

Fundamentals of Database Systems

COMPSCI 351

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SQL

Data Definition and Manipulation Language

A Standard Language for Relational Databases

Need a language that implements the relational model in a real DBMS

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An Industry Standard for Relational Database Systems

- We will consider a subset of SQL-2008
- Newest features out of scope and mostly syntactic sugar
- Although standard, different implementations do differ

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SEQUEL = **S**tructured **E**nglish **QUE**ry **L**anguage

SQL is the industry standard for...

- Giving data definitions (defining schemata and instances)
- Manipulating data definitions (updates)
- Querying data

SQL - DDL, DML, and QL

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SQL provides many more constructs, for example for

- external schema definitions (**views**),
- (limited) physical access path definitions (**indices**),
- coupling with programming languages (**embedded SQL**, **dynamic SQL**) and
- authorization (**access rights**)

Data Definition Language

CREATE statement to define relation schemata

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CREATE TABLE <table_name> <attribute_specification> ;
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A (comma separated) list of items:

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each of which may be followed by an optional NOT NULL

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each of which may be followed by an optional NOT NULL

In SQL names are not case-sensitive

DROP TABLE

removes relation schemata from a database schema

More Constructs for DDL

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removes relation schemata from a database schema

ALTER TABLE

used to change existing relation schemata

Some Domains (1)

CHARACTER and VARCHAR

- character strings of fixed or variable length
- maximum length given as parameter, e.g. VARCHAR(32)

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- maximum length given as parameter, e.g. VARCHAR(32)

NATIONAL CHARACTER

handles character strings using another (national) font, e.g.,

- German
- Cyrillic
- Mandarin
- Hindi
- Kanji

and the corresponding encoding

Some Domains (2)

INTEGER and SMALLINT

- handles domains of integers
- integers between -2^n und $2^n - 1$, where n depends on the actual implementation

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NUMERIC and DECIMAL

- handle fixed point numbers with parameters
 - *precision* for the total number of digits and
 - *scale* for the number of digits following the decimal point
- for DECIMAL there is a system-dependent maximum number of digits

Some Domains (3)

FLOAT, REAL and DOUBLE PRECISION

- handle floating point numbers
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BIT and BIT VARYING

handle bit strings analogously to CHARACTER and VARCHAR

Some Domains (4)

DATE

handles date values (year, month, day)

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TIME

- handles time values (hour, minute, second)
- the number of digits for seconds can be put in as a parameter

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For other domains or variants refer to system manuals

Representing Missing Information

To insert some tuple into a relation, we must know all values of the tuple

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That would be a severe restriction in practice

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SQL permits occurrences of a single kind of *null marker*

- We extend domains by a null marker symbol `null`
- Different `null` occurrences may have different meanings
- A tuple t is called X -total, if $t(A) \neq \text{null}$ for all $A \in X$

Example: Null Marker Occurrences

<i>id</i>	<i>first_name</i>	<i>last_name</i>	<i>year_born</i>
001	null	Plato	427 BC
002	null	Timberlake	1981

Example: Null Marker Occurrences

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Null marker interpretation

- First row: *value does not exist*
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Duplicate Tuples

Duplicate tuples have matching values on every attribute

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Relations

- Every relation is a set, i.e., a collection of well-distinguished elements
- Hence, relations cannot contain any duplicate tuples (by definition)

In practice, database instances and results of queries are large

- Duplicate removal is an expensive operation
- Hence, duplicates are tolerated (but can be avoided if needed)

Example: Duplicate Tuples

<i>id</i>	<i>first_name</i>	<i>last_name</i>	<i>year_born</i>
002	Justin	Timberlake	1981
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A relation?

