Relational Model

- **Domain**: Set of atomic values
- **Relation**: Set of tuples
- **Superkey**: Subset of attributes that uniquely identifies one tuple
- **Key**: Minimal superkey
- **Candidate Keys**: Set of all keys
- **Primary Key**: Chosen candidate key; cannot be NULL
- **Foreign Key**: Refers to a primary key in another relation; must apear as a primary key of another relation or have NULL for an attribute

Relational Algebra

$\sigma_{[\sigma]}(R)$: Select
- Select rows that satisfy condition *c*
- Principle of Acceptance

$\pi_{[l]}(R)$: Project
- Select columns listed in *l*

$\rho_{[B_1 \leftarrow A_1, B_2 \leftarrow A_2]}(R)$: Rename
- Order does not matter
- No two attributes can be renamed to the same name
- No attributes can be renamed more than once in a single operation

Set Operations
- Relations must be union compatible:
  1. Have same number of attributes
  2. Attributes have same or compatible domains

Cross Product
- Set of attributes must be disjoint
- |R × S| = |R| × |S|
- If either R or S is empty, result is an empty relation

Join
- **Inner Joins**
  - $\bowtie_{\theta}$: choose if tuples satisfy the condition
  - $\bowtie_{=}$: choose if tuples satisfy the condition; condition only uses =
  - $\bowtie$: choose if all common attributes between two tuples are equal. Becomes cross product if no common attributes
  - Common attributes (i.e. columns) can can appear twice in output relation, unless natural join is used (then only appear once)
- **Outer Joins**
  - $⟕$: $R \bowtie \mathbf{S}$, plus dangling tuples in R. Dangling tuples have values NULL for attributes from S
  - $⟖$: $R \bowtie \mathbf{S}$, plus dangling tuples in S. Dangling tuples have values NULL for attributes from R
  - $⟗$: $R \bowtie \mathbf{S}$, plus dangling tuples in R and S

Equivalence
- Strong equivalence: Both queries produce error or both queries always produce the same results
- Weak equivalence: Both queries always produce the same results if neither queries produce an error

Joins	Select and Project
$R \times S \not\equiv S \times R$ $R \bowtie S \not\equiv S \bowtie R$ $(R \times S) \times T \equiv R \times (S \times T)$ $(R \bowtie S) \bowtie T \equiv R \bowtie (S \bowtie T)$ $(R \bowtie_{\theta} S) \bowtie_{\theta} T \not\equiv R \bowtie_{\theta} (S \bowtie_{\theta} T)$ (weak)	$\sigma_{c_1}(\sigma_{c_2}(R)) \equiv \sigma_{c_2}(\sigma_{c_1}(R))$ $\sigma_{c_1}(\sigma_{c_1}(R)) \equiv \sigma_{c_1 \wedge c_2}(R)$ $\pi_{\ell_1}(\pi_{\ell_2}(R)) \not\equiv \pi_{\ell_1}$(weak, unless $\ell_1 \subseteq \ell_2$) $\pi_{\ell}(\sigma_{\theta}(R)) \not\equiv \sigma_{\theta}(\pi_{\ell}(R))$ (weak) $\sigma_{\theta}(R \times S) \not\equiv \sigma_{\theta}(R) \times S$ (weak)
Set operations	
$R \cup S \equiv S \cup R$ $R \cap S \equiv S \cap R$ $(R \cup S) \cup T \equiv R \cup (S \cup T)$ $(R \cap S) \cap T \equiv R \cap (S \cap T)$ $R - S \not\equiv S - R$ $\sigma_c(R - S) \equiv \sigma_c(R) - S \not\equiv \sigma_c(R) - \sigma_c(S)$ (unless R and S have some common attribute names used in c) $\pi_{\ell}(R \cup S) \equiv \pi_{\ell}(R) \cup \pi_{\ell}(S)$	

SQL DDL

CREATE
```
CREATE TABLE <table_name> (
   <attr1> <type> [<col_constraint>],
   ...
   [<table_constraints]
);
```

