Relational Database Design

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www.wa4e.com

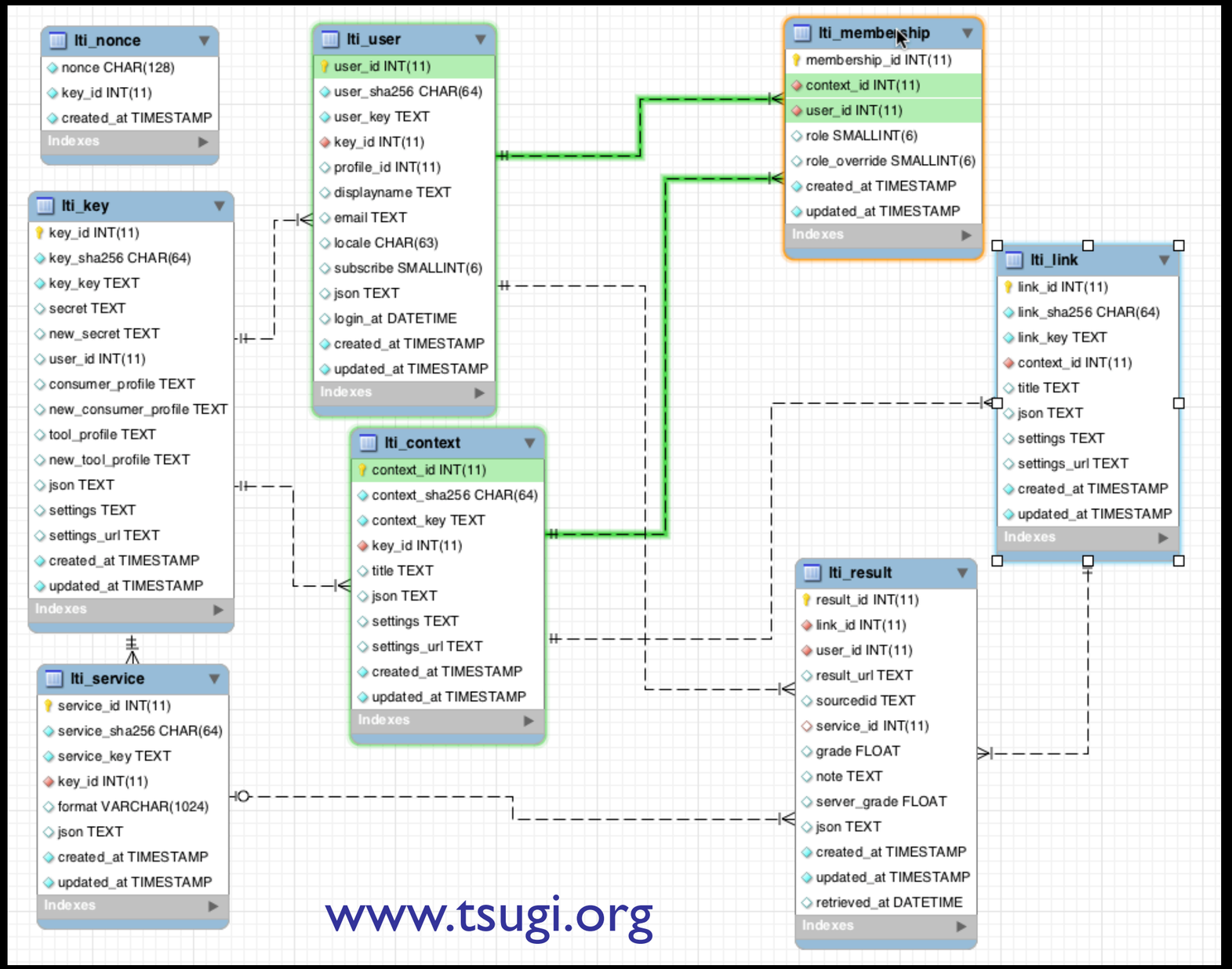
http://www.wa4e.com/lectures/SQL-02-MySQL-Design-Handout.txt

Relational Database Design

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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role_override SMALLINT(6)
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updated_at TIMESTAMP
Indexes
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key_sha256 CHAR(64)
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secret TEXT
new_secret TEXT
user_id INT(11)
consumer_profile TEXT
new_consumer_profile TEXT
tool_profile TEXT
new_tool_profile TEXT
json TEXT
settings TEXT
settings_url TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
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link_id INT(11)
link_sha256 CHAR(64)
link_key TEXT
context_id INT(11)
title TEXT
json TEXT
settings TEXT
settings_url TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
lti_context
context_id INT(11)
context_sha256 CHAR(64)
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key_id INT(11)
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json TEXT
settings TEXT
settings_url TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
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user_id INT(11)
result_url TEXT
sourcedid TEXT
service_id INT(11)
grade FLOAT
note TEXT
server_grade FLOAT
json TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
retrieved_at DATETIME
Indexes
lti_service
service_id INT(11)
service_sha256 CHAR(64)
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key_id INT(11)
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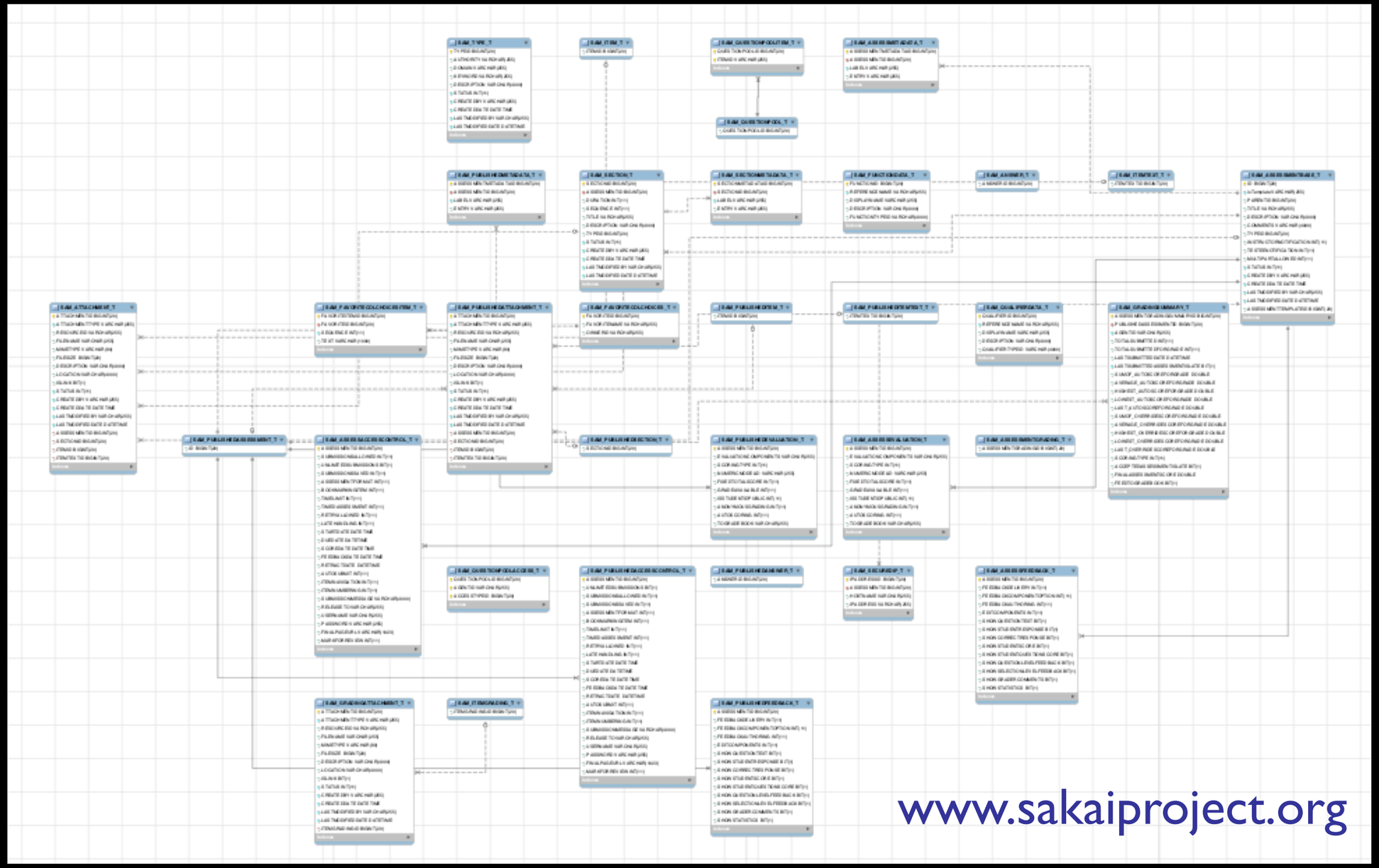
updated_at TIMESTAMP
Indexes
www.tsugi.org



www.sakaiproject.org

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

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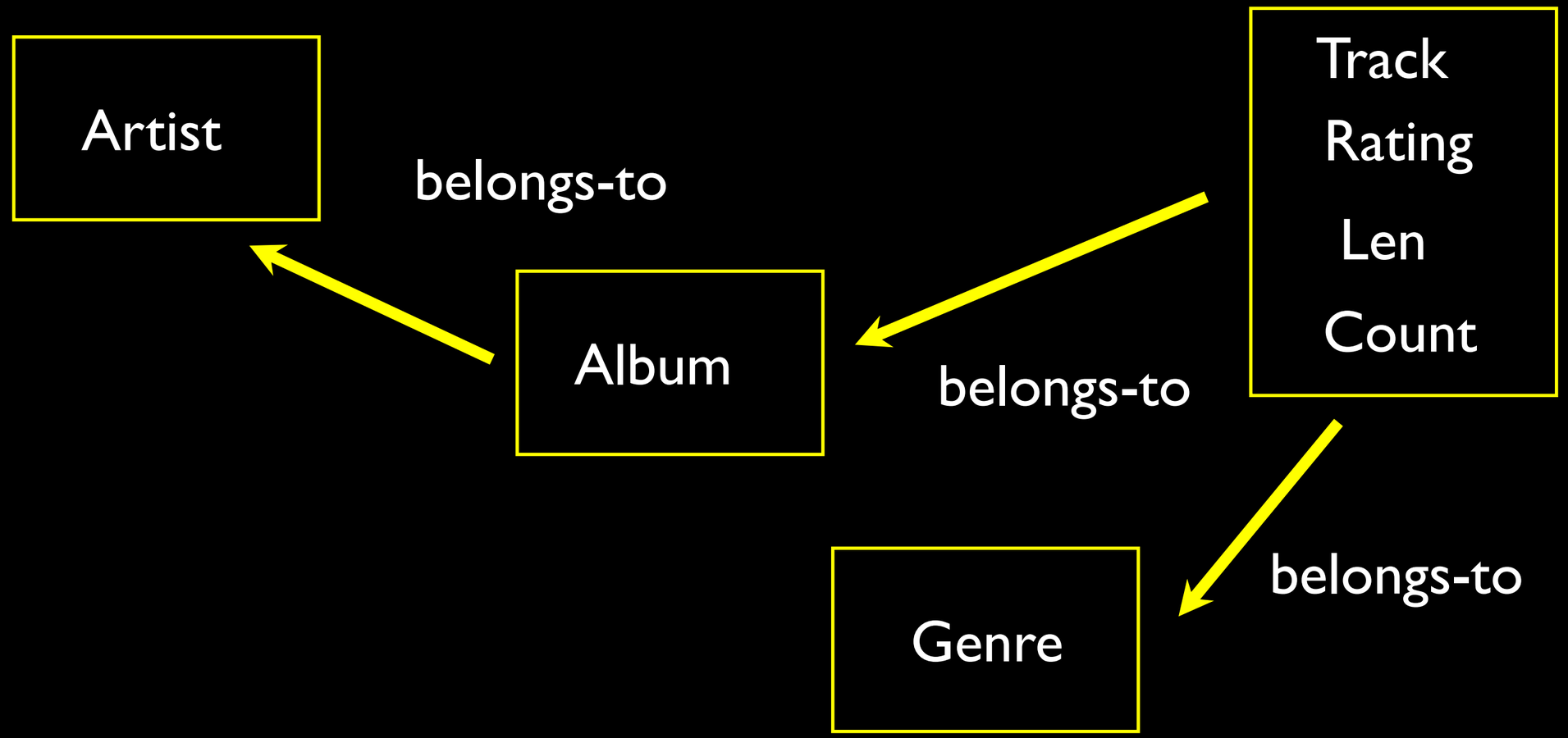
Now You Are Gone	3:08	America	Greatest Hits	Easy Listen...	★★★★★	18
Tin Man	3:30	America	Greatest Hits	Easy Listen...	★★★★★	23

