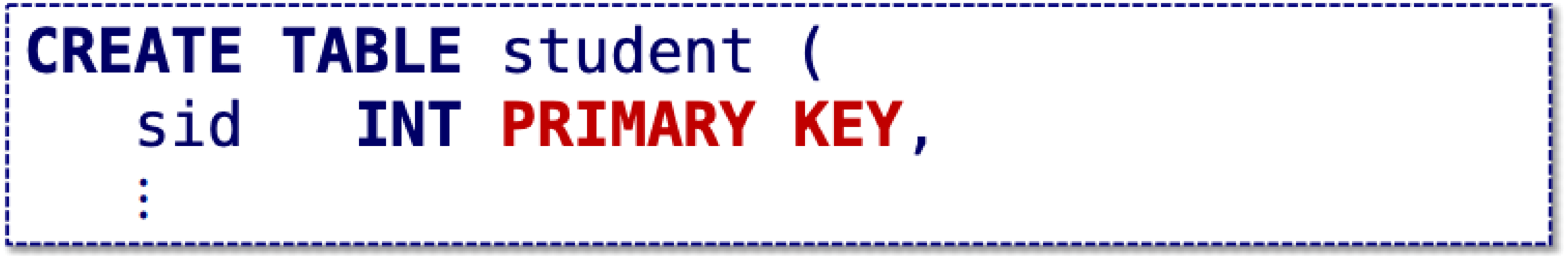
```
CREATE TABLE student (
   sid   INT PRIMARY KEY,
   name  VARCHAR(16),
   login VARCHAR(32) UNIQUE,
   age   SMALLINT CHECK (age > 0),
   gpa   FLOAT
);

CREATE TABLE enrolled (
   sid   INT REFERENCES student (sid),
   cid   VARCHAR(32) NOT NULL,
   grade CHAR(1),
   PRIMARY KEY (sid, cid)
);
```

PKey Definition
Type Attributes
FKey Definition

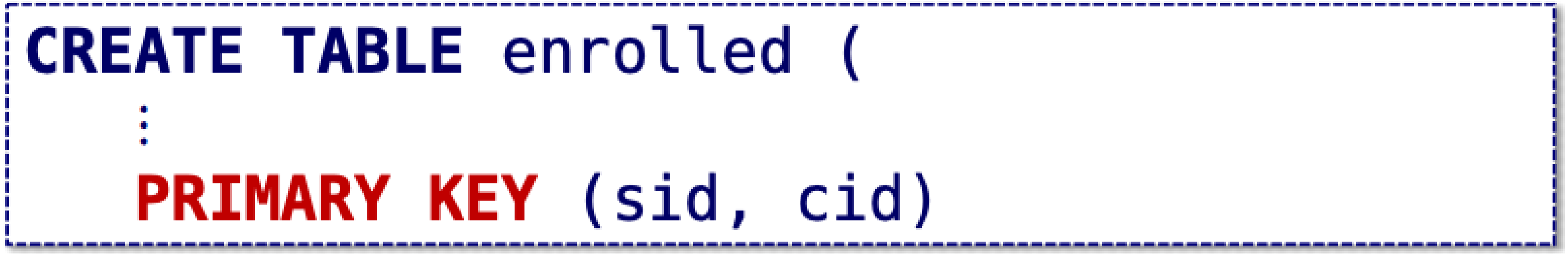
Primary Keys

- Single-column primary key:



```
CREATE TABLE student (
    sid   INT PRIMARY KEY,
    ⋮
```

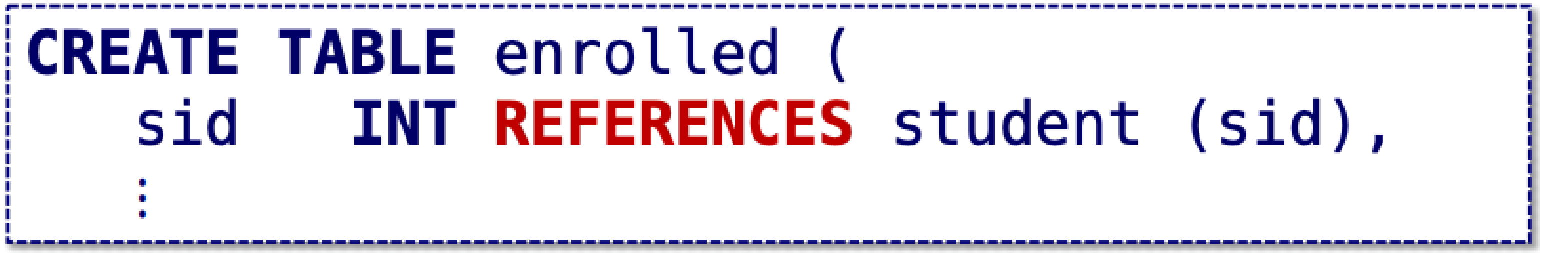
- Multi-column primary key:



```
CREATE TABLE enrolled (
    ⋮
    PRIMARY KEY (sid, cid)
```

