SQL: Part II

Basic SQL features

- Query
  - SELECT-FROM-WHERE statements
  - Set/bag (DISTINCT, UNION/EXCEPT/INTERSECT (ALL))
  - Subqueries (table, scalar, IN, EXISTS, ALL, ANY)
  - Aggregation and grouping (GROUP BY, HAVING)
  - Ordering (ORDER)
  - Outerjoins (and Nulls)
- Modification
  - INSERT/DELETE/UPDATE
- Constraints

THIS PPT

Incomplete information

- Example: *User* (*uid*, *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*

```
SELECT AVG(pop) FROM User;
```

Incorrect answers

```
SELECT AVG(pop) FROM User WHERE pop <> -1;
```

Complicated

Solution 2

- A valid-bit for every column
  - *User* (*uid*,
    name, *name_is_valid*,
    age, *age_is_valid*,
    pop, *pop_is_valid*)

```
SELECT AVG(pop) FROM User WHERE pop_is_valid;
```

  - Complicates schema and queries

Solution 3

- Decompose the table; missing row = missing value
  - *UserName* (*uid*, *name*)
  - *UserAge* (*uid*, *age*)
  - *UserPop* (*uid*, *pop*)
  - *UserID* (*uid*)

- Conceptually the cleanest solution
- 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⟩

Three-valued logic

TRUE = 1, FALSE = 0, UNKNOWN = 0.5

x AND $y = \min(x, y)$

x OR $y = \max(x, y)$

NOT $x = 1 - x$

- Comparing a NULL with another value (including another NULL) using $=$, $>$, etc., the result is NULL
- WHERE and HAVING clauses only select rows for output if the condition evaluates to TRUE
  - NULL is not enough to select/reject a row
- Aggregate functions ignore NULL, except COUNT(*)

Unfortunate consequences

- Q1a = Q1b?

```
Q1a. SELECT AVG(pop) FROM User;
```

```
Q1b. SELECT SUM(pop)/COUNT(*) FROM User;
```

- Q2a = Q2b?

```
Q2a. SELECT * FROM User;
```

```
Q2b SELECT * FROM User WHERE pop=pop;
```

- Be careful: NULL breaks many equivalences

Another problem

- Example: Who has *pop* values as NULL?

```
SELECT * FROM User WHERE pop = NULL;
```

Does not work!

```
(SELEC * FROM User)
EXCEPT ALL
(SELECT * FROM USER WHERE pop=pop);
```

Works, but ugly

- SQL introduced special, built-in predicates IS NULL and IS NOT NULL

```
SELECT * FROM User WHERE pop IS NULL;
```

Outerjoin motivation

User (*uid* int, *name* string, *age* int, *pop* float)
Group (*gid* string, *name* string)
Member (*uid* int, *gid* string)

- Example: a master group membership list (Groups with its members)

```
SELECT g.gid, g.name AS gname,
       u.uid, u.name AS uname
FROM Group g, Member m, User u
WHERE g.gid = m.gid AND m.uid = u.uid;
```

- What if a group is empty?
- It may be reasonable for the master list to include empty groups as well
  - For these groups, *uid* and *uname* columns would be NULL

Outerjoin examples

Group

gid	*name*
abc	Book Club
gov	Student Government
dps	Dead Putting Society
nuk	United Nuclear Workers

Member

uid	*gid*
142	dps
123	gov
857	abc
857	gov
789	foo

Group ⟕ *Member*

gid	*name*	*uid*
abc	Book Club	857
gov	Student Government	123
gov	Student Government	857
dps	Dead Putting Society	142

A full outerjoin between *R* and *S*:

- All rows in the result of $R \bowtie S$, plus
- R rows (those that do not join with any S rows) padded with NULL's for S's columns, plus

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Group ⟕ *Member*

gid	*name*	*uid*
abc	Book Club	857
gov	Student Government	123
gov	Student Government	857
dps	Dead Putting Society	142
nuk	**United Nuclear Workers**	**NULL**