INSERT
```
INSERT INTO <table_name> [(attr1, attr2,...)]
VALUES (val1, val2,...), ...;
```
- Either all are inserted, or none inserted

DELETE
```
DELETE FROM <table_name>
[WHERE <conditions>];
```
- Delete all tuples that match given condition; if no condition, all tuples are deleted
- Principle of **ACCEPTANCE**

Integrity Contraints
- Principle of **REJECTION**

Common constraints		
	Column	Table
Primary Key	PRIMARY KEY	PRIMARY KEY (attr1, attr2)
Unique	UNIQUE	UNIQUE (attr1, attr2)
Foreign Key	REFERENCES R(attr1, attr2)	FOREIGN KEY (attr1, attr2) REFERENCES R(attr3, attr4)
CHECK	CHECK(attr <op>)	CHECK(attr <op>)

- Foreign Keys `ON UPDATE/ON DELETE` specifies behaviour of referencing table when data in referenced table is deleted/updated
  - `NO ACTION` : reject update/delete if violates constraint
  - `RESTRICT` : NO ACTION, but not deferrable
  - `CASCADE` : propagate delete/update to referencing tuples
  - `SET DEFAULT` : Set FK in referencing tuples to default values; default values must be PK in the referenced table
  - `SET NULL` : Set FK in referencing tuples to NULL; affected columns must no have NOT NULL constraint
- UNIQUE constraints check individual attributes using <>; 2 tuples are unique if either one contains NULL

ALTER
- Useful for circular references ($FK_R \rightarrow PK_S$, $FK_S \rightarrow PK_R$)

```
ALTER TABLE <table_name>
[ALTER/ADD/DROP] [COLUMN/CONSTRAINT] <name>
<changes>
```

DROP TABLE
```
DROP TABLE [IF EXISTS]
<table_name> [, <table_name2>, ...]
[CASCADE]
```

DEFFERABLE CONSTRAINTS
- `NOT DEFERRABLE` : (default). Constraints checked at end of SQL statement and aborts if violated
- `DEFERRABLE INITIALLY DEFERRED` : Constraints checked on COMMIT, can be temporarily violated in transaction
- `DEFERRABLE INITIALLY DEFERRED` : Constraints initially not deferrable, but can be set to deferrable later with `SET CONTRAINTS <name> DEFERRED`
- Transaction: `BEGIN ... COMMIT;`

SQL DQL

```
SELECT [DISTINCT] <attrs>
FROM <relations>
WHERE <conditions>
```

- Aliasing: `column AS alias`
- Operations
  - Maths: +-*/, |/, ^ %, etc.
  - String: || (concatenate), LOWER(s), UPPER(s), etc.
  - Date Time: +, NOW(), etc.
- Principle of **ACCEPTANCE**
- = and <> can be safely used if you do not want NULL values, else use `IS NULL`
- Regex `LIKE <regex>`
  - _: Any single character
  - %: Any sequence of 0 or more characters

UNION/INTERSECT/EXCEPT
- Must be union compatible
- `UNION ALL` : # dups = #dup in R + #dup in S
- `INTERSECT ALL` : # dups = min{#dup in R, #dup in S}
- `EXCEPT ALL` : # dups = #dup in R - #dup in S

JOIN
- Cross product `FROM R1 [AS][Alias], R2, R3,…`
  - Set of attributes need not be disjoint
- `JOIN R JOIN S ON <cond>`
- `NATURAL JOIN R NATURAL JOIN S`
  - Becomes cross product if no common attributes
- OUTER JOIN `R LEFT/RIGHT/FULL [OUTER] JOIN S ON <cond>`

ORDER
- Default: ASC
- `ORDER BY <attr1> DESC/ASC [, <attr2> DESC/ASC]`
- Stable sort from rightmost to left