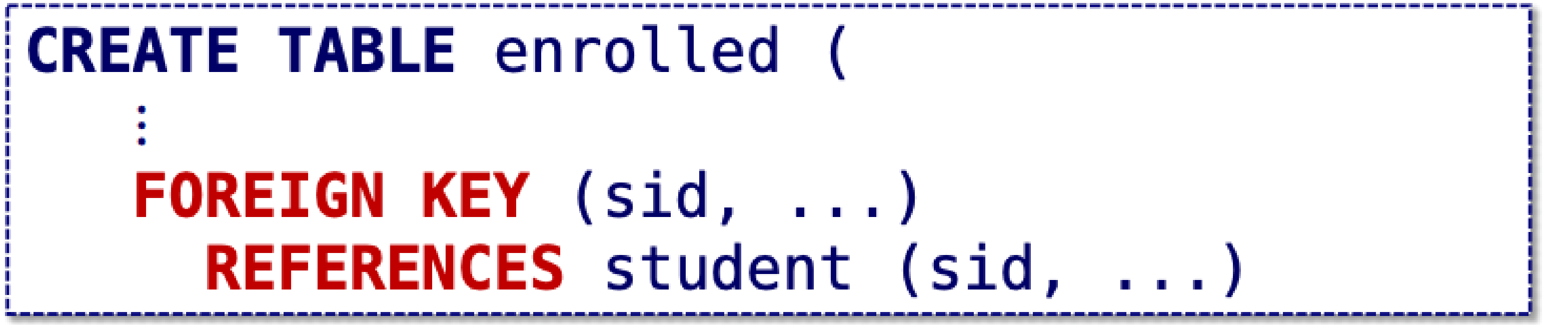
Foreign Key References

- Single-column reference:



```
CREATE TABLE enrolled (
    sid    INT REFERENCES student (sid),
    ⋮
```

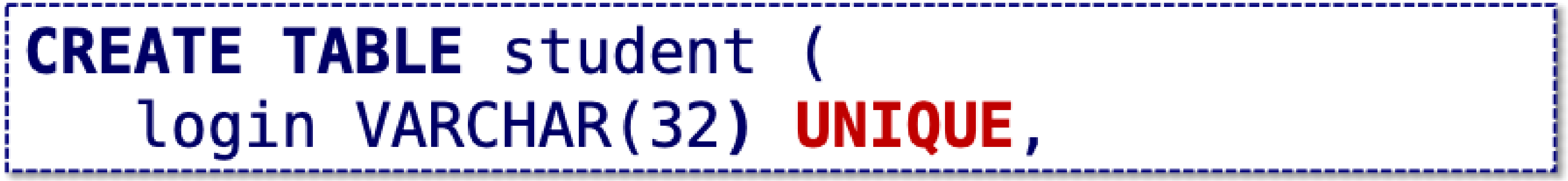
- Multi-column reference:



```
CREATE TABLE enrolled (
    ⋮
    FOREIGN KEY (sid, ...)
      REFERENCES student (sid, ...)
```

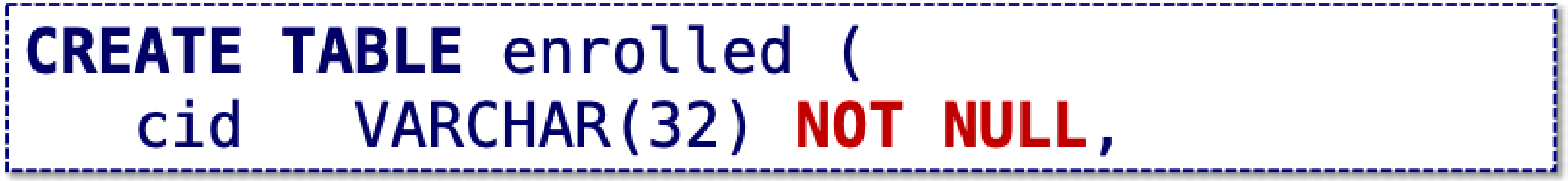
Value Constraints

- Ensure one-and-only-one value exists:



```
CREATE TABLE student (
    login VARCHAR(32) UNIQUE,
```

- Make sure a value is not null:



```
CREATE TABLE enrolled (
    cid   VARCHAR(32) NOT NULL,
```

Tuple- and Attribute- based **Checks**

- Associated with a ***single table***
- Only checked ***when a tuple/attribute is inserted/updated***
  - **Reject** if the condition evaluates to **FALSE**
  - ***TRUE*** and ***UNKNOWN*** are fine
- Examples:
  - CREATE TABLE User(... age INTEGER CHECK(age IS NULL OR age > 0), ...);
  - CREATE TABLE Member
    (uid INTEGER NOT NULL,
    CHECK(uid IN (SELECT uid FROM User)), ...);
    - Is it a referential integrity constraint?
    - Not quite; not checked when the User is modified

Review of Data Manipulation Language

- SELECT A_1, A_2, …, A_n
  FROM R_1, R_2, …, R_m
  WHERE condition;
- Also called as SPJ (selection-projection-join) query
- Can correspond to (but not exactly equivalent to) relational algebra query:

$$\pi_{A_1,A_2,\ldots,A_n}\left(\sigma_{condition}(R_1 \times R_2 \times \cdots \times R_m)\right)$$