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Definition (Table Schema)

A finite non-empty set of attributes

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- but domains of an attribute extended by null marker `null`

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Definition (Table)

A finite multi-set r of partial tuples

- partiality of tuple t means that $t(A)$ may be `null` for some attribute A
- multi-set means that duplicate (partial) tuples may occur
- table is said to be X -total, if all its tuples are X -total

Example: A Table that is not a Relation

<i>id</i>	<i>first_name</i>	<i>last_name</i>	<i>year_born</i>
002	null	Timberlake	1981
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Properties

- is defined over table schema $\{id, first_name, last_name, year_born\}$
- is $\{id, last_name, year_born\}$ -total
- is not a relation as it contains two duplicate tuples

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- is not a relation as it contains two duplicate tuples

Relations are idealized special cases of tables where neither duplicate tuples nor partial tuples are permitted to occur

NOT NULL Constraints

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NOT NULL constraints can be attached to an attribute

- disallow any occurrences of the null marker on that attribute
- a table satisfies the NOT NULL constraint on A , if it is A -total

UNIQUE Constraints

Uniqueness constraints are specified using the keyword `UNIQUE`, that is,

```
UNIQUE ( <attribute-list> )
```

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Uniqueness constraints are specified using the keyword UNIQUE, that is,

UNIQUE (\langle attribute-list \rangle)

Semantics

- different tuples must not have total matching values on all attributes in the list
- A table satisfies $\text{UNIQUE}(X)$ (shorter: $u(X)$), if there are no different X -total tuples t, t' in the table such that $t(X) = t'(X)$

PRIMARY KEY Constraints

Primary keys can be defined by

`PRIMARY KEY (<attribute-list>)`

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- satisfied by tables that satisfy `UNIQUE(\langle attribute-list \rangle)`, and
- `NOT NULL` for every attribute from the list

Alternatively, the keyword `PRIMARY KEY` can simply be attached to an attribute, if there is just one attribute in the uniqueness constraint

Example for UNIQUE and PRIMARY KEY constraints

<i>title</i>	<i>author</i>	<i>journal</i>
The uRNA database	Zwieb C	Nucleic Acids 1997
The uRNA database	Zwieb C	Nucleic Acids 1996
Genome wide detect.	Ragh. R	null

UNIQUE?

PRIMARY KEYs?

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PRIMARY KEYs?

none!

Genius Question

What is remarkable about this example?

Syntax of Referential Constraints

Foreign keys can be defined by

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FOREIGN KEY ( <attribute-list> ) REFERENCES <table-name> ( <attribute-list> );
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Naming convention for foreign keys

- child schema: table schema on which foreign key is defined
- parent schema: table schema which foreign key references
- FOREIGN KEY (A_1, \dots, A_n) REFERENCES $P(B_1, \dots, B_n)$ on child schema C

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- Attribute-list (B_1, \dots, B_n) can be omitted, if $A_1 = B_1, \dots, A_n = B_n$
- UNIQUE(B_1, \dots, B_n) must be enforced on P

FOREIGN KEY (A_1, \dots, A_n) REFERENCES $P(B_1, \dots, B_n)$

Foreign key enforces that...

- for every $\{A_1, \dots, A_n\}$ -total tuple t_c in child table there is
- some tuple t_p in parent table such that
- $t_c(A_1) = t_p(B_1), \dots, t_c(A_n) = t_p(B_n)$

Example of a Relational Database Schema

MOVIE=

{title, year, country, run_time, genre}

with key {title, year}

PERSON=

{id, first_name, last_name, year_born}

with key {id}

ACTOR={id, title, year, role}

- with key {id, title, year, role}
- and foreign keys:
 - $[id] \subseteq \text{PERSON}[id]$
 - $[title, year] \subseteq \text{MOVIE}[title, year]$

DIRECTOR={id, title, year}

- with key {title, year}
- foreign keys:
 - $[id] \subseteq \text{PERSON}[id]$
 - $[title, year] \subseteq \text{MOVIE}[title, year]$

SQL Definition of Example

```
CREATE TABLE MOVIE (  
    title varchar(40) NOT NULL,  
    year number(4) NOT NULL,  
    country varchar(20) NOT NULL,  
    run_time number(4) NOT NULL,  
    genre varchar(10) NOT NULL,  
    CONSTRAINT pk_movie PRIMARY KEY(title,year) );
```

