

# Relational Database Design

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[www.pg4e.com](http://www.pg4e.com)

<http://www.pg4e.com/lectures/02-Database-Design-Many-to-Many.txt>

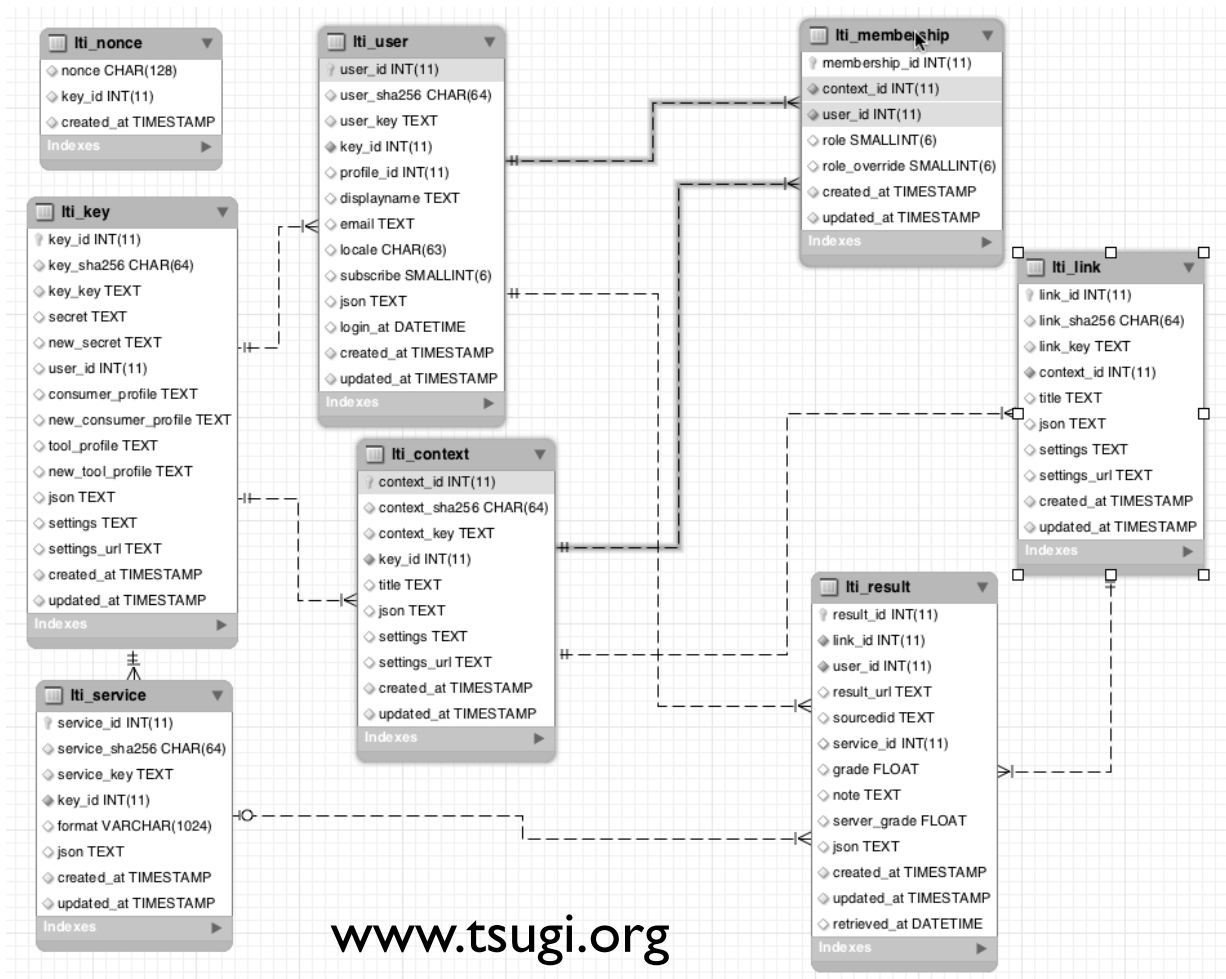


# Relational Database Design

[http://en.wikipedia.org/wiki/Relational\\_model](http://en.wikipedia.org/wiki/Relational_model)

# Database Design

- Database design is an art form of its own with particular skills and experience.
- Our goal is to avoid the really bad mistakes and design clean and easily understood databases.
- Others may performance tune things later.
- Database design starts with a picture...



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# Building a Data Model

- Drawing a picture of the data objects for our application and then figuring out how to represent the objects and their relationships
- Basic Rule: Don't put the same string data in twice - use a relationship instead
- When there is one thing in the “real world” there should only be one copy of that thing in the database

Track	Len	Artist	Album	Genre	Rating	Count
<input checked="" type="checkbox"/> Hells Bells	5:13	AC/DC	Who Made Who	Rock	★★★★★	61
<input checked="" type="checkbox"/> Shake Your Foundations	3:54	AC/DC	Who Made Who	Rock	★★★★★	70
<input checked="" type="checkbox"/> Chase the Ace	3:01	AC/DC	Who Made Who	Rock		56
<input checked="" type="checkbox"/> For Those About To Rock (We ...	5:54	AC/DC	Who Made Who	Rock	★★★★★	61
<input checked="" type="checkbox"/> Dúlamán	3:43	Altan	Natural Wonders M...	New Age		31
<input checked="" type="checkbox"/> Rode Across the Desert	4:10	America	Greatest Hits	Easy Listen...	★★★★★	23
<input checked="" type="checkbox"/> Now You Are Gone	3:08	America	Greatest Hits	Easy Listen...	★★★★★	18
<input checked="" type="checkbox"/> Tin Man	3:30	America	Greatest Hits	Easy Listen...	★★★★★	23
<input checked="" type="checkbox"/> Sister Golden Hair	3:22	America	Greatest Hits	Easy Listen...	★★★★★	24
<input checked="" type="checkbox"/> Track 01	4:22	Billy Price	Danger Zone	Blues/R&B	★★★★★	26
<input checked="" type="checkbox"/> Track 02	2:45	Billy Price	Danger Zone	Blues/R&B	★★★★★	18
<input checked="" type="checkbox"/> Track 03	3:26	Billy Price	Danger Zone	Blues/R&B	★★★★★	22
<input checked="" type="checkbox"/> Track 04	4:17	Billy Price	Danger Zone	Blues/R&B	★★★★★	18
<input checked="" type="checkbox"/> Track 05	3:50	Billy Price	Danger Zone	Blues/R&B	★★★★★	21
<input checked="" type="checkbox"/> War Pigs/Luke's Wall	7:58	Black Sabbath	Paranoid	Metal	★★★★★	25
<input checked="" type="checkbox"/> Paranoid	2:53	Black Sabbath	Paranoid	Metal	★★★★★	22
<input checked="" type="checkbox"/> Planet Caravan	4:35	Black Sabbath	Paranoid	Metal	★★★★★	25
<input checked="" type="checkbox"/> Iron Man	5:59	Black Sabbath	Paranoid	Metal	★★★★★	26
<input checked="" type="checkbox"/> Electric Funeral	4:53	Black Sabbath	Paranoid	Metal	★★★★★	22
<input checked="" type="checkbox"/> Hand of Doom	7:10	Black Sabbath	Paranoid	Metal	★★★★★	23
<input checked="" type="checkbox"/> Rat Salad	2:30	Black Sabbath	Paranoid	Metal	★★★★★	31
<input checked="" type="checkbox"/> Jack the Stripper/Fairies Wear ...	6:14	Black Sabbath	Paranoid	Metal	★★★★★	24
<input checked="" type="checkbox"/> Bomb Squad (TECH)	3:28	Brent	Brent's Album			1
<input checked="" type="checkbox"/> clay techno	4:36	Brent	Brent's Album			2
<input checked="" type="checkbox"/> Heavy	3:08	Brent	Brent's Album			1
<input checked="" type="checkbox"/> Hi metal man	4:20	Brent	Brent's Album			1
<input checked="" type="checkbox"/> Mistro	2:58	Brent	Brent's Album			1