Why SFW statements

- Out of many possible ways of structuring SQL statements, *why did the designers choose SELECT-FROM-WHERE*?
  - A large number of queries can be written using only selection, projection, and cross-product (or join)
  - Any query that uses only these operators can be written in a canonical form:

    $$\pi_L\left(\sigma_p(R_1\times\cdots\times R_m)\right)$$

  - SELECT-FROM-WHERE captures this canonical form

Example Database

User

uid	name	age	pop
142	Bart	10	0.9
123	Milhouse	10	0.2
857	Lisa	8	0.7
456	Ralph	8	0.3
…	…	…	…

Member

uid	gid
142	dps
123	gov
857	abc
857	gov
456	abc
456	gov
…	…

Group

gid	name
abc	Book Club
gov	Student Government
dps	Dead Putting Society
…	…

Example: reading a table

- SELECT * FROM User;
  - Single-table query, so no cross product here
  - WHERE clause is optional
  - * is a short hand for “all columns”

Example: selection and projection

- Name of users under 18
  - SELECT name
    FROM User
    WHERE age < 18
- When was Lisa born?
  - SELECT 2025-age
    FROM User
    WHERE name = 'Lisa’;
  - SELECT list can contain expressions
    - Can also use built-in functions such as SUBSTR, ABS, etc.
  - String literals (case sensitive) are enclosed in single quotes

Example: join

- ID’s and names of groups with a user whose name contains “Simpson”

User

uid	*name*	*age*	*pop*
142	Bart	10	0.9
123	Milhouse	10	0.2
857	Lisa	8	0.7
456	Ralph	8	0.3

Member

uid	*gid*
142	dps
123	gov
857	abc
857	gov
456	abc
456	gov
…	…

Group

gid	*name*
abc	Book Club
gov	Student Government
dps	Dead Putting Society
…	…

Example: join

User

uid	name	age	pop
142	Bart	10	0.9
123	Milhouse	10	0.2
857	Lisa	8	0.7
456	Ralph	8	0.3
…	…	…	…

Member

uid	gid
142	dps
123	gov
857	abc
857	gov
456	abc
456	gov
…	…

- ID’s and names of groups with a user whose name contains “Simpson”
  - SELECT Group.gid, Group.name
    FROM User, Member, Group
    WHERE User.uid = Member.uid
    AND Member.gid = Group.gid
    AND User.name LIKE '%Simpson%’;
  - **LIKE** matches a string against a pattern
  - % matches any sequence of zero or more characters
  - Okay to omit table_name in table_name.column_name if column_name is unique

Group

gid	name
abc	Book Club
gov	Student Government
dps	Dead Putting Society
…	…

SQL Intermediate

Today’s Agenda

- Data Definition Language
- **Data Manipulation Language**
  - Basic Queries (SELECT-FROM-WHERE)
  - **ORDER BY**

Order By

- SELECT … FROM … WHERE … ORDER BY output_column [ASC|DESC], …;

(In the future: SELECT [DISTINCT] … FROM … WHERE … GROUP BY … HAVING … ORDER BY output_column [ASC|DESC], …;)

- ASC = ascending, DESC = descending
- **Semantics:** After the **SELECT** list has been computed and optional duplicate elimination has been carried out***, sort the output according to ORDER BY specification***

User

uid	*name*	*age*	*pop*
142	Bart	10	0.9
123	Milhouse	10	0.2
857	Lisa	8	0.7
456	Ralph	8	0.3
…	…	…	…

Order By example

- List all users, sort them by popularity (descending) and name (ascending)
  - SELECT uid, name, age, pop FROM User
    ORDER BY pop DESC, name;
  - ASC is the default option
  - Strictly speaking, only output columns can appear in the ORDER BY clause (although some DBMS support more)
  - Can use sequence numbers instead of names to refer to output columns: ORDER BY 4 DESC, 2;

Today’s Agenda

- Data Definition Language
- **Data Manipulation Language**
  - Basic Queries (SELECT-FROM-WHERE)
  - ORDER BY
  - **Set Operations**

Forcing set semantics

User

uid	name	age	pop
142	Bart	10	0.9
123	Milhouse	10	0.2
857	Lisa	8	0.7
456	Ralph	8	0.3
…	…	…	…

Member

uid	gid
142	dps
123	gov
857	abc
857	gov
456	abc
456	gov
…	…

Group

gid	name
abc	Book Club
gov	Student Government
dps	Dead Putting Society
…	…

- IDs of all pairs of users that belong to one group
  - SELECT m1.uid AS uid1, m2.uid AS uid2
    FROM Member AS m1, Member AS m2
    WHERE m1.gid = m2.gid AND m1.uid > m2.uid;

    (finds pairs of members who belong to the same group.)