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- All rows in the result of $R \bowtie S$, plus
- R rows (those that do not join with any S rows) padded with NULL's for S's columns, plus
- S rows (those that do not join with any R rows) padded with NULL's for R's columns

Outerjoin examples

Group

gid	name
abc	Book Club
gov	Student Government
dps	Dead Putting Society
nuk	United Nuclear Workers

Member

uid	gid
142	dps
123	gov
857	abc
857	gov
789	foo

Group ⟗ *Member*

gid	name	uid
abc	Book Club	857
gov	Student Government	123
gov	Student Government	857
dps	Dead Putting Society	142
nuk	United Nuclear Workers	NULL
foo	NULL	789

A full outerjoin between *R* and *S*:

- All rows in the result of $R \bowtie S$, plus
- R rows (those that do not join with any S rows) padded with NULL's for S's columns, plus
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Outerjoin examples

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dps	Dead Putting Society
nuk	United Nuclear Workers

Member

uid	gid
142	dps
123	gov
857	abc
857	gov
789	foo

Group $\bowtie$ *Member*

gid	name	uid
abc	Book Club	857
gov	Student Government	123
gov	Student Government	857
dps	Dead Putting Society	142
nuk	United Nuclear Workers	NULL

- A left outerjoin ($R \bowtie S$) includes rows in $R \bowtie S$ plus dangling R rows padded with NULL's

Group $\bowtie$ *Member*

gid	name	uid
abc	Book Club	857
gov	Student Government	123
gov	Student Government	857
dps	Dead Putting Society	142
foo	NULL	789

- A right outerjoin ($R \bowtie S$) includes rows in $R \bowtie S$ plus dangling S rows padded with NULL's

Outerjoin syntax

```
SELECT * FROM Group LEFT OUTER JOIN Member
        ON Group.gid = Member.gid;
```

$\approx Group \overset{}{\underset{Group.\text{gid}=Member.\text{gid}}{\bowtie}} Member$

```
SELECT * FROM Group RIGHT OUTER JOIN Member
        ON Group.gid = Member.gid;
```

$\approx Group \overset{}{\underset{Group.\text{gid}=Member.\text{gid}}{\bowtie}} Member$

```
SELECT * FROM Group FULL OUTER JOIN Member
        ON Group.gid = Member.gid;
```

$\approx Group \overset{}{\underset{Group.\text{gid}=Member.\text{gid}}{\bowtie}} Member$

☞A similar construct exists for regular (“inner”) joins: (Duplicate col.)

```
SELECT * FROM Group JOIN Member ON Group.gid = Member.gid;
```

☞For natural joins, add keyword NATURAL; don’t use ON

```
SELECT * FROM Group NATURAL JOIN Member;
```

SQL features covered so far

- SELECT-FROM-WHERE statements
- Set and bag operations
- Table expressions, subqueries
- Aggregation and grouping
- Ordering
- NULL's and outerjoins

☞ Next: data modification statements, constraints

INSERT

- Insert one row
  - User 789 joins Dead Putting Society (dps)

```
INSERT INTO Member VALUES (789, 'dps');
```

- Insert the result of a query
  - Everybody joins Dead Putting Society!

```
INSERT INTO Member
    (SELECT uid, 'dps' FROM User
    WHERE uid NOT IN (SELECT uid
        FROM Member
        WHERE gid = 'dps'));
```

DELETE

- Delete everything from a table

```
DELETE FROM Member;
```

- Delete according to a WHERE condition
  - Example: User 789 leaves Dead Putting Society

```
DELETE FROM Member WHERE uid=789 AND gid='dps';
```

  - Example: Users under age 18 must be removed from Group id "nuk"

```
DELETE FROM Member
WHERE uid IN (SELECT uid FROM User WHERE age < 18)
      AND gid = 'nuk';
```

UPDATE

- Example: User 142 changes name to “Ravi”

```
UPDATE User
SET name = ‘Ravi’
WHERE uid = 142;
```

- Example: We are all popular!

```
UPDATE User
SET pop = (SELECT AVG(pop) FROM User);
```

