SQL, the Database, and You

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Why this talk?

- Your app is your data
- Databases are one of the first and almost universal dependencies
- Databases can be one of the first performance bottlenecks
- Data storage and querying is not very intuitive
- Useful knowledge for all types of devs

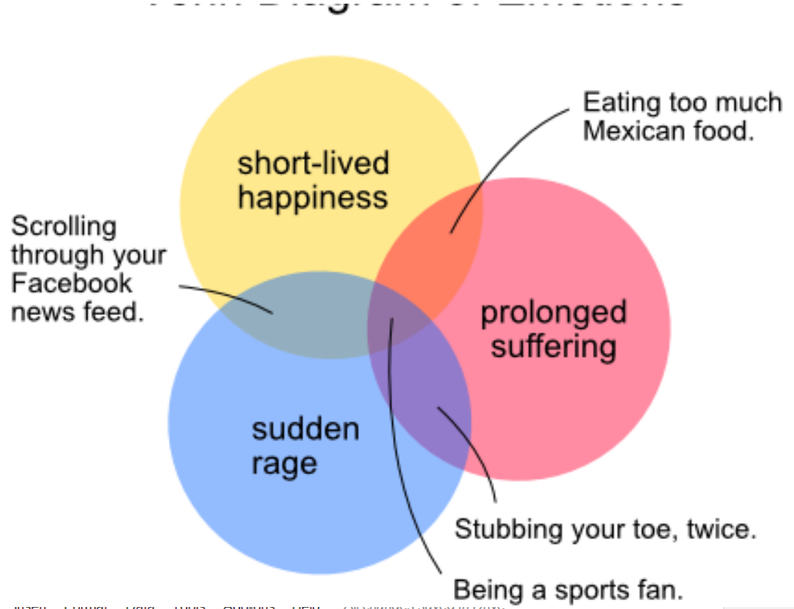
Talk structure

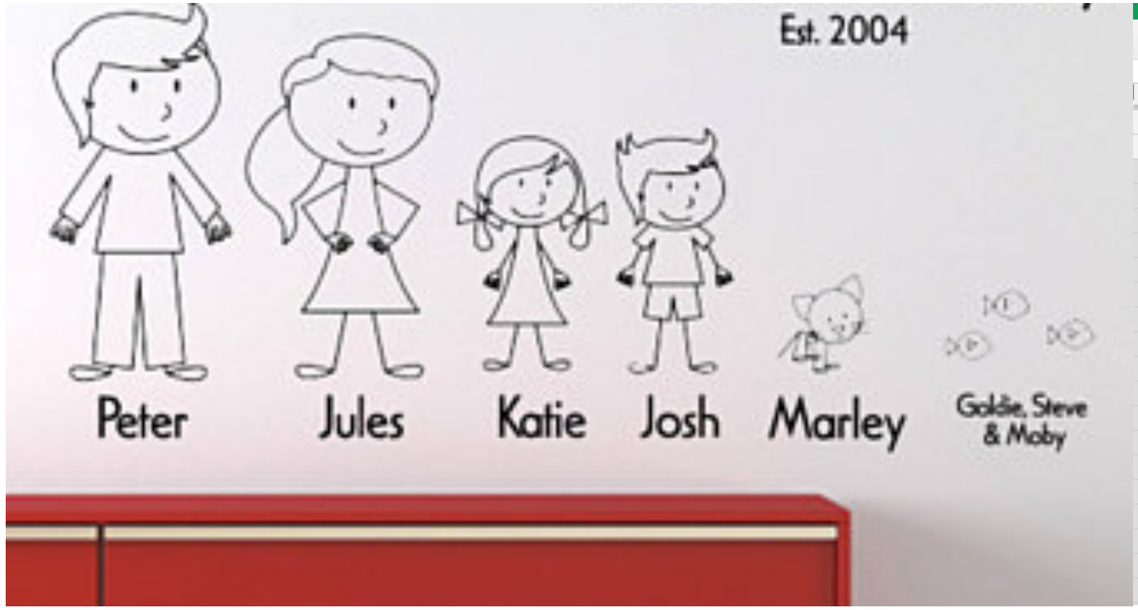
1. Structuring data for a relational database
2. Querying (SQL)
3. Associations
4. Data integrity
5. Performance

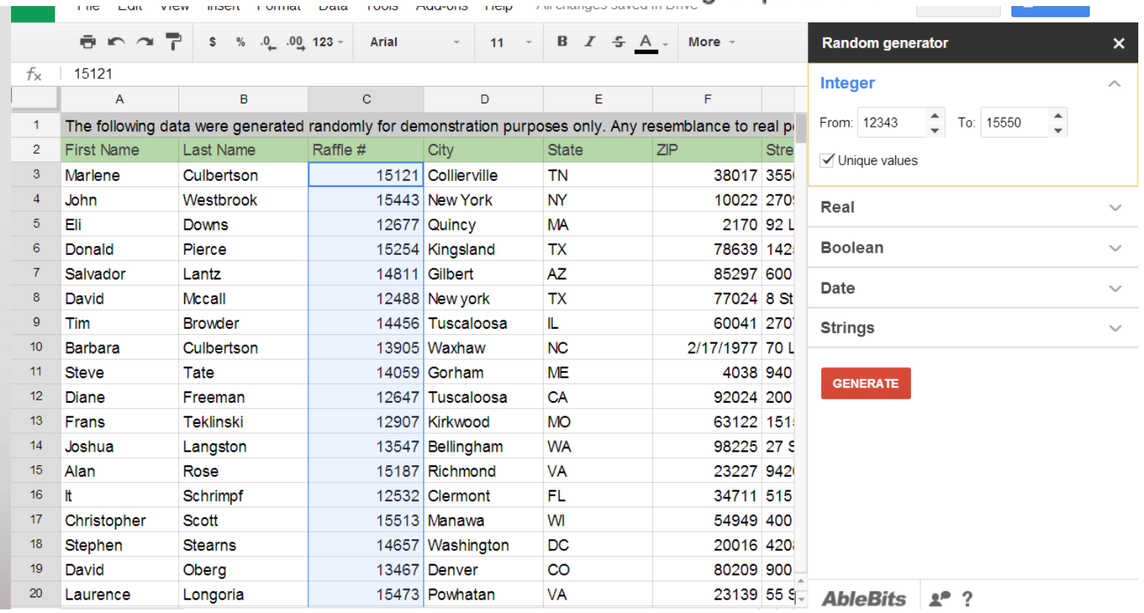
1. Structuring data for a relational database


petco
grooming
FIRE LANE
NO
PARKING
TOW-AWAY ZONE
101
grooming
salon

```
{
  person: {
    name: “John Smith”,
    age: 50,
    email: “john@smith.com”
  }
}
```







Databases

food	tastiness	cost	health
sushi	10	10	7
pizza	8	5	3
salad	2	8	9
water	0	0	10

What is "good" structure?