  - *Say Lisa and Ralph are in both the book club and the student government*

*Forcing set semantics means ensuring that a query returns **unique results** by explicitly removing duplicates, typically using operations like DISTINCT, rather than allowing duplicate entries in the result set*

- SELECT DISTINCT m1.uid AS uid1, m2.uid AS uid2 …

  - With DISTINCT, all duplicate (uid1, uid2) pairs are removed from the output

Set Semantics of SFW

- SELECT [DISTINCT] E_1, E_2, …, E_n
  FROM R_1, R_2, …, R_m
  WHERE condition;

SQL set

- UNION, EXCEPT, INTERSECT
  - Set semantics
  - Duplicates in input tables, if any, are first eliminated
  - Duplicates in result are also eliminated (for UNION)
  - Exactly like set ∪, −, and ∩ in relational algebra

Examples of set operations

- Poke (uid1, uid2, timestamp)
  - (SELECT uid1 FROM Poke)
    EXCEPT
    (SELECT uid2 FROM Poke);

Examples of set operations

- Poke (uid1, uid2, timestamp)
  - (SELECT uid1 FROM Poke)
    EXCEPT
    (SELECT uid2 FROM Poke);
    - **Users who poked others but never got poked by others**

- The EXCEPT operator returns the **set difference** between the two subqueries.
- It gives you all the uid1 values (users who poked others) that are **not** present in the uid2 values (users whom someone poked).

Today’s Agenda

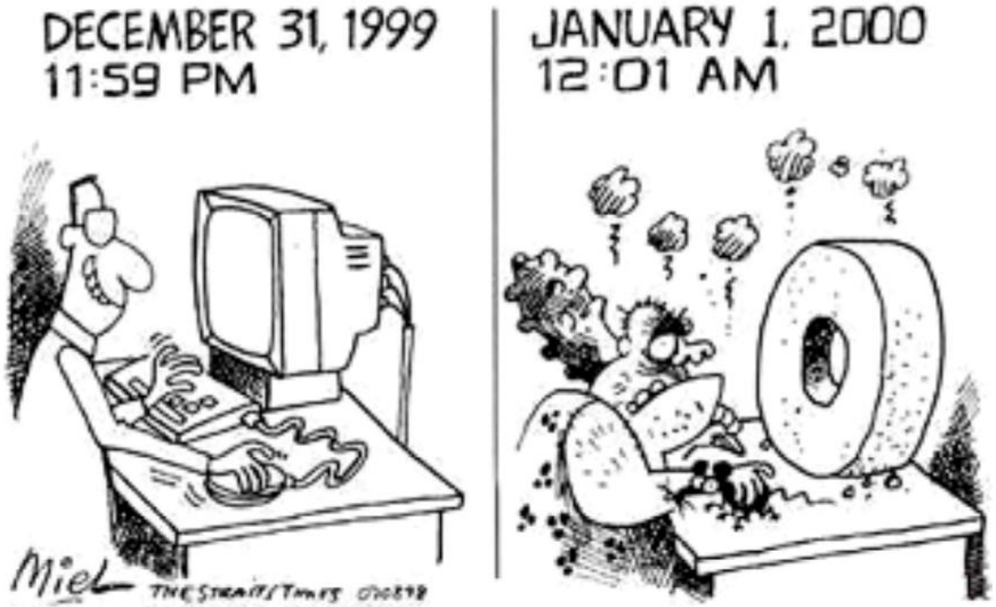
- Data Definition Language
- **Data Manipulation Language**
  - Basic Queries (SELECT-FROM-WHERE)
  - ORDER BY
  - Set Operations
  - **Null Values**

Missing Information

- Example: User (<u>uid</u>, name, age, pop)
- Value unknown
  - We do not know Nelson’s age
- Value not applicable
  - Suppose pop is based on interactions with others on our social networking site
  - Nelson is new to our site; what is his pop?

Solution 1

- Dedicate a value from each domain (type)
  - pop cannot be −1, so use −1 as a special value to indicate a missing or invalid pop
- Leads to incorrect answers if not careful
  - SELECT AVG(pop) FROM User;
- Complicates applications
  - SELECT AVG(pop) FROM User WHERE pop <> -1;
- Perhaps the value is not as special as you think!
  - Ever heard of the Y2K bug? “00” was used as a missing or invalid year value



http://www.90s411.com/images/y2k-cartoon.jpg

Solution 2 (using a flag)

- A valid-bit for every column
- User (uid, name,

  name**_is_valid** ,

  age, age**_is_valid** ,

  pop, pop**_is_valid**)
- Complicates schema and queries
- SELECT AVG(pop) FROM User WHERE pop**_is_valid** ;

Solution 3

- Decompose the table; missing row = missing value
  - UserName (uid, name)
  - UserAge (uid, age)
  - UserPop (uid, pop)
  - UserID (uid)
  - Still complicates schema and queries
    - How to get all information about users in a table?
    - Natural join doesn’t work!