Track
Album
Artist
Genre
Rating
Len
Count



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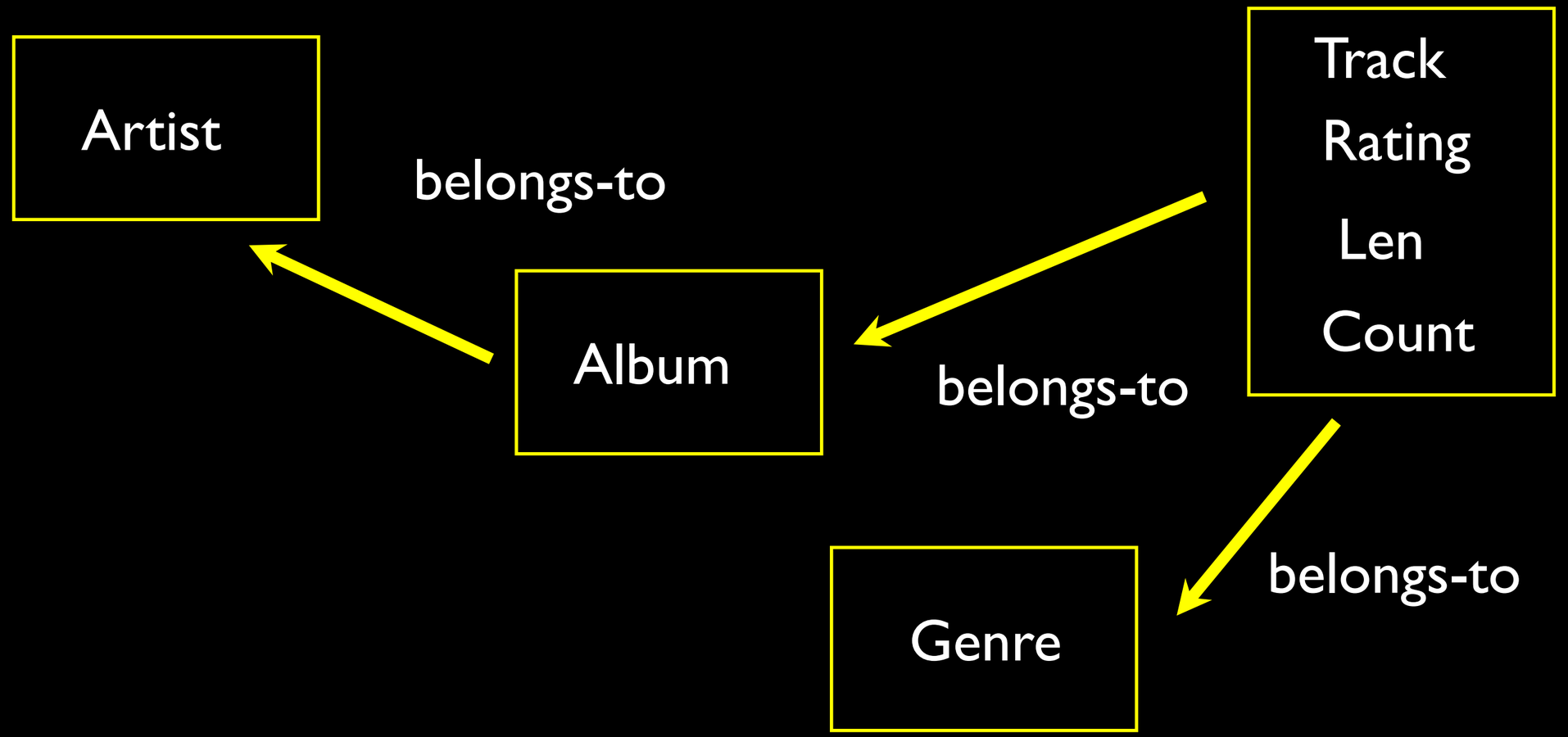

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Shake Your Foundations	3:54	AC/DC	Who Made Who	Rock	★★★★★	70
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Normalization and Foreign Keys

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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

Integer Reference Pattern

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

Artist

	artist_id	name
	1	Led Zepplin
	2	AC/DC

Album

	album_id	title	artist_id
	1	Who Made Who	2
	2	IV	1

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

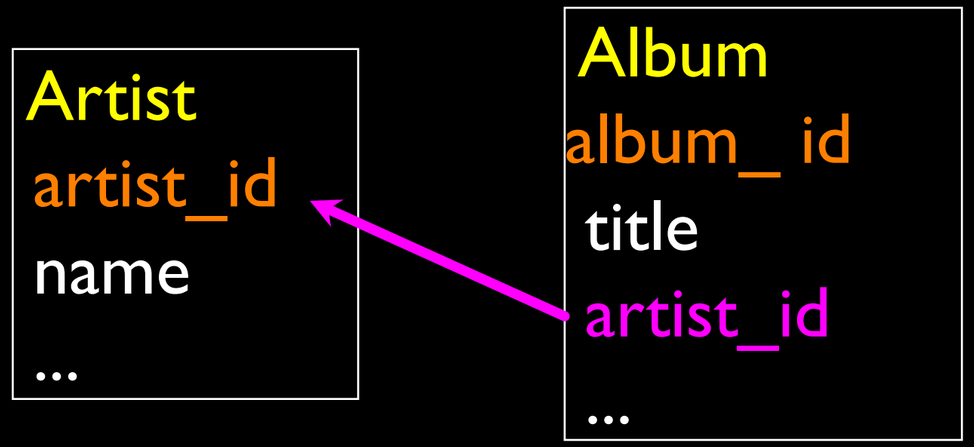
Best practices:

- 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.

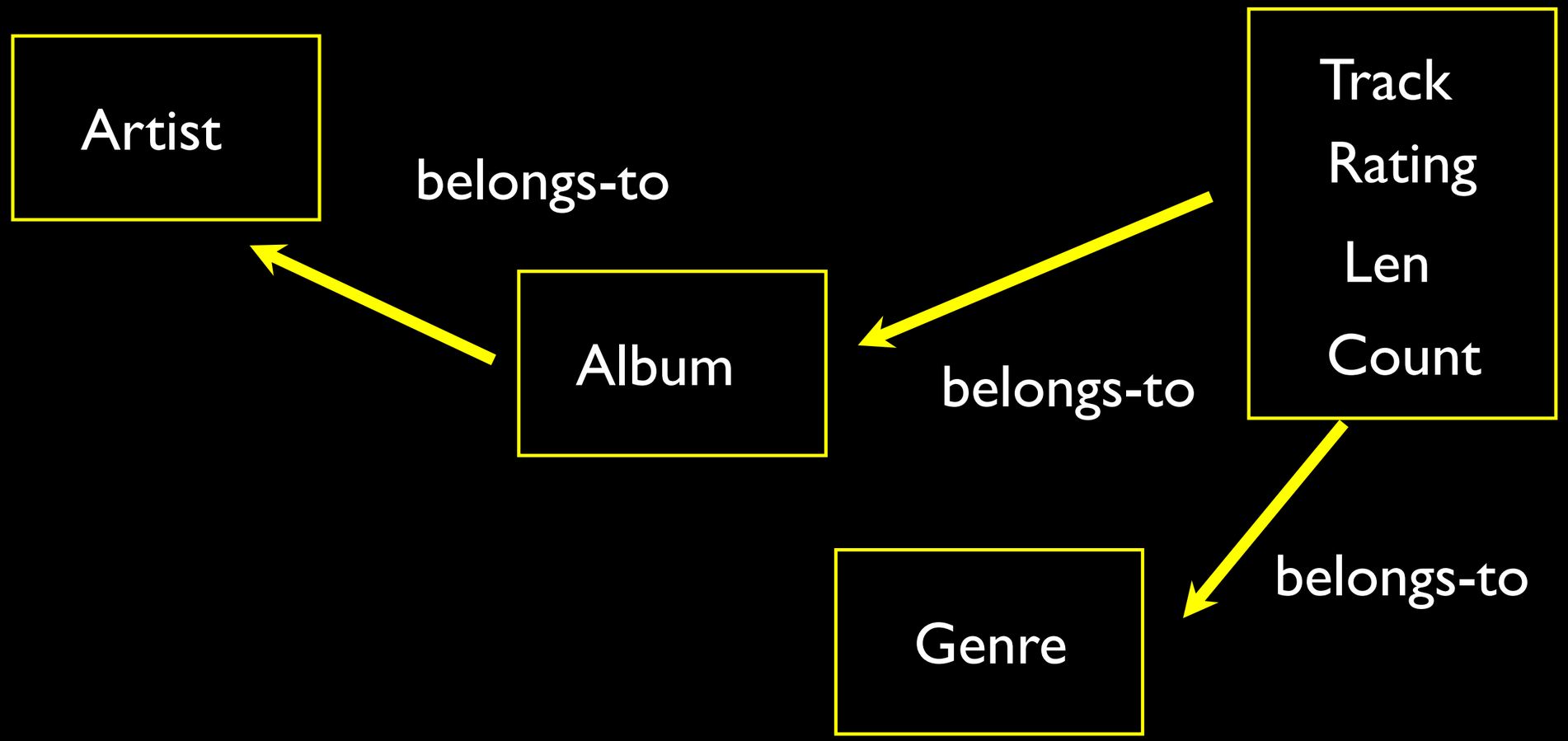
User
user_id
email
password
name
created_at
modified_at
login_at

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.