LIMIT & OFFSET

```
OFFSET <n> LIMIT <j>
```

CASE

```
SELECT (
   CASE
      WHEN <cond> THEN <result>
      ...
      ELSE <result>
   END
) FROM ...
```

```
SELECT (
   CASE <expr>
      WHEN <value> THEN <result>
      ...
      ELSE <result>
   END
) FROM ...
```

ELSE is optional; returns NULL if no conditions matched

COASLESCE

```
SELECT (
   COALESCE(<value1>, <value2>, ...)
) FROM ...
```

Returns first non-NULL value, or NULL if all values are NULL

NULLIF

```
SELECT (
   NULLIF(<value1>, <value2>)
) FROM ...
```

Returns NULL if <value1> = <value2>, otherwise returns <value1>

SQL Subqueries

Scalar Subqueries

```
SELECT (
   SELECT <attr> FROM <table_name> WHERE <cond>
) FROM ...
```

- Query returning at most one row and one column (i.e. single value) or NULL

Operation	Syntax	Subquery Behaviour
IN	WHERE <expr> IN <subquery | tuple>	Returns 1 column; Empty → vacuously **false**
NOT IN	WHERE <expr> IN <subquery | tuple>	Returns 1 column; Empty → vacuously **true**
ANY	WHERE <expr> <op> ANY <subquery>	Returns 1 column; Empty → vacuously **false**
ALL	WHERE <expr> <op> ALL <subquery>	Returns 1 column; Empty → vacuously **true**
EXISTS	WHERE EXISTS <subquery>	
NOT EXISTS	WHERE NOT EXISTS <subquery>	

SQL Aggregates

- Queries with aggregate return a single row

Operation	Behaviour	Empty/All NULL table
MIN(attr)	min. non-NULL value in attr	NULL
MAX(attr)	max. non-NULL value in attr	NULL
AVG(attr)	avg of all. non-NULL values in attr	NULL
SUM(attr)	sum of all. non-NULL values in attr	NULL
COUNT(attr)	# of non-NULL values in attr	0
COUNT(*)	# of rows in table	# of rows in table

- Use DISTINCT (e.g. SUM(DISTINCT attr)) to ignore duplicates

GROUP BY & HAVING

```
GROUP BY attr1, attr2
HAVING <condition>
```

- Treat tuples with same values for the listed attributes "as one group"
- Aggregate functions now apply to each group (vs entire table)
- HAVING is a WHERE clause that applies to an entire group (vs individual rows)
- Column X can appear in SELECT / HAVING if:
  - X appears in GROUP BY clause, or
  - X appears as an input to an aggregate function, or
  - PK of table X belongs to appears in GROUP BY clause (UNIQUE constraint is insufficient)

SQL MISC.

Common Table Expressions

```
WITH
   <table_name> AS <query>,
   …
<main_query>
```

- CTEs can reference any CTEs declared before it

Recursive Queries

```
WITH RECURSIVE
   <CTE_name> AS (
      Q_1
      UNION [ALL]
      Q_2
   )
Q_0
```

- Q_1 is non-recursive; Only Q_2 and Q_0 can reference the CTE

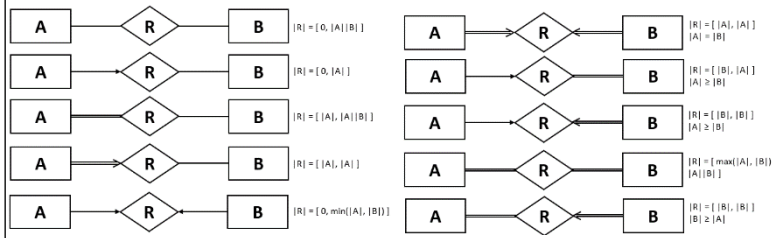
Universal Quantification

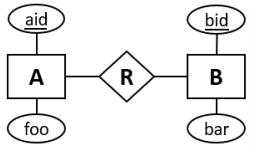
1. Split query into two sets: R and S
2. Figure out cardinality:
   - If R⊇S, then $|R \cup S| = |R|$
   - If R⊆S, then $|R \cap S| = |R|$
3. Craft 2 scalar subqueries queries
   - Query 1: Count # entries in $R \cup S$ or $R \cap S$
   - Query 2: Count # entries in R
   - Check count is the same in both queries

SQL Order of Execution

ORDER	CLAUSE	FUNCTION
1	from	Choose and join tables to get base data.
2	where	Filters the base data.
3	group by	Aggregates the base data.
4	having	Filters the aggregated data.
5	select	Returns the final data.
6	order by	Sorts the final data.
7	limit	Limits the returned data to a row count.