Constraints

- Restrictions on allowable data in a database
  - In addition to the simple structure and type restrictions imposed by the table definitions
- Why use constraints?
  - Protect data integrity (catch errors)
  - Tell the DBMS about the data (so it can optimize better)
- Declared as part of the schema and enforced by the DBMS

Types of SQL constraints

- NOT NULL
- Key
- Referential integrity (foreign key)
- General assertion
- Tuple- and attribute-based CHECK's

NOT NULL constraint examples

```
CREATE TABLE User
(uid DECIMAL(3,0) NOT NULL,
 name VARCHAR(30) NOT NULL,
 twitterid VARCHAR(15) NOT NULL,
 age DECIMAL (2,0),
 pop DECIMAL(3,2));
```

```
CREATE TABLE Group
(gid CHAR(10) NOT NULL,
 name VARCHAR(100) NOT NULL);
```

```
CREATE TABLE Member
(uid DECIMAL(3,0) NOT NULL,
 gid CHAR(10) NOT NULL);
```

Key declaration examples

```
CREATE TABLE User
(uid DECIMAL(3,0) NOT NULL PRIMARY KEY,
 name VARCHAR(30) NOT NULL,
 twitterid VARCHAR(15) NOT NULL UNIQUE,
 age DECIMAL (2,0),
 pop DECIMAL(3,2));
```

At most one primary key per table

Any number of UNIQUE keys per table

```
CREATE TABLE Group
(gid CHAR(10) NOT NULL PRIMARY KEY,
 name VARCHAR(100) NOT NULL);
```

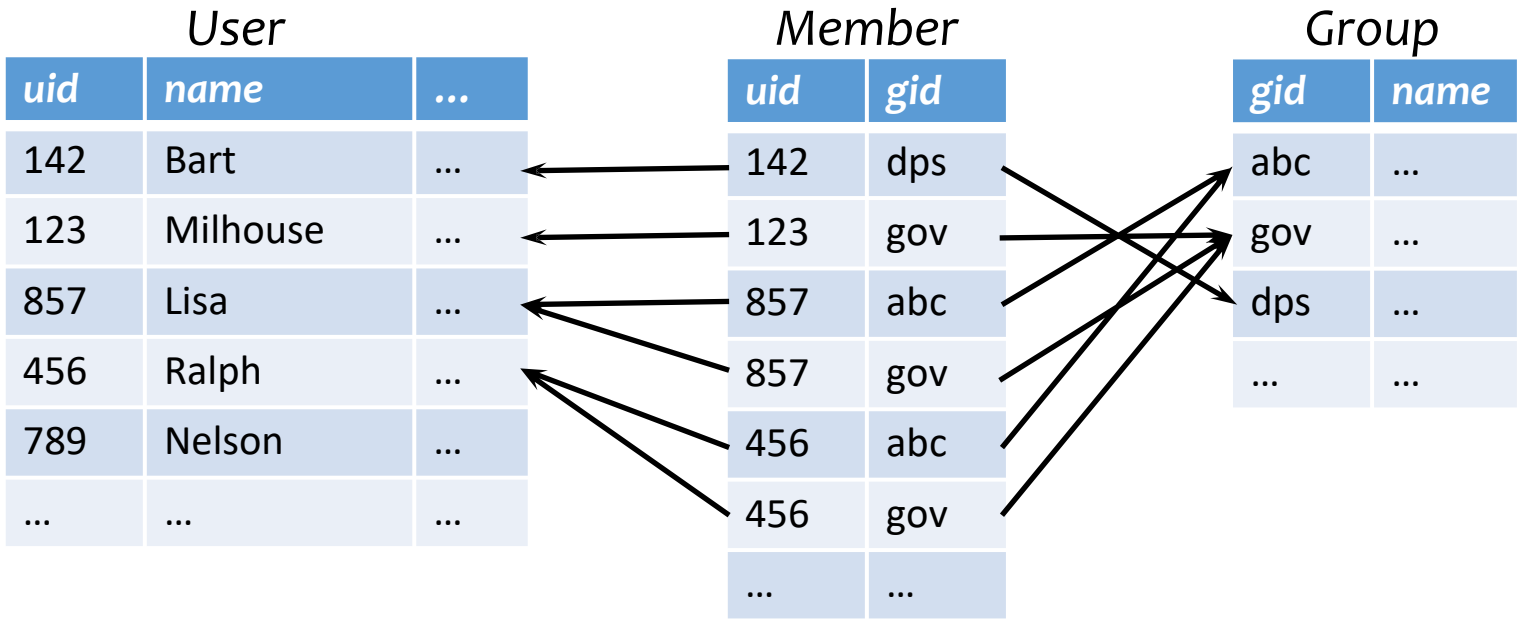
```
CREATE TABLE Member
(uid DECIMAL(3,0) NOT NULL,
 gid CHAR(10) NOT NULL,
PRIMARY KEY(uid,gid));
```