Building a Physical Data Schema



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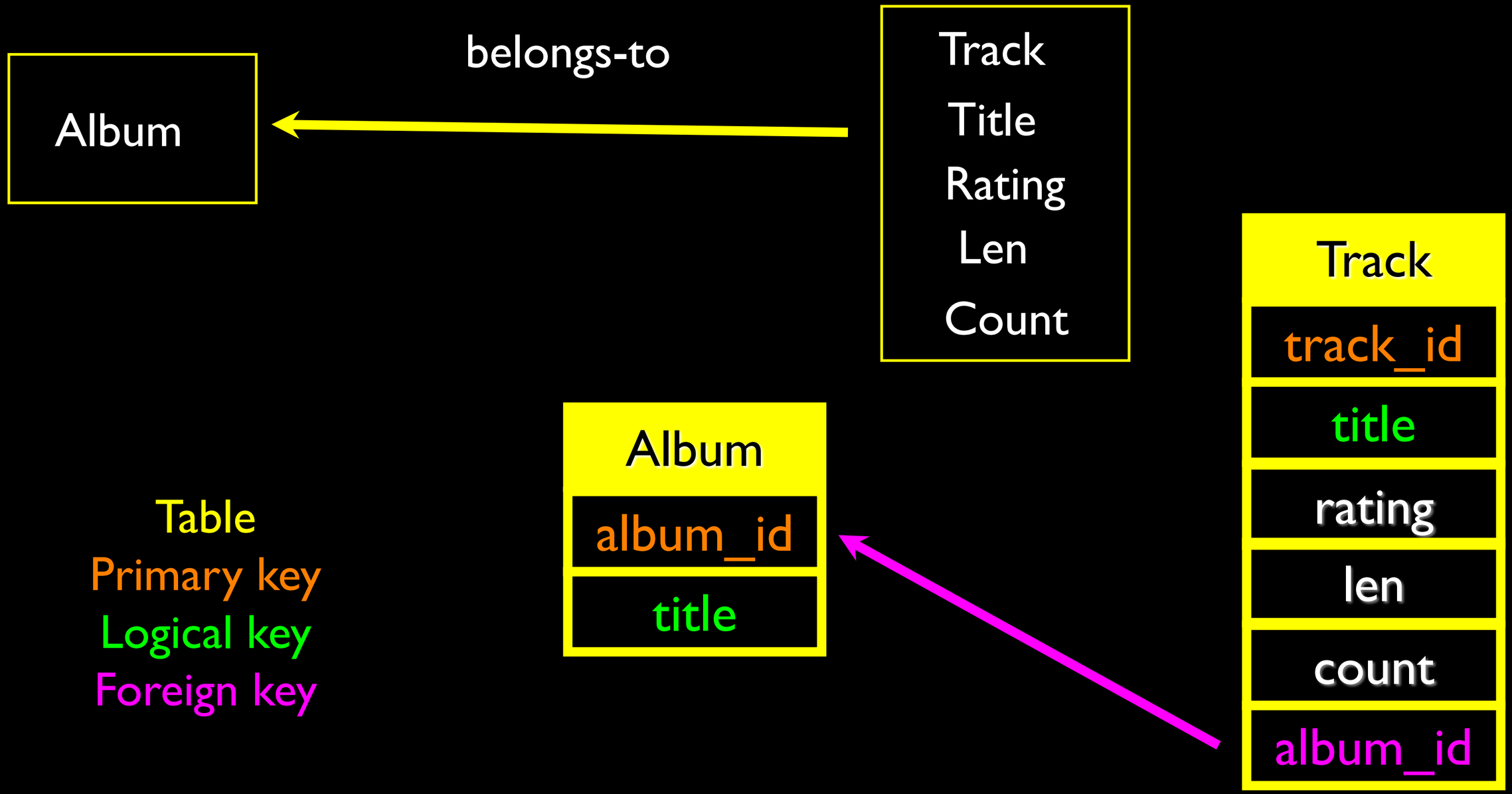
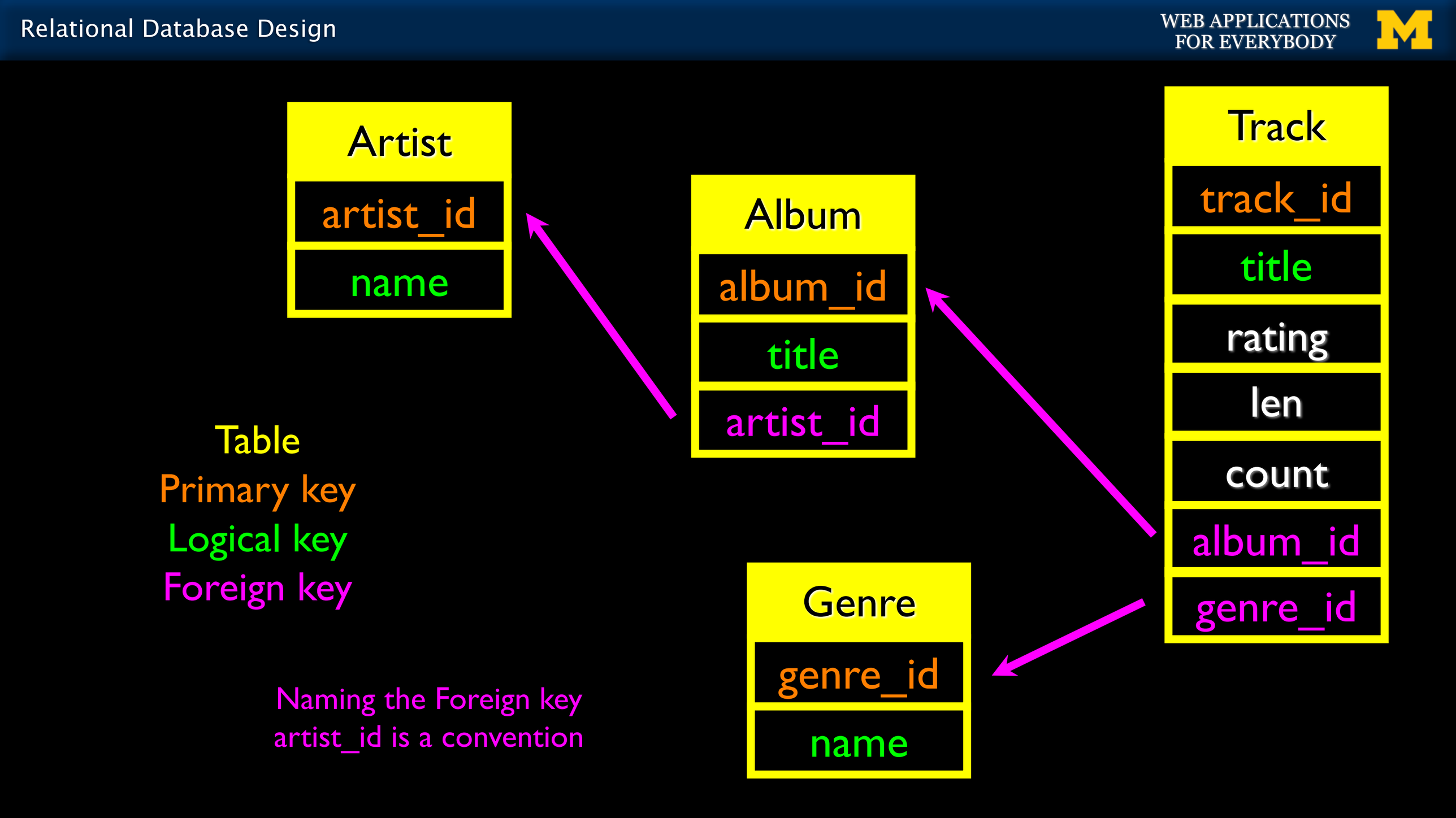

Album
belongs-to
Track
Title
Rating
Len
Count
Table
Primary key
Logical key
Foreign key
Album
album_id
title
Track
track_id
title
rating
len
count
album_id

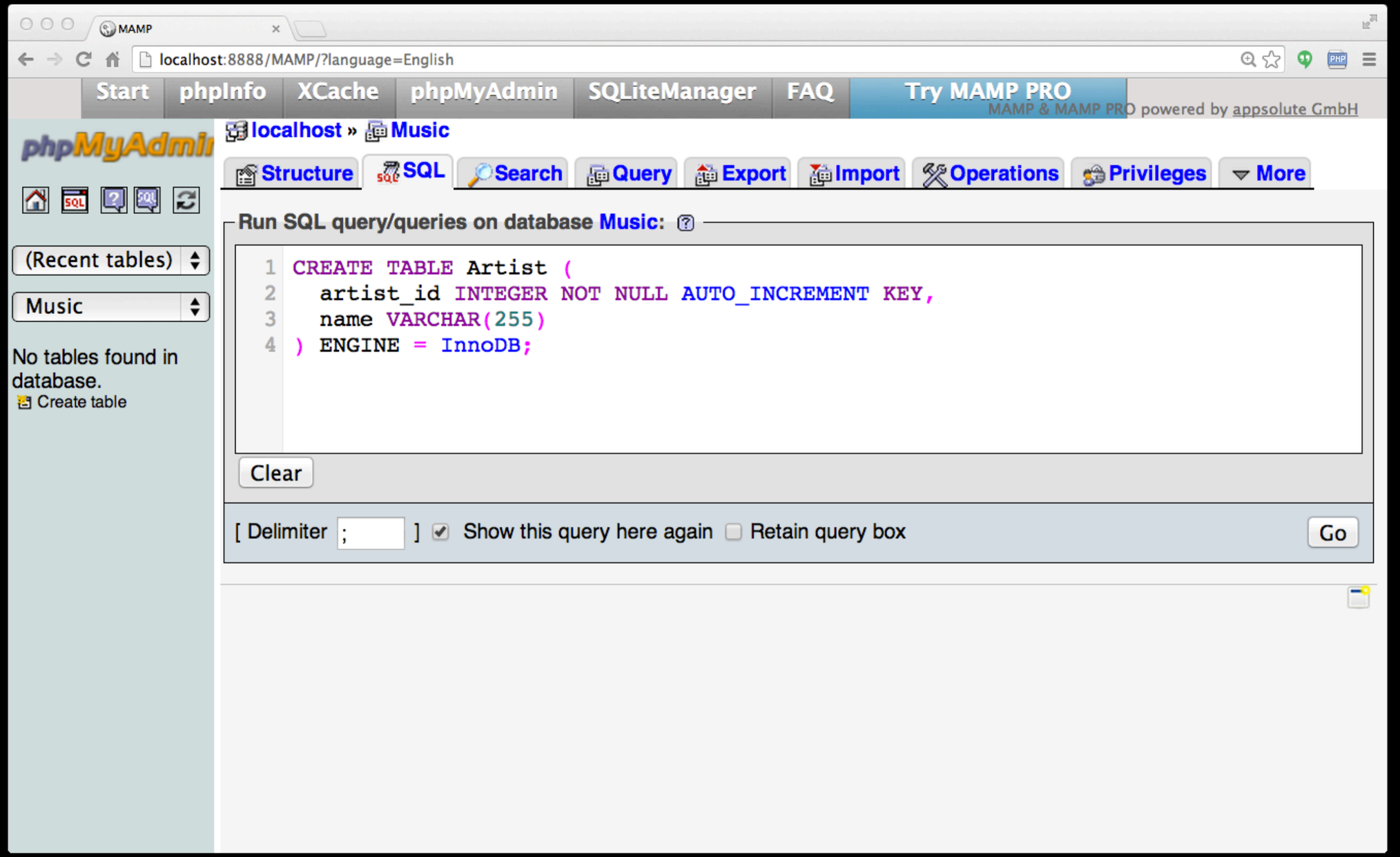

Artist
artist_id
name
Album
album_id
title
artist_id
Track
track_id
title
rating
len
count
album_id
genre_id
Genre
genre_id
name
Table
Primary key
Logical key
Foreign key
Naming the Foreign key
artist_id is a convention

