BITAH05 - Databanktechnologie

Jasper Anckaert

Lecture 2 – Database schema, normalization and MySQL Workbench

Previously

- Database
  - Collection of data that needs to be stored
  - Structured
  - Used everywhere
- Database system
  - Hardware – data – software – users
  - Storage space – quick – little redundancy – secure – clear structure
- Database Management System (DBMS)
  - Software application that interacts with the user, other applications, and the database itself to capture and analyse data
  - Storage – Retrieval – Manipulation – Authentication & authorization
- Relational databases – Relational Database Management System (RDBMS)
  - Enforce data integrity
  - Enforce referential intigrety
  - Rules of E. Codd

Previously

- MySQL
    - Install, connect to and secure server
    - User – host – database – table
    - Privileges
    - Options file

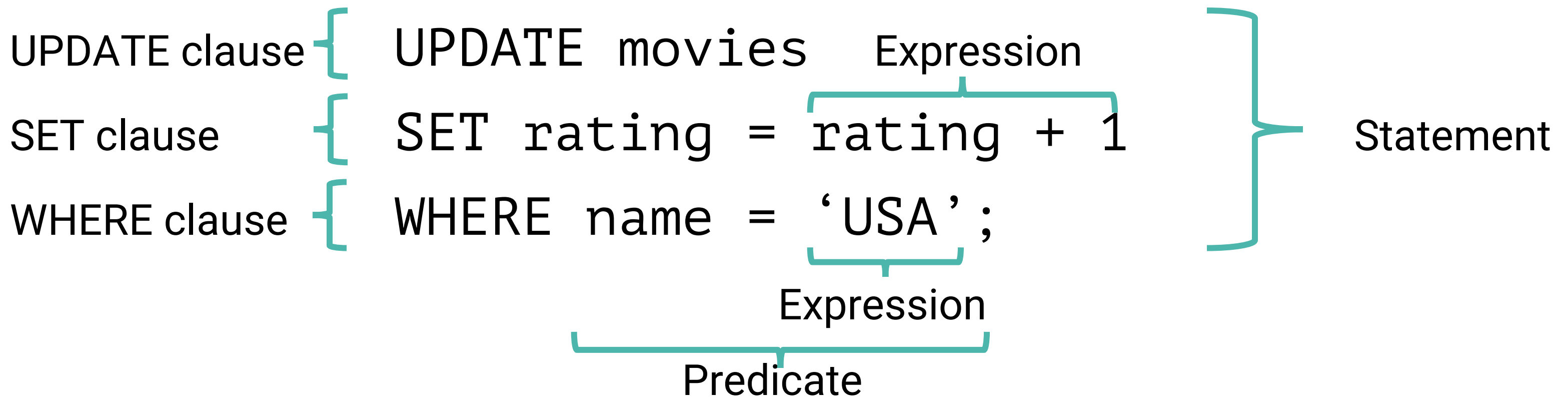
    - Create database
    - Grant privileges
    - Show databases, tables columns, create statement

Previously

- `SQL`
  - Data definition language
    - Statements to design database
    - `CREATE`, `ALTER`, `DROP`, …
  - Data manipulation language
    - Statements to manage data
    - CRUD
    - `SELECT`, `INSERT`, `UPDATE`, `DELETE`
  - Data control language
    - Statements to manage database rights
    - `GRANT`, `REVOKE`

Previously

SQL: Structured Query Language



```
UPDATE movies
SET rating = rating + 1
WHERE name = 'USA';
```