# For each “piece of info” ...

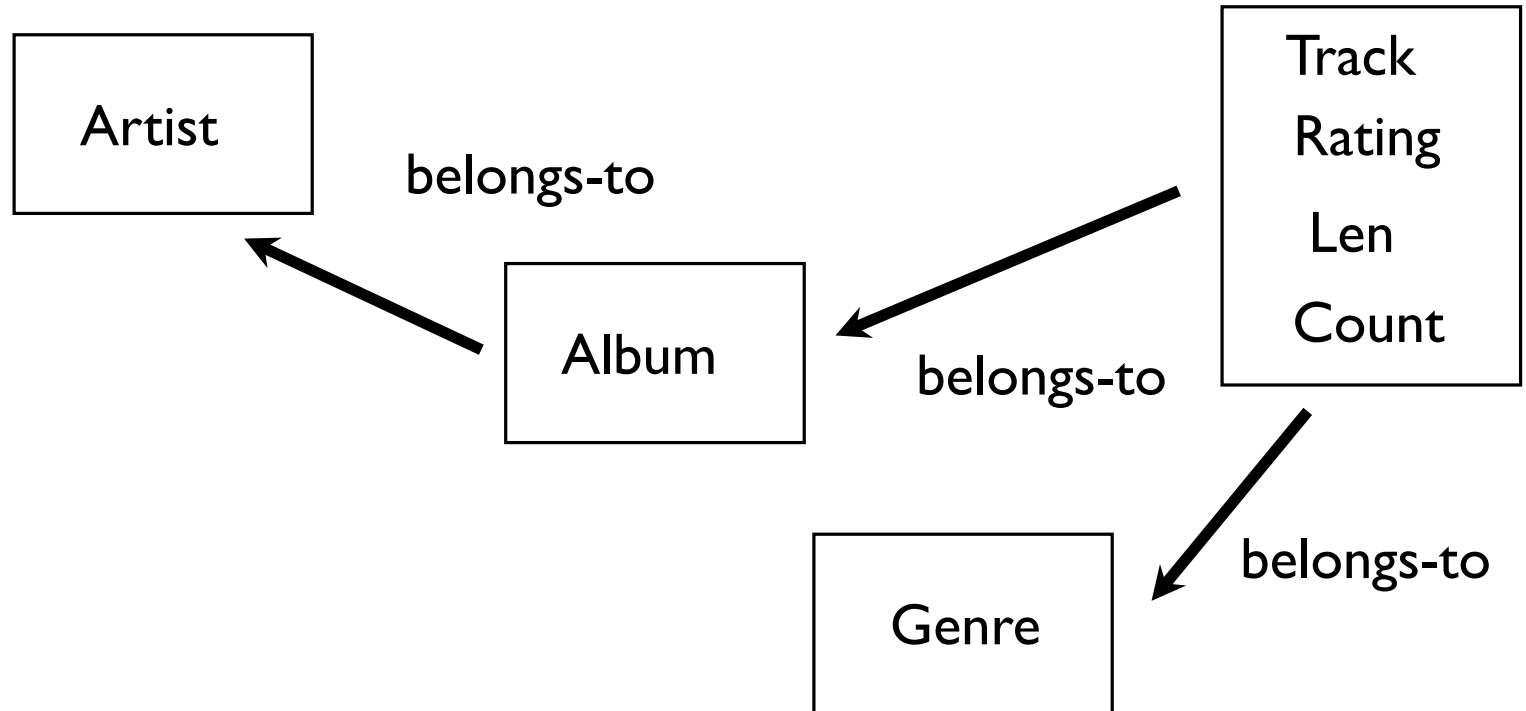
- Is the column an object or an attribute of another object?
- Once we define objects, we need to define the relationships between objects.

Len                      Album  
Genre  
Artist                      Rating  
Track                      Count

<input checked="" type="checkbox"/> Hells Bells	5:13	AC/DC	Who Made Who	Rock	★★★★★	61
<input checked="" type="checkbox"/> Shake Your Foundations	3:54	AC/DC	Who Made Who	Rock	★★★★★	70
<input checked="" type="checkbox"/> Chase the Ace	3:01	AC/DC	Who Made Who	Rock		56
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<input checked="" type="checkbox"/> Tin Man	3:30	America	Greatest Hits	Easy Listen...	★★★★★	22



Track  
Album  
Artist  
Genre  
Rating  
Len  
Count



<input checked="" type="checkbox"/> Hells Bells	5:13	AC/DC	Who Made Who	Rock	★★★★★	61
<input checked="" type="checkbox"/> Shake Your Foundations	3:54	AC/DC	Who Made Who	Rock	★★★★★	70
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<input checked="" type="checkbox"/> Now You Are Gone	3:08	America	Greatest Hits	Easy Listen...	★★★★★	18
<input checked="" type="checkbox"/> Tin Man	3:20	America	Greatest Hits	Easy Listen...	★★★★★	22

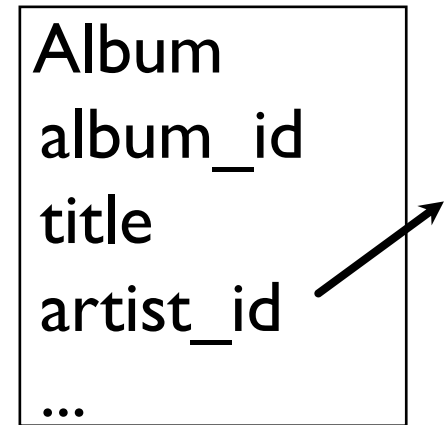


# Key Terminology

Finding our way around....

