(**Name:** Warren Kim, **UID:** 305600694)

Relation: consists of a *set* of tuples (records). Each tuple is a row and has n attributes or columns. Each tuple contains the exact same attributes in the same order.
Superkey: a set of $k \leq n$ attributes that uniquely identifies a tuple. There are at most $2^n - 1$ superkeys for an n-attribute relation.
Candidate Key: is a minimal superkey s.t. no subset of its attributes form a superkey itself. A candidate key may be `null`.
Primay Key: is a candidate key chosen by the DB designer to enforce uniqueness based on use case. A primary key may not be `null`. If a primary key is composite, no component can be `null`
Foreign Key: in S points to a primary key in R. FK's need not be unique in S, but must be unique (by def.) in R. FK's are primarily used for referential integrity. Further, the FK $\in S$ need not have the same name as the PK $\in R$.

Selection: $\sigma_\psi(R) = \{t \in R : \psi(t)\}$. $\sigma_\psi(R) \approx$ `SELECT * FROM` R `WHERE` $\psi(t)$. It filters on ***tuples*** using: $=, \neq, <, >, \leq, \geq, \neg, \vee, \wedge$.
Projection: $\Pi_{a_i}(R) = \{t[a_i] : t \in R, i \leq n\}$. $\Pi \approx$ `SELECT` $a_1, \ldots, a_n$ `FROM` R. Also, $\Pi_{f(a_i) \to a'}$ where f is any reasonable function.
Cartesian Product: $R \times S = \{(r, s) : r \in R, s \in S\}$. They are very bad and inefficient.
Natural Join: $R \bowtie S = \Pi_{R \cup S}(\sigma_{R.k=S.k}(R \times S)) = \{(r, s) : r \in R, s \in S, r[k] = s[k]\}$. Only to be used in relational algebra.
Natural Join Edge Cases: If $k = \emptyset$, $R \bowtie S = R \times S$. **If** $\forall r \in R, s \in S, r[k] \neq s[k]$, $R \bowtie S = \emptyset$.
Join Key: is the set of $k \leq n$ attributes that we join R, S on. All conditions are equality $\implies$ equijoin. Otherwise, non-equijoin.
Theta Join: $R \bowtie_\theta S = \sigma_\theta(R \times S) = \{(r, s) : r \in R, s \in S, \theta((r, s))\}$. Name clash $\to$ alias. We choose the join key.
Inner Join: Include all rows that satisfy $\theta((r, s))$. Throw out all rows that don't satisfy $\theta((r, s))$.
Aggregation: ${}_{\text{group}}\gamma_{f(a_i)}(R)$ where f is an aggregation function. Some include `SUM, AVG, MIN, MAX, DISTINCT-COUNT`.
Rename: $\rho_S(R)$ renames a ***relation*** $R \to S$. $\rho_{a/b}(R)$ renames an ***attribute*** $a \to b \in R$. Usually used in $rho_S(R) \times R$.
Union: $R \cup S = \{r_1, \ldots, r_{|R|}, s_1, \ldots, s_{|S|} : r_i \in R, s_j \in S\}$. R, S must have the same set of attributes for this to work.
Set Difference: $R - S = \{t : t \in R, t \notin S\}$. **Note: Division $\div$ is not implemented in SQL**.
Intersection: $R \cap S = \{t : t \in R, S\}$. R, S must have the same set of attributes for this to work. Note: $R \cap S = R - (R - S)$.
Order of Operations: $\sigma, \Pi, \rho \to \times, \bowtie \to \cap \to \cup, -$.