Previously

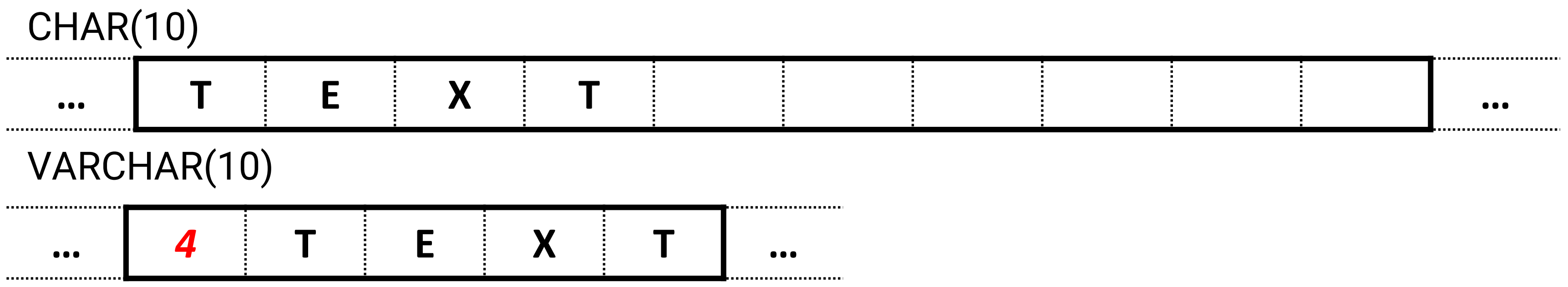
Column types

- INT
  - Integer
  - SIGNED: -2 147 483 648 tot 2 147 483 647
  - UNSIGNED: 0 tot 4 294 967 295
  - TINYINT, BIGINT, SMALLINT
- FLOAT & DOUBLE
  - Numbers with decimal point
  - FLOAT: 7 digits after decimal point, DOUBLE: 15 digits after decimal point
- DATE
  - YYYY-MM-DD
  - DATETIME
    - YYYY-MM-DD HH:MM:SS
    - ! TIMESTAMP ! No dates < 1970 and > 2038

Previously

Column types

- VARCHAR & CHAR
  - String with a certain number of characters
  - Define max number of characters e.g. VARCHAR(200)
  - VARCHAR: up to 65 535 characters
  - CHAR: up to 255 characters, spaces are added to reach required length



  - VARCHAR is more efficient in storage, CHAR is faster for reading data
  - Similar for INT vs BIGINT vs …

Previously

Column types

- TEXT & BLOB
  - Used for texts that are not queried often or do not have to be searchable
  - BLOB for binary data (images, …)
- ENUM
  - List of permitted values
    - E.g. Set of colours: ’red’, ‘green’, ‘blue’
  - Very efficient

Previously

Constraints

On top of column types, there are some additional requirements per column

- Primary key
    - Only 1 PK per table, all values must be unique
- UNIQUE
    - All values (or combinations) must be unique
- NOT NULL
    - Field can not be empty when adding data (empty = null)
- Default
    - Default value for a field
- Foreign key
    - Same constraints as referenced column
    - Security when adjusting linked data possible

Previously

- INSERT

  `INSERT INTO` *`tbl`* `(`*`col1`*`, `*`col2`*`) VALUES (`*`val1`*`, `*`val2`*`);`

- SELECT

  `SELECT` *`columns`* `FROM` *`tbl;`*

- ORDER BY

  `SELECT` *`columns`* `FROM` *`tbl`* `ORDER BY` *`col1`* `[`*`asc|desc`*`] [, `*`col2`*` [`*`asc|desc`*`]...]`*`;`*

- Calculated rows
  - Built in functions for numbers, strings, dates
- Column aliases
  - Can be used in the `ORDER BY` clause
- WHERE

  `SELECT` *`columns`* `FROM` *`tbl`* `WHERE` *`condition(s)`* `[ORDER BY` *`sortcol`*`]`*`;`*

- NULL values

  `SELECT … WHERE` *`col`* `IS [NOT] NULL;`

  `SELECT ifnull(`*`col`*`, `*`value`*`) …`

Previously

- AND, OR, NOT, XOR
  - Boolean logic
- DISTINCT

  `SELECT DISTINCT(`*`cols`*`) FROM …`
- LIMIT, OFFSET

  `SELECT … LIMIT `*`n`*` [OFFSET `*`r`*`];`
- Aggregation
  - Built in functions e.g. `count()`, `sum()`, `min()`, `max()`, …
- GROUP BY

  `SELECT [`*`col`*`,] `*`aggregatefunctions`*` FROM `*`src`*` [WHERE `*`cond`*`] GROUP BY `*`col`*` [ORDER BY …];`
- HAVING

  `SELECT [`*`col`*`, ] `*`aggregatefunctions`*` FROM `*`src`*` [WHERE `*`cond1`*`] GROUP BY `*`col`*` HAVING `*`cond2`*` [ORDER BY …];`

Previously

Execution order

1. Input columns are determined
2. `WHERE` – input columns are filtered
3. `GROUP BY` – sorting & grouping of filtered input
4. Aggregation functions are calculated
5. `HAVING` – aggregation functions are filtered
6. `ORDER BY` – output is sorted
7. `LIMIT/OFFSET` – output is chopped

Previously

- JOIN

  ```
  SELECT * FROM tbl1 JOIN tbl2 ON tbl1.col1 = tbl2.col2;
  ```

- INNER, LEFT, RIGHT, OUTER
- Foreign key
  - Primary key of other table
  - Index
- Relations between tables
  - 1:n   one-to-many relationship
  - n:m   many-to-many relationship (xref-table)
- Views

  ```
  CREATE VIEW viewname as SELECT …
  ```