SQL’s solution

- A special value NULL
  - For every domain
  - Special rules for dealing with NULL’s
- Example: User (uid, name, age, pop)
  - <789, “Nelson”, NULL, NULL>

Computing with NULLs

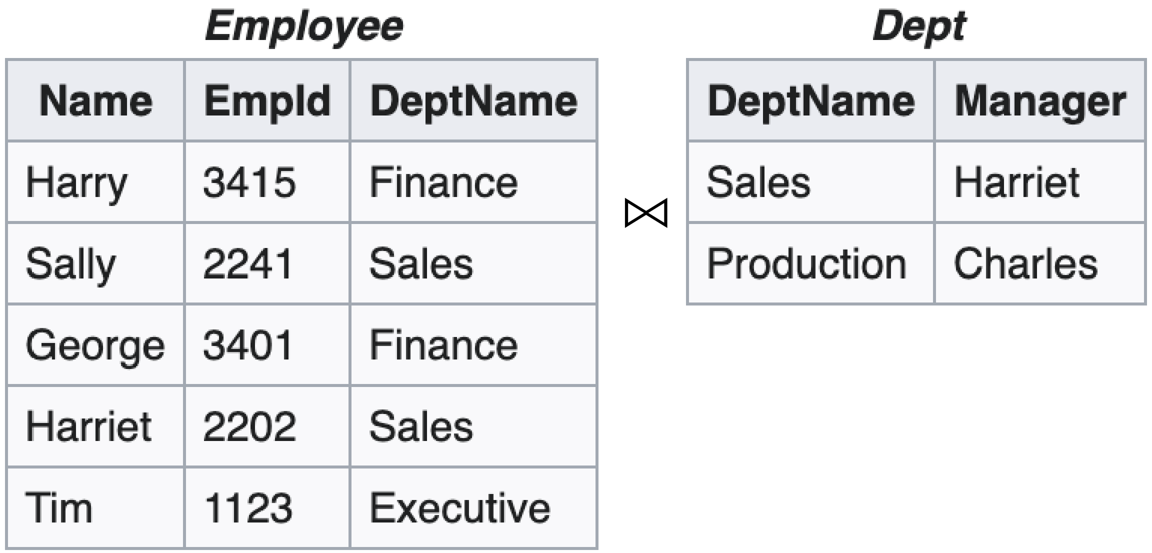
- When we operate on a NULL and another value (including another NULL) using +, −, etc., the result is NULL
- Aggregate functions ignore NULL, except COUNT(*) (since it counts rows)

IS NULL/IS NOT NULL

- Example: Who has NULL pop values?
  - SELECT * FROM User WHERE pop = NULL;
    - Does not work; never returns anything
- SQL introduced special, built-in predicates IS NULL and IS NOT NULL
  - SELECT * FROM User WHERE pop IS NULL;

Outerjoin motivation

First let’s see: what is the natural join result?



Employee

Name	EmpId	DeptName
Harry	3415	Finance
Sally	2241	Sales
George	3401	Finance
Harriet	2202	Sales
Tim	1123	Executive

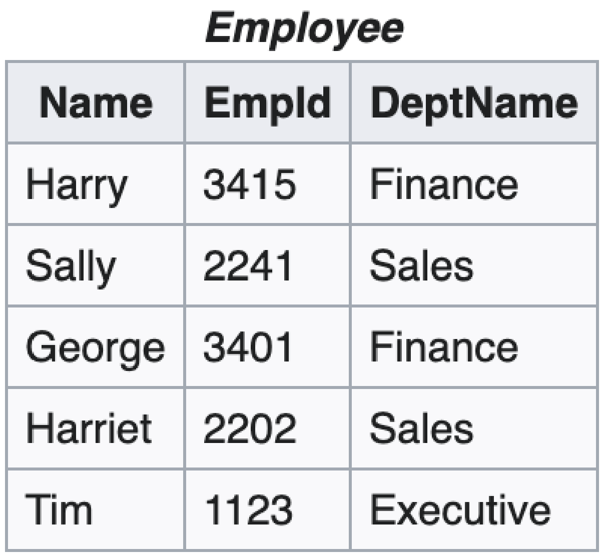
$\bowtie$

Dept

DeptName	Manager
Sales	Harriet
Production	Charles

Outerjoin motivation

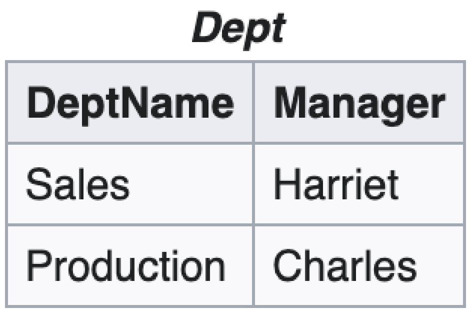
First let’s see: what is the natural join result?



Employee

Name	EmpId	DeptName
Harry	3415	Finance
Sally	2241	Sales
George	3401	Finance
Harriet	2202	Sales
Tim	1123	Executive