Creating our Music Database

```
CREATE DATABASE Music
    DEFAULT CHARACTER SET utf8;

USE Music;
```

```
CREATE TABLE Artist (
  artist_id INTEGER NOT NULL AUTO_INCREMENT PRIMARY KEY,
  name VARCHAR(255)
) ENGINE = InnoDB;

CREATE TABLE Album (
  album_id INTEGER NOT NULL AUTO_INCREMENT PRIMARY KEY,
  title VARCHAR(255),
  artist_id INTEGER,

  INDEX USING BTREE (title),

  CONSTRAINT FOREIGN KEY (artist_id)
    REFERENCES Artist (artist_id)
    ON DELETE CASCADE ON UPDATE CASCADE
) ENGINE = InnoDB;
```

```
CREATE TABLE Genre (
  genre_id INTEGER NOT NULL AUTO_INCREMENT PRIMARY KEY,
  name VARCHAR(255),
  INDEX USING BTREE (name)
) ENGINE = InnoDB;

CREATE TABLE Track (
  track_id INTEGER NOT NULL AUTO_INCREMENT PRIMARY KEY,
  title VARCHAR(255),
  len INTEGER,
  rating INTEGER,
  count INTEGER,
  album_id INTEGER,
  genre_id INTEGER,

  INDEX USING BTREE (title),

  CONSTRAINT FOREIGN KEY (album_id) REFERENCES Album (album_id)
    ON DELETE CASCADE ON UPDATE CASCADE,
  CONSTRAINT FOREIGN KEY (genre_id) REFERENCES Genre (genre_id)
    ON DELETE CASCADE ON UPDATE CASCADE
) ENGINE = InnoDB;
```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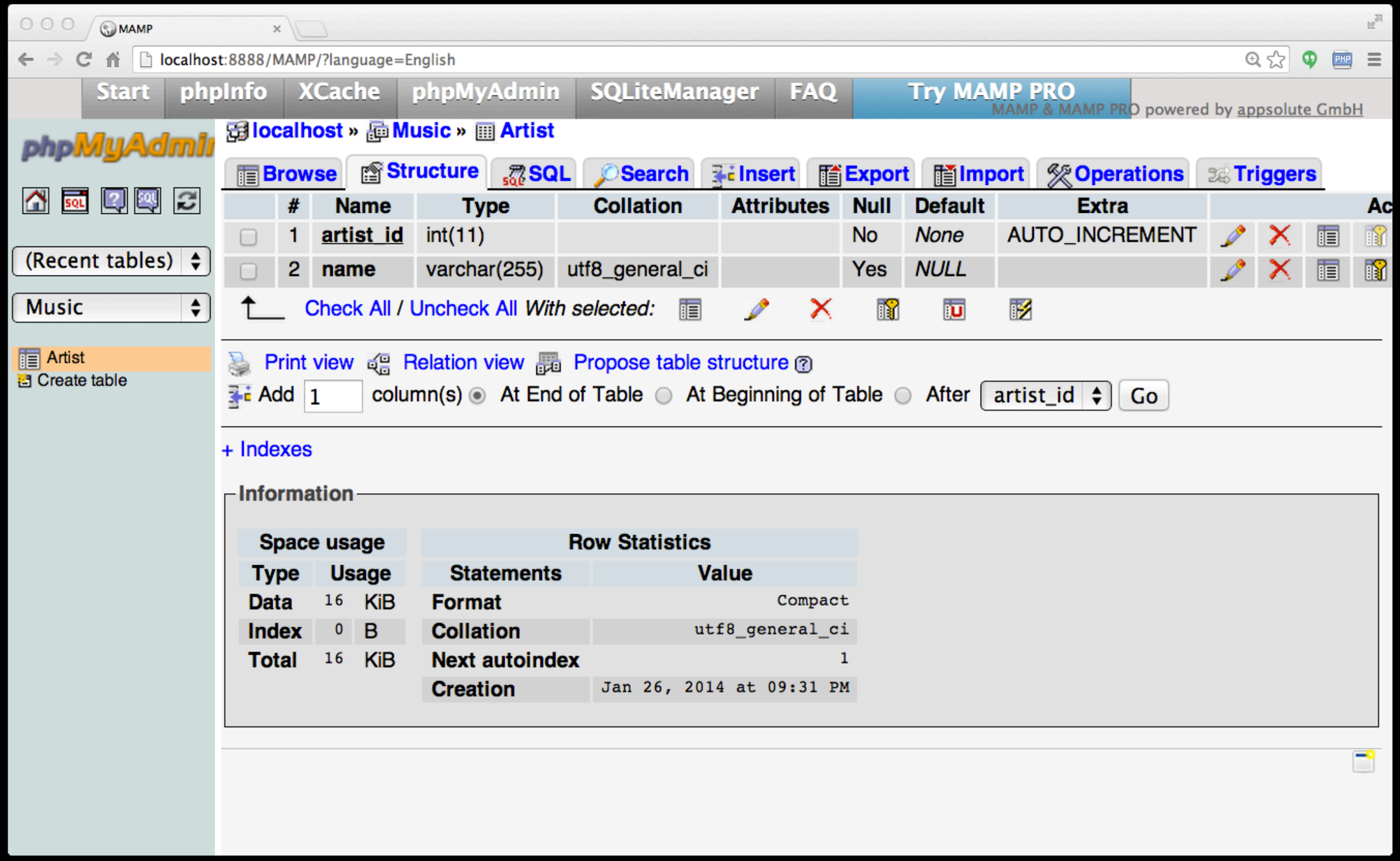
localhost:8888/MAMP/?language=English
Start
phpInfo
XCache
phpMyAdmin
SQLiteManager
FAQ
Try MAMP PRO
MAMP & MAMP PRO powered by appsolute GmbH
phpMyAdmin
localhost » Music
Structure
SQL
Search
Query
Export
Import
Operations
Privileges
More
(Recent tables)
Music
No tables found in database.
Create table
Run SQL query/queries on database Music:
1 CREATE TABLE Artist (
2 artist_id INTEGER NOT NULL AUTO_INCREMENT KEY,
3 name VARCHAR(255)
4) ENGINE = InnoDB;
Clear
[Delimiter ;]
Show this query here again
Retain query box
Go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Try MAMP PRO
MAMP & MAMP PRO powered by appsolute GmbH
phpMyAdmin
localhost » Music » Artist
Browse
Structure
SQL
Search
Insert
Export
Import
Operations
Triggers
Name Type Collation Attributes Null Default Extra
1 artist_id int(11) No None AUTO_INCREMENT
2 name varchar(255) utf8_general_ci Yes NULL
Check All / Uncheck All With selected:
(Recent tables)
Music
Artist
Create table
Print view
Relation view
Propose table structure
Add 1 column(s) At End of Table At Beginning of Table After artist_id Go
+ Indexes
Information
Space usage
Type Usage
Data 16 KiB
Index 0 B
Total 16 KiB
Row Statistics
Statements Value
Format Compact
Collation utf8_general_ci
Next autoindex 1
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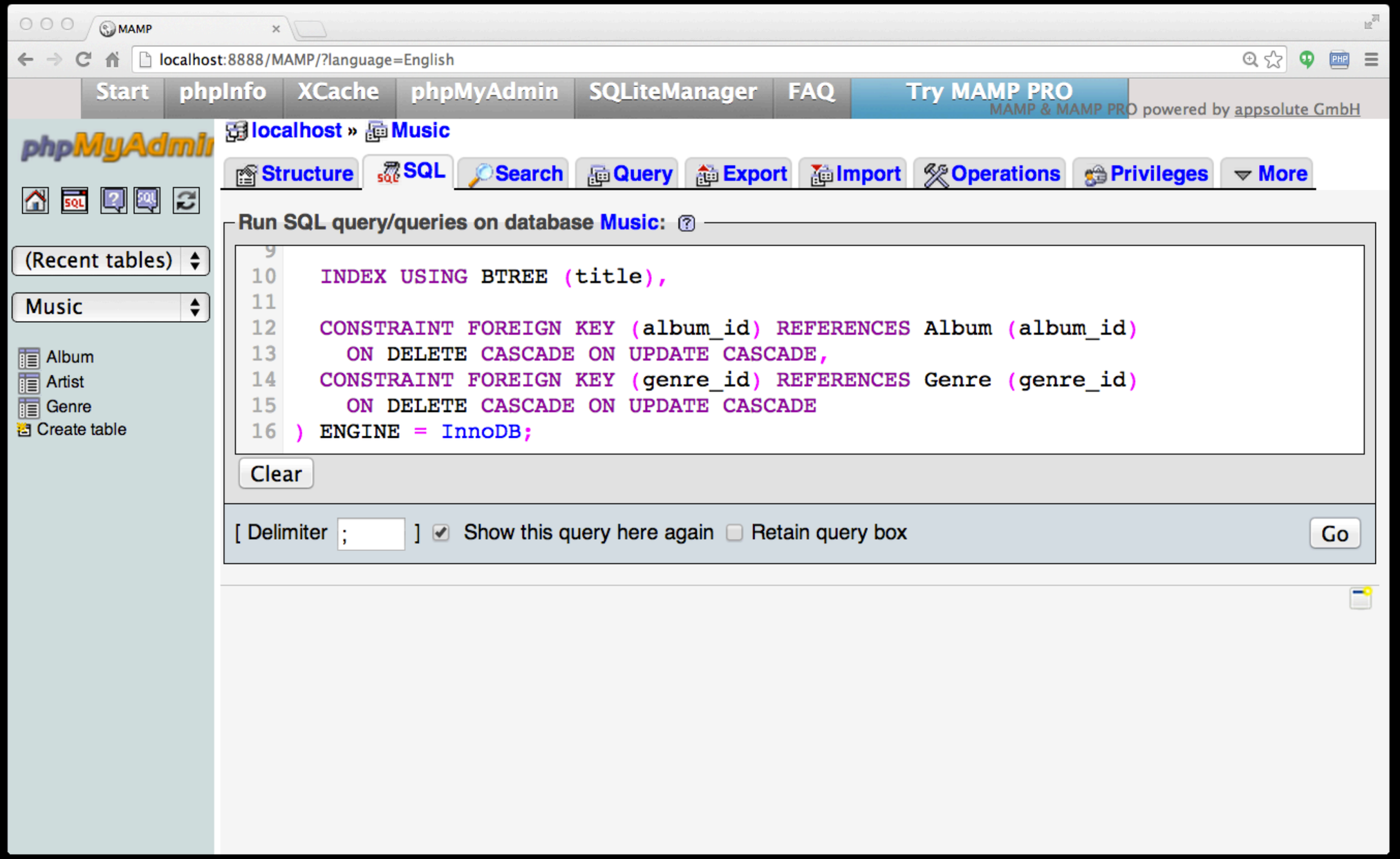
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Structure
SQL
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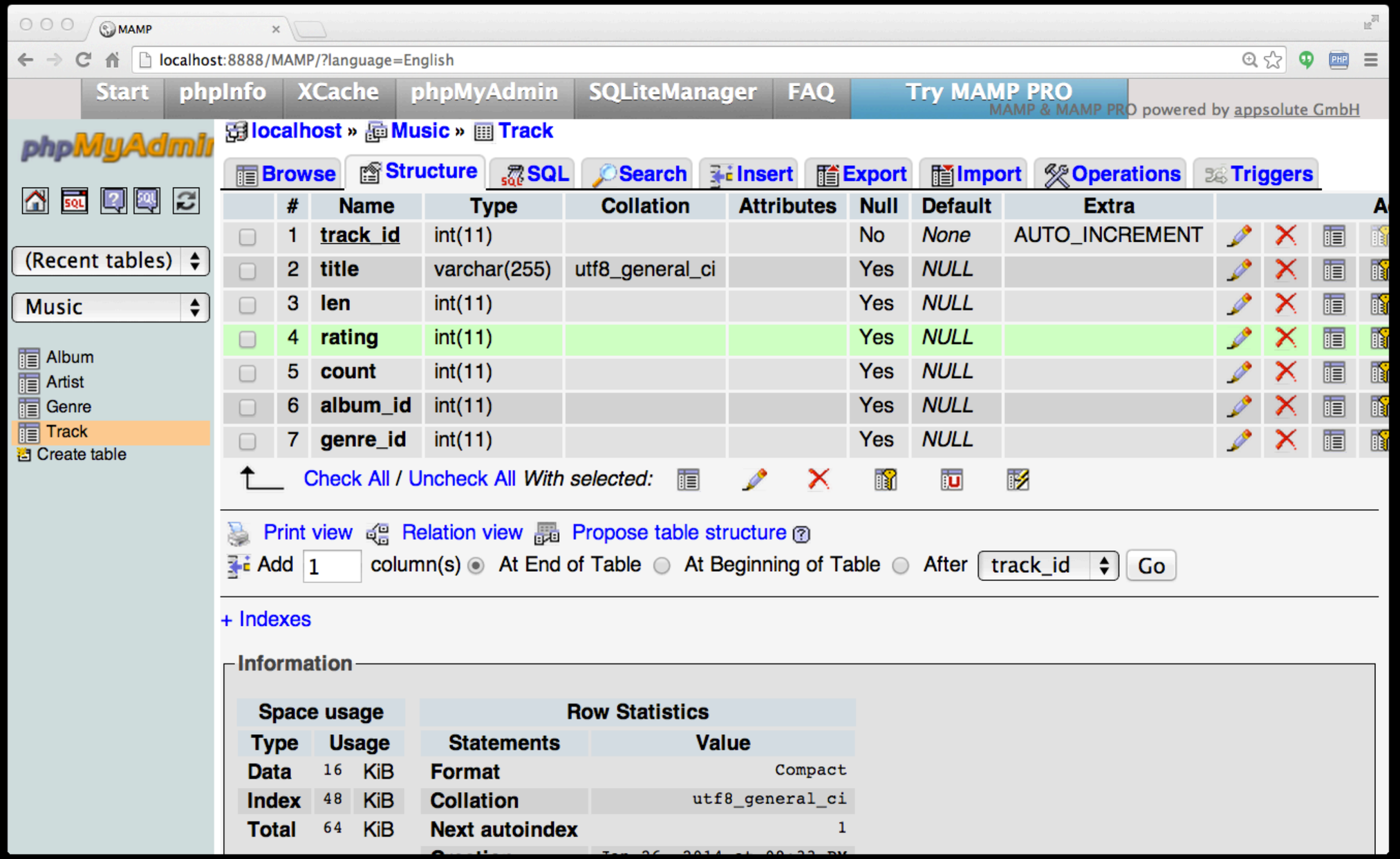
Operations
Privileges
More
(Recent tables)
Music
Album
Artist
Genre
Create table
Run SQL query/queries on database Music:
INDEX USING BTREE (title),
CONSTRAINT FOREIGN KEY (album_id) REFERENCES Album (album_id)
ON DELETE CASCADE ON UPDATE CASCADE,
CONSTRAINT FOREIGN KEY (genre_id) REFERENCES Genre (genre_id)
ON DELETE CASCADE ON UPDATE CASCADE
) ENGINE = InnoDB;
Clear
[Delimiter ;] Show this query here again Retain query box
Go