- Index
  - 1 per query

Previously

- Allow redundancy

SNOWFLAKE	STAR
No redundancy	Redundant data
Easy to maintain and change	Less easy to maintain/change
Complex queries	Lower query complexity
Slower (more JOINs)	Faster
Uses less space	Uses more space (data is stored twice or more)
Bottom up	Top down

- DUMP
  - Create database backup

Relational databases with MySQL - JOINs

Exercises (bioinf db)

- Give the accession number for the 3 longest human genes in the database
- How many genes are in the database for species with a genome size of at least 3000
- For the gene with accession number *NM_008220*, give
    - The length of the gene
    - The total genome size
- Retrieve all genes comming from a genome that was published in the first half of the year
- Retrieve all unique class names for model organisms with al least 10 chromosomes

MySQL Workbench

Database schema

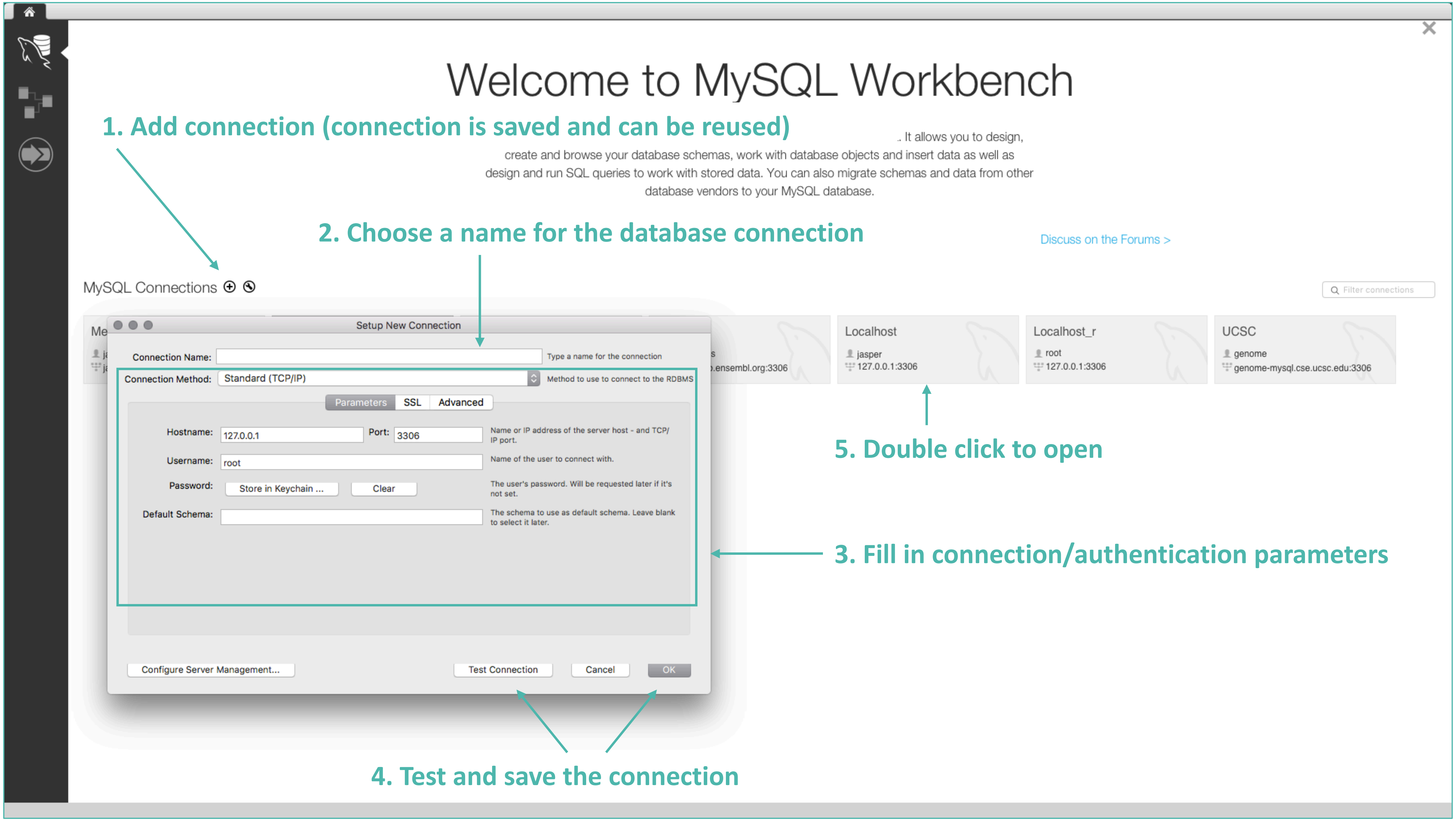
- MySQL monitor to execute DDL commands
  - Servers
  - Advanced users
- GUI
  - HeidiSQL
  - MySQL Workbench