⋈



Dept

DeptName	Manager
Sales	Harriet
Production	Charles

=

Name	EmpId	DeptName	Manager

Outerjoin motivation

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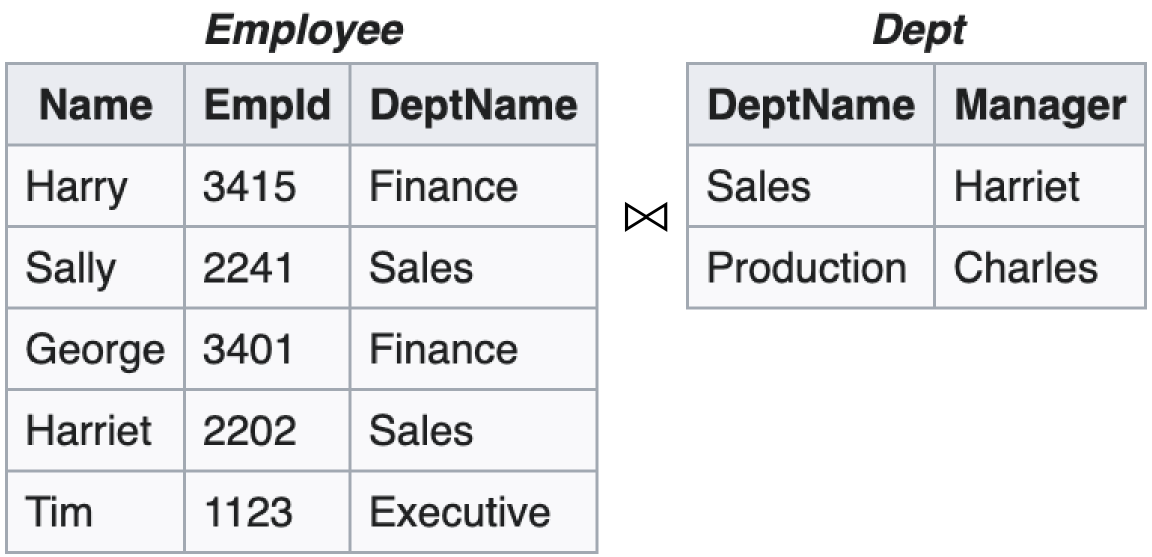

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Outerjoin motivation

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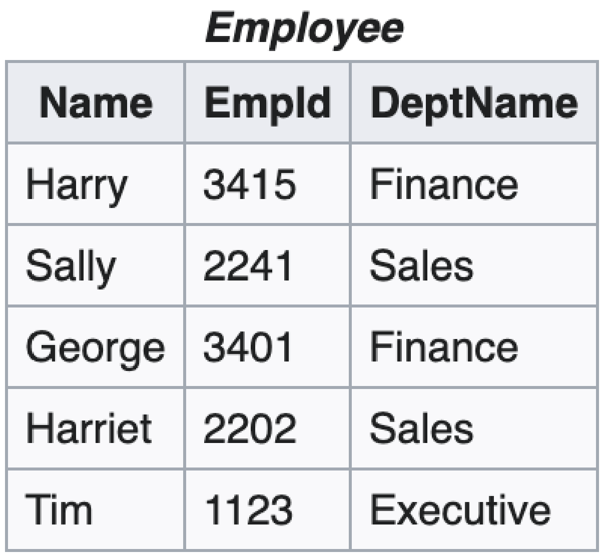

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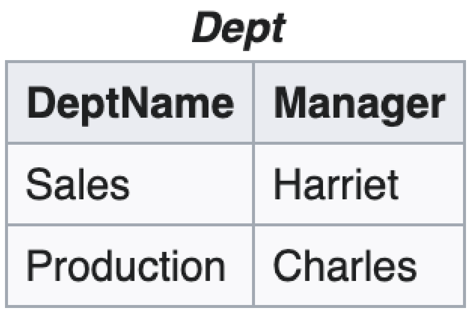
$\bowtie$



Dept

DeptName	Manager
Sales	Harriet
Production	Charles

=

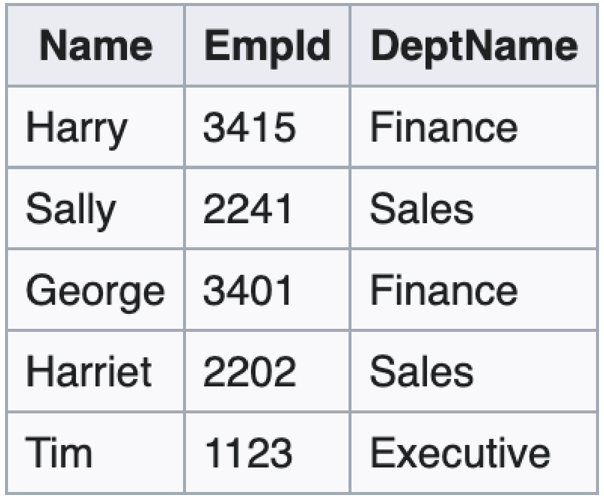
Name	EmpId	DeptName	Manager
Sally	2241	Sales	Harriet
Harriet	2202	Sales	Harriet

Bad, other employee information get lost, because their departments do not have a record in the Dept table

Optional: Left Outer Natural Join

- In a left outer join, Employee rows without a matching Department row appear in the result, but not vice versa.