- Goal: to reduce data redundancy and improve data integrity
- Free from change anomalies

FEATURE REQUEST

"People and their pets"

"People and their pets"

person_name	person_age	work_place	work_phone	pet_name	pet_type	pet_legs
John	26	Pizza Palace	555-555-5555	Ruby	Dog	4
Susan	22	Pizza Hut	111-111-1111	Pete	Bird	2
Jim	30	Pizza Town	333-333-3333	Fluffy	Cat	4

Adding a pet

person_name	person_age	work_place	work_phone	pet_name	pet_type	pet_legs
John	26	Pizza Palace	555-555-5555	Ruby	Dog	4
Susan	22	Pizza Hut	111-111-1111	Pete	Bird	2
Jim	30	Pizza Town	333-333-3333	Fluffy	Cat	4
John	26	Pizza Palace	555-555-5555	Buddy	Dog	4

Adding a pet

person_name	person_age	work_place	work_phone	pet1_name	pet1_type	pet1_legs	pet2_name	pet2_type	pet2_legs
John	26	Pizza Palace	555-555-5555	Ruby	Dog	4	Buddy	Dog	4
Susan	22	Pizza Hut	111-111-1111	Pete	Bird	2			
Jim	30	Pizza Town	333-333-3333	Fluffy	Cat	4			

Owner gives up a pet

person_name	person_age	work_place	work_phone	pet_name	pet_type	pet_legs
John	26	Pizza Palace	555-555-5555	Ruby	Dog	4
???	??	Pizza Hut	111-111-1111	Pete	Bird	2
Jim	30	Pizza Town	333-333-3333	Fluffy	Cat	4

Database "Normalization"

The Three "Normal Forms"

- Introduced by Dr. Edgar F. Codd
- Meets our goal of "reduce data redundancy and improve data integrity"

1st Normal Form

"The information is stored in a relational table and each column contains atomic values, and there are not repeating groups of columns."[1]

person_name	person_age	pet1_name	pet1_type	pet1_legs	pet2_name	pet2_type	pet2_legs
John	26	Ruby	Dog	4	Buddy	Dog	4
Susan	22	Pete	Bird	2			
Jim	30	Fluffy	Cat	4			

[1] https://www.essentialsql.com/get-ready-to-learn-sql-database-normalization-explained-in-simple-english/

1st Normal Form

people

person_name	person_age	work_place	work_phone
John	26	Pizza Palace	555-555-5555
Susan	22	Pizza Hut	111-111-1111
Jim	30	Pizza Town	333-333-3333

pets

person_name	pet_name	pet_type	pet_legs
John	Ruby	Dog	4
Susan	Pete	Bird	2
Jim	Fluffy	Cat	4

2nd Normal Form

"The table is in first normal form and all the columns depend on the table's primary key."[1]

people

person_name	person_age	work_place	work_phone
John	26	Pizza Palace	555-555-5555
Susan	22	Pizza Hut	111-111-1111
Jim	30	Pizza Town	333-333-3333

[1] https://www.essentialsql.com/get-ready-to-learn-sql-database-normalization-explained-in-simple-english/

2nd Normal Form

people

person_name	person_age
John	26
Susan	22
Jim	30

work_places

person_name	work_place	work_phone
John	Pizza Palace	555-555-5555
Susan	Pizza Hut	111-111-1111
Jim	Pizza Town	333-333-3333

3rd Normal Form

"The table is in second normal form and all of its columns are not transitively dependent on the primary key."[1]

Or

"Every non-key attribute must provide a fact about the key, the whole key, and nothing but the key, so help me Codd."[2]

---

[1] https://www.essentialsql.com/get-ready-to-learn-sql-database-normalization-explained-in-simple-english/

[2] Credited to Bill Kent on Wikipedia

3rd Normal Form

pets

person_name	pet_name	pet_type	pet_legs
John	Ruby	Dog	4
Susan	Pete	Bird	2
Jim	Fluffy	Cat	4
John	Buddy	Dog	4

3rd Normal Form

pets

person_name	pet_name	pet_type
John	Ruby	Dog
Susan	Pete	Bird
Jim	Fluffy	Cat
John	Buddy	Dog

pet_types

pet_type	pet_legs
Dog	4
Bird	2
Cat	4

Almost There

people

person_name	person_age
John	26
Susan	22
Jim	30

pets

person_name	pet_name	pet_type
John	Ruby	Dog
Susan	Pete	Bird
Jim	Fluffy	Cat
John	Buddy	Dog

IDs and Primary Keys

Primary key - one or more columns that uniquely identifies each row

people

id	person_name	person_age
1	John	26
2	Susan	22
3	Jim	30

pets

id	person_id	pet_name	pet_type
20	1	Ruby	Dog
21	2	Pete	Bird
22	3	Fluffy	Cat
23	1	Buddy	Dog

Foreign Keys

Foreign key - a reference to a primary key in another table

people

id (PK)	person_name	person_age
1	John	26
2	Susan	22
3	Jim	30

pets

id (PK)	person_id (FK)	pet_name	pet_type
20	1	Ruby	Dog
21	2	Pete	Bird
22	3	Fluffy	Cat
23	1	Buddy	Dog

2. Querying

Structured Query Language (SQL)

Most modern Database Management Systems (DBMS) adhere to the SQL Standard.

Creating a table

```
CREATE TABLE people (
  first_name VARCHAR,
  last_name  VARCHAR,
  age        INTEGER
)

---

CREATE TABLE
```

Data types

- `CHAR/VARCHAR/TEXT`
- `INTEGER`
- `BOOLEAN`
- `DATE/DATETIME`

SELECT

```
SELECT *
FROM people

---

0 rows
```

(* = all columns)

SELECT

```
SELECT first_name, last_name
FROM people

---

0 rows
```

INSERT

```
INSERT INTO people (first_name, last_name, age) VALUES
  ('John', 'Mosesman', 26),
  ('Bob', 'Smith', 40),
  ('Jane', 'Doe', 32)

---

INSERT 0 3
```

WHERE

```
SELECT *
FROM people
WHERE first_name = 'John'
```

```
+------------+-----------+-----+
| first_name | last_name | age |
+------------+-----------+-----+
| John       | Mosesman  |  26 |
+------------+-----------+-----+
```

WHERE

```
INSERT INTO people
SELECT 'John', 'Smith', 100

---

SELECT *
FROM people
WHERE first_name = 'John'

---

+------------+-----------+-----+
| first_name | last_name | age |
+------------+-----------+-----+
| John       | Mosesman  |  26 |
| John       | Smith     | 100 |
+------------+-----------+-----+
```

AND and OR

```
SELECT *
FROM people
WHERE first_name = 'John'
  AND last_name = 'Mosesman'

---

SELECT *
FROM people
WHERE age > 50
  OR age < 20
```

ALTER

```
ALTER TABLE people ADD COLUMN id SERIAL PRIMARY KEY;

---

SELECT *
FROM people
WHERE id = 1

---

+----+------------+-----------+-----+
| id | first_name | last_name | age |
+----+------------+-----------+-----+
|  1 | John       | Mosesman  |  26 |
+----+------------+-----------+-----+
```

UPDATE

```
UPDATE people
SET first_name = 'Jack'
WHERE id = 2

---

UPDATE 1
```