`ENUM`: Order of defined when type is constructed. Values are case sensitive, whitespace matters. ***Can:*** add, rename values. ***Cannot:*** delete, reorder values. 4 bytes.
Create Enum/Table:

```
CREATE TYPE enum_name AS ENUM ('value_1', ..., 'value_n');
CREATE TABLE table_name (
    column_1     type OPTIONS,
    ...
    column_n     type OPTIONS
    );
```

where `type` is a data type and `OPTIONS` can be none or more of: `NOT NULL, DEFAULT [DEFAULT VALUE], UNIQUE, PRIMARY KEY, FOREIGN KEY REFERENCES other_table(other_table_ukey) ON DELETE/UPDATE CASCADE/RESTRICT/SET NULL`. We can set the PK/FK inline or at the bottom using `PRIMARY KEY (column_i)` and `FOREIGN KEY (column_j) REFERENCES other_table(other_table_ukey)`.
Changing Schema: Don't lmao. Use `extra` (if you were smart enough to think ahead) or create another table with a join key.
Alter Table: add/drop columns, constraints (e.g. PK/FK), rename tables/columns, change data types of columns.

```
ALTER TABLE table_name
    DROP col_i,                         -- delete column
    ALTER COLUMN col_j TYPE new_type,   -- changes type of col_j to new_type
    ADD col_k type,                     -- adds col_k
    DROP CONSTRAINT table_name_pkey,    -- drops PK constraint
    ADD PRIMARY KEY col_l,              -- adds PK constraint to col_l
    RENAME COLUMN col_m TO new_col_name, -- renames col_m to new_col_name
    RENAME TO new_table_name;           -- renames table_name to new_table_name
```

Drop, Truncate, Delete: `DROP [TABLE/SCHEMA/DATABASE] table_name/schema_name/db_name;` deletes the table/schema/db. If inside a script, use `IF EXISTS`. `TRUNCATE table_name` will delete all of the data inside `table_name`, but will preserve the schema. This is the same as `DELETE FROM table_name WHERE 1=1`.
Select: `SELECT col_1, ..., col_n FROM table_name WHERE condition;`.
Where: pre-filters ***rows*** in a table. It acts on values in columns and transformation functions applied on rows independently (***NOT*** aggregation functions). Note: `WHERE c BETWEEN x AND y` $\simeq$ `WHERE c <= y AND c >= x`.
Query Order: `SELECT` $\to$ `FROM` $\to$ `JOIN` $\to$ `ON(s)` $\to$ `WHERE` $\to$ `GROUP BY` $\to$ `HAVING` $\to$ `ORDER BY` $\to$ `LIMIT` $\to$ `OFFSET`
Execution Order: `FROM` $\to$ `ON` $\to$ `JOIN` $\to$ `WHERE` $\to$ `GROUP BY` $\to$ `HAVING` $\to$ `SELECT` $\to$ `DISTINCT` $\to$ `ORDER BY`

Aggregation/Group By: Aggregations over a relation does not need a `GROUP BY`. Aggregations over groups requires a `GROUP BY`. For example: `SELECT AVG(one) AS avg FROM table_name;` and `SELECT one, AVG(two) AS avg FROM table_name GROUP BY one;`
Having: post-filters result of an aggregation. `SELECT one AVG(two) AS avg FROM r_name GROUP BY one HAVING AVG(two) < 100;`
Outer Join: keep rows that don't have a match, replacing the "other side" as `null`. We use `LEFT/RIGHT/FULL OUTER JOIN` where `OUTER` is optional.
Left Join: keeps all rows in the LHS of the join.
Right Join: keeps all rows in the RHS of the join.
Full Join: keeps rows from both sides of the join.
Coalesce: `COALESCE(expr, replacement value)` where `expr` may return `null`. It can take multiple arguments and returns the first that is not `null`.

Nested Query/Subquery: Innermost query gets evaluated first.
Derived Table Subquery: returns a table.

```
SELECT uid, last, first, mi, scores.career, midterm, (midterm - mean) / sd AS z_score
FROM (
    SELECT career, AVG(midterm) AS mean, STDDEV(midterm) AS sd
    FROM midterm_scores
    GROUP BY career
) aggregated
JOIN midterm_scores scores
ON scores.career = aggregated.career;
```

Scalar Subquery: returns a scalar.

```
SELECT uid, last, first, mi, midterm
FROM midterm_scores
WHERE midterm > (
    SELECT AVG(midterm) + 0.5 * STDDEV(midterm)
    FROM midterm_scores
);
```

```
SELECT uid, last, first, mi, midterm,
  (midterm - (SELECT AVG(midterm) FROM midterm_scores))
  / (SELECT STDDEV(midterm) FROM midterm_scores)
  AS zscore
FROM midterm_scores;
```