Employee



Name	EmpId	DeptName
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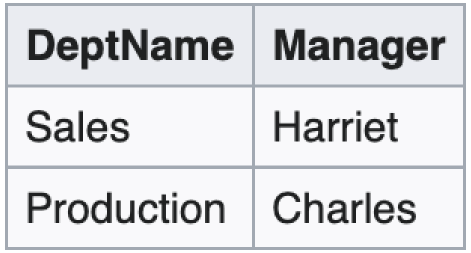
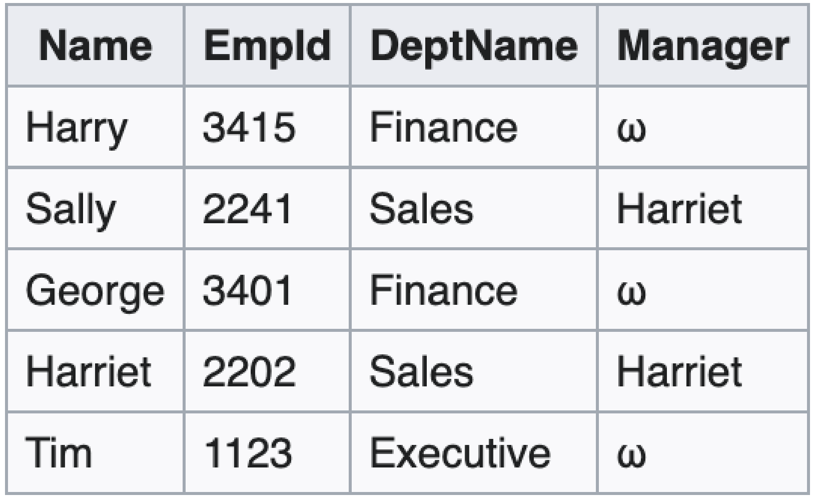
Tim	1123	Executive

Dept



DeptName	Manager
Sales	Harriet
Production	Charles

Employee ⟕ Dept



Name	EmpId	DeptName	Manager
Harry	3415	Finance	ω
Sally	2241	Sales	Harriet
George	3401	Finance	ω
Harriet	2202	Sales	Harriet
Tim	1123	Executive	ω

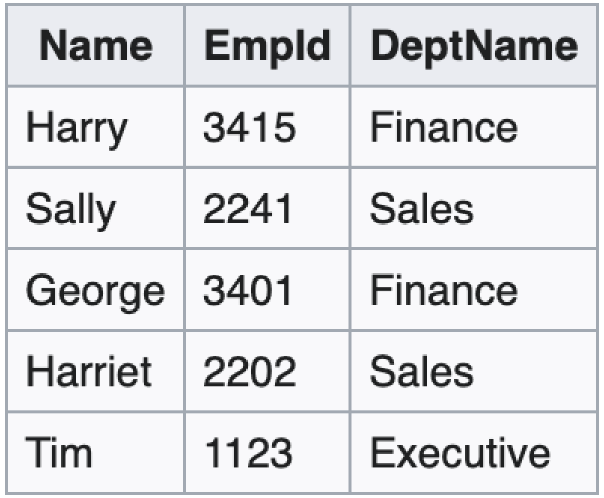
Optional: Left Outer Natural Join

- ⟕

$$(R \bowtie S) \cup ((R - \pi_{r_1, r_2, \ldots, r_n}(R \bowtie S)) \times \{(\omega, \ldots \omega)\})$$

- In a left outer join, Employee rows without a matching Department row appear in the result, but not vice versa.

Employee



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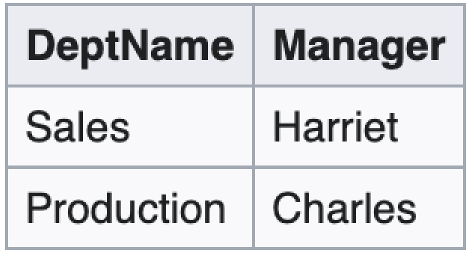
Dept



DeptName	Manager
Sales	Harriet
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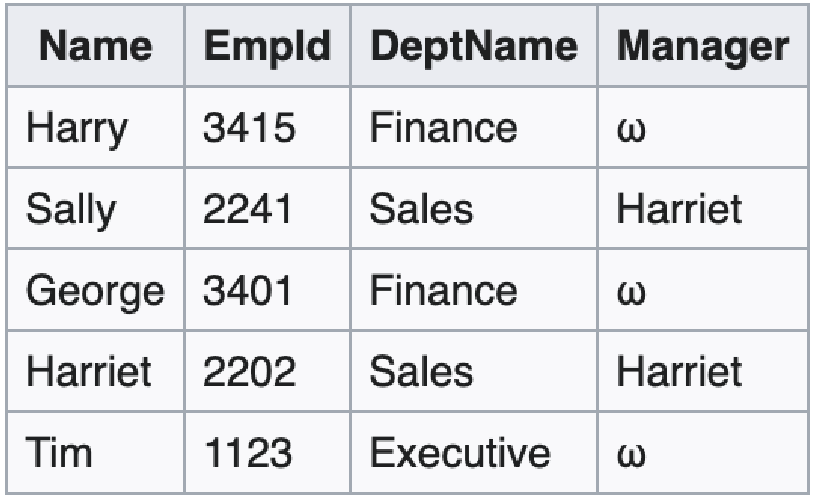
Employee ⟕ Dept



Name	EmpId	DeptName	Manager
Harry	3415	Finance	ω
Sally	2241	Sales	Harriet
George	3401	Finance	ω
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Tim	1123	Executive	ω

SQL Continued..