MySQL Workbench

Installation

- Available as for download (several operationg systems)
  - http://dev.mysql.com/downloads/workbench/

- To install DEB package
  ```
  # dpkg -i package.deb
  ```
- To install RPM package
  ```
  # rpm -Uvh package.rpm
  ```
- To install on Windows/Mac
  - Double click `package.msi` or `package.dmg`



Welcome to MySQL Workbench

1. Add connection (connection is saved and can be reused)

. It allows you to design, create and browse your database schemas, work with database objects and insert data as well as design and run SQL queries to work with stored data. You can also migrate schemas and data from other database vendors to your MySQL database.

2. Choose a name for the database connection

Discuss on the Forums >

MySQL Connections

Setup New Connection

Connection Name: Type a name for the connection

Connection Method: Standard (TCP/IP) Method to use to connect to the RDBMS

Parameters | SSL | Advanced

Hostname: 127.0.0.1 Port: 3306 Name or IP address of the server host - and TCP/IP port.

Username: root Name of the user to connect with.

Password: Store in Keychain ... Clear The user's password. Will be requested later if it's not set.

Default Schema: The schema to use as default schema. Leave blank to select it later.

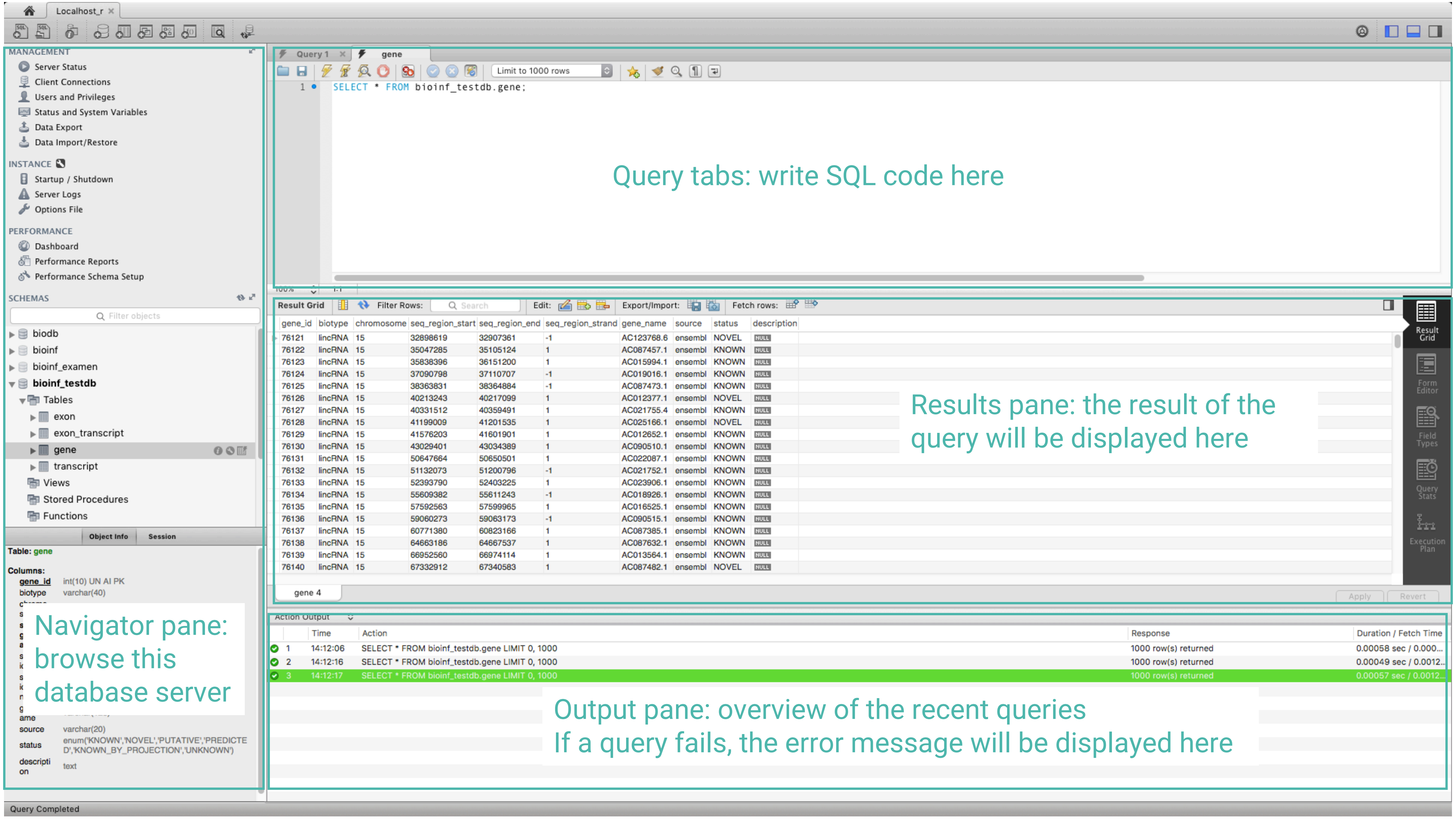
Configure Server Management... Test Connection Cancel OK