# Three Kinds of Keys

- Primary key - generally an integer auto-increment field
- Logical key - what the outside world uses for lookup
- Foreign key - generally an integer key pointing to a row in another table



# Primary Key Rules

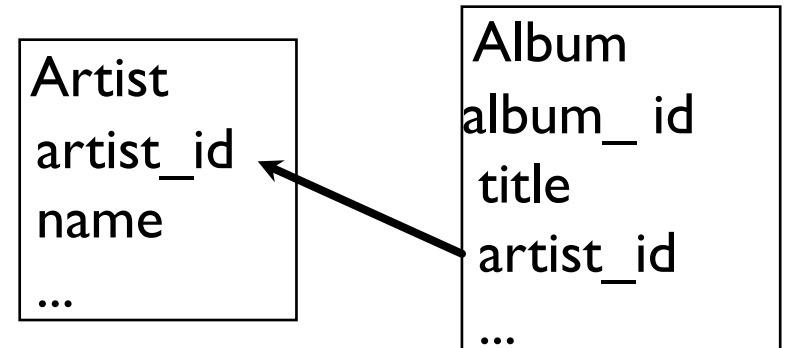
Best practices:

- Never use your logical key as the primary key.
- Logical keys can and do change, albeit slowly.
- Relationships that are based on matching string fields are less efficient than integers.

User  
user\_id  
email  
password  
name  
created\_at  
modified\_at  
login\_at

# Foreign Keys

- A foreign key is when a table has a column containing a key that points to the primary key of another table.
- When all primary keys are integers, then all foreign keys are integers. This is good - very good.



# Normalization and Foreign Keys

<input checked="" type="checkbox"/> Hells Bells	5:13	AC/DC	Who Made Who	Rock	★★★★★	61
<input checked="" type="checkbox"/> Shake Your Foundations	3:54	AC/DC	Who Made Who	Rock	★★★★★	70
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<input checked="" type="checkbox"/> Now You Are Gone	3:08	America	Greatest Hits	Easy Listen...	★★★★★	18
<input checked="" type="checkbox"/> Tin Man	3:30	America	Greatest Hits	Easy Listen...	★★★★★	22

We want to keep track of which band is the “creator” of each music track...  
 What album does this song “belong to”?

Which album is this song related to?



# Database Normalization (3NF)

There is \*tons\* of database theory - way too much to understand without excessive predicate calculus

- Do not replicate data. Instead, reference data. Point at data.
- Use integers for keys and for references.
- Add a special “key” column to each table, which you will make references to.

[http://en.wikipedia.org/wiki/Database\\_normalization](http://en.wikipedia.org/wiki/Database_normalization)

# Integer Reference Pattern

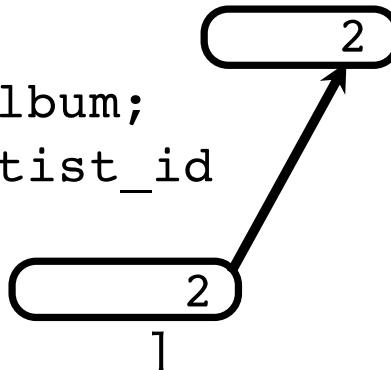
We use integer columns in one table to reference (or look up) rows in another table.

music=> SELECT \* FROM album;

id	title	artist_id
1	Who Made Who	
2	IV	

music=> SELECT \* FROM artist;

id	name
1	Led Zeppelin
2	AC/DC



# Building a Physical Data Schema

Artist

belongs-to

Album

Track  
Rating  
Len  
Count

belongs-to

Genre

belongs-to

<input checked="" type="checkbox"/> Hells Bells	5:13	AC/DC	Who Made Who	Rock	★★★★★	61
<input checked="" type="checkbox"/> Shake Your Foundations	3:54	AC/DC	Who Made Who	Rock	★★★★★	70
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<input checked="" type="checkbox"/> Now You Are Gone	3:08	America	Greatest Hits	Easy Listen...	★★★★★	18
<input checked="" type="checkbox"/> Tin Man	3:20	America	Greatest Hits	Easy Listen...	★★★★★	23

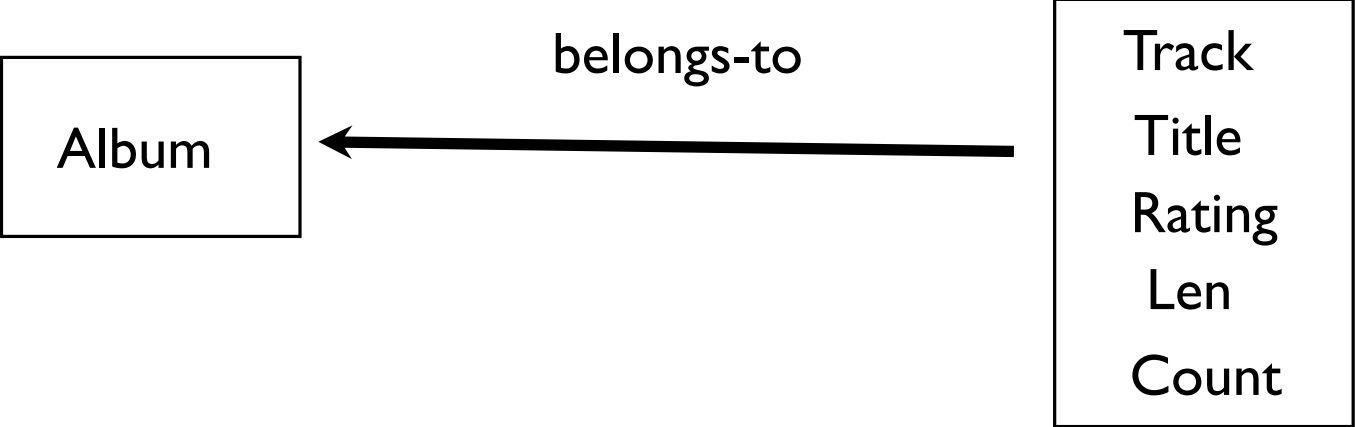
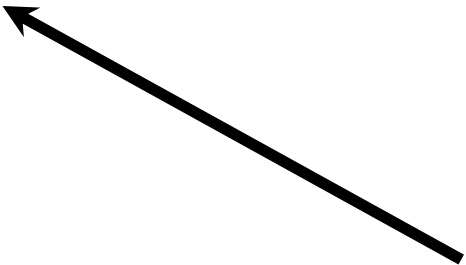


Table  
Primary key  
Logical key  
Foreign key

Album
id
title

Track
id
title
rating
len
count
album_id





Artist
id
name

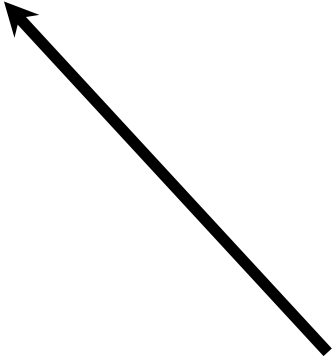
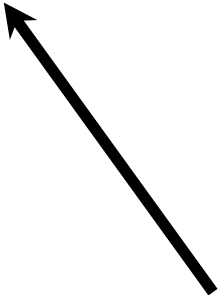
Album
id
title
artist_id