Filter Subquery: using `IN/NOT IN` is a semijoin if we project out all of the columns from the `flights` table.

```
SELECT flights.*
FROM flights
    WHERE flights.tail IN (
    SELECT tail FROM airtran_aircraft
);
```

Correlated Subquery: They suck, lol. This reexecutes the subquery for every row in the outer query.

```
SELECT uid, last, first, mi, midterm
FROM midterm_scores m1
WHERE midterm > (
    SELECT AVG(midterm) + 0.5 * STDDEV(midterm)
    FROM midterm_scores m2
    WHERE m1.career = m2.career
);
```

Subqueries v. Joins: Subqueries are typically faster. Joins are slow so we want to filter as much as possible before joining.
Adding Rows: `INSERT INTO table_name VALUES ('val11', ..., 'val1n'), ('val21', ..., 'val2n'),...;` requires us to know the schema. Order matters, and all values must be specified. Another way is:
`INSERT INTO table_name (col1_name, ..., colk_name) VALUES ('val11', ..., 'val1k'), ('val21', ..., 'val2k'), ...;`
We just specify the names of the columns we insert into. Order doesn't matter but we need to be consistent.
Modifying Rows: `UPDATE table_name SET column_name = new_value WHERE condition;`
Check Constraint: `CONSTRAINT Constraint_Name CHECK (condition);` is put at the end of a `CREATE TABLE`. They can be added using `ALTER TABLE`. We can only use check constraints on rows.
Casting: Cast with `column_name::new_type`.
NullIf: `NULLIF(var, replacement)`. If `var` is `null`, replace with `replacement`.
Control Flow: Case and Searched Case statements:

```
SELECT ...,
    CASE column_name
        WHEN condition_1 THEN result_1
        ...
        WHEN condition_n THEN result_n
        ELSE default_result
    END AS new_column_name
FROM midterm_scores;
```

```
SELECT ...,
    CASE
        WHEN column_name = condition_1 THEN result_1
        ...
        WHEN column_name = condition_n THEN result_n
        ELSE default_result
    END AS new_column_name
FROM midterm_scores;
```

SQL Injection: If we don't use a prepared query, consider `SELECT uid FROM bruinbase WHERE uid='{}'`. In place of "{}", we can inject `'; DROP DATABASE students; --` to drop the `students` database.
Caching: Caching is fast and decreases the workload on the DB. We can either talk to the cache and DB directly or have a broker/proxy talk to the DB and cache.
Logging: is important, so do it lmao. But, minimize the amount of private data.

Salt and Pepper: A string (salt) is randomly chosen to be affixed to the data before it is hashed. This hash and salt are stored. Peppering is similar, but is stored in a separate table. This makes it more difficult to steal than salting. Peppering is not widely implemented.

Normalization: Normalization is the process of refactoring tables to reduce redundancy in a relation. It involves splitting a table with redundant data into two or more non-redundant tables. Tables without redundancies are called ***normalized.*** When there are redundancies, we can ***decompose*** the table using ***functional dependencies***.

Problems with Deormalized Tables: Redundancy, data integrity issues (update/insert), delay in creating new records. Normalized tables allow for separation of concerns.

Functional Dependency: $X \to Y$: X functionally determines Y if every $x \in X$ is associated with exactly one $y \in Y$. If there exists $X \to Y$, we can decompose the table into two: $R(X, Y)$ and $R(X, Z)$ where $Z := R \setminus Y$. For example:

X	Y	A	B
α	β	σ	π
α	β	γ	Δ
γ	η	π	Δ

Here, $X \to Y$ since $\alpha \mapsto \beta, \gamma \mapsto \eta$, so we can decompose the relation into $R_1 :=$

X	Y
α	β
α	β
γ	η

and $R_2 :=$

X	A	B
α	σ	π
α	γ	Δ
γ	π	Δ

Functional Dependency Properties (Armstrong's Axioms [1-3] and Corollaries [4-7]): $\alpha, \beta, \gamma \in r(R)$.