.ensembl.org:3306		
Localhost	jasper	127.0.0.1:3306
Localhost_r	root	127.0.0.1:3306
UCSC	genome	genome-mysql.cse.ucsc.edu:3306

5. Double click to open

3. Fill in connection/authentication parameters

4. Test and save the connection



```
SELECT * FROM bioinf_testdb.gene;
```

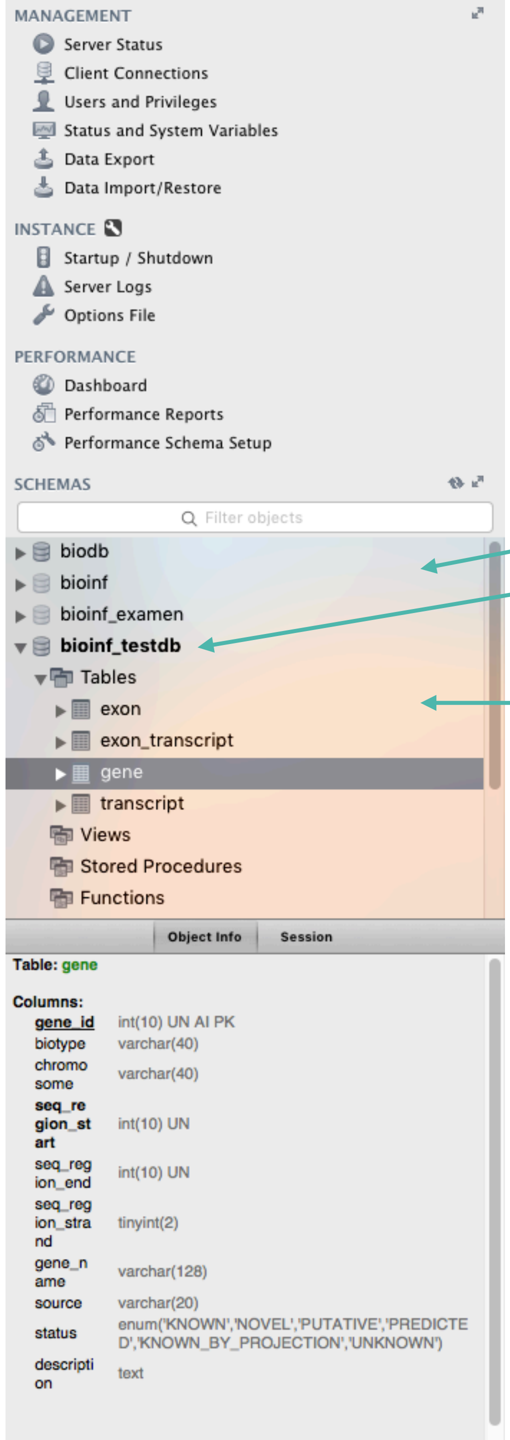
Table: gene

Columns:

gene_id	int(10) UN AI PK
biotype	varchar(40)
ame	
source	varchar(20)
status	enum('KNOWN','NOVEL','PUTATIVE','PREDICTED','KNOWN_BY_PROJECTION','UNKNOWN')
description	text