Track
id
title
rating
len
count
album_id
genre_id

Genre
id
name

Table  
Primary key  
Logical key  
Foreign key

Naming the Foreign key  
artist\_id is a convention



# Creating our Music Database

```
sudo -u postgres psql postgres
```

```
postgres=# CREATE DATABASE music  
          WITH OWNER 'pg4e' ENCODING 'UTF8';  
CREATE DATABASE  
postgres=#
```

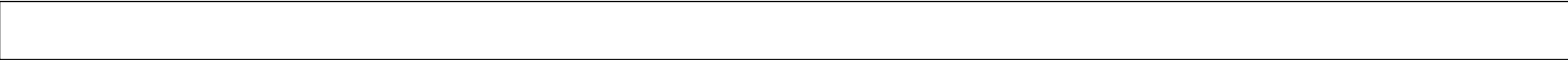
```
CREATE TABLE artist (  
    id SERIAL,  
    name VARCHAR(128) UNIQUE,  
    PRIMARY_KEY(id)  
);
```

```
CREATE TABLE album (  
    id SERIAL,  
    title VARCHAR(128) UNIQUE,  
    artist_id INTEGER REFERENCES artist(id) ON DELETE CASCADE,  
    PRIMARY KEY(id)  
);
```



```
CREATE TABLE genre (  
    id SERIAL,  
    name VARCHAR(128) UNIQUE,  
    PRIMARY_KEY(id)  
);
```

```
CREATE TABLE track (  
    id SERIAL,  
    title VARCHAR(128),  
    len INTEGER,  
    rating INTEGER,  
    count INTEGER,  
    album_id INTEGER REFERENCES genre(id) ON DELETE CASCADE,  
    genre_id INTEGER REFERENCES album(id) ON DELETE CASCADE,  
    UNIQUE(title, album_id),  
    PRIMARY KEY(id)  
);
```



music=> \d track

Table "public.track"		
Column	Type	Modifiers
id	integer	not null default nextval('track_id_seq'::regclass)
title	character varying(128)	
len	integer	
rating	integer	
count	integer	
album_id	integer	
genre_id	integer	

Indexes:

- "track\_pkey" PRIMARY KEY, btree (id)
- "track\_title\_album\_id\_key" UNIQUE CONSTRAINT, btree (title, album\_id)

Foreign-key constraints:

- "track\_album\_id\_fkey" FOREIGN KEY (album\_id) REFERENCES album(id) ON DELETE CASCADE
- "track\_genre\_id\_fkey" FOREIGN KEY (genre\_id) REFERENCES genre(id) ON DELETE CASCADE

music=>

```
music=> INSERT INTO artist (name) VALUES ('Led Zeppelin');
```

```
INSERT 0 1
```

```
music=> INSERT INTO artist (name) VALUES ('AC/DC');
```

```
INSERT 0 1
```

```
music=> SELECT * FROM artist;
```

```
  id |      name
-----+-----
   1 | Led Zeppelin
   2 | AC/DC
```

```
(2 rows)
```

```
music=>
```

```
music=> INSERT INTO album (title, artist_id) VALUES ('Who Made Who', 2);  
INSERT 0 1
```

```
music=> INSERT INTO album (title, artist_id) VALUES ('IV', 1);  
INSERT 0 1
```

```
music=> SELECT * FROM album;
```

id	title	artist_id
1	Who Made Who	2
2	IV	1

(2 rows)

```
music=> INSERT INTO genre (name) VALUES ('Rock');
INSERT 0 1
music=> INSERT INTO genre (name) VALUES ('Metal');
INSERT 0 1
music=> SELECT * FROM genre;
 id | name
----+-----
  1 | Rock
  2 | Metal
(2 rows)
```

```

music=> INSERT INTO track (title, rating, len, count, album_id, genre_id)
music->      VALUES ('Black Dog', 5, 297, 0, 2, 1) ;
INSERT 0 1
music=> INSERT INTO track (title, rating, len, count, album_id, genre_id)
music->      VALUES ('Stairway', 5, 482, 0, 2, 1) ;
INSERT 0 1
music=> INSERT INTO track (title, rating, len, count, album_id, genre_id)
music->      VALUES ('About to Rock', 5, 313, 0, 1, 2) ;
INSERT 0 1
music=> INSERT INTO track (title, rating, len, count, album_id, genre_id)
music->      VALUES ('Who Made Who', 5, 207, 0, 1, 2) ;
INSERT 0 1
music=> SELECT * FROM track;
  id |      title      | len | rating | count | album_id | genre_id
----+-----+-----+-----+-----+-----+-----
  1 | Black Dog       | 297 |      5 |      0 |         2 |        1
  2 | Stairway        | 482 |      5 |      0 |         2 |        1
  3 | About to Rock   | 313 |      5 |      0 |         1 |        2
  4 | Who Made Who    | 207 |      5 |      0 |         1 |        2
(4 rows)

```

music=> SELECT \* FROM track;

id	title	len	rating	count	album_id	genre_id
1	Black Dog	297	5	0	2	1
2	Stairway	482	5	0	2	1
3	About to Rock	313	5	0	1	2
4	Who Made Who	207	5	0	1	2

music=> SELECT \* FROM genre;

id	name
1	Rock
2	Metal

music=> SELECT \* FROM album;

id	title	artist_id
1	Who Made Who	2
2	IV	1

music=> SELECT \* FROM artist;

id	name
1	Led Zeppelin
2	AC/DC

# We Have Relationships!

# Using Join Across Tables

[http://en.wikipedia.org/wiki/Join\\_\(SQL\)](http://en.wikipedia.org/wiki/Join_(SQL))



# Relational Power

- By removing the replicated data and replacing it with references to a single copy of each bit of data, we build a “web” of information that the relational database can read through very quickly - even for very large amounts of data.
- Often when you want some data it comes from a number of tables linked by these foreign keys.