MAMP
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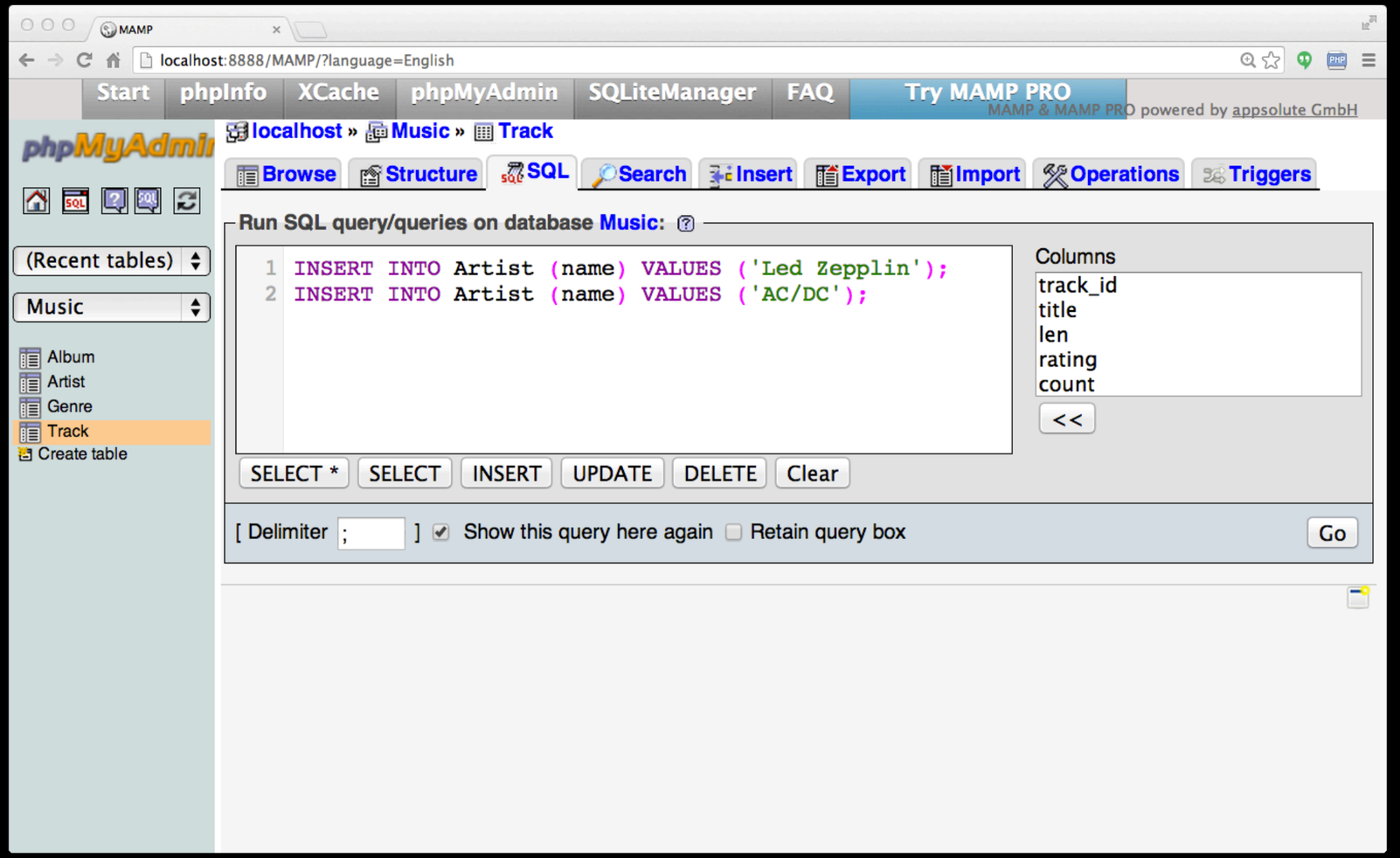
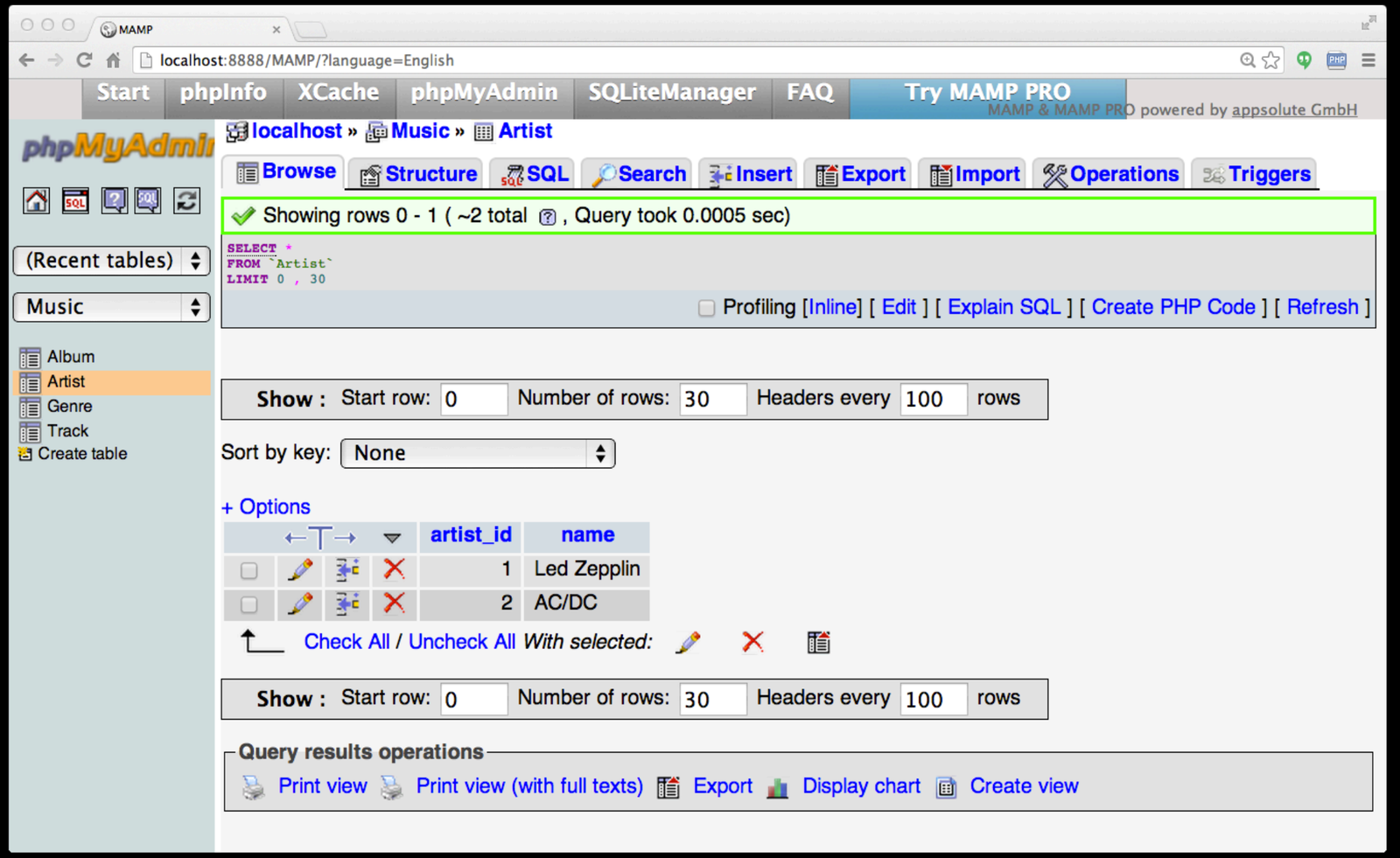
SQLiteManager
FAQ
Try MAMP PRO
MAMP & MAMP PRO powered by appsolute GmbH
phpMyAdmin
(Recent tables)
Music
Album
Artist
Genre
Track
Create table
localhost » Music » Track
Browse
Structure
SQL
Search
Insert
Export
Import
Operations
Triggers
Name Type Collation Attributes Null Default Extra
1 track_id int(11) No None AUTO_INCREMENT
2 title varchar(255) utf8_general_ci Yes NULL
3 len int(11) Yes NULL
4 rating int(11) Yes NULL
5 count int(11) Yes NULL
6 album_id int(11) Yes NULL
7 genre_id int(11) Yes NULL
Check All / Uncheck All With selected:
Print view
Relation view
Propose table structure
Add 1 column(s) At End of Table At Beginning of Table After track_id Go
+ Indexes
Information
Space usage
Type Usage
Data 16 KiB
Index 48 KiB
Total 64 KiB
Row Statistics
Statements Value
Format Compact
Collation utf8_general_ci
Next autoindex 1



INSERT INTO Artist (name) VALUES ('Led Zepplin');
INSERT INTO Artist (name) VALUES ('AC/DC');