(1) Reflexivity: If $\beta \subseteq \alpha$, then $\alpha \to \beta$. **Ex:** $A \subseteq A \implies A \to A, A \subseteq AB \implies AB \to A$.

(2) Augmentation: If $\alpha \to \beta$, then $\alpha\gamma \to \beta\gamma$. **Ex:** $\{uid\} \to \{name\} \implies \{uid, major\} \to \{name, major\}$.

(3) Transitivity: If $\alpha \to \beta$ and $\beta \to \gamma$, then $\alpha \to \gamma$. **Ex:** $\{uid\} \to \{room\ \#\}, \{room\ \#\} \to \{room\ type\} \implies \{uid\} \to \{room\ type\}$.

(4) Union: If $\alpha \to \beta$ and $\alpha \to \gamma$, then $\alpha \to \beta\gamma$. **Pf.** $(\alpha \to \gamma \implies \alpha\alpha \to \alpha\gamma \iff \alpha \to \alpha\gamma), (\alpha \to \beta \implies \alpha\gamma \to \beta\gamma) \implies \alpha \to \alpha\gamma \to \beta\gamma$.

(5) Composition: If $\alpha \to \beta, \gamma \to \Delta$, then $\alpha\gamma \to \beta\Delta$.

(6) Decomposition: If $\alpha \to \beta\gamma$, then $\alpha \to \beta$ and $\alpha \to \gamma$.

(7) Pseudotransitivity: If $\alpha \to beta$, $\Delta\beta \to \gamma$, then $\Delta\alpha \to \gamma$.

Canonical Cover: $F_c \subseteq F^+$ is the basis set of the set of all functional dependencies F^+. It is ***not*** unique.

Finding F_c: **(1)** Decompose RHS: ($X \to YZA$ becomes $X \to Y, X \to Z, X \to A$). **(2)** Remove extraneous attributes: ($AB \to C, B \to C$, $AB \to C$ is extraneous). **(3)** Remove trivial, duplicate, inferred FD's (by transitivity). **(4)** Union and repeat until set doesn't change.

Example: Given $\{B \to D, C \to D, AB \to C, B \to E, C \to F, A \to BCDEF, AB \to D, AB \to F\}$,
After **(1)**, we get $\{A \to B, A \to C, A \to D, A \to E, A \to F, B \to D, C \to D, AB \to C, B \to E, C \to F, AB \to D, AB \to F\}$.
After **(2)**, we get $\{A \to B, A \to C, A \to D, A \to E, A \to F, B \to D, C \to D, B \to E, C \to F\}$.
After **(3)**, we get $\{A \to B, A \to C, B \to D, C \to D, B \to E, C \to F\}$.
After **(4)**, we get $F_c := \{A \to BC, B \to DE, C \to DF\}$. Then we have $R_1(A, B, C), R_2(B, D, E), R_3(C, D, F)$.

Normal Forms: There are 8 normal forms, but we discuss 1NF, 2NF, 3NF, and BCNF (3.5NF).

First Normal Form (1NF): Atomic attributes (flat, no nesting/collections), no repeated groups, there is a unique key, no `null` values.

Second Normal Form (2NF): R is 1NF and does not contain any composite keys. More generally, R is 2NF $\iff \forall a \in R$, ***either*** **(1)** $a \in$ CK or **(2)** $a \in R$ depends on an ***entire*** key; i.e. it is not partially dependent on ***any*** composite candidate key.

Third Normal Form (3NF): All non-prime $a \in R$ depend directly on a CK (no transitivity); i.e. if all $a \in R$ are part of a candidate key, R is 3NF. **Zaniolo's 3NF:** $\forall f \in F$, at least one is true: **(1)** $a \to \beta$ is trivial. **(2)** $\alpha \in R$ is SK. **(3)** $\beta \in$ CK.

BCNF: $\forall f : \alpha \to \beta \in F$, at least one is true: **(1)** f is trivial ($\beta \subseteq \alpha$) or **(2)** α is a SK for R.