Aggregations

```
SELECT AVG(age) FROM people      -- 49.5

SELECT SUM(age) FROM people      -- 198

SELECT COUNT(*) FROM people      -- 4
```

3. Associations

Our Pet Store

people

id	name	age
1	John	26
2	Susan	22
3	Jim	30

pets

id	person_id	name	type	age
20	1	Ruby	Dog	3
21	2	Pete	Bird	5
22	3	Fluffy	Cat	12
23	1	Buddy	Dog	1

Our Pet Store (in SQL)

```
CREATE TABLE people (
  id SERIAL PRIMARY KEY,
  name VARCHAR,
  age INTEGER
)
```

Our Pet Store (in SQL)

```
CREATE TABLE people (
  id SERIAL PRIMARY KEY,
  name VARCHAR,
  age INTEGER
)

CREATE TABLE pets (
  id SERIAL PRIMARY KEY,
  person_id INTEGER REFERENCES people,
  name VARCHAR,
  age INTEGER
)
```

FEATURE REQUEST

"Find all of a person's pets"

Finding pets

```
SELECT *
FROM pets
WHERE person_id = 1

---

+----+-----------+-------+-----+
| id | person_id | name  | age |
+----+-----------+-------+-----+
|  1 |         1 | Ruby  |   1 |
|  4 |         1 | Buddy |   3 |
+----+-----------+-------+-----+
```

FEATURE REQUEST

"Get everyone and their pets"

JOINs

"Join" two tables together by matching related rows.

people.id	people.name	people.age	pets.id	pets.person_id	pets.name	pets.age
1	John	26	20	1	Ruby	3
...						

Naive JOIN implementation

1. Combine every row from `people` with every row from `pets`
2. Filter out rows that don't match

Cartesian Product or "Cross Join"

```
+--------+
| letter |
+--------+
| A      |
| B      |
+--------+

+--------+
| number |
+--------+
|      1 |
|      2 |
+--------+
```

Cartesian Product or "Cross Join"

letter	number
A	1
A	2
B	1
B	2

CROSS JOIN of `people` and `pets`

```
SELECT *
FROM people
  CROSS JOIN pets

---

16 rows

+----+---------------+-----+----+-----------+--------+-----+
| id |     name      | age | id | person_id |  name  | age |
+----+---------------+-----+----+-----------+--------+-----+
|  1 | John Mosesman |  26 |  1 |         1 | Ruby   |   1 |
|  1 | John Mosesman |  26 |  2 |         2 | Pete   |   5 |
|  1 | John Mosesman |  26 |  3 |         3 | Fluffy |  12 |
|  1 | John Mosesman |  26 |  4 |         1 | Buddy  |   3 |
|  2 | Bob Smith     |  40 |  1 |         1 | Ruby   |   1 |
|  2 | Bob Smith     |  40 |  2 |         2 | Pete   |   5 |
|  2 | Bob Smith     |  40 |  3 |         3 | Fluffy |  12 |
|  2 | Bob Smith     |  40 |  4 |         1 | Buddy  |   3 |
|  3 | Jane Doe      |  32 |  1 |         1 | Ruby   |   1 |
|  ...                                                    |
+----+---------------+-----+----+-----------+--------+-----+
```

CROSS JOIN of `people` and `pets`

```
+----+----------------+-----+----+-----------+--------+-----+
| id |      name      | age | id | person_id |  name  | age |
+----+----------------+-----+----+-----------+--------+-----+
|  1 | John Mosesman  |  26 |  1 |         1 | Ruby   |   1 |
|  1 | John Mosesman  |  26 |  2 |   2 (???) | Pete   |   5 |
| ...                                                       |
+----+----------------+-----+----+-----------+--------+-----+
```

CROSS JOIN with filter

```
SELECT *
FROM people
  CROSS JOIN pets
WHERE people.id = pets.person_id

---

4 rows

+----+---------------+-----+----+-----------+--------+-----+
| id |     name      | age | id | person_id |  name  | age |
+----+---------------+-----+----+-----------+--------+-----+
|  1 | John Mosesman |  26 |  1 |         1 | Ruby   |   1 |
|  2 | Bob Smith     |  40 |  2 |         2 | Pete   |   5 |
|  3 | Jane Doe      |  32 |  3 |         3 | Fluffy |  12 |
|  1 | John Mosesman |  26 |  4 |         1 | Buddy  |   3 |
+----+---------------+-----+----+-----------+--------+-----+
```

JOIN

```
SELECT *
FROM people
  JOIN pets ON pets.person_id = people.id
```

JOIN filtering

```
SELECT *
FROM people
  JOIN pets ON pets.person_id = people.id
    AND pets.age > 2

---

SELECT *
FROM people
  JOIN pets ON pets.person_id = people.id
    AND pets.age > 2
WHERE people.age < 30
```

Order of Operations

1. FROM
2. JOIN
3. WHERE
4. SELECT

Order of Operations

```
SELECT *
FROM people
  JOIN pets ON pets.person_id = people.id
    AND pets.age > 2
WHERE people.age < 30

---

SELECT *
FROM people
  JOIN pets ON pets.person_id = people.id
WHERE people.age < 30
  AND pets.age > 2
```

FEATURE REQUEST

"Track pet shot records."

Multiple JOINs

```
CREATE TABLE shot_records (
  id SERIAL PRIMARY KEY,
  pet_id INTEGER REFERENCES pets,
  shot_name VARCHAR,
  date DATE
);

---

INSERT INTO shot_records (pet_id, shot_name, date) VALUES
(1, 'Rabies', CURRENT_DATE),
(1, 'Bordetella', CURRENT_DATE)
```

Multiple JOINs

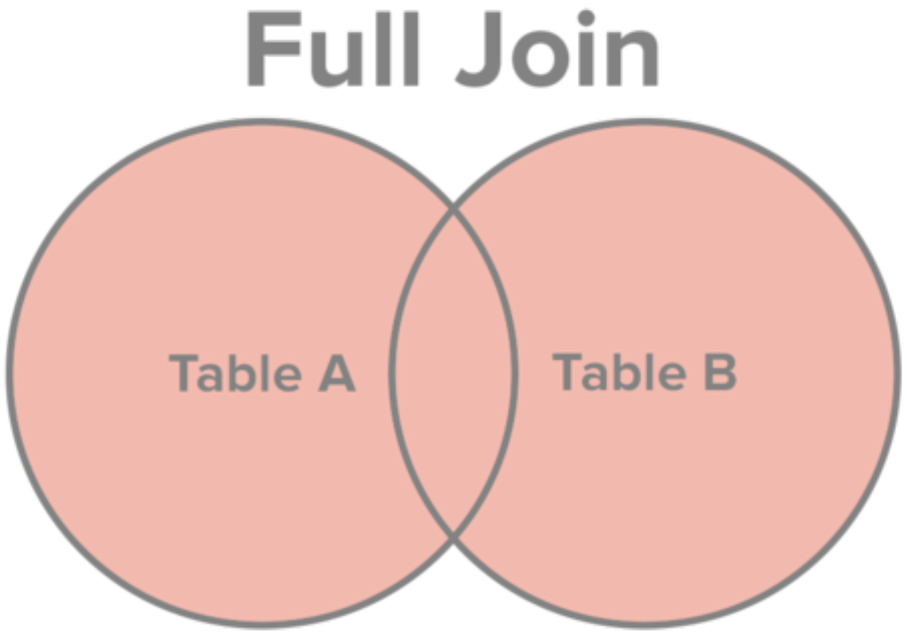
```
SELECT *
FROM people
  JOIN pets ON pets.person_id = people.id
  JOIN shot_records sr ON sr.pet_id = pets.id

---

+----+---------------+-----+----+-----------+------+-----+----+--------+------------+------------+
| id |     name      | age | id | person_id | name | age | id | pet_id | shot_name  |    date    |
+----+---------------+-----+----+-----------+------+-----+----+--------+------------+------------+
|  1 | John Mosesman |  26 |  1 |         1 | Ruby |   1 |  1 |      1 | Rabies     | 2017-07-20 |
|  1 | John Mosesman |  26 |  1 |         1 | Ruby |   1 |  2 |      1 | Bordetella | 2017-07-20 |
+----+---------------+-----+----+-----------+------+-----+----+--------+------------+------------+
```