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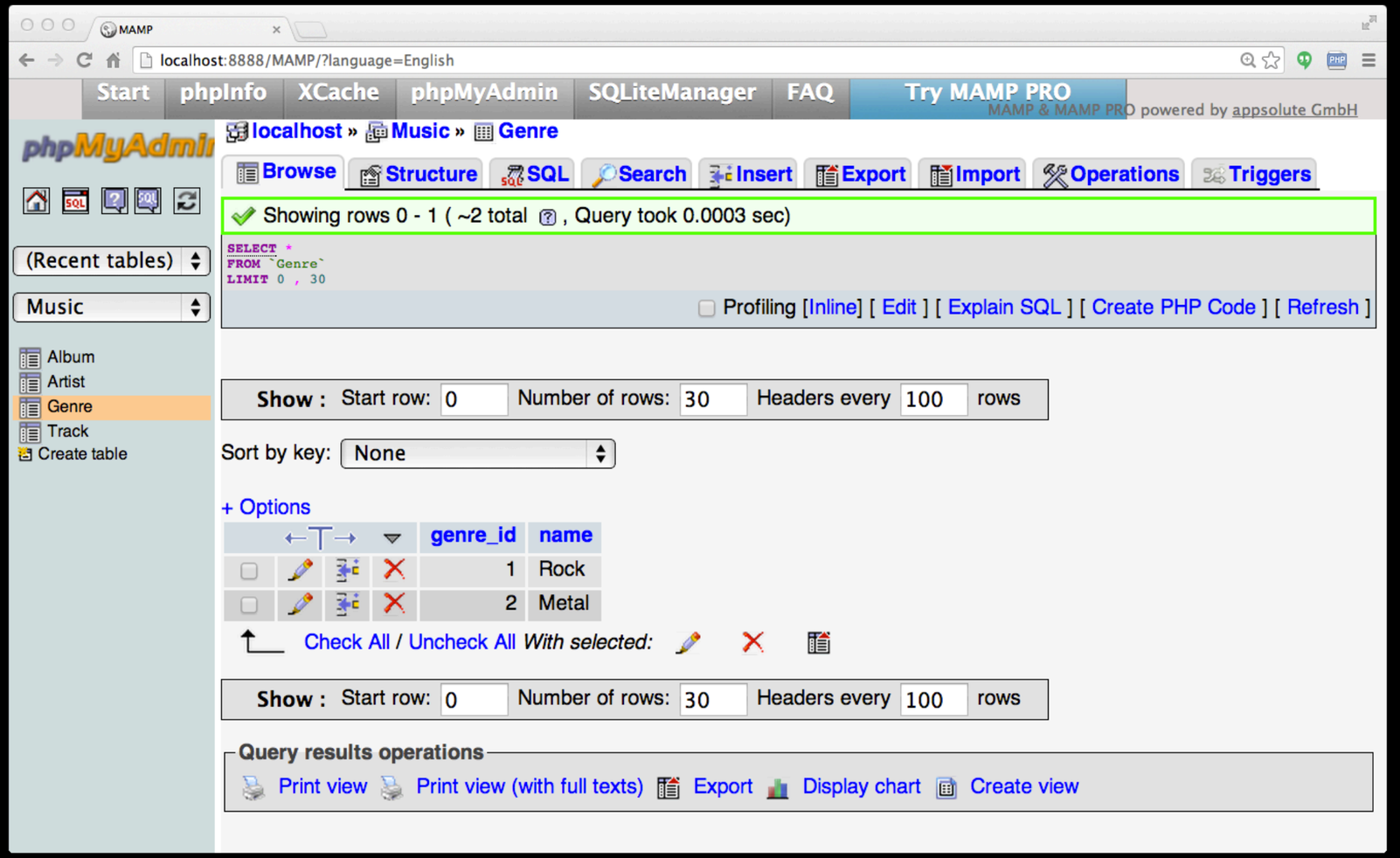
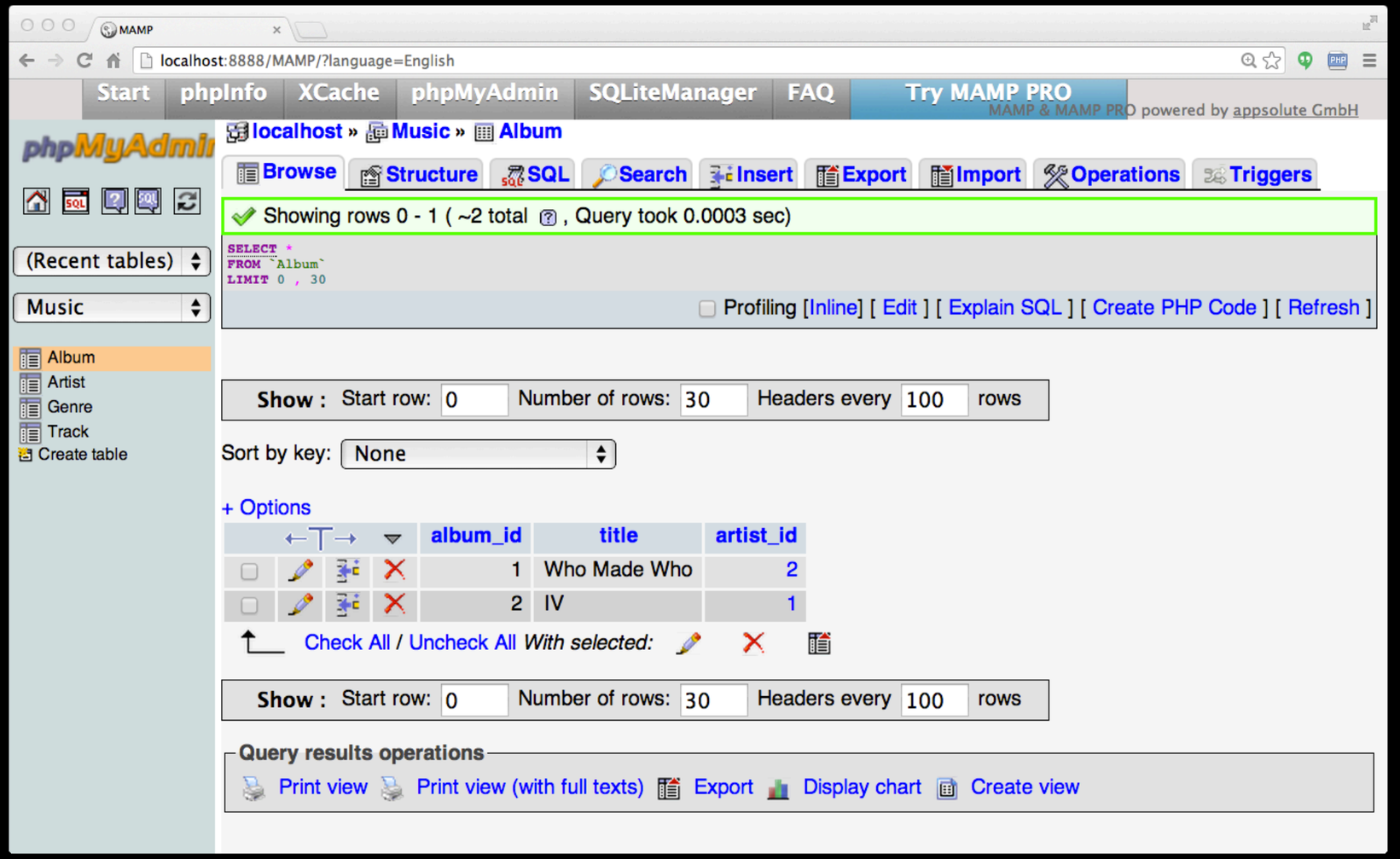



```
INSERT INTO Genre (name) VALUES ('Rock');
INSERT INTO Genre (name) VALUES ('Metal');
```




```
INSERT INTO Album (title, artist_id) VALUES ('Who Made Who', 2);
INSERT INTO Album (title, artist_id) VALUES ('IV', 1);
```

```
INSERT INTO Track
  (title, rating, len, count, album_id, genre_id)
  VALUES ('Black Dog', 5, 297, 0, 2, 1);
INSERT INTO Track
  (title, rating, len, count, album_id, genre_id)
  VALUES ('Stairway', 5, 482, 0, 2, 1);
INSERT INTO Track
  (title, rating, len, count, album_id, genre_id)
  VALUES ('About to Rock', 5, 313, 0, 1, 2);
INSERT INTO Track
  (title, rating, len, count, album_id, genre_id)
  VALUES ('Who Made Who', 5, 207, 0, 1, 2);
```

	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

We Have Relationships!

Track

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

Album

album_id	title	artist_id
1	Who Made Who	2
2	IV	1

Genre

genre_id	name
1	Rock
2	Metal

Artist

artist_id	name
1	Led Zepplin
2	AC/DC

Using Join Across Tables

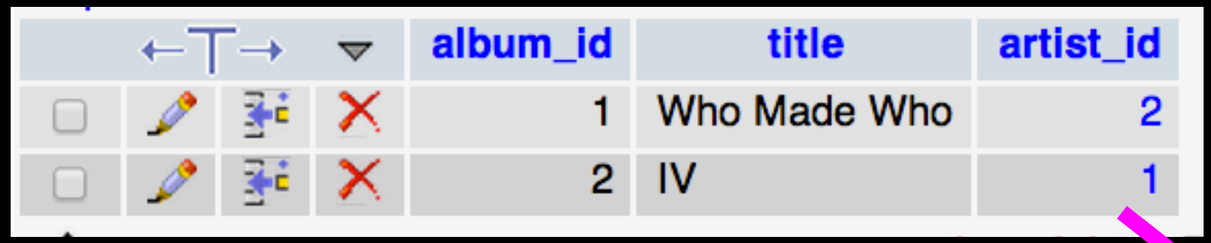
http://en.wikipedia.org/wiki/Join_(SQL)

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.



album_id	title	artist_id
1	Who Made Who	2
2	IV	1

artist_id	name
1	Led Zepplin
2	AC/DC

title	name
IV	Led Zepplin
Who Made Who	AC/DC

The tables that hold the data

```
SELECT Album.title, Artist.name FROM Album JOIN Artist ON
Album.artist_id = Artist.artist_id
```

What we want to see

How the tables are linked

album_id	title	artist_id
1	Who Made Who	2
2	IV	1

artist_id	name
1	Led Zepplin
2	AC/DC

Album.title Album.artist_id Artist.artist_id Artist.name

title	artist_id	artist_id	name
IV	1	1	Led Zepplin
Who Made Who	2	2	AC/DC

```
SELECT Album.title, Album.artist_id, Artist.artist_id, Artist.name
FROM Album JOIN Artist ON Album.artist_id = Artist.artist_id
```

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

```
SELECT Track.title,
    Track.genre_id,
    Genre.genre_id,
   Genre.name
FROM Track JOIN Genre
```

Joining two tables without an ON clause gives all possible combinations of rows.

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

genre_id	name
1	Rock
2	Metal

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

SELECT Track.title, Genre.name FROM Track JOIN Genre
ON Track.genre_id = Genre.genre_id

It Can Get Complex...

```
SELECT Track.title, Artist.name, Album.title, Genre.name
FROM Track JOIN Genre JOIN Album JOIN Artist ON
Track.genre_id = Genre.genre_id AND Track.album_id =
Album.album_id AND Album.artist_id = Artist.artist_id
```