Note - BCNF: As Normal Form $\uparrow$, Redundancy $\downarrow$, but Data Integrity may also $\downarrow$.

Note - BCNF: BCNF removes all redundancy due to functional dependencies only. There may be redundancy due to other causes.

Losslessness: A decomposition is lossless if $R_1 \bowtie R_2 = R$. We can also check **(1)** $R_1 \cup R_2 = R$, **(2)** $R_1 \cap R_2 \neq \emptyset$, and **(3)** $(R_1 \cap R_2)^+$ forms an SK for either R_1 or R_2.

Note - Losslessness: 1NF, 2NF, 3NF, BCNF guarantee losslessness.

Attribute Closure: α^+ is the set of attributes inferred by α. If, $\alpha^+ = R$, then α is an SK.

Example - Lossless: $R(A, B, C, D, E, G)$ with $R_1(A, B, C, G), R_2(A, D, E), F = \{A \to B, A \to C, CD \to E, B \to D, E \to A\}$ is lossless. **(1)** $R_1 \cup R_2 = \{A, B, C, D, E, G\} = R$. **(2)** $R_1 \cap R_2 = \{A\} \neq \emptyset$. **(3)** $(R_1 \cap R_2)^+ = \{A\}^+ = ABCDE$ is SK for R_1 so $R_1 \cap R_2 \to R_2$.

Example - Not 3NF: $F = \{AB \to CD, C \to D\}$, CK $= AB$. Then, $AB \to C, AB \to D, C \to D$. $AB \to D$ is transitive so $R \notin$ 3NF. Normalized, we get $R_1(A, B, C), R_2(C, D)$.

Example - Not BCNF: $R(A, B, C, D, E), F = \{A \to BC, C \to B, D \to E, E \to D\}$. $A \to BC$: $A^+ = ABC \neq ABCDE$. *(i)* not trivial *(ii)* A is not an SK. $R \notin$ BCNF. Normalized, we get $R_1(A, B, C), R_2(A, D, E)$. which is BCNF by inspection.

Example - Not BCNF: $R(A, B, C), F = \{AB \to C, C \to B\}$. $AB \to C$ (✓): $(AB)^+ = ABC = R$ *(i)* not trivial *(ii)* AB is SK. $C \to B$ (**x**): *(i)* not trivial *(ii)* C not SK. $R \notin$ BCNF. Normalized, we get $R_1(B, C), R_2(A, C)$.

Example- 3NF, Not BCNF: $R(A, B, C)$, CK $= AB$, $F = \{AB \to C, C \to B\}$. $AB \to C$ (✓): *(i)* not trivial *(ii)* AB is SK. $C \to B$ (**x**): *(i)* not trivial *(ii)* C not SK. $R \notin$ BCNF. $R \in$ 3NF since C depends on AB.

BCNF Decomposition Algorithm:

```
for any R_i in the schema
    if (α → β holds on R_i and
        α → β is non-trivial and
        α is not a superkey), then
            Decompose R_i into R_{i_1}(α^+) and R_{i_2}(α ∪ (R_i − α^+))
            // α is the common attriute(s)
repeat until no more decompositions are necessary
```

Example - BCNF Decomposition: $R(A, B, C), F = \{A \to B, B \to C\}$. $A^+ = ABC$. $A \to B$ (✓): *(i)* not trivial *(ii)* A is SK. $B \to C$ (**x**): *(i)* not trivial *(ii)* B not SK. $R \notin$ BCNF. Decomposing, we get $R_1(B, C), R_2(A, B)$.

Example - BCNF Decomposition: $R(A, B, C, D), F = \{C \to D, C \to A, B \to C\}$. $B+ = BCDA = R$. $C \to AD$ (**x**): *(i)* not trivial *(ii)* C not SK. $B \to C$ (✓): *(i)* not trivial *(ii)* B is SK. $R \notin$ BCNF. Decomposing, we get $R_1(A, C, D), R_2(B, C)$.

Functional Dependencies as Constraints: By definition, a functional dependency is a constraint. When designing DB, we want BCNF/3NF, losslessness, and dependency preservation.
Dependency Preservation: 1NF, 2NF, 3NF guarantee dependency preservation.