- Data Definition Language
- **Data Manipulation Language**
  - Basic Queries (SELECT-FROM-WHERE)
  - ORDER BY
  - Set Operations
  - Null Values
  - **Aggregation**

Aggregates

- Standard SQL aggregate functions: COUNT, SUM, AVG, MIN, MAX
- Example: number of users under 18, and their average popularity
  - SELECT COUNT(*)
    FROM User
    WHERE age < 18;
  - COUNT(*) counts the number of rows

Aggregates with Distinct

- Example: How many users are in some group?

-
  ```
  SELECT COUNT(DISTINCT uid)
   FROM Member;
  ```

is equivalent to:

-
  ```
  SELECT COUNT(*)
    FROM (SELECT DISTINCT uid FROM Member);
  ```

Grouping

- SELECT … FROM … WHERE …
  GROUP BY list_of_columns

- Example: compute average popularity for each age group

  ```
  SELECT age, AVG(pop)
  FROM User
  GROUP BY age
  ```

Example of Grouping By

- SELECT age, AVG(pop) FROM User GROUP BY age;

uid	name	age	pop
142	Bart	10	0.9
857	Lisa	8	0.7
123	Milhouse	10	0.2
456	Ralph	8	0.3

Compute GROUP BY: group rows according to the values of GROUP BY columns

uid	name	age	pop
142	Bart	10	0.9
123	Milhouse	10	0.2
857	Lisa	8	0.7
456	Ralph	8	0.3

Compute SELECT for each group

age	avg_pop
10	0.55
8	0.50

Example of Aggregates (with no Group By)

- An aggregate query with no GROUP BY clause = all rows go into one group

SELECT AVG(pop) AS avg_pop
FROM User

uid	name	age	pop
142	Bart	10	0.9
857	Lisa	8	0.7
123	Milhouse	10	0.2
456	Ralph	8	0.3

Group all rows into one group

uid	name	age	pop
142	Bart	10	0.9
857	Lisa	8	0.7
123	Milhouse	10	0.2
456	Ralph	8	0.3

Aggregate over the whole group

avg_pop
0.525

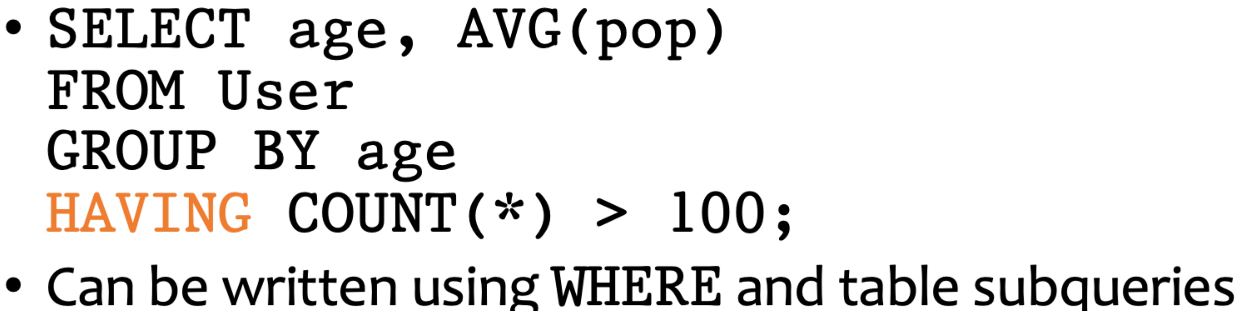
Having

- Used to filter groups based on the group properties (e.g., aggregate values, GROUP BY column values)
- SELECT … FROM … WHERE … GROUP BY …

  HAVING condition;

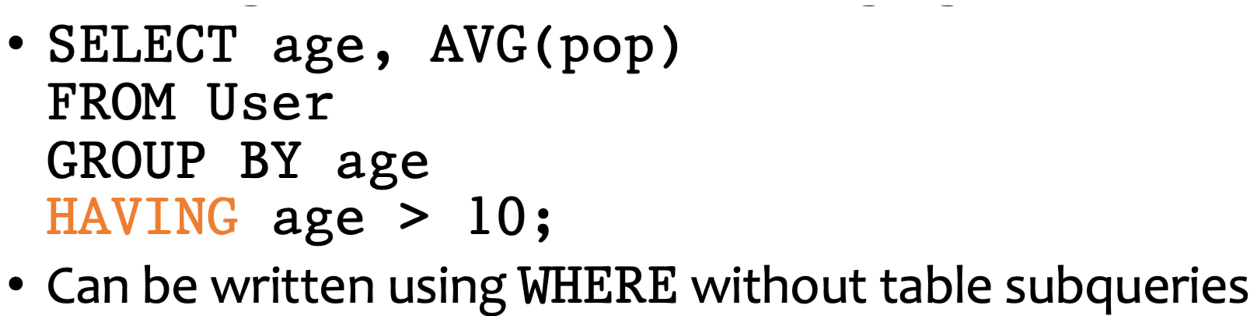
Having examples

- List the average popularity for each age group with more than a hundred users



  -
    ```
    SELECT age, AVG(pop)
    FROM User
    GROUP BY age
    HAVING COUNT(*) > 100;
    ```
  - Can be written using WHERE and table subqueries

- Find average popularity for each age group over 10



  -
    ```
    SELECT age, AVG(pop)
    FROM User
    GROUP BY age
    HAVING age > 10;
    ```
  - Can be written using WHERE without table subqueries