This form is required for multi-attribute keys

Referential integrity example

- If an *uid* appears in *Member*, it must appear in *User*
  - *Member.uid* references *User.uid*
- If a *gid* appears in *Member*, it must appear in *Group*
  - *Member.gid* references *Group.gid*

☞That is, no "dangling pointers"



Referential integrity in SQL

- Referenced column(s) must be PRIMARY KEY
- Referencing column(s) form a FOREIGN KEY

Referential integrity in SQL

- Referenced column(s) must be PRIMARY KEY
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- Example

```
CREATE TABLE Member
(uid DECIMAL(3,0) NOT NULL REFERENCES User(uid),
 gid CHAR(10) NOT NULL,
PRIMARY KEY(uid,gid),
FOREIGN KEY (gid) REFERENCES Group(gid));
```

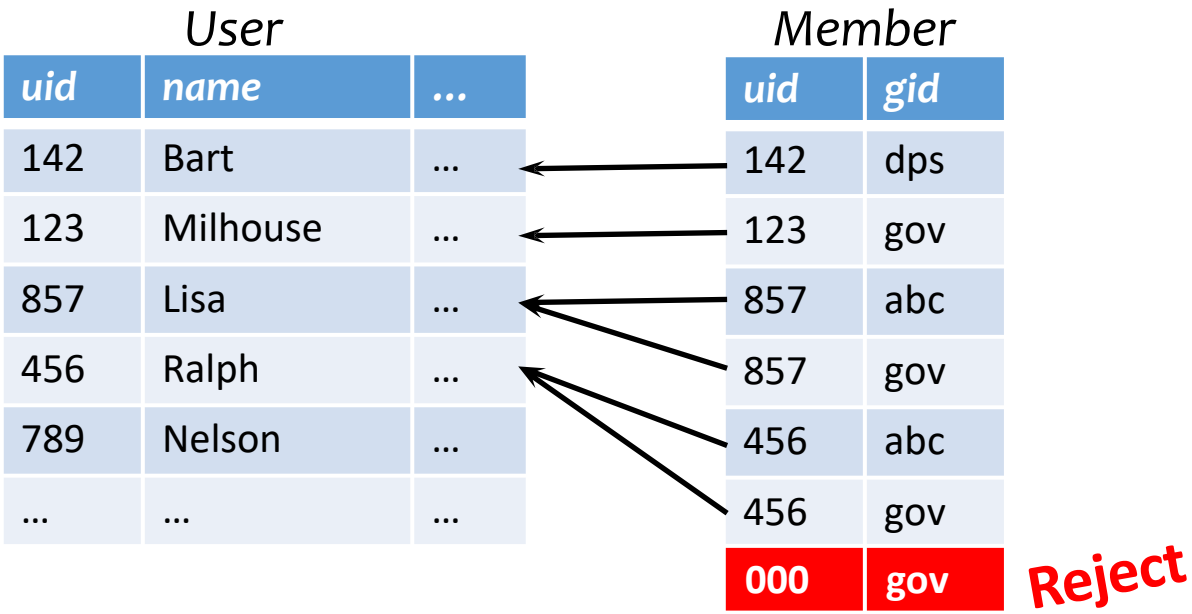
This form is required for multi-attribute foreign keys

```
CREATE TABLE MemberBenefits
(…..
FOREIGN KEY (uid,gid) REFERENCES Member(uid,gid));
```