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    genre varchar(10) NOT NULL,  
    CONSTRAINT pk_movie PRIMARY KEY(title,year) );
```

```
CREATE TABLE PERSON(  
    id char(8) PRIMARY KEY,  
    first_name varchar(15) NOT NULL,  
    last_name varchar(15) NOT NULL,  
    year_born number(4),  
    PRIMARY KEY(id) );
```

SQL Definition of Example Continued

```
CREATE TABLE ACTOR(  
    id char(8) NOT NULL,  
    title varchar(40) NOT NULL,  
    year number(4) NOT NULL,  
    role varchar(40) NOT NULL,  
    PRIMARY KEY(id, title, year, role),  
    FOREIGN KEY(title, year) REFERENCES MOVIE(title, year),  
    FOREIGN KEY(id) REFERENCES PERSON );
```

SQL Definition of Example Continued

```
CREATE TABLE ACTOR(  
    id char(8) NOT NULL,  
    title varchar(40) NOT NULL,  
    year number(4) NOT NULL,  
    role varchar(40) NOT NULL,  
    PRIMARY KEY(id, title, year, role),  
    FOREIGN KEY(title, year) REFERENCES MOVIE(title, year),  
    FOREIGN KEY(id) REFERENCES PERSON );
```

```
CREATE TABLE DIRECTOR(  
    id char(8) NOT NULL,  
    title varchar(40) NOT NULL,  
    year number(4) NOT NULL,  
    PRIMARY KEY(title, year),  
    FOREIGN KEY(title, year) REFERENCES MOVIE(title, year),  
    FOREIGN KEY(id) REFERENCES PERSON(id) );
```

Pop-quiz

Four different SQL table definitions (without domains)

- `CREATE TABLE S1(id PRIMARY KEY, name NOT NULL);`
- `CREATE TABLE S2(id NOT NULL, name NOT NULL);`
- `CREATE TABLE S3(id UNIQUE, name NOT NULL);`
- `CREATE TABLE S4(id, name NOT NULL);`

<i>t₁</i>	
<i>id</i>	<i>name</i>
1	Rihanna
2	Gaga

<i>t₂</i>	
<i>id</i>	<i>name</i>
1	Rihanna
1	Gaga

<i>t₃</i>	
<i>id</i>	<i>name</i>
null	Eminem
3	Eminem

<i>t₄</i>	
<i>id</i>	<i>name</i>
null	Eminem
1	Rihanna
1	Gaga

Which tables are instances of which table schema?

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- CREATE TABLE S2(id NOT NULL, name NOT NULL);
- CREATE TABLE S3(id UNIQUE, name NOT NULL);
- CREATE TABLE S4(id, name NOT NULL);

t_1	
<i>id</i>	<i>name</i>
1	Rihanna
2	Gaga

over S1-S4

t_2	
<i>id</i>	<i>name</i>
1	Rihanna
1	Gaga

over S2 and S4

t_3	
<i>id</i>	<i>name</i>
null	Eminem
3	Eminem

over S3 and S4

t_4	
<i>id</i>	<i>name</i>
null	Eminem
1	Rihanna
1	Gaga

over S4

Foreign Key Example

Consider the following version of our SQL schema

```
CREATE TABLE MOVIE' (  
  title varchar(40),  
  year number(4),  
  country varchar(20),  
  run_time number(4),  
  genre varchar(10),  
  PRIMARY KEY(title,year) );
```

```
CREATE TABLE DIRECTOR'(  
  id char(8) NOT NULL,  
  title varchar(40),  
  year number(4),  
  UNIQUE(title, year),  
  FOREIGN KEY(title, year) REFERENCES MOVIE'(title, year),  
  FOREIGN KEY(id) REFERENCES PERSON(id) );
```

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  UNIQUE(title, year),  
  FOREIGN KEY(title, year) REFERENCES MOVIE'(title, year),  
  FOREIGN KEY(id) REFERENCES PERSON(id) );
```

Does the following database satisfy the foreign key

FOREIGN KEY(title, year) REFERENCES MOVIE'(title, year)?