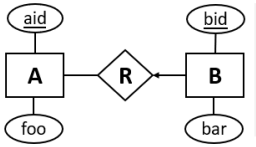
ER Model





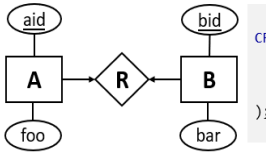

```
CREATE TABLE R (
   aid INT REFERENCES A,
   bid INT REFERENCES B,
   PRIMARY KEY(aid, bid)
);
```

```
CREATE TABLE A (
   aid INT PRIMARY KEY,
   foo INT
);
CREATE TABLE B (
   bid INT PRIMARY KEY,
   bar INT
);
```



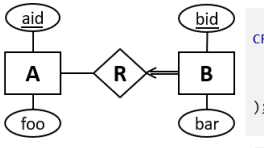

```
CREATE TABLE R (
   bid INT PRIMARY KEY,
   aid INT REFERENCES A,
   bar INT
);
```

```
CREATE TABLE A (
   aid INT PRIMARY KEY,
   foo INT
);
```



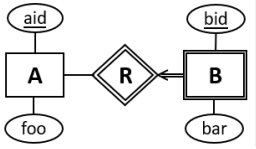

```
CREATE TABLE R (
   bid INT PRIMARY KEY,
   aid INT UNIQUE REFERENCES A,
   bar INT
);
```

```
CREATE TABLE A (
   aid INT PRIMARY KEY,
   foo INT
);
```



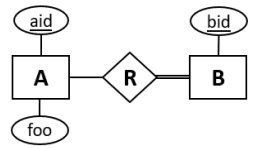

```
CREATE TABLE R (
   bid INT PRIMARY KEY,
   aid INT NOT NULL REFERENCES A,
   bar INT
);
```

```
CREATE TABLE A (
   aid INT PRIMARY KEY,
   foo INT
);
```



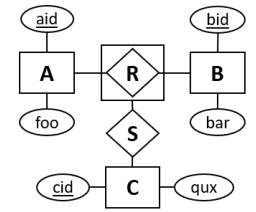

```
CREATE TABLE A (
   aid INT PRIMARY KEY,
   foo INT
);
```

```
CREATE TABLE B (
   bid INT,
   bar INT,
   aid INT REFERENCES A
      ON DELETE CASCADE
      ON UPDATE CASCADE,
   PRIMARY KEY (aid, bid)
);
```




```
CREATE TABLE R (
   bid INT,
   aid INT UNIQUE REFERENCES A,
   PRIMARY KEY (bid, aid)
);
```

```
CREATE TABLE A (
   aid INT PRIMARY KEY,
   foo INT
);
```

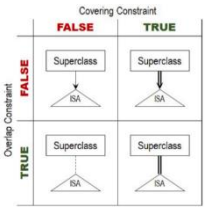



```
CREATE TABLE R (
   aid INT REFERENCES A,
   bid INT REFERENCES B,
   PRIMARY KEY (aid, bid)
);
```

```
CREATE TABLE S (
   aid INT,
   bid INT,
   cid INT REFERENCES C
   PRIMARY KEY (aid, bid, cid),
   FOREIGN KEY (aid bid)
      REFERENCES R(aid, bid)
);
```

ISA Hierarchies

- Inherited primary key of child references the primary key of the direct parent
- Specify ON DELETE/ON UPDATE on child foreign keys