Query Examples

```
SELECT l.departure_time, l.tail, l.flight,
       SUM(r.distance) AS miles
FROM (
    SELECT departure_time, tail, a.flight, distance
    FROM equipment_flight a
    JOIN flights b
    ON a.flight = b.flight
) l -- earlier flight
JOIN (
    SELECT departure_time, tail, a.flight, distance
    FROM equipment_flight a
    JOIN flights b
    ON a.flight = b.flight
) r -- later flight
ON l.tail = r.tail AND l.departure_time < r.departure_time
   AND HOURDIFF(l.departure_time, r.departure_time) <= 12
WHERE DATE(l.departure_time) = CURDATE()
GROUP BY l.tail, l.departure_time, l.flight;
```

```
SELECT tail, COUNT(*) as total
FROM equipment_flight
WHERE DATE(departure_time) = YESTERDAY()
GROUP BY tai
HAVING COUNT(*) > 5;
```

Example - BCNF Decomposition: $R(A,B,C,D,E,G)$, $F=\{A\to B, A\to C, C\to E, B\to D\}$. $A^+=ABCDE$, $B^+=BD$, $C^+=CE$.
$A\to BC$ (**x**): *(i)* not trivial *(ii)* A not SK.
$C\to E$ (**x**): *(i)* not trivial *(ii)* C not SK.
$B\to D$ (**x**): *(i)* not trivial *(ii)* B not SK.
$R\notin$ BCNF. Decomposing on $C\to E$, we get $R_1(C,E), R_2(A,B,C,D,G)$.
$A\to BC$ (**x**): *(i)* not trivial *(ii)* A not SK.
$B\to D$ (**x**): *(i)* not trivial *(ii)* B not SK.
$R_2\notin$ BCNF. Decomposing on $B\to D$, we get $R_1(C,E), R_3(B,D), R_4(A,B,C,G)$.
$A\to BC$ (**x**): *(i)* not trivial *(ii)* A not SK.
$R_4\notin$ BCNF. Decomposing on $A\to BC$, we get $R_1(C,E), R_3(B,D), R_5(A,B,C), R_6(A,G)$.

A	B	C
Mighty Mighty Bosstones	The Impression That I Get	ska
Hoku	Perfect Day	pop
The 1975	Somebody Else	alt
beabadoobee	Space Cadet	alt
beabadoobee	Care	alt
Duran Duran	Perfect Day	nw
Dave Matthews Band	Ants Marching	rock
ABC	Poison Arrow	nw

$F=\{A\to C, AB\to C, BC\to A\}$, $F_c=\{AB\to C, BC\to A\}$. R is in 3NF since we have no non-prime attributes. AB, BC are candidate keys since $(AB)^+=(BC)^+=ABC$.

Cross Join v. Full Join A Cross join is the cartesian product. A full join requires a join condition, matching on it but leaving `null`'s whenever there is no match on the LHS or RHS.

Theory v. Practice: Relations must have a key, but tables need not. `null`'s not allowed in Theory, allowed in practice.
Example - Update w/ Subquery: `UPDATE scores SET midterm = midterm + (SELECT 100 - MAX(midterm) FROM scores);`

Example - Having:

```
SELECT major, AVG(gpa)::decimal(3, 2) AS average
FROM bruinbase
WHERE career = 'UG'
GROUP BY major
HAVING AVG(gpa) < 3.95
ORDER BY average DESC
LIMIT 2;
```

returns all majors that have an undergrad GPA of less than 3.95.

Sketching out a Query: `FROM` $\to$ `WHERE` $\to$ `GROUP BY` $\to$ `HAVING` $\to$ `SELECT (AS)` $\to$ `ORDER BY` $\to$ `LIMIT`

Example - Multiple Joins

```
SELECT instructor_name AS name, course_name AS course
FROM instructor l
JOIN course r
ON l.ID = r.ID
LEFT JOIN course_offering t
ON r.course = t.course;
```

we can join on attributes not in the `SELECT`.