DIRECTOR'

<i>id</i>	<i>title</i>	<i>year</i>
1	null	2012
8	Nosferatu	1922

MOVIE'

<i>title</i>	<i>year</i>	<i>country</i>	<i>run_time</i>	<i>genre</i>
Nosferatu	1922	Germany	80	Horror
Mana Waka	1937	New Zealand	85	History

Specify what happens in case of deleting or updating referenced tuples

Referential Actions

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- **SET DEFAULT** will force the corresponding values in the referencing tuples to be set to a specified default value
- **NO ACTION** does nothing, i.e., the foreign key constraint will be violated

Example for Referential Action

Consider a foreign key on DIRECTOR again

```
FOREIGN KEY(title,year) REFERENCES MOVIE(title,year) ON DELETE CASCADE
```

Example for Referential Action

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the deletion of a movie would trigger the deletion of its director

Another Example for Referential Action

Consider a different foreign key on `DIRECTOR`

```
FOREIGN KEY(title,year) REFERENCES MOVIE(title,year) ON DELETE SET NULL
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Another Example for Referential Action

Consider a different foreign key on DIRECTOR

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FOREIGN KEY(title,year) REFERENCES MOVIE(title,year) ON DELETE SET NULL
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the deletion of a movie would trigger that the information of the person who is the director of that movie is kept, but we lose the information which movie was directed

Extensions of the CREATE Statement

So far, we only considered the definition of relation schemata (`CREATE TABLE`)

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Define integrity constraints outside the definition of relation schemata

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CREATE ASSERTION ⟨name⟩ CHECK ...
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Define integrity constraints outside the definition of relation schemata

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Define new domains together with a check-clause

```
CREATE DOMAIN ...
```

More Extensions of the CREATE Statement

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```
CREATE VIEW <name> AS <query>
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More Extensions of the CREATE Statement

Define views (external schemata)

```
CREATE VIEW <name> AS <query>
```

Define table schema only for duration of the current SQL session

```
CREATE GLOBAL TEMPORARY TABLE ...
```

Define temporary table schema only to be accessed in one module or ESQL program

```
CREATE LOCAL TEMPORARY TABLE ...
```

Example for Views and Temporary Tables

```
CREATE VIEW DIRECTED_ROLES AS
    SELECT d.id, a.role
    FROM DIRECTOR d, ACTOR a
    WHERE d.title = a.title
    AND d.year = a.year ;
```


Example for Views and Temporary Tables

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CREATE VIEW DIRECTED_ROLES AS
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    FROM DIRECTOR d, ACTOR a
    WHERE d.title = a.title
    AND d.year = a.year ;
```

```
CREATE GLOBAL TEMPORARY TABLE ACTORS_ROLES(
    id char(8) NOT NULL,
    first_name varchar(15) NOT NULL,
    last_name varchar(15) NOT NULL,
    role varchar(30) NOT NULL,
    PRIMARY KEY (id, role) );
```

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- `INSERT INTO <name> <query> ;`

For deletions we use a form similar to queries

```
DELETE FROM <name> WHERE <condition> ;
```

For updates we use value assignments `<attribute> = <value>` in

```
UPDATE <name> SET <value-assignment-list> WHERE <condition> ;
```

Example for Data Manipulation

- INSERT INTO PERSON
VALUES (10, 'Taylor', 'Lautner', 1992);

PERSON			
<i>id</i>	<i>f_name</i>	<i>l_name</i>	<i>year_born</i>

Example for Data Manipulation

- INSERT INTO PERSON
VALUES (10, 'Taylor', 'Lautner', 1992);

PERSON			
<i>id</i>	<i>f_name</i>	<i>l_name</i>	<i>year_born</i>
10	Taylor	Lautner	1992

Example for Data Manipulation

- INSERT INTO PERSON
VALUES (10, 'Taylor', 'Lautner', 1992);
- INSERT INTO PERSON
VALUES (11, 'Ziyi', 'Zhang', 1979);