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

What we want to see

The tables that hold the data

How the tables are linked

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

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

ON DELETE CASCADE

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

Child

We are telling MySQL to "clean up" broken references

genre_id	name
1	Rock
2	Metal

Parent

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

ON DELETE CASCADE

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

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

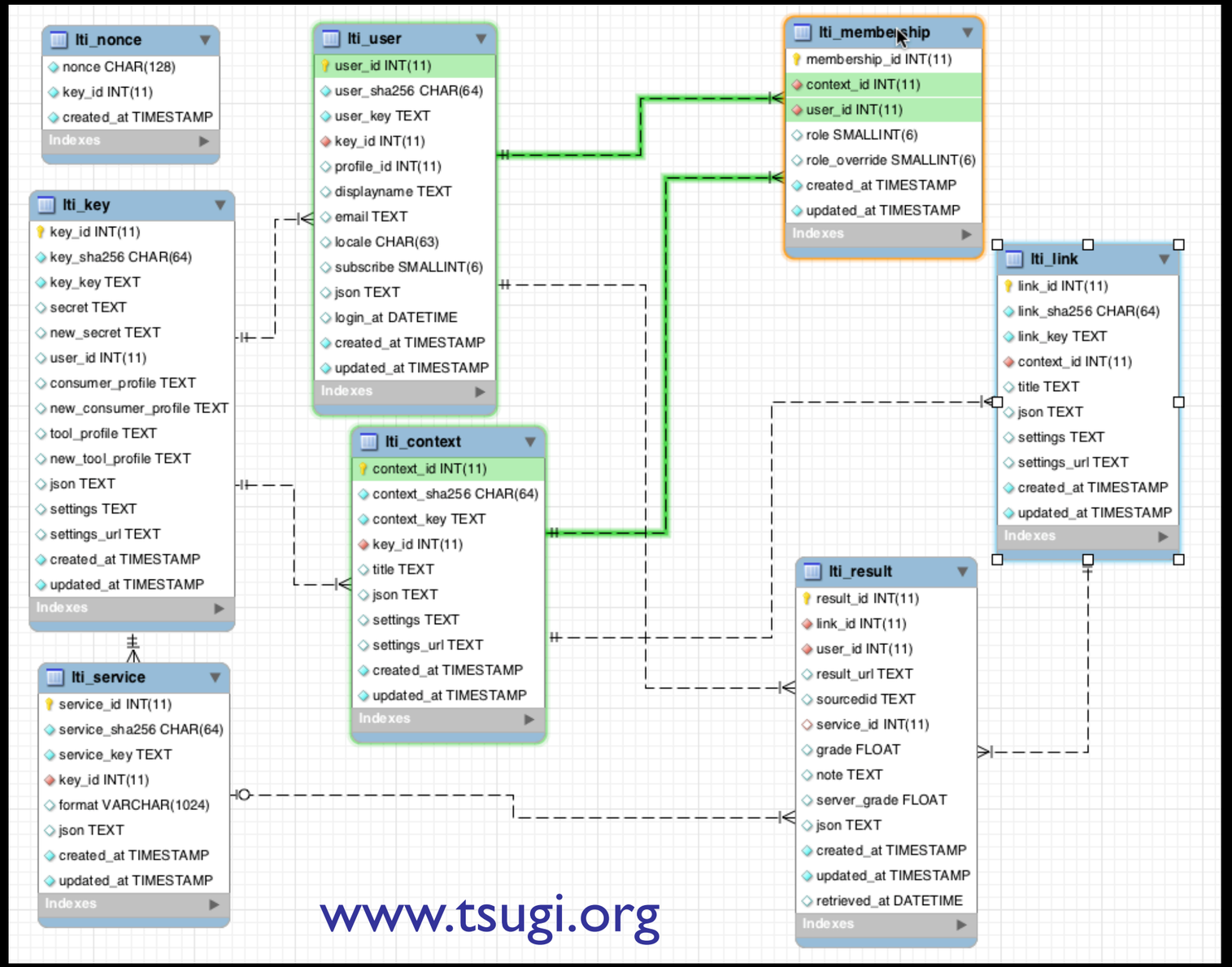
track_id	title	len	rating	count	album_id	genre_id
1	Black Dog	297	5	0	2	1
2	Stairway	482	5	0	2	1

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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Indexes
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user_id INT(11)
user_sha256 CHAR(64)
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profile_id INT(11)
displayname TEXT
email TEXT
locale CHAR(63)
subscribe SMALLINT(6)
json TEXT
login_at DATETIME
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
lti_membership
membership_id INT(11)
context_id INT(11)
user_id INT(11)
role SMALLINT(6)
role_override SMALLINT(6)
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
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key_id INT(11)
key_sha256 CHAR(64)
key_key TEXT
secret TEXT
new_secret TEXT
user_id INT(11)
consumer_profile TEXT
new_consumer_profile TEXT
tool_profile TEXT
new_tool_profile TEXT
json TEXT
settings TEXT
settings_url TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
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link_id INT(11)
link_sha256 CHAR(64)
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context_id INT(11)
title TEXT
json TEXT
settings TEXT
settings_url TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
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context_sha256 CHAR(64)
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key_id INT(11)
title TEXT
json TEXT
settings TEXT
settings_url TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
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result_id INT(11)
link_id INT(11)
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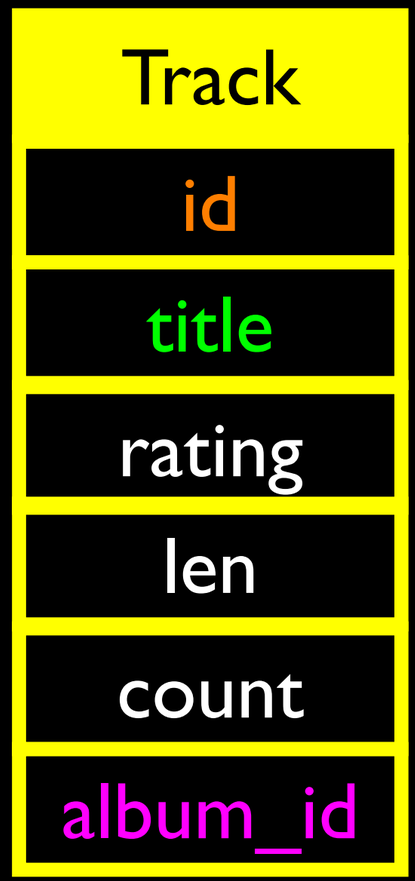
result_url TEXT
sourcedid TEXT
service_id INT(11)
grade FLOAT
note TEXT
server_grade FLOAT
json TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
retrieved_at DATETIME
Indexes
lti_service
service_id INT(11)
service_sha256 CHAR(64)
service_key TEXT
key_id INT(11)
format VARCHAR(1024)
json TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
www.tsugi.org

Review:
One to Many

Table
Primary key
Logical key
Foreign key



https://en.wikipedia.org/wiki/One-to-many_(data_model)

id	name
Filter	Filter
1	Rock
2	Metal

One

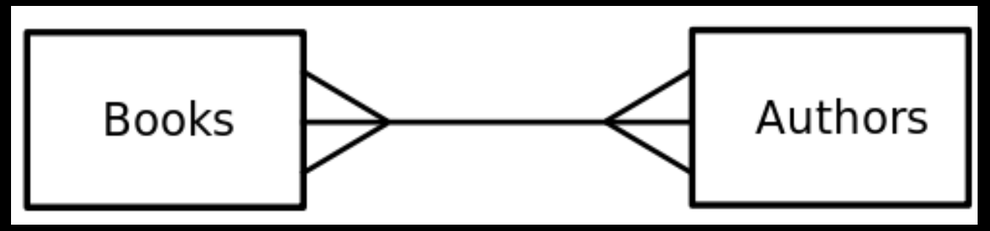
Many

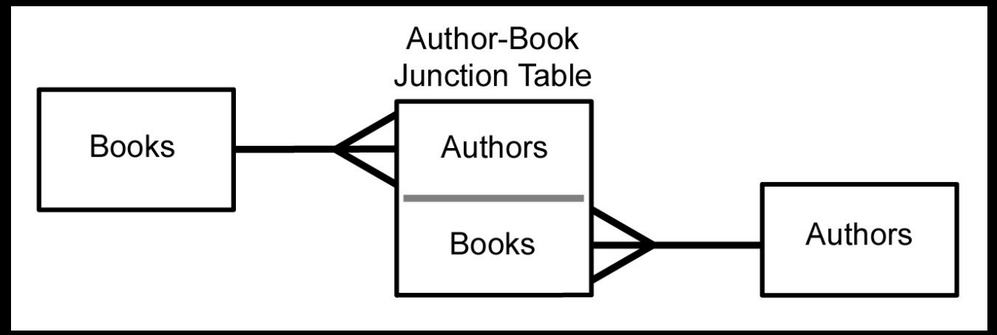
id	title	album_id	genre_id	len	rating	count
Filter	Filter	Filter	Filter	Filter	Filter	Filter
1	Black Dog	2	1	297	5	0
2	Stairway	2	1	482	5	0
3	About to Rock	1	2	313	5	0
4	Who Made Who	1	2	207	5	0

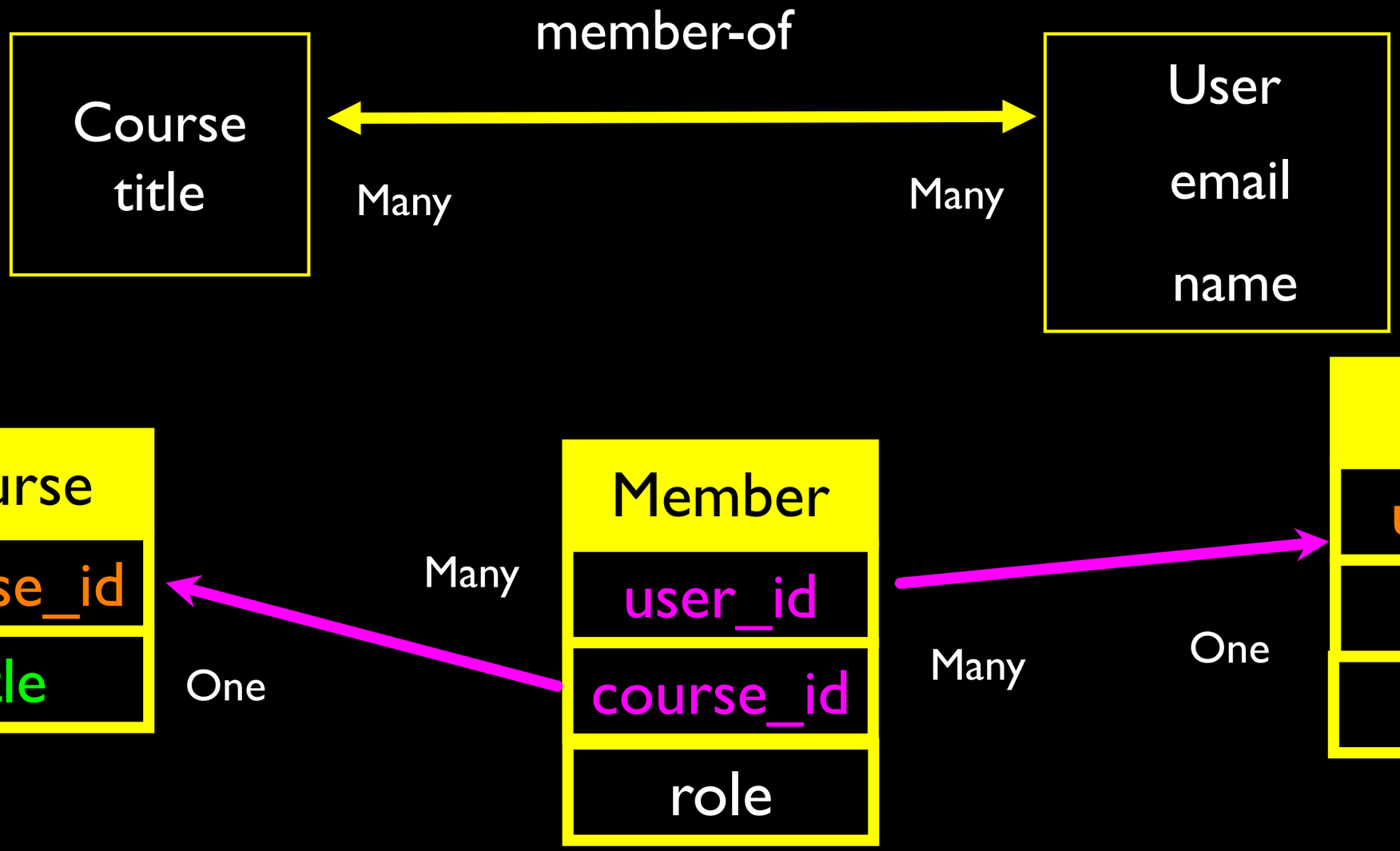
https://en.wikipedia.org/wiki/One-to-many_(data_model)

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.