gene_id	biotype	chromosome	seq_region_start	seq_region_end	seq_region_strand	gene_name	source	status	description
76121	lincRNA	15	32898619	32907361	-1	AC123768.6	ensembl	NOVEL	NULL
76122	lincRNA	15	35047285	35105124	1	AC087457.1	ensembl	KNOWN	NULL
76123	lincRNA	15	35838396	36151200	1	AC015994.1	ensembl	KNOWN	NULL
76124	lincRNA	15	37090798	37110707	-1	AC019016.1	ensembl	KNOWN	NULL
76125	lincRNA	15	38363831	38364884	-1	AC087473.1	ensembl	KNOWN	NULL
76126	lincRNA	15	40213243	40217099	1	AC012377.1	ensembl	NOVEL	NULL
76127	lincRNA	15	40331512	40359491	1	AC021755.4	ensembl	KNOWN	NULL
76128	lincRNA	15	41199009	41201535	1	AC025166.1	ensembl	NOVEL	NULL
76129	lincRNA	15	41576203	41601901	1	AC012652.1	ensembl	KNOWN	NULL
76130	lincRNA	15	43029401	43034389	1	AC090510.1	ensembl	KNOWN	NULL
76131	lincRNA	15	50647664	50650501	1	AC022087.1	ensembl	KNOWN	NULL
76132	lincRNA	15	51132073	51200796	-1	AC021752.1	ensembl	KNOWN	NULL
76133	lincRNA	15	52393790	52403225	1	AC023906.1	ensembl	KNOWN	NULL
76134	lincRNA	15	55609382	55611243	-1	AC018926.1	ensembl	KNOWN	NULL
76135	lincRNA	15	57592563	57599965	1	AC016525.1	ensembl	KNOWN	NULL
76136	lincRNA	15	59060273	59063173	-1	AC090515.1	ensembl	KNOWN	NULL
76137	lincRNA	15	60771380	60823166	1	AC087385.1	ensembl	KNOWN	NULL
76138	lincRNA	15	64663186	64667537	1	AC087632.1	ensembl	KNOWN	NULL
76139	lincRNA	15	66952560	66974114	1	AC013564.1	ensembl	KNOWN	NULL
76140	lincRNA	15	67332912	67340583	1	AC087482.1	ensembl	NOVEL	NULL

	Time	Action	Response	Duration / Fetch Time
✓ 1	14:12:06	SELECT * FROM bioinf_testdb.gene LIMIT 0, 1000	1000 row(s) returned	0.00058 sec / 0.000...
✓ 2	14:12:16	SELECT * FROM bioinf_testdb.gene LIMIT 0, 1000	1000 row(s) returned	0.00049 sec / 0.0012...
✓ 3	14:12:17	SELECT * FROM bioinf_testdb.gene LIMIT 0, 1000	1000 row(s) returned	0.00057 sec / 0.0012...



MANAGEMENT
- Server Status
- Client Connections
- Users and Privileges
- Status and System Variables
- Data Export
- Data Import/Restore

INSTANCE
- Startup / Shutdown
- Server Logs
- Options File

PERFORMANCE
- Dashboard
- Performance Reports
- Performance Schema Setup

SCHEMAS

Filter objects

- biodb
- bioinf
- bioinf_examen
- **bioinf_testdb**
  - Tables
    - exon
    - exon_transcript
    - gene
    - transcript
  - Views
  - Stored Procedures
  - Functions

Object Info | Session

Table: gene

Columns:

gene_id	int(10) UN AI PK
biotype	varchar(40)
chromosome	varchar(40)
seq_region_start	int(10) UN
seq_region_end	int(10) UN
seq_region_strand	tinyint(2)
gene_name	varchar(128)
source	varchar(20)
status	enum('KNOWN','NOVEL','PUTATIVE','PREDICTED','KNOWN_BY_PROJECTION','UNKNOWN')
description	text

Different databases on this server
BOLD = currently active database, all queries will be executed in this db, double click to change

Browse tables in the db here

More information on the currently selected item

MySQL Workbench

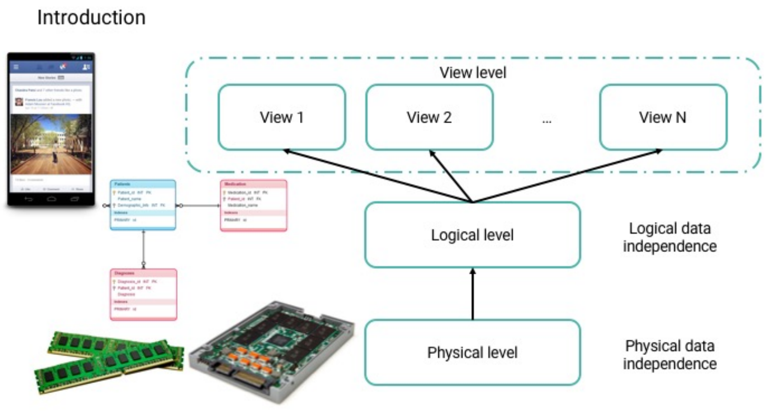
Exercices

- Connect to the MySQL database server
- Explore the server
  - How many databases are available to you?
  - How many tables does each database have?
  - What are the column types of the gene table (bioinf_testdb)?