Enforcing referential integrity

Example: *Member.uid* references *User.uid*

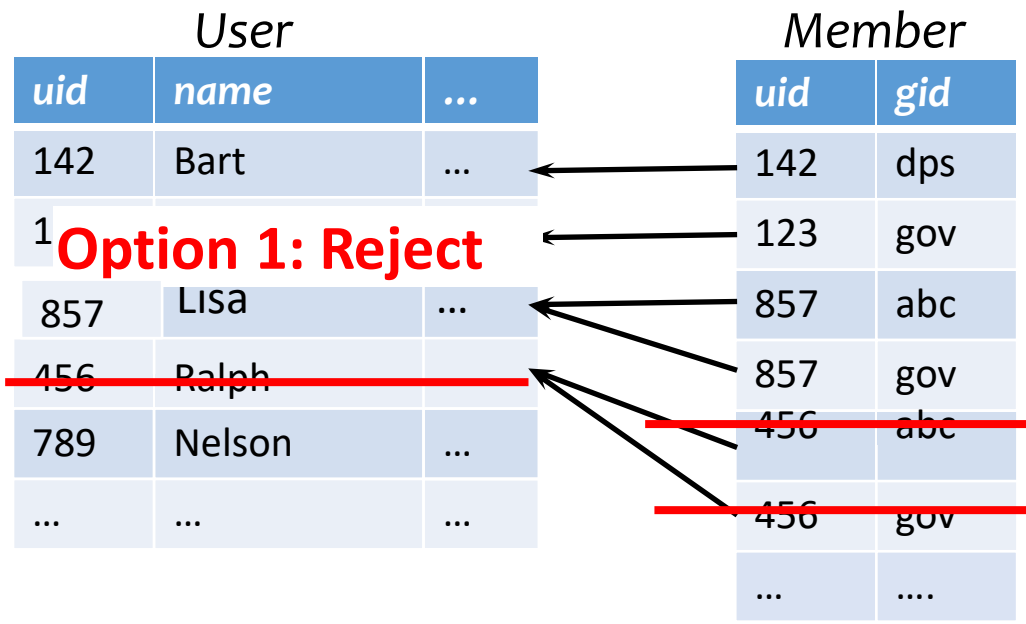
- Insert or update a *Member* row so it refers to a non-existent *uid*
  - Reject



Enforcing referential integrity

Example: *Member.uid* references *User.uid*

- Delete or update a *User* row whose *uid* is referenced by some *Member* row
  - Multiple Options (in SQL)




```
CREATE TABLE Member
(uid DECIMAL(3,0) NOT NULL
REFERENCES User(uid)
ON DELETE CASCADE,
……);
```

Option 2: Cascade
(ripple changes to all referring rows)