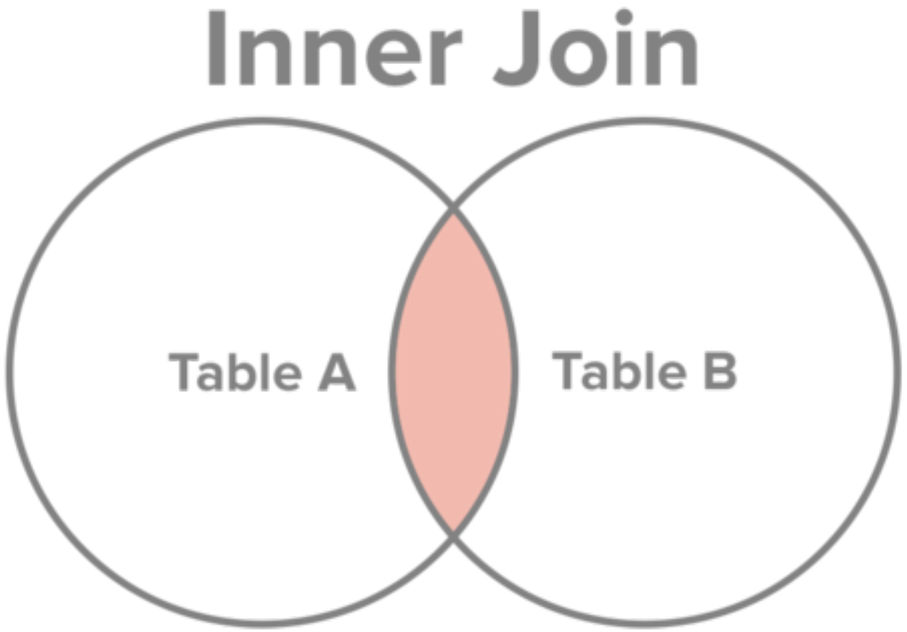
Join Types

CROSS JOIN (Union)[4]



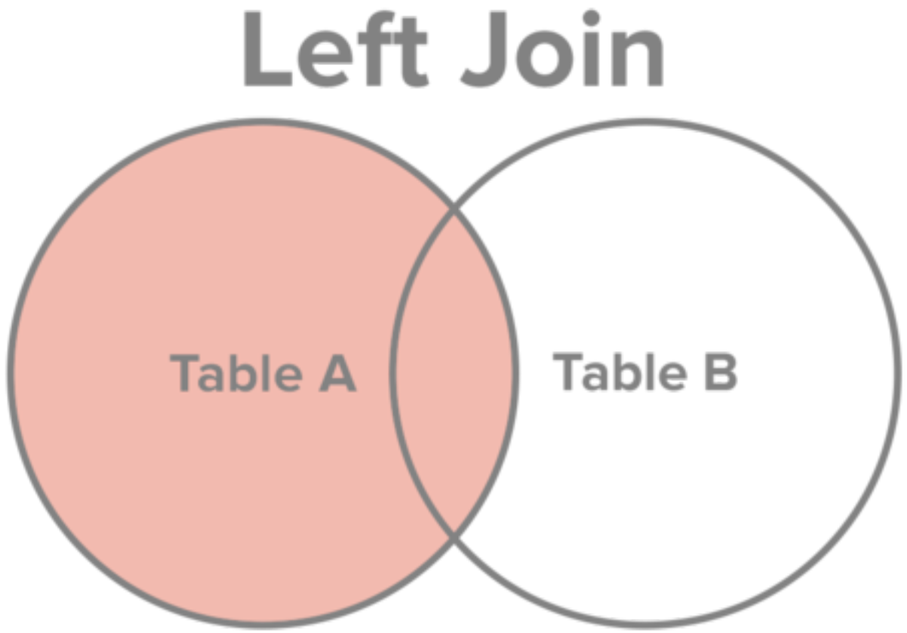
[4] http://www.sql-join.com/sql-join-types/

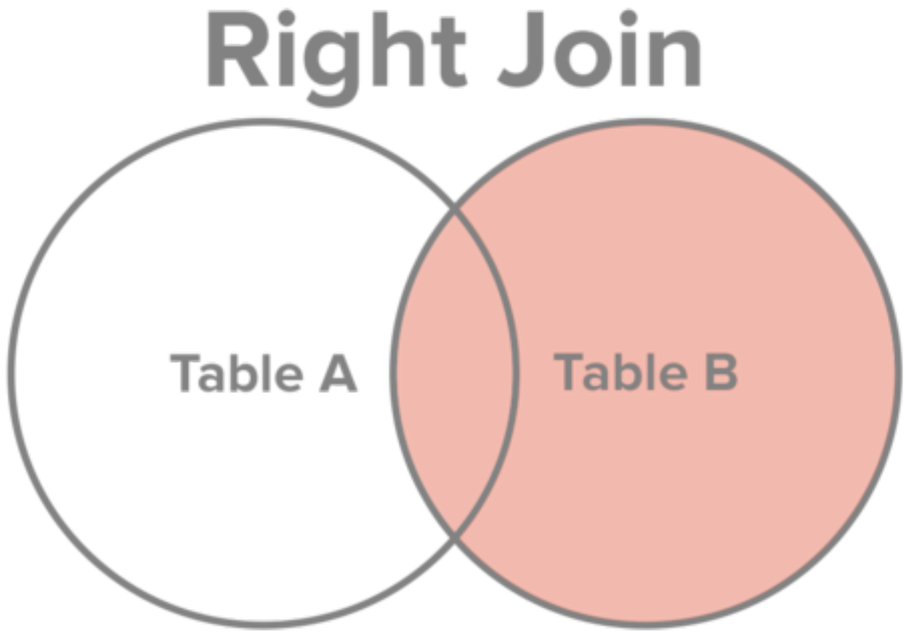
INNER JOIN (Intersection)[4]