# The JOIN Operation

- The JOIN operation links across several tables as part of a SELECT operation.
- You must tell the JOIN how to use the keys that make the connection between the tables using an ON clause.

```
music=> SELECT * FROM album;
id | title | artist_id
```

```
-----+-----
1 | Who Made Who | 2
2 | IV | 1
```

```
music=> SELECT * FROM artist;
id | name
```

```
-----+-----
1 | Led Zeppelin
2 | AC/DC
```



```
music=> SELECT album.title, artist.name
music-> FROM album JOIN artist
music-> ON album.artist_id = artist.id;
```

```
title | name
-----+-----
Who Made Who | AC/DC
IV | Led Zeppelin
```

What we want to see  
The tables that hold the data  
How the tables are linked

```
music=> SELECT * FROM album;
id | title | artist_id
```

```
-----+-----+-----
1 | Who Made Who |
2 | IV |
```

2  
1

```
music=> SELECT * FROM artist;
id | name
```

```
-----+-----
1 | Led Zeppelin
2 | AC/DC
```



```
music=> SELECT album.title, album.artist_id, artist.id, artist.name
music-> FROM album INNER JOIN artist ON album.artist_id = artist.id;
```

```
title | artist_id | id | name
-----+-----+-----
Who Made Who | 2 | 2 | AC/DC
IV | 1 | 1 | Led Zepplin
```

```
music=> SELECT track.title, track.genre_id, genre.id, genre.name
music->      FROM track CROSS JOIN genre;
```

title	genre_id	id	name
Black Dog	1	1	Rock
Stairway	1	1	Rock
About to Rock	2	1	Rock
Who Made Who	2	1	Rock
Black Dog	1	2	Metal
Stairway	1	2	Metal
About to Rock	2	2	Metal
Who Made Who	2	2	Metal

music=> SELECT \* FROM track;

id	title	len	rating	count	album_id	genre_id
1	Black Dog	297	5	0	2	1
2	Stairway	482	5	0	2	1
3	About to Rock	313	5	0	1	2
4	Who Made Who	207	5	0	1	2

music=> SELECT \* FROM genre;

id	name
1	Rock
2	Metal

music=> SELECT track.title, genre.name

music-> FROM track JOIN genre

music-> ON track.genre\_id = genre.id;

title	name
Black Dog	Rock
Stairway	Rock
About to Rock	Metal
Who Made Who	Metal

# It Can Get Complex...

```
music=> SELECT track.title, artist.name, album.title, genre.name
music-> FROM track
music->      JOIN genre ON track.genre_id = genre.id
music->      JOIN album ON track.album_id = album.id
music->      JOIN artist ON album.artist_id = artist.id;
```

title	name	title	genre
Black Dog	Led Zeppelin	IV	Rock
Stairway	Led Zeppelin	IV	Rock
About to Rock	AC/DC	Who Made Who	Metal
Who Made Who	AC/DC	Who Made Who	Metal


<input checked="" type="checkbox"/> Hells Bells	5:13	AC/DC	Who Made Who	Rock	★★★★★	61
<input checked="" type="checkbox"/> Shake Your Foundations	3:54	AC/DC	Who Made Who	Rock	★★★★★	70
<input checked="" type="checkbox"/> Chase the Ace	3:01	AC/DC	Who Made Who	Rock		56
<input checked="" type="checkbox"/> For Those About To Rock (We ...	5:54	AC/DC	Who Made Who	Rock	★★★★★	61
<input checked="" type="checkbox"/> Dúlamán	3:43	Altan	Natural Wonders M...	New Age		31
<input checked="" type="checkbox"/> Rode Across the Desert	4:10	America	Greatest Hits	Easy Listen...	★★★★★	23
<input checked="" type="checkbox"/> Now You Are Gone	3:08	America	Greatest Hits	Easy Listen...	★★★★★	18
<input checked="" type="checkbox"/> Tin Man	3:30	America	Greatest Hits	Easy Listen...	★★★★★	23
<input checked="" type="checkbox"/> Sister Golden Hair	3:22	America	Greatest Hits	Easy Listen...	★★★★★	24
<input checked="" type="checkbox"/> Track 01	4:22	Billy Price	Danger Zone	Blues/R&B	★★★★★	26
<input checked="" type="checkbox"/> Track 02	2:45	Billy Price	Danger Zone	Blues/R&B	★★★★★	18
<input checked="" type="checkbox"/> Track 03	3:26	Billy Price	Danger Zone	Blues/R&B	★★★★★	22
<input checked="" type="checkbox"/> Track 04	4:17	Billy Price	Danger Zone	Blues/R&B	★★★★★	18
<input checked="" type="checkbox"/> Track 05	3:50	Billy Price	Danger Zone	Blues/R&B	★★★★★	21
<input checked="" type="checkbox"/> War Pigs/Luke's Wall						
<input checked="" type="checkbox"/> Paranoid						
<input checked="" type="checkbox"/> Planet Caravan						
<input checked="" type="checkbox"/> Iron Man						
<input checked="" type="checkbox"/> Electric Funeral						
<input checked="" type="checkbox"/> Hand of Doom						
<input checked="" type="checkbox"/> Rat Salad						
<input checked="" type="checkbox"/> Jack the Stripper/Fair						
<input checked="" type="checkbox"/> Bomb Squad (TECH)						
<input checked="" type="checkbox"/> clay techno						
<input checked="" type="checkbox"/> Heavy						
<input checked="" type="checkbox"/> Hi metal man	4:20	Brent	Brent's Album			1
<input checked="" type="checkbox"/> Mistro	2:58	Brent	Brent's Album			1

title	name	title	name
Black Dog	Led Zeppelin	IV	Rock
Stairway	Led Zeppelin	IV	Rock
About to Rock	AC/DC	Who Made Who	Metal
Who Made Who	AC/DC	Who Made Who	Metal



# ON DELETE CASCADE

							Child
music=> SELECT * FROM track;							
id	title	len	rating	count	album_id	genre_id	
1	Black Dog	297	5	0	2	1	
2	Stairway	482	5	0	2	1	
3	About to Rock	313	5	0	1	2	music=> SELECT * FROM genre; id   name ----+----- 1   Rock 2   Metal
4	Who Made Who	207	5	0	1	2	



We are telling Postgres to  
"clean up" broken references

```
DELETE FROM Genre WHERE name = 'Metal'
```

# ON DELETE CASCADE

```
music=> SELECT * FROM track;
```

id	title	len	rating	count	album_id	genre_id
1	Black Dog	297	5	0	2	1
2	Stairway	482	5	0	2	1
3	About to Rock	313	5	0	1	2
4	Who Made Who	207	5	0	1	2

(4 rows)

```
music=> DELETE FROM genre WHERE name='Metal';
```

```
DELETE 1
```

```
music=> SELECT * FROM track;
```

id	title	len	rating	count	album_id	genre_id
1	Black Dog	297	5	0	2	1
2	Stairway	482	5	0	2	1