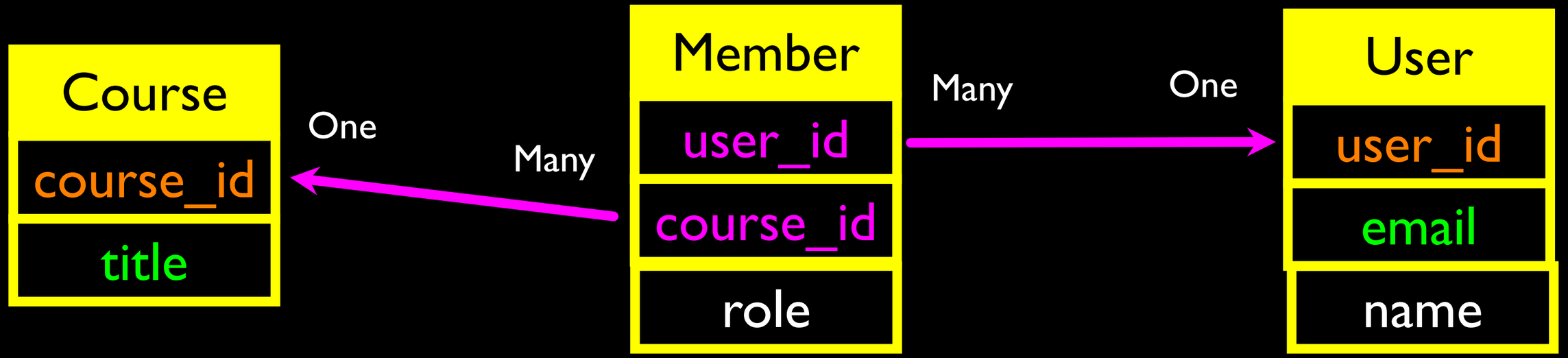


https://en.wikipedia.org/wiki/Many-to-many_(data_model)

Start with a Fresh Database

```
CREATE TABLE User (
    user_id     INTEGER NOT NULL AUTO_INCREMENT PRIMARY KEY,
    email       VARCHAR(128) UNIQUE,
    name        VARCHAR(128)
) ENGINE=InnoDB CHARACTER SET=utf8;

CREATE TABLE Course (
    course_id     INTEGER NOT NULL AUTO_INCREMENT PRIMARY KEY,
    title         VARCHAR(128) UNIQUE
) ENGINE=InnoDB CHARACTER SET=utf8;
```




```
CREATE TABLE Member (
    user_id         INTEGER,
    course_id       INTEGER,
    role            INTEGER,

    CONSTRAINT FOREIGN KEY (user_id) REFERENCES User (user_id)
      ON DELETE CASCADE ON UPDATE CASCADE,
    CONSTRAINT FOREIGN KEY (course_id) REFERENCES Course (course_id)
       ON DELETE CASCADE ON UPDATE CASCADE,

    PRIMARY KEY (user_id, course_id)
) ENGINE=InnoDB CHARACTER SET=utf8;
```

Insert Users and Courses

```
INSERT INTO User (name, email) VALUES ('Jane', 'jane@tsugi.org');
INSERT INTO User (name, email) VALUES ('Ed', 'ed@tsugi.org');
INSERT INTO User (name, email) VALUES ('Sue', 'sue@tsugi.org');

INSERT INTO Course (title) VALUES ('Python');
INSERT INTO Course (title) VALUES ('SQL');
INSERT INTO Course (title) VALUES ('PHP');
```

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

course_id	title
1	Python
2	SQL
3	PHP

Insert Memberships

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

course_id	title
1	Python
2	SQL
3	PHP

```
INSERT INTO Member (user_id, course_id, role) VALUES (1, 1, 1);
INSERT INTO Member (user_id, course_id, role) VALUES (2, 1, 0);
INSERT INTO Member (user_id, course_id, role) VALUES (3, 1, 0);

INSERT INTO Member (user_id, course_id, role) VALUES (1, 2, 0);
INSERT INTO Member (user_id, course_id, role) VALUES (2, 2, 1);

INSERT INTO Member (user_id, course_id, role) VALUES (2, 3, 1);
INSERT INTO Member (user_id, course_id, role) VALUES (3, 3, 0);
```

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

course_id	title
1	Python
2	SQL
3	PHP

user_id	course_id	role
1	1	1
1	2	0
2	1	0
2	2	1
2	3	1
3	1	0
3	3	0

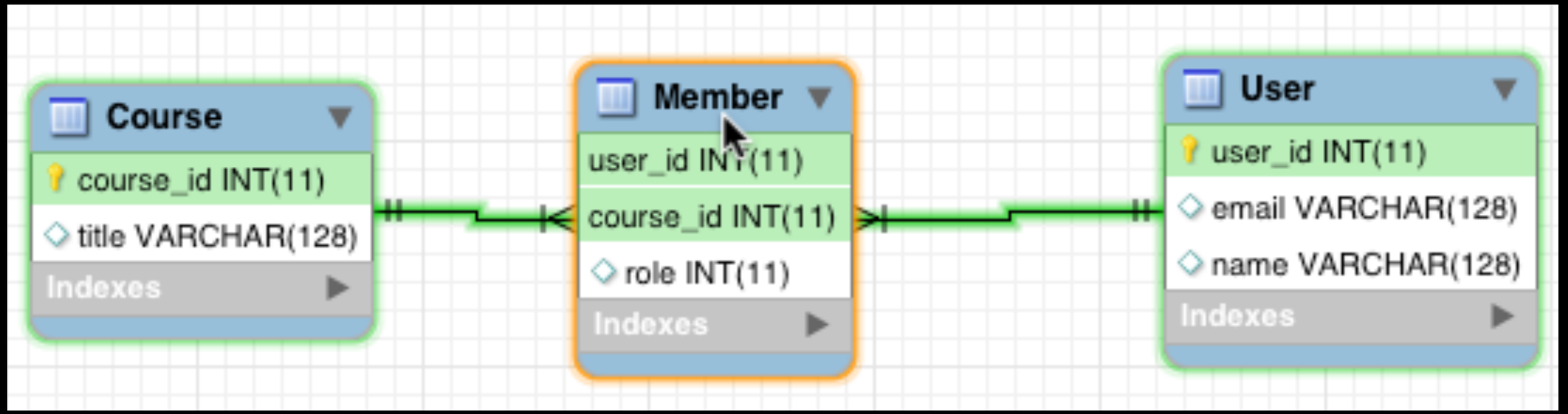
user_id	email	name
1	jane@tsugi.org	Jane
2	ed@tsugi.org	Ed
3	sue@tsugi.org	Sue

user_id	course_id	role
1	1	1
1	2	0
2	1	0
2	2	1
2	3	1
3	1	0
3	3	0

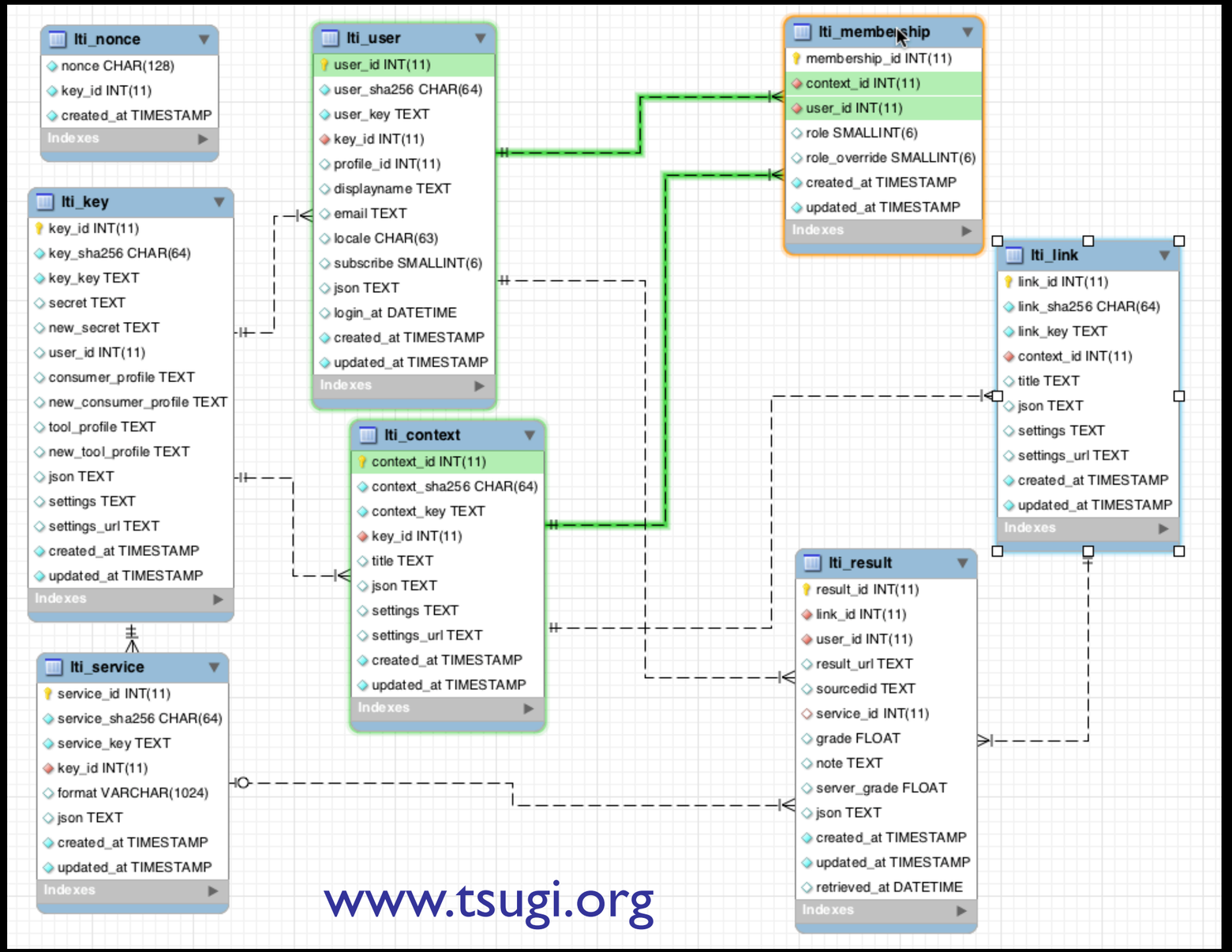
course_id ▲	title
1	Python
2	SQL
3	PHP

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

```
SELECT User.name, Member.role, Course.title
FROM User JOIN Member JOIN Course
ON Member.user_id = User.user_id AND
Member.course_id = Course.course_id
ORDER BY Course.title, Member.role DESC, User.name
```



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


lti_nonce
nonce CHAR(128)
key_id INT(11)
created_at TIMESTAMP
Indexes
lti_user
user_id INT(11)
user_sha256 CHAR(64)
user_key TEXT
key_id INT(11)
profile_id INT(11)
displayname TEXT
email TEXT
locale CHAR(63)
subscribe SMALLINT(6)
json TEXT
login_at DATETIME
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
lti_membership
membership_id INT(11)
context_id INT(11)
user_id INT(11)
role SMALLINT(6)
role_override SMALLINT(6)
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
lti_key
key_id INT(11)
key_sha256 CHAR(64)
key_key TEXT
secret TEXT
new_secret TEXT
user_id INT(11)
consumer_profile TEXT
new_consumer_profile TEXT
tool_profile TEXT
new_tool_profile TEXT
json TEXT
settings TEXT
settings_url TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
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link_id INT(11)
link_sha256 CHAR(64)
link_key TEXT
context_id INT(11)
title TEXT
json TEXT
settings TEXT
settings_url TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
lti_context
context_id INT(11)
context_sha256 CHAR(64)
context_key TEXT
key_id INT(11)
title TEXT
json TEXT
settings TEXT
settings_url TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
lti_result
result_id INT(11)
link_id INT(11)
user_id INT(11)
result_url TEXT
sourcedid TEXT
service_id INT(11)
grade FLOAT
note TEXT
server_grade FLOAT
json TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
retrieved_at DATETIME
Indexes
lti_service
service_id INT(11)
service_sha256 CHAR(64)
service_key TEXT
key_id INT(11)
format VARCHAR(1024)
json TEXT
created_at TIMESTAMP
updated_at TIMESTAMP
Indexes
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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

Initial Development: Charles Severance, University of Michigan School of Information

Insert new Contributors and Translators here including names and dates

Continue new Contributors and Translators here