[4] http://www.sql-join.com/sql-join-types/

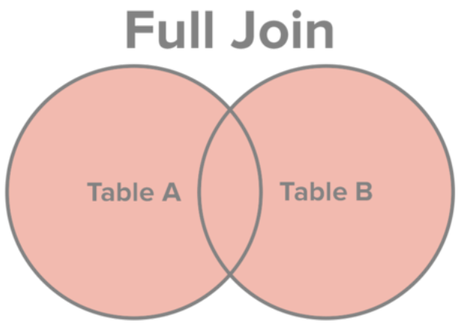
OUTER JOIN[4]

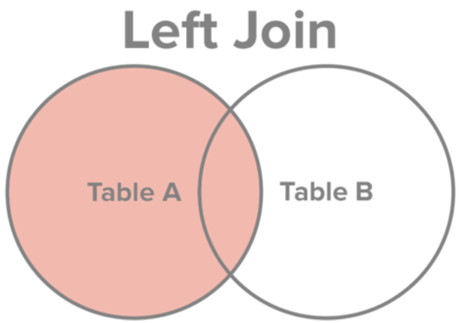


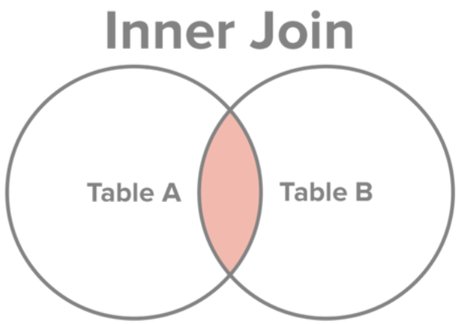


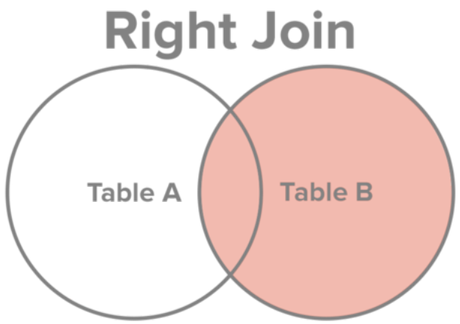
[4] http://www.sql-join.com/sql-join-types/

Join Types[4]









[4] http://www.sql-join.com/sql-join-types/

A brief detour: NULL

NULL In Other Languages

```
irb(main):001:0> nil == nil
=> true
irb(main):002:0> nil == 1
=> false
```

NULL - "An unknown value"

```
SELECT 1 = 1
```

NULL - "An unknown value"

```
SELECT 1 = 1                    -- TRUE
```

NULL - "An unknown value"

```
SELECT 1 = 1                    -- TRUE
SELECT 1 <> 1
```

NULL - "An unknown value"

```
SELECT 1 = 1                    -- TRUE
SELECT 1 <> 1                   -- FALSE
```

NULL - "An unknown value"

```
SELECT 1 = 1                    -- TRUE
SELECT 1 <> 1                   -- FALSE
SELECT 1 = NULL
```

NULL - "An unknown value"

```
SELECT 1 = 1                    -- TRUE
SELECT 1 <> 1                   -- FALSE
SELECT 1 = NULL                 -- NULL
```

NULL - "An unknown value"

```
SELECT 1 = 1                    -- TRUE
SELECT 1 <> 1                   -- FALSE
SELECT 1 = NULL                 -- NULL
SELECT 0 = NULL
```

NULL - "An unknown value"

```
SELECT 1 = 1                    -- TRUE
SELECT 1 <> 1                   -- FALSE
SELECT 1 = NULL                 -- NULL
SELECT 0 = NULL                 -- NULL
```

NULL - "An unknown value"

```
SELECT 1 = 1                    -- TRUE
SELECT 1 <> 1                   -- FALSE
SELECT 1 = NULL                 -- NULL
SELECT 0 = NULL                 -- NULL
SELECT '' = NULL
```

NULL - "An unknown value"

```
SELECT 1 = 1                    -- TRUE
SELECT 1 <> 1                   -- FALSE
SELECT 1 = NULL                 -- NULL
SELECT 0 = NULL                 -- NULL
SELECT '' = NULL                -- NULL
```

NULL - "An unknown value"

```
SELECT 1 = 1                    -- TRUE
SELECT 1 <> 1                   -- FALSE
SELECT 1 = NULL                 -- NULL
SELECT 0 = NULL                 -- NULL
SELECT '' = NULL                -- NULL
SELECT NULL = NULL
```

NULL - "An unknown value"

```
SELECT 1 = 1                    -- TRUE
SELECT 1 <> 1                   -- FALSE
SELECT 1 = NULL                 -- NULL
SELECT 0 = NULL                 -- NULL
SELECT '' = NULL                -- NULL
SELECT NULL = NULL              -- NULL
```

IS NULL / IS NOT NULL

```
SELECT 1 IS NULL
```

IS NULL / IS NOT NULL

```
SELECT 1 IS NULL                    -- FALSE
```

IS NULL / IS NOT NULL

```
SELECT 1 IS NULL                -- FALSE
SELECT 'pizza' IS NOT NULL
```

IS NULL / IS NOT NULL

```
SELECT 1 IS NULL                -- FALSE
SELECT 'pizza' IS NOT NULL  -- TRUE
```

IS NULL / IS NOT NULL

```
SELECT 1 IS NULL                  -- FALSE
SELECT 'pizza' IS NOT NULL  -- TRUE
SELECT NULL IS NULL
```

IS NULL / IS NOT NULL

```
SELECT 1 IS NULL                -- FALSE
SELECT 'pizza' IS NOT NULL      -- TRUE
SELECT NULL IS NULL             -- TRUE
```

IS NULL / IS NOT NULL

```
SELECT 1 IS NULL                -- FALSE
SELECT 'pizza' IS NOT NULL      -- TRUE
SELECT NULL IS NULL             -- TRUE
SELECT NULL IS NOT NULL
```

IS NULL / IS NOT NULL

```
SELECT 1 IS NULL                -- FALSE
SELECT 'pizza' IS NOT NULL      -- TRUE
SELECT NULL IS NULL             -- TRUE
SELECT NULL IS NOT NULL         -- FALSE
```

Back to JOINs

FEATURE REQUEST

"All people in our database, and their pet data —if they have any."