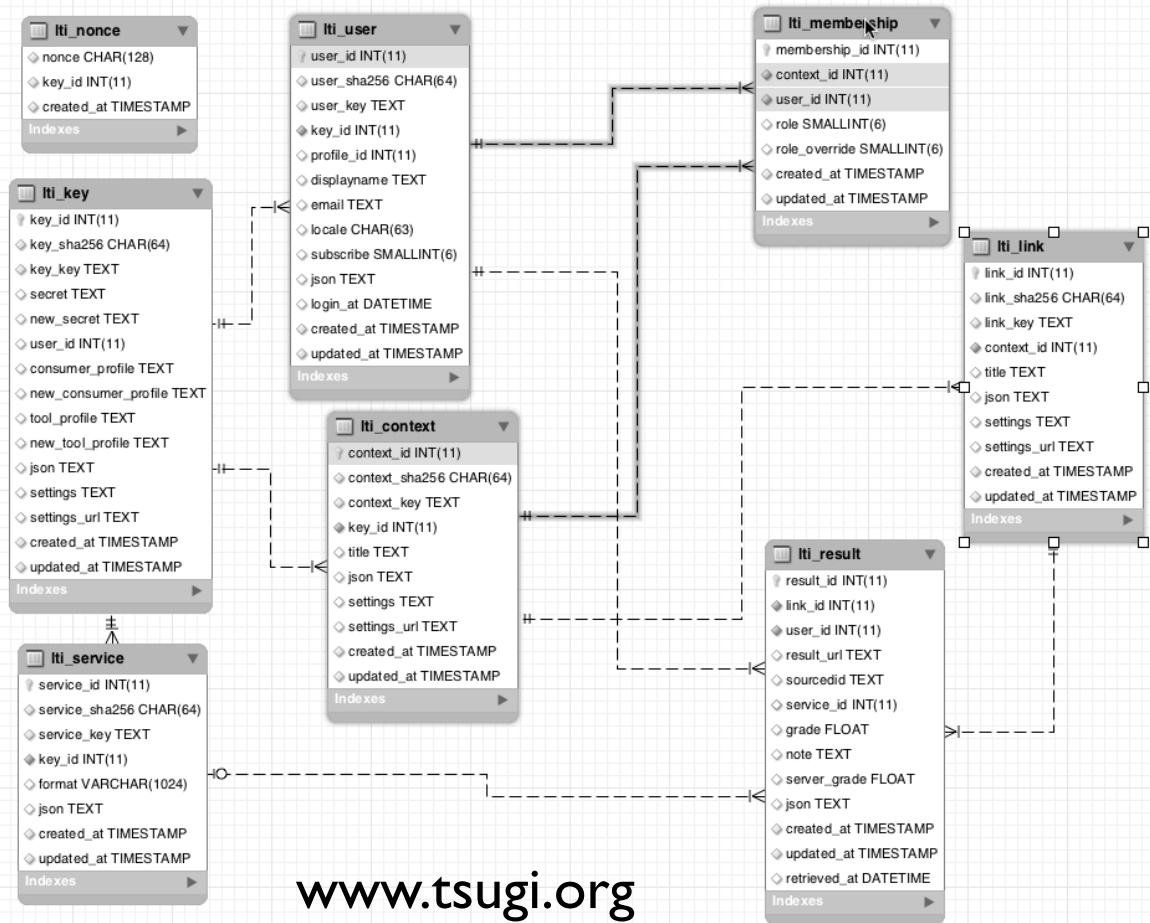
(2 rows)

# ON DELETE Choices

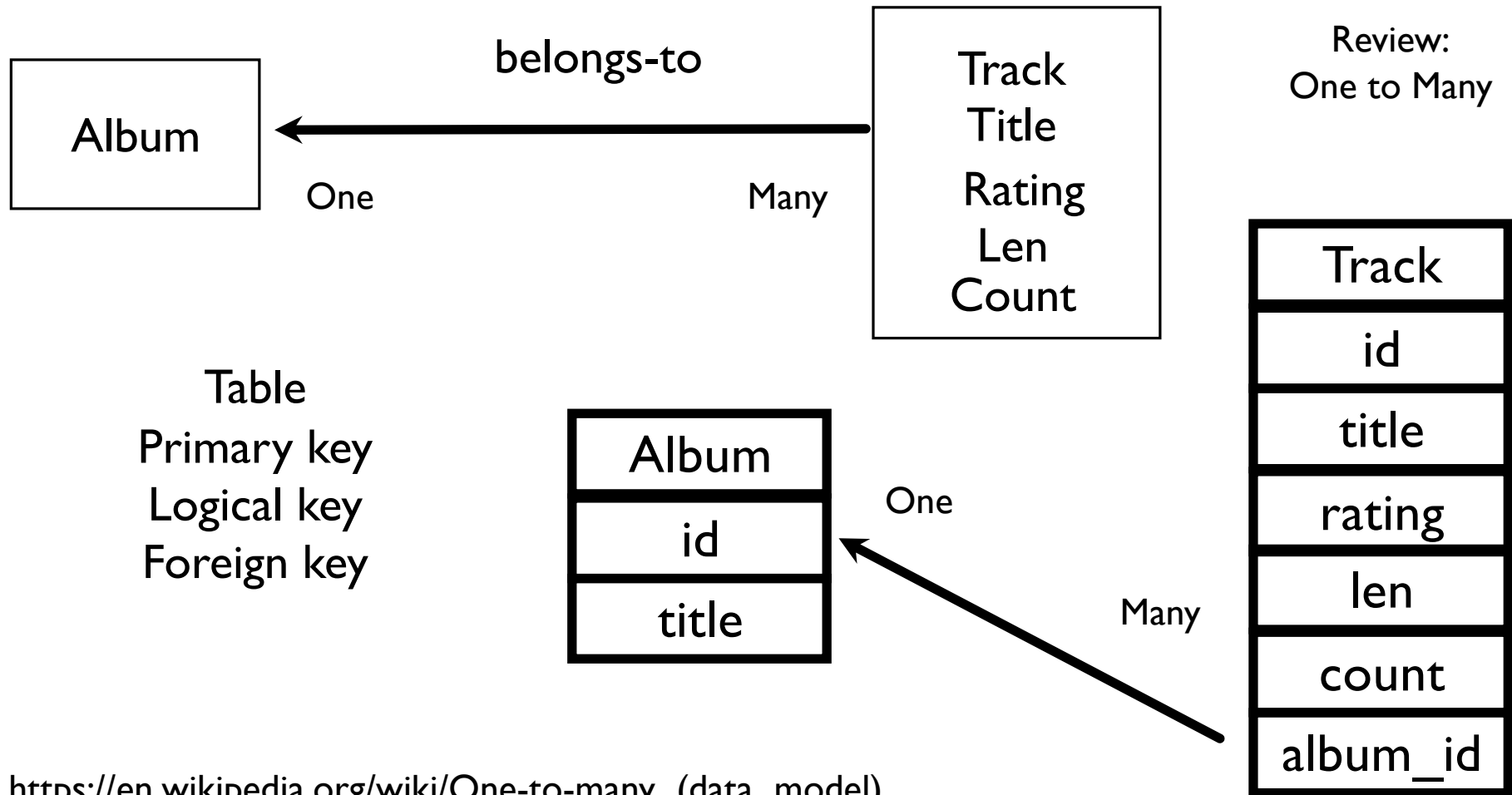
- Default / RESTRICT – Don't allow changes that break the constraint
- CASCADE – Adjust child rows by removing or updating to maintain consistency
- SET NULL – Set the foreign key columns in the child rows to null

<http://stackoverflow.com/questions/1027656/what-is-mysqls-default-on-delete-behavior>