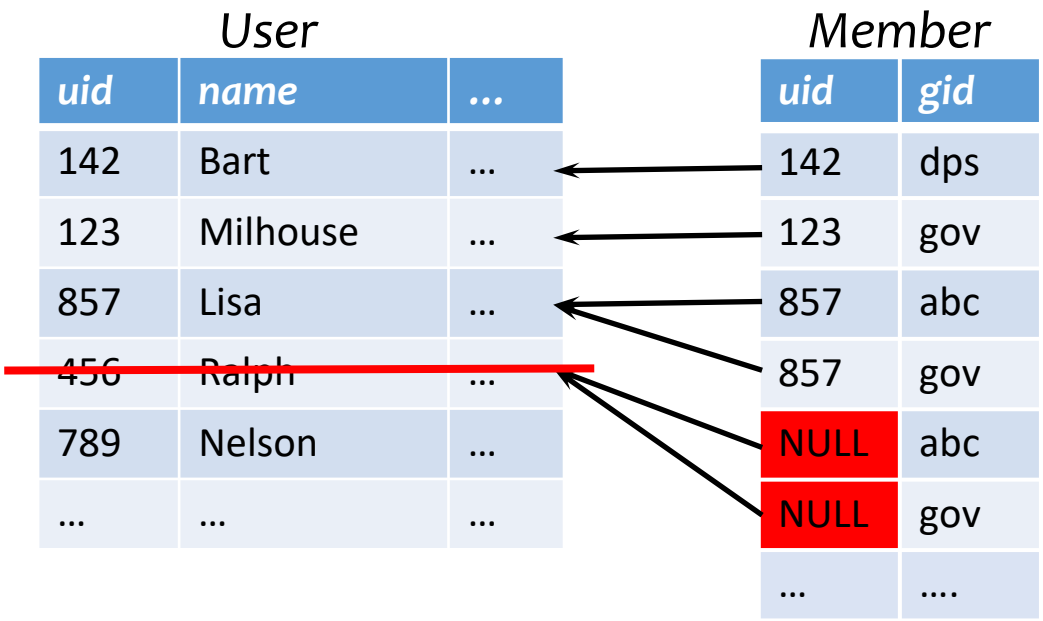
Enforcing referential integrity

Example: *Member.uid* references *User.uid*

- Delete or update a *User* row whose *uid* is referenced by some *Member* row
  - Multiple Options (in SQL)

```
CREATE TABLE Member
(uid DECIMAL(3,0) NOT NULL
REFERENCES User(uid)
ON DELETE SET NULL,
……);
```

Option 3: Set NULL
(set all references to NULL)



Deferred constraint checking

- Example:

```
CREATE TABLE Dept
(name CHAR(20) NOT NULL PRIMARY KEY,
 chair CHAR(30) NOT NULL
        REFERENCES Prof(name));

CREATE TABLE Prof
(name CHAR(30) NOT NULL PRIMARY KEY,
 dept CHAR(20) NOT NULL
        REFERENCES Dept(name));
```

  - The first INSERT will always violate a constraint!
- Deferred constraint checking is necessary
  - Check only at the end of a transaction
  - Allowed in SQL as an option

Example

```
Create Table T1 (C varchar(10) Primary Key);
Create Table T2 (C varchar(10) Primary Key);

Alter Table T1 Add Constrained Fk1 Foreign Key(C) references  T2(C);
Alter Table T2 Add Constrained Fk2 Foreign Key(C) references  T1(C);

Insert into T1 Values('X');     OR      Insert into T2 Values('Y');
```

Example

Create Table T1 (C varchar(10) Primary Key);
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Throughs ERROR report – Integrity Constraint Violation

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Insert into T1 Values('X'); OR Insert into T2 Values('Y');
Throughs ERROR report – Integrity Constraint Violation

Alter Table T1 Add Constrained Fk1 Foreign Key(C) references T2(C)
Deferrable Initially Deferred;
Alter Table T2 Add Constrained Fk2 Foreign Key(C) references T1(C)
Deferrable Initially Deferred;

Insert into T1 Values('X'); AND Insert into T2 Values('X');
Commit;

Example

Drop Table T1; or Drop Table T;

Gives Error

Alter Table T1 Drop Constrained Fk1;
Alter Table T2 Drop Constrained Fk2;

Then Drop table…..

General assertion

- CREATE ASSERTION *assertion_name*
  CHECK assertion_condition;
- assertion_condition is checked for each modification that could potentially violate it

- Example: *Member.uid* references *User.uid*

```
CREATE ASSERTION MemberUserRefIntegrity
CHECK (NOT EXISTS
      (SELECT * FROM Member
       WHERE uid NOT IN
       (SELECT uid FROM User)));
```

Tuple- and attribute-based CHECK's

- Associated with a single table
- Only checked when a tuple/attribute is inserted/updated
  - Reject if 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)),
 ...);
```

Question: How does it differ from a referential integrity constraint?

SQL features covered so far

- Query
  - SELECT-FROM-WHERE statements
  - Set and bag operations
  - Table expressions, subqueries
  - Aggregation and grouping
  - Ordering
  - Outerjoins (and NULL)
- Modification
  - INSERT/DELETE/UPDATE
- Constraints

☞ Next: triggers, views, indexes