PERSON			
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- INSERT INTO PERSON
VALUES (10, 'Taylor', 'Lautner', 1992);
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VALUES (11, 'Ziyi', 'Zhang', 1979);
- INSERT INTO PERSON (id, first_name, last_name)
VALUES (12, 'Benicio', 'Del Toro');

PERSON			
<i>id</i>	<i>f_name</i>	<i>l_name</i>	<i>year_born</i>
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11	Ziyi	Zhang	1979
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- INSERT INTO PERSON (id, first_name, last_name)
VALUES (13, 'Sophie', 'Marceau');

PERSON			
<i>id</i>	<i>f_name</i>	<i>l_name</i>	<i>year_born</i>
10	Taylor	Lautner	1992
11	Ziyi	Zhang	1979
12	Benicio	Del Toro	null

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PERSON			
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11	Ziyi	Zhang	1979
12	Benicio	Del Toro	null
13	Sophie	Marceau	null

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- INSERT INTO PERSON (id, first_name, last_name)
VALUES (13, 'Sophie', 'Marceau');
- UPDATE PERSON SET year_born = '1966'
WHERE id = 13;

PERSON

<i>id</i>	<i>f_name</i>	<i>l_name</i>	<i>year_born</i>
10	Taylor	Lautner	1992
11	Ziyi	Zhang	1979
12	Benicio	Del Toro	null
13	Sophie	Marceau	null

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PERSON			
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10	Taylor	Lautner	1992
11	Ziyi	Zhang	1979
12	Benicio	Del Toro	null
13	Sophie	Marceau	1966

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- INSERT INTO PERSON
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- INSERT INTO PERSON (id, first_name, last_name)
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- UPDATE PERSON SET year_born = '1966'
WHERE id = 13;
- DELETE FROM PERSON
WHERE last_name = 'Del Toro' OR
first_name = 'Taylor';

PERSON

<i>id</i>	<i>f_name</i>	<i>l_name</i>	<i>year_born</i>
10	Taylor	Lautner	1992
11	Ziyi	Zhang	1979
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WHERE id = 13;
- DELETE FROM PERSON
WHERE last_name = 'Del Toro' OR
first_name = 'Taylor';

PERSON			
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11	Ziyi	Zhang	1979
13	Sophie	Marceau	1966

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VALUES (12, 'Benicio', 'Del Toro');
- INSERT INTO PERSON (id, first_name, last_name)
VALUES (13, 'Sophie', 'Marceau');
- UPDATE PERSON SET year_born = '1966'
WHERE id = 13;
- DELETE FROM PERSON
WHERE last_name = 'Del Toro' OR
first_name = 'Taylor';
- DELETE FROM PERSON WHERE id >= 11;

PERSON			
<i>id</i>	<i>f_name</i>	<i>l_name</i>	<i>year_born</i>
11	Ziyi	Zhang	1979
13	Sophie	Marceau	1966

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- INSERT INTO PERSON (id, first_name, last_name)
VALUES (13, 'Sophie', 'Marceau');
- UPDATE PERSON SET year_born = '1966'
WHERE id = 13;
- DELETE FROM PERSON
WHERE last_name = 'Del Toro' OR
first_name = 'Taylor';
- DELETE FROM PERSON WHERE id >= 11;

PERSON			
<i>id</i>	<i>f_name</i>	<i>l_name</i>	<i>year_born</i>

Summary of SQL as a DDL and DML

- SQL is the industry standard for defining and querying data
- SQL is founded on the relational model of data
- SQL allows us to specify relational database schemata
- SQL allows us to specify integrity constraints to restrict the data to those considered meaningful to the application at hand
 - domain constraints
 - uniqueness constraints, keys and foreign keys
 - triggers can enforce more expressive integrity constraints
- SQL allows us to manipulate data: insert, delete, update
- SQL allows us to use `null` markers to ease data entry
- SQL's default is to preserve duplicate tuples to facilitate data processing
- SQL's features as a query language are discussed later on