PL/pgSQL

Functions

```
CREATE OR REPLACE
FUNCTION <fn_name> ([IN/OUT/INOUT] <param> <type> …)
RETURNS <return_type> AS $$
DECLARE  --plpgsql
  ...
BEGIN    --plpgsql
  ...
END;
$$ LANGUAGE <sql/plpgsql>;
```

- `IN/OUT/INOUT`:
  - `IN`: (default) Parameter is an input. A constant; cannot be reassigned
  - `OUT`: Parameter is return value. An uninitialised variable; must be assigned a value later
  - `INOUT`: Parameter is both an input and return value. An initialised variable; should be but not value later
- Return types
  - `<table_name>`: Returns one existing tuple from the table
  - `SETOF <table_name>`: Returns one or more existing tuples from the table
  - `RECORD`: Returns one new tuple from the table containing the `OUT/INOUT` attributes specified in the parameters list
  - `SETOF RECORD`: Returns one or more new tuples containing the `OUT/INOUT` attributes specified in the parameters list
  - `TABLE(<attr> <type>, …)`: Returns a new table with the specified schema. Parameters list should not contain `OUT/INOUT`
    - plpgsql: Function should call one or more `RETURN NEXT` to populate the table

Procedures

```
CREATE OR REPLACE
PROCEDURE <procedure_name> (<param> <type> …)
AS $$
...
$$ LANGUAGE <sql/plpgsql>;

CALL procedure_name(params…)
```

IF ELSE & Control Flow

```
IF <cond> THEN
  ...
ELSE
  ...
END IF;
```

```
LOOP
  EXIT WHEN <cond>
  ...

END LOOP
```

Cursor

```
DECLARE
  curs CURSOR FOR <table_name>;
  r RECORD
  ...
BEGIN
  OPEN curs;
  LOOP
    FETCH curs INTO r; --get current tuple
    EXIT WHEN NOT FOUND; --exit when end of table
    ...
    RETURN NEXT; --insert tuple into table
  END LOOP;
  CLOSE curs;
  ...
```

Triggers

```
CREATE TRIGGER <trigger_name>
AFTER/BEFORE INSERT/UPDATE/DELETE OR [...] ON <table>
[DEFERRABLE INITIALLY DEFERRED/IMMEDIATE]
FOR EACH ROW/STATEMENT
[WHEN <cond>]
EXECUTE FUNCTION <fn_name>();

CREATE OR REPLACE FUNCTION <fn_name>
RETURNS TRIGGER ...
```

- Special variables
  - `NEW`: INSERT/UPDATE: the new tuple; DELETE: NULL
  - `OLD`: DELETE/UPDATE: the old tuple; INSERT: NULL
  - `TG_OP`: INSERT/UPDATE/DELETE
  - `TG_TABLE_NAME`: Table associated with the trigger
- Only AFTER and FOR EACH ROW triggers can be deferred

Return Types

- **BEFORE**
  - INSERT: Null → nothing inserted; Non-null *t* → insert *t*
  - UPDATE: Null → not updated; Non-null *t* → updated to *t*
  - DELETE: Null → not deleted; Non-null *t* → delete (not nec. *t*)
- **AFTER**
  - Does not matter; just return NULL for convenience
- **INSTEAD OF**
  - NULL → ugnore rest of the operation on current row; Non-null → proceed as normal
  - INSTEAD OF is only defined on VIEWS and ROW-LEVEL

RAISE

- `RAISE NOTICE '…'`: Prints warning message, but does not prevent the operation
- `RAISE EXCEPTION '…'`: Prints warning message and prevents the operation

WHEN

- No SELECT in WHEN()
- No OLD in WHEN() for INSERT
- No NEW in WHEN() for DELETE
- No WHEN for INSTEAD OF

Order of Execution

- BEFORE statement > BEFORE row > INSTEAD OF > AFTER row > AFTER statement
- Within each category triggers are activated in alphabetical order of their names (A → Z)
- If a BEFORE row-level trigger returns NULL, then subsequent triggers on the same row are omitted