# Many-to-Many Relationships



www.tsugi.org



[https://en.wikipedia.org/wiki/One-to-many\\_\(data\\_model\)](https://en.wikipedia.org/wiki/One-to-many_(data_model))

music=> SELECT \* FROM track;

id	title	len	rating	count	album_id	genre_id
1	Black Dog	297	5	0	2	1
2	Stairway	482	5	0	2	1
3	About to Rock	313	5	0	1	2
4	Who Made Who	207	5	0	1	2

One

Many

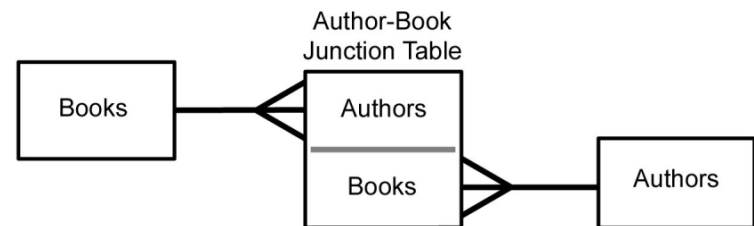
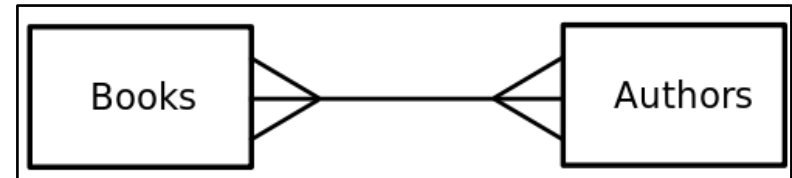
music=> SELECT \* FROM genre;

id	name
1	Rock
2	Metal

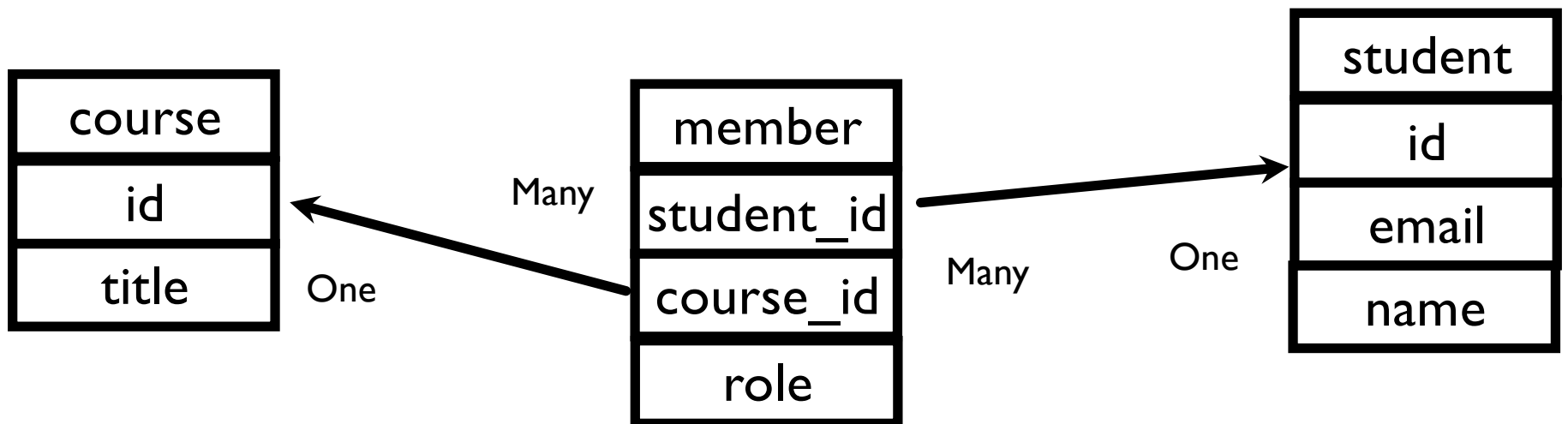
[https://en.wikipedia.org/wiki/One-to-many\\_\(data\\_model\)](https://en.wikipedia.org/wiki/One-to-many_(data_model))

# Many to Many

- Sometimes we need to model a relationship that is many to many.
- We need to add a “connection” table with two foreign keys.
- There is usually no separate primary key.





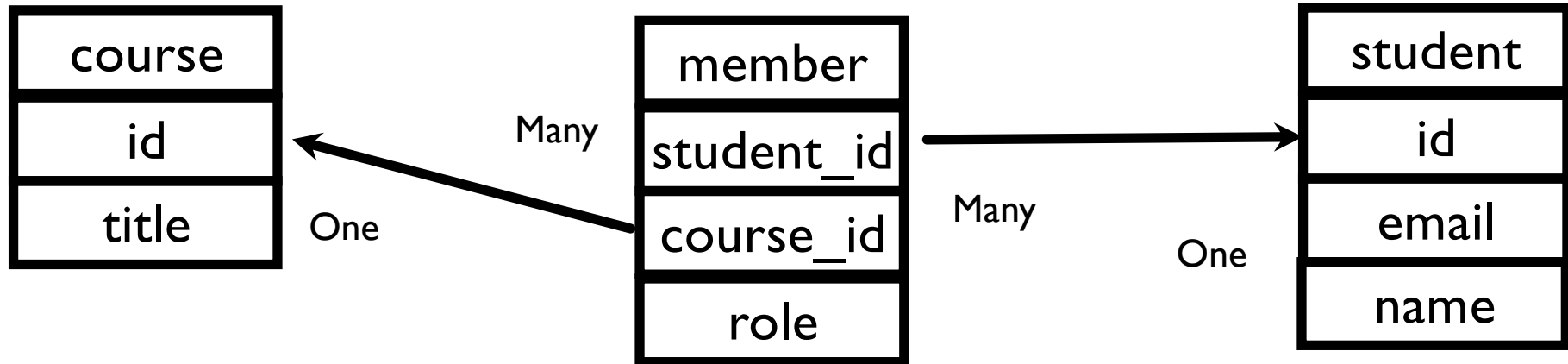


[https://en.wikipedia.org/wiki/Many-to-many\\_\(data\\_model\)](https://en.wikipedia.org/wiki/Many-to-many_(data_model))

# Start with a Fresh Database

```
CREATE TABLE student (  
    id SERIAL,  
    name VARCHAR(128),  
    email VARCHAR(128) UNIQUE,  
    PRIMARY KEY(id)  
);
```

```
CREATE TABLE course (  
    id SERIAL,  
    title VARCHAR(128) UNIQUE,  
    PRIMARY KEY(id)  
);
```



```
CREATE TABLE member (  
    student_id INTEGER REFERENCES student(id) ON DELETE CASCADE,  
    course_id  INTEGER REFERENCES course(id) ON DELETE CASCADE,  
    role       INTEGER,  
    PRIMARY KEY (student_id, course_id)  
);
```