OUTER JOIN (LEFT or RIGHT)

`people LEFT JOIN pets` => All people data, and pets if they have them

`people RIGHT JOIN pets` => All pets data, and people data if they have an owner

people LEFT JOIN pets

```
SELECT *
FROM people
  LEFT JOIN pets ON pets.person_id = people.id

---

+----+---------------+-----+----+-----------+--------+-----+
| id |     name      | age | id | person_id |  name  | age |
+----+---------------+-----+----+-----------+--------+-----+
|  1 | John Mosesman |  26 |  1 |         1 | Ruby   |   1 |
|  2 | Bob Smith     |  40 |  2 |         2 | Pete   |   5 |
|  3 | Jane Doe      |  32 |  3 |         3 | Fluffy |  12 |
|  1 | John Mosesman |  26 |  4 |         1 | Buddy  |   3 |
|  4 | Jack Smith    | 100 |    |           |        |     |
+----+---------------+-----+----+-----------+--------+-----+
```

people LEFT JOIN pets

```
SELECT *
FROM people
  LEFT JOIN pets ON pets.person_id = people.id

---

+----+---------------+-----+------+-----------+--------+------+
| id |     name      | age |  id  | person_id |  name  | age  |
+----+---------------+-----+------+-----------+--------+------+
|  1 | John Mosesman |  26 | 1    | 1         | Ruby   | 1    |
|  2 | Bob Smith     |  40 | 2    | 2         | Pete   | 5    |
|  3 | Jane Doe      |  32 | 3    | 3         | Fluffy | 12   |
|  1 | John Mosesman |  26 | 4    | 1         | Buddy  | 3    |
|  4 | Jack Smith    | 100 | NULL | NULL      | NULL   | NULL |
+----+---------------+-----+------+-----------+--------+------+
```

People without pets

```
SELECT *
FROM people
  LEFT JOIN pets ON pets.person_id = people.id
WHERE pets.id IS NULL
```

```
+----+-------------+-----+----+-----------+------+-----+
| id |     name    | age | id | person_id | name | age |
+----+-------------+-----+----+-----------+------+-----+
|  4 | Jack Smith | 100 |    |           |      |     |
+----+-------------+-----+----+-----------+------+-----+
```

FEATURE REQUEST

"People with pets that don't have their shots."

Pets Without Shots

```
SELECT *
FROM people
  JOIN pets ON pets.person_id = people.id
  LEFT JOIN shot_records sr ON sr.pet_id = pets.id
WHERE sr.id IS NULL
```

```
+----+--------------+-----+----+-----------+--------+-----+----+--------+-----------+------+
| id |     name     | age | id | person_id |  name  | age | id | pet_id | shot_name | date |
+----+--------------+-----+----+-----------+--------+-----+----+--------+-----------+------+
|  2 | Bob Smith    |  40 |  2 |         2 | Pete   |   5 |    |        |           |      |
|  1 | John Mosesman |  26 |  4 |         1 | Buddy  |   3 |    |        |           |      |
|  3 | Jane Doe     |  32 |  3 |         3 | Fluffy |  12 |    |        |           |      |
+----+--------------+-----+----+-----------+--------+-----+----+--------+-----------+------+
```

Pets Without Shots

```
SELECT people.*, pets.*
FROM people
  JOIN pets ON pets.person_id = people.id
  LEFT JOIN shot_records sr ON sr.pet_id = pets.id
WHERE sr.id IS NULL
```

```
+----+---------------+-----+----+-----------+--------+-----+
| id |     name      | age | id | person_id |  name  | age |
+----+---------------+-----+----+-----------+--------+-----+
|  2 | Bob Smith     |  40 |  2 |         2 | Pete   |   5 |
|  1 | John Mosesman |  26 |  4 |         1 | Buddy  |   3 |
|  3 | Jane Doe      |  32 |  3 |         3 | Fluffy |  12 |
+----+---------------+-----+----+-----------+--------+-----+
```

FEATURE REQUEST

"Find each person and the number of pets they have."

Basic aggregations

```
SELECT AVG(age) FROM people

SELECT SUM(age) FROM people

SELECT COUNT(*) FROM people
```

Group by person

```
SELECT *
FROM people
  JOIN pets ON pets.person_id = people.id
```

Group by person

```
SELECT *
FROM people
  JOIN pets ON pets.person_id = people.id
GROUP BY people.id
```

Group by person

```
SELECT *
FROM people
  JOIN pets ON pets.person_id = people.id
GROUP BY people.id

---

ERROR:  column "pets.id" must appear in the GROUP BY clause or be used in an aggregate function
LINE 1: SELECT *
               ^
```

Group by person and get pet count

```
SELECT people.id, COUNT(pets.id)
FROM people
  JOIN pets ON pets.person_id = people.id
GROUP BY people.id
```

```
+----+-------+
| id | count |
+----+-------+
|  2 |     1 |
|  1 |     2 |
|  3 |     1 |
+----+-------+
```

Group by person and get pet count

```
SELECT people.id, people.name, COUNT(pets.id)
FROM people
  JOIN pets ON pets.person_id = people.id
GROUP BY people.id, people.name
```

```
+----+---------------+-------+
| id |     name      | count |
+----+---------------+-------+
|  2 | Bob Smith     |     1 |
|  1 | John Mosesman |     2 |
|  3 | Jane Doe      |     1 |
+----+---------------+-------+
```

FEATURE REQUEST

"People with more pets are more likely to adopt more pets."

ORDER BY

```
SELECT people.id, people.name, COUNT(pets.id)
FROM people
  JOIN pets ON pets.person_id = people.id
GROUP BY people.id, people.name
ORDER BY COUNT(pets.id) DESC
```

```
+----+---------------+-------+
| id |     name      | count |
+----+---------------+-------+
|  1 | John Mosesman |     2 |
|  2 | Bob Smith     |     1 |
|  3 | Jane Doe      |     1 |
+----+---------------+-------+
```

ALIAS

```
SELECT people.id, people.name, COUNT(pets.id) AS num_pets
FROM people
  JOIN pets ON pets.person_id = people.id
GROUP BY people.id, people.name
ORDER BY num_pets DESC
```

FEATURE REQUEST

"People with 2 or more pets are more likely to adopt more pets."

HAVING

```
SELECT people.id, people.name, COUNT(pets.id) AS num_pets
FROM people
  JOIN pets ON pets.person_id = people.id
GROUP BY people.id, people.name
HAVING num_pets >= 2
ORDER BY num_pets DESC
```

HAVING

```
SELECT people.id, people.name, COUNT(pets.id) AS num_pets
FROM people
  JOIN pets ON pets.person_id = people.id
GROUP BY people.id, people.name
HAVING num_pets >= 2
ORDER BY num_pets DESC

---

ERROR:  column "num_pets" does not exist
LINE 5: HAVING num_pets >= 2
               ^
```

Order of Operations, Again.

1. FROM
2. ON (JOIN)
3. WHERE
4. GROUP BY
5. HAVING
6. SELECT <-- ALIAS happens here
7. ORDER BY <-- Can be used here as well

HAVING, Again.

```
SELECT people.id, people.name, COUNT(pets.id) AS num_pets
FROM people
  JOIN pets ON pets.person_id = people.id
GROUP BY people.id, people.name
HAVING COUNT(pets.id) >= 2
ORDER BY num_pets DESC
```

```
+----+---------------+----------+
| id |     name      | num_pets |
+----+---------------+----------+
|  1 | John Mosesman |        2 |
+----+---------------+----------+
```

WHERE vs HAVING

"HAVING eliminates group rows that do not satisfy the condition. HAVING is different from WHERE: WHERE filters individual rows before the application of GROUP BY, while HAVING filters group rows created by GROUP BY."[3]

---

[3] Postgres docs - https://www.postgresql.org/docs/9.0/static/tutorial-agg.html

LIMIT

```
SELECT people.id, people.name, COUNT(pets.id) AS num_pets
FROM people
  JOIN pets ON pets.person_id = people.id
GROUP BY people.id, people.name
HAVING COUNT(pets.id) >= 2
ORDER BY num_pets DESC
LIMIT 5
```

"Has Many"

- A person "has many" pets (one-to-many relationship)
- A pet "belongs to" an owner (one-to-one relationship).