MySQL Workbench

Data model

- Determines the structure of data
  - Conceptual data model
    - Structure of and relations between entities
    - Entity Relationship Diagram
  - Logical data model
    - Structure of and references between tables
    - Relations → foreign key constraints
    - Data Structure Diagram
  - Physical data model
    - Physical means by which data are stored (partitions, CPUs, tablespaces, …)



MySQL Workbench

Database models

- Flat model
    - Single two-dimensional array of data elements
    - E.g. spreadsheet
- Hierarchical model
    - Data is organized into a tree-like structure
    - Records are connected through links
- Network model
    - Each record can have multiple parents and child records

MySQL Workbench

Database models

- Relational model
  - Tables are relations
  - Links between tables are not explicitely defined → use keys
  - What we’ve been using so far but with deviations
- Object-relational model
  - Relational model with object-oriented features
  - PostgreSQL
- Object oriented model
  - Data is represented in the form of objects
  - Use same model of representation as in programming language

MySQL Workbench

Creating a database - Normalisation

- Organizing columns and tables
    - Reduce redundancy
    - Improve integrity

- Remember E. Codd?

MySQL Workbench

Normalisation

- UNF
  - Unnormalized form
  - Group all data in one entity
- 1NF
  - Eliminate repeating (and calculated) groups in individual tables
  - Create separate table for each set of related data
  - Identify each set of related data with a primary key
- 2NF
  - Every non-prime attribute of the table is dependent on the whole key of every candidate key
- 3NF
  - Every non-prime attribute is non-transitively dependent on every key

MySQL Workbench

Normalisation

- BCNF
  - Any attribute on which some other attribute is fully functionally dependent = determinant
  - Every determinant is a candidate key

- 4NF – ETNF – 5NF – 6NF – DKNF

MySQL Workbench

Normalisation – example

Patient_no	Patient_name	Appointment_id	Time	Doctor
1	John	0	09:00	Zorro
2	Kerr	0	09:00	Killer
3	Adam	1	10:00	Zorro
4	Robert	0	13:00	Killer
5	Zane	1	14:00	Zorro

UNF	DB(Patno,PatName,appNo,time,doctor)
1NF	DB($\underline{\text{Patno,}}$PatName$\underline{\text{,appNo}}$,time,doctor)

2NF	DB($\underline{\text{Patno,appNo}}$,time,doctor)
	R1($\underline{\text{Patno}}$,PatName)

3NF	2NF

BCNF	DB($\underline{\text{Patno,time}}$,doctor)
	R1($\underline{\text{Patno}}$,PatName)
	R2($\underline{\text{time}}$,appNo)

MySQL Workbench

Normalisation – example

- Why is this table not in 1NF?
- Normalize up to 3NF
- Identify all keys in your 3NF relations

branchNo	branchAddress	telNos
B001	8 Jefferson Way, Portland, OR 97201	503-555-3618, 503-555-2727, 503-555-6534
B002	City Center Plaza, Seattle, WA 98122	206-555-6756, 206-555-8836
B003	14 – 8th Avenue, New York, NY 10012	212-371-3000
B004	16 – 14th Avenue, Seattle, WA 98128	206-555-3131, 206-555-4112