# Insert Users and Courses

```
music=> INSERT INTO student (name, email) VALUES ('Jane', 'jane@tsugi.org');
music=> INSERT INTO student (name, email) VALUES ('Ed', 'ed@tsugi.org');
music=> INSERT INTO student (name, email) VALUES ('Sue', 'sue@tsugi.org');
music=> SELECT * FROM student;
```

id	name	email
1	Jane	jane@tsugi.org
2	Ed	ed@tsugi.org
3	Sue	sue@tsugi.org

```
music=> INSERT INTO course (title) VALUES ('Python');
music=> INSERT INTO course (title) VALUES ('SQL');
music=> INSERT INTO course (title) VALUES ('PHP');
music=> SELECT * FROM COURSE;
```

id	title
1	Python
2	SQL
3	PHP

# Insert Memberships

```
music=> SELECT * FROM student;
```

id	name	email
1	Jane	jane@tsugi.org
2	Ed	ed@tsugi.org
3	Sue	sue@tsugi.org

```
music=> SELECT * FROM course;
```

id	title
1	Python
2	SQL
3	PHP

```
INSERT INTO member (student_id, course_id, role) VALUES (1, 1, 1);
INSERT INTO member (student_id, course_id, role) VALUES (2, 1, 0);
INSERT INTO member (student_id, course_id, role) VALUES (3, 1, 0);
```

```
INSERT INTO member (student_id, course_id, role) VALUES (1, 2, 0);
INSERT INTO member (student_id, course_id, role) VALUES (2, 2, 1);
```

```
INSERT INTO member (student_id, course_id, role) VALUES (2, 3, 1);
INSERT INTO member (student_id, course_id, role) VALUES (3, 3, 0);
```

```
music=> SELECT * FROM student;
```

id	name	email
1	Jane	jane@tsugi.org
2	Ed	ed@tsugi.org
3	Sue	sue@tsugi.org

```
music=> SELECT * FROM course;
```

id	title
1	Python
2	SQL
3	PHP

```
music=> SELECT * FROM member;
```

student_id	course_id	role
1	1	1
2	1	0
3	1	0
1	2	0
2	2	1
2	3	1
3	3	0

```
music=> SELECT student.name, member.role, course.title
music-> FROM student
music-> JOIN member ON member.student_id = student.id
music-> JOIN course ON member.course_id = course. id
music-> ORDER BY course.title, member.role DESC,
student.name;
```

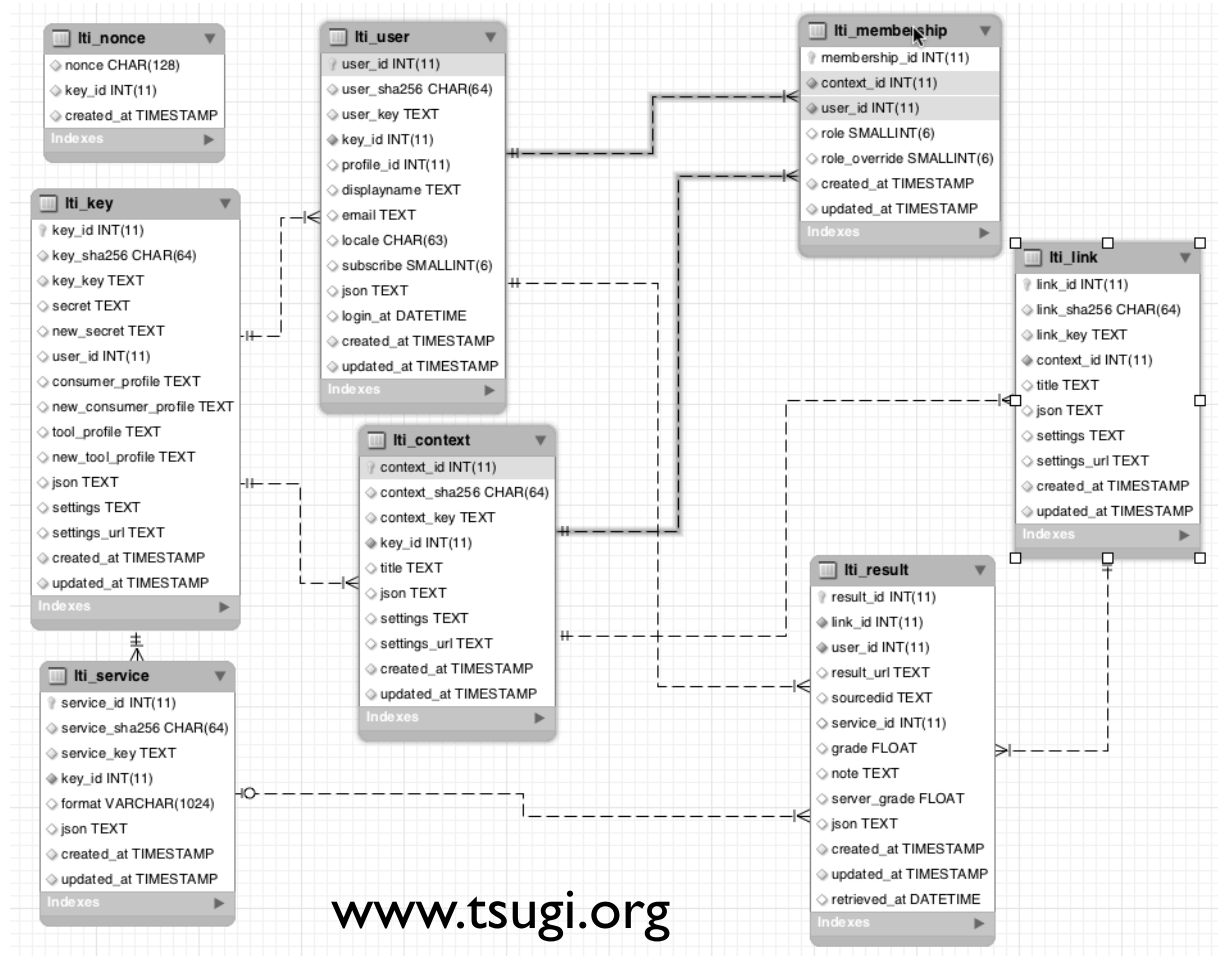
name	role	title
Ed	1	PHP
Sue	0	PHP
Jane	1	Python
Ed	0	Python
Sue	0	Python
Ed	1	SQL
Jane	0	SQL

(7 rows)



<https://www.mysql.com/products/workbench/>





www.tsugi.org

# Complexity Enables Speed

- Complexity makes speed possible and allows you to get very fast results as the data size grows.
- By normalizing the data and linking it with integer keys, the overall amount of data which the relational database must *scan* is far lower than if the data were simply flattened out.
- It might seem like a tradeoff - spend some time designing your database so it continues to be fast when your application is a success.

# Summary

- Relational databases allow us to scale to very large amounts of data.
- The key is to have one copy of any data element and use relations and joins to link the data to multiple places.
- This greatly reduces the amount of data that must be scanned when doing complex operations across large amounts of data.
- Database and SQL design is a bit of an art form.

# Acknowledgements / Contributions



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