FEATURE REQUEST

"Pets can belong to more than one owner."

Has And Belongs To Many (HABTM)

```
CREATE TABLE people (
  id SERIAL PRIMARY KEY,
  ...
);

CREATE TABLE pets (
  id SERIAL PRIMARY KEY,
  ...
)
```

Has And Belongs To Many (HABTM)

```
CREATE TABLE people (
  id SERIAL PRIMARY KEY,
  ...
);

CREATE TABLE pets (
  id SERIAL PRIMARY KEY,
  ...
)

CREATE TABLE families (
  person_id INTEGER REFERENCES people,
  pet_id    INTEGER REFERENCES pets
)
```

Adding Another Owner

```
INSERT INTO people (name, age) VALUES
('Danielle Mosesman', 26)

---

INSERT INTO families (person_id, pet_id) VALUES
(1, 1),     -- John and Ruby
(5, 1)      -- Danielle and Ruby
```

Families Table

```
SELECT *
FROM families
WHERE pet_id = 1    -- Ruby

---

+-----------+--------+
| person_id | pet_id |
+-----------+--------+
|         1 |      1 |
|         5 |      1 |
+-----------+--------+
```

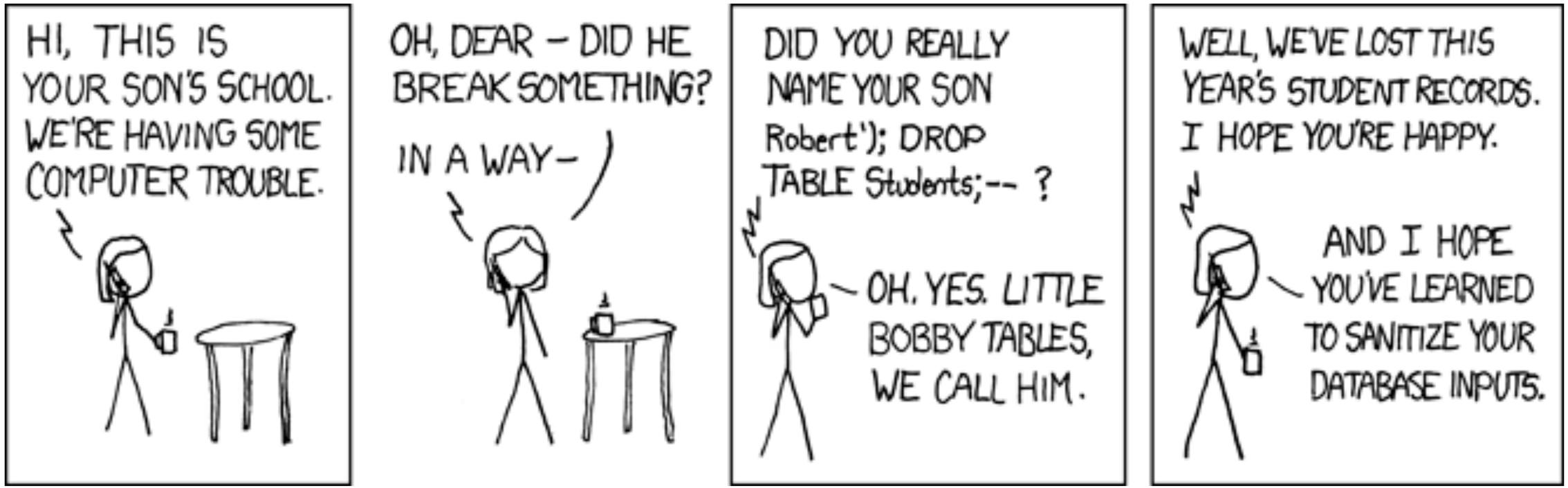
Owners of Ruby

```
SELECT *
FROM people
 JOIN families f ON f.person_id = people.id
 JOIN pets ON pets.id = f.pet_id
WHERE pets.id = 1
```

```
+----+-------------------+-----+-----------+--------+----+------+-----+
| id |       name        | age | person_id | pet_id | id | name | age |
+----+-------------------+-----+-----------+--------+----+------+-----+
|  1 | John Mosesman     |  26 |         1 |      1 |  1 | Ruby |   1 |
|  5 | Danielle Mosesman |  26 |         5 |      1 |  1 | Ruby |   1 |
+----+-------------------+-----+-----------+--------+----+------+-----+
```

4. Data Integrity

"Exploits of a Mom" - https://xkcd.com/327/



Bad Data

- Corrupted data is useless
- It makes application development more difficult

Constraints

Constraints

```
ALTER TABLE people ADD CONSTRAINT age CHECK (age > 0 AND age < 120)

---

INSERT INTO people (name, age) VALUES
('Somebody', -10)

---

ERROR:  new row for relation "people" violates check constraint "age"
DETAIL:  Failing row contains (8, Somebody, -10).
```

Constraint Creation

```
CREATE TABLE people (
  id SERIAL PRIMARY KEY,
  name VARCHAR,
  age INTEGER CHECK (age > 0 AND age < 120)
);

---

CREATE TABLE people (
  id SERIAL PRIMARY KEY,
  name VARCHAR,
  age INTEGER CONSTRAINT valid_age CHECK (age > 0 AND age < 120)
);
```

Unique

```
CREATE TABLE people (
  id SERIAL PRIMARY KEY,
  name VARCHAR,
  age INTEGER,
  email VARCHAR UNIQUE
);
```

NOT NULL

```
CREATE TABLE people (
  id SERIAL PRIMARY KEY,
  name VARCHAR NOT NULL,
  age INTEGER NOT NULL
);
```

"Tip: In most database designs the majority of columns should be marked not null."[5]

---

[5] Postgres docs - https://www.postgresql.org/docs/9.4/static/ddl-constraints.html

Primary Key Constraint

```
CREATE TABLE people (
  id SERIAL PRIMARY KEY
);

---

CREATE TABLE people (
  id SERIAL UNIQUE NOT NULL
);
```

Foreign Key Constraint

```
CREATE TABLE pets (
  id SERIAL PRIMARY KEY,
  person_id INTEGER REFERENCES people
)

---

INSERT INTO pets(person_id, name) VALUES
(9999, 'Simba')

---

ERROR:  insert or update on table "pets" violates foreign key constraint "pets_person_id_fkey"
DETAIL:  Key (person_id)=(9999) is not present in table "people".

=> "pets_person_id_fkey" is the default name postgres gave it
```

5. Performance

How do we increase performance?

- Process fewer things
- Process things faster

"Sequential Scan"

- Check every row in the table

Indexes

What is an index?