Self Join: joins a table with itself. Typically used for graph traversals.
Example - Friend of a Friend: Given

id	friend_id
1	2
1	3
3	5
5	2
3	1

the joined relation is

l.id	l.friend_id	r.id	r.friend_id
1	3	3	5
1	3	3	1
3	5	5	2
3	1	1	2

where FOAF is between `l.id` and `r.friend_id`.

(1) Compute the cartesian product: $R \times R := \rho_l(R) \times R$.
(2) $\theta := l.friend\_id = r.id \wedge l.id \neq r.friend\_id$.
(3) $\Pi_{l.id \to id, r.friend\_id \to foaf}(\sigma_\theta(R \times R))$.
Then the full expression is $\Pi_{l.id \to id, r.friend\_id \to foaf}(\sigma_{l.friend\_id = r.id \wedge l.id \neq r.friend\_id}(\rho_l(R) \times R))$.
The SQL for it is

```
SELECT DISTINCT l.id AS user, r.friend_id AS foaf
FROM friends l
JOIN friends r
ON l.friend_id = r.id AND l.id != r.friend_id;
```

Example - Left Join:

```
SELECT l.trip_id AS trip_id
l.time AS start_time
r.time AS end_time
FROM trip_start l
LEFT JOIN trip_end r
ON l.trip_id = r.trip_id;
```

will return all the rows in `trip_start` but may have `null`'s for unmatched columns.

Example - Non-Equi Self Join as Window Function:

```
SELECT l.trans_id, l.customer_id, SUM(r.result) AS chargebacks
FROM purchase L
JOIN purchase R
ON l.customer_id = r.customer_id
AND l.transtime - r.transtime + 1 <= 5
AND r.transtime <= l.transtime
GROUP BY l.trans_id, l.customer_id
ORDER BY trans_id DESC;
```

returns the total number of chargebacks within a particular window of time.

Nested/Sub Queries:
(1) Construct derived tables in `FROM` or `JOIN`.
(2) Compute scalar subqueries in `WHERE` or `HAVING`.
(3) Set membership with `IN`/`NOT IN` (e.g. `SELECT * FROM table WHERE r.foo IN (SELECT ...);`).
(4) Testing for empty relations using `EXISTS`.
(5) Set comparison with `ANY` or `ALL`.
(6) Uniqueness using `UNIQUE`.

Constraints in Databases v. Applications: Rule of thumb: Business logic in the app, data integrity in the database.

Pros (Database):
(1) Purpose of DB is data integrity.
(2) Set syntax for checking constraints.
(3) Don't need to trust the app developer.
(4) Changes to the app don't break data integrity.
Cons (Database):
(1) Limited functionality.
(2) Less flexibility
(3) More CPU load due to checking constraints over CRUD.

Pros (Application):
(1) Constraints can be more complex with more sophisticated data structures.
(2) Failures are easier to debug.
Cons (Application):
(1) We need to manually handle bad user input.
(2) Reimplement check constraints if stack changes.
(3) Not as fast (potentially).

RegEx: `SELECT name FROM ta_restaurant WHERE name LIKE '% Lotus %';`
Example Queries:

```
SELECT city
FROM ta_restaurant l
JOIN ta_cuisine r
ON l.id = r.id
WHERE r.cuisine = 'Indian'
GROUP BY city
HAVING AVG(rating) > 4.2
ORDER BY AVG(rating);
```

```
SELECT origin, destination
FROM flights l
LEFT JOIN snacks r
ON l.flight = r.flight
WHERE snack IS NULL;
```

Relational Algebra Examples:
$\Pi_{id,name}(\sigma_{building='Watson'}(department) \bowtie instructor)$. – id, name of each instructor in a dept. located in the Watson building.
$\Pi_{course\_id}(\sigma_{semester='Spring' \wedge year=2009}(section)$. – All course id's of courses taught in Spring 2009.
$\Pi_{name,salary}(\sigma_{salary=max.salary}(instructor \times \gamma_{MAX(salary) \to max.salary}(instructor)))$. – name, salary of instructors with the highest salary.