- Pre-computed data structure for efficient targetting of specific rows
- Keeps track of values and where they exist on disk
- Different types, but usually a b-tree (balanced tree)

Many Constraints Use Indexes

- UNIQUE
- PK / FK

Example

```
CREATE TABLE users (
  name VARCHAR,
  email VARCHAR,
  age INTEGER,
  created_at timestamp,
  updated_at timestamp
)

~475k rows

---

Made a copy - `users_2`

---

CREATE UNIQUE INDEX ON users (email)
```

Index vs No Index

```
SELECT *
FROM users
WHERE email = 'buck@rippin.co'

---

Un-indexed table (users_2)  - ~100ms
Indexed table (users)       - ~1ms
```

Q: How do we know what's actually going on?

A: View the Query Plan

Query Planner

- Most modern Database Management Systems (DBMS) have a query planner
- Query planner analyzes and optimizes queries based on internal stats it collects

EXPLAIN (No Index)

```
EXPLAIN VERBOSE SELECT *
FROM users_2
WHERE email = 'buck@rippin.co'

---

+-----------------------------------------------------------------+
|                            QUERY PLAN                           |
+-----------------------------------------------------------------+
| Seq Scan on public.users_2  (cost=0.00..11535.80 rows=1 width=63) |
|   Output: id, name, email, age, created_at, updated_at          |
|   Filter: ((users_2.email)::text = 'buck@rippin.co'::text)      |
+-----------------------------------------------------------------+
```

EXPLAIN (With Index)

```
EXPLAIN VERBOSE SELECT *
FROM users
WHERE email = 'buck@rippin.co'

---

+-----------------------------------------------------------------------------------------+
|                                       QUERY PLAN                                        |
+-----------------------------------------------------------------------------------------+
| Index Scan using users_email_idx on public.users  (cost=0.42..8.44 rows=1 width=67) |
|   Output: id, name, email, age, created_at, updated_at                                  |
|   Index Cond: ((users.email)::text = 'buck@rippin.co'::text)                            |
+-----------------------------------------------------------------------------------------+
```

ANALYZE

```
EXPLAIN ANALYZE VERBOSE SELECT *
FROM users
WHERE email = 'buck@rippin.co'
```

ANALYZE

```
+-------------------------------------------------------------------------------------------------------------------------------------------+
|                                                                QUERY PLAN                                                                 |
+-------------------------------------------------------------------------------------------------------------------------------------------+
| Index Scan using users_email_idx on public.users  (cost=0.42..8.44 rows=1 width=67) (actual time=0.071..0.071 rows=1 loops=1)            |
|   Output: id, name, email, age, created_at, updated_at                                                                                    |
|   Index Cond: ((users.email)::text = 'buck@rippin.co'::text)                                                                              |
| Planning time: 0.145 ms                                                                                                                   |
| Execution time: 0.106 ms                                                                                                                  |
+-------------------------------------------------------------------------------------------------------------------------------------------+
```


INDEX ALL THE THINGS!
memegenerator.net

Drawbacks of Indicies

- Have to be maintained as table changes
- Take up disk space
- Lose their efficiency if they get too big
- Can hurt performance on write-heavy tables

N + 1 Queries

N + 1 Queries

```
users = User.all

users.each do |user|
  user.pets.each do |pet|
    puts pet.name
  end
end
```

N + 1 Queries

```
User Load (0.7ms)  SELECT "users".* FROM "users"

Pet Load (0.4ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 1]]
Pet Load (0.5ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 2]]
Pet Load (0.3ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 3]]
Pet Load (0.5ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 4]]
Pet Load (0.4ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 5]]
Pet Load (0.3ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 6]]
Pet Load (0.2ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 7]]
Pet Load (0.3ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 8]]
Pet Load (0.2ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 9]]
Pet Load (0.2ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 10]]
Pet Load (0.2ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 11]]
Pet Load (0.3ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 12]]
Pet Load (0.2ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 13]]
Pet Load (0.2ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id" = $1  [["user_id", 14]]

Completed 200 OK in 290ms (Views: 266.7ms | ActiveRecord: 15.5ms)
```

Fixing N + 1 Queries

```
User.all => User.all.includes(:pets)

---

User Load (0.6ms)  SELECT "users".* FROM "users"

Pet Load (1.2ms)  SELECT "pets".* FROM "pets" WHERE "pets"."user_id"
    IN (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14)

Completed 200 OK in 43ms (Views: 32.6ms | ActiveRecord: 8.4ms)
```

Some Final Tips For Running queries...

"Drag from the bottom up"

```
13
14
15 DELETE FROM p
16  JOIN stuff ON ...
17  JOIN more_stuff ON...
18    AND some_condition > 50
19    OR something_else = 'this'
20  LEFT JOIN a_thing ON blah...
21    AND thing ILIKE '%bleh%'
22 GROUP BY some_stuff
23 HAVING AVG(more_stuff) = 45
24 ORDER BY MAX(bleh) / MIN(bluh)
25 LIMIT 10
26
```

```
13
14
15 --DELETE FROM p
16  JOIN stuff ON ...
17  JOIN more_stuff ON...
18   AND some_condition > 50
19   OR something_else = 'this'
20  LEFT JOIN a_thing ON blah...
21   AND thing ILIKE '%bleh%'
22 GROUP BY some_stuff
23 HAVING AVG(more_stuff) = 45
24 ORDER BY MAX(bleh) / MIN(bluh)
25 LIMIT 10
26
```

```
14
15 --DELETE FROM p
16  JOIN stuff ON ...
17  JOIN more_stuff ON...
18   AND some_condition > 50
19   OR something_else = 'this'
20  LEFT JOIN a_thing ON blah...
21   AND thing ILIKE '%bleh%'
22 GROUP BY some_stuff
23 HAVING AVG(more_stuff) = 45
```

Load Query...

Save Query...

```
13
14
15 --DELETE FROM p
16  JOIN stuff ON ...
17  JOIN more_stuff ON...
18   AND some_condition > 50
19   OR something_else = 'this'
20  LEFT JOIN a_thing ON blah...
21   AND thing ILIKE '%bleh%'
22 GROUP BY some_stuff
23 HAVING AVG(more_stuff) = 45
24 ORDER BY MAX(bleh) / MIN(bluh)
25 LIMIT 10
26
```

```
12
13
14
15 --DELETE FROM p
16  JOIN stuff ON ...
17  JOIN more_stuff ON...
18    AND some_condition > 50
19    OR something_else = 'this'
20  LEFT JOIN a_thing ON blah...
21    AND thing ILIKE '%bleh%'
22 GROUP BY some_stuff
23 HAVING AVG(more_stuff) = 45
24 ORDER BY MAX(bleh) / MIN(bluh)
25 LIMIT 10
26
```

Load Query... Save Query...

```
ERROR:  syntax error at or near "AND"
LINE 1:    AND some_condition > 50
           ^
```

```
12
13
14
15 --DELETE FROM p
16  JOIN stuff ON ...
17  JOIN more_stuff ON...
18   AND some_condition > 50
19   OR something_else = 'this'
20  LEFT JOIN a_thing ON blah...
21   AND thing ILIKE '%bleh%'
22 GROUP BY some_stuff
23 HAVING AVG(more_stuff) = 45
24 ORDER BY MAX(bleh) / MIN(bluh)
25 LIMIT 10
26
```

Questions?

Thanks!

@johnmosesman