MySQL Workbench

Exercises

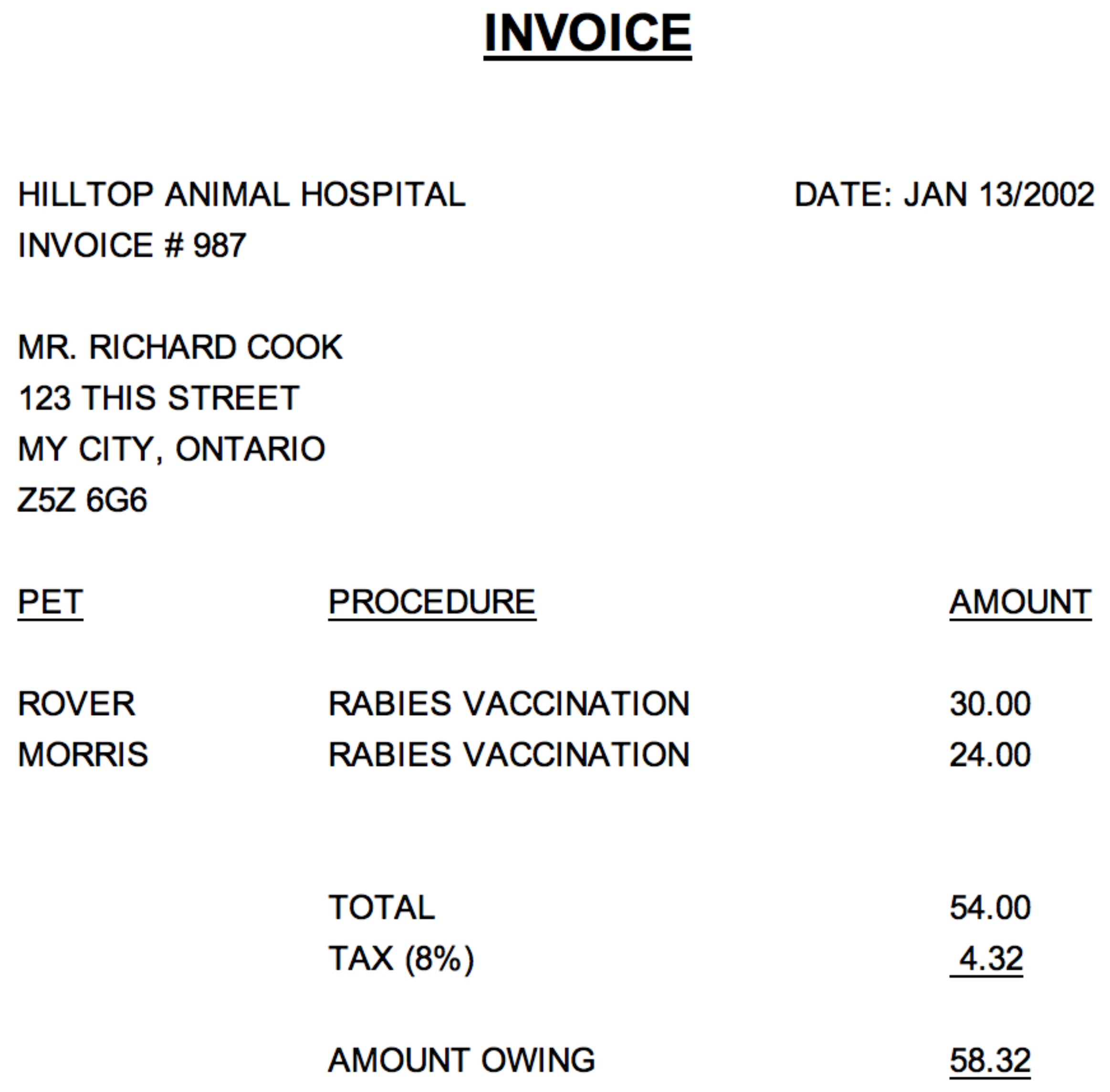
- Normalise up to 3NF (note: a procedure may occur on multiple dates)

Pet_id	Pet_name	Pet_type	Pet_age	owner	Visit_date	procedure
246	Rover	dog	12	Sam Coock	2002-01-13	01 – Rabies vaccination
					2005-03-27	10 - Examination
					2003-04-02	05 – Heart worm test
296	Spot	dog	2	Terry Kim	2002-01-21	08 – Tetanus vaccination
					200-03-10	05 – Heart worm test
341	Morris	cat	4	Sam Coock	2001-01-23	01– Rabies vaccination
					2002-01-13	01 – Rabies vaccination
519	Tweedy	bird	2	Terry Kim	2002-04-30	20 – Check up
					2002-04-30	12 – Eye wash

MySQL Workbench

Exercises

- Normalise up to 3NF



INVOICE

HILLTOP ANIMAL HOSPITAL DATE: JAN 13/2002
INVOICE # 987

MR. RICHARD COOK
123 THIS STREET
MY CITY, ONTARIO
Z5Z 6G6

PET	PROCEDURE	AMOUNT
ROVER	RABIES VACCINATION	30.00
MORRIS	RABIES VACCINATION	24.00
	TOTAL	54.00
	TAX (8%)	4.32
	AMOUNT OWING	58.32

MySQL Workbench

Exercises

- Normalise up to BCNF
  - Grade_report(StudNo,StudName,(Major,Adviser,(CourseNo,Ctitle,InstrucName,InstructLocn,Grade)))
  - Functional dependencies
    - StudNo -> StudName
      CourseNo -> Ctitle,InstrucName
      InstrucName -> InstrucLocn
      StudNo,CourseNo,Major -> Grade
      StudNo,Major -> Advisor
      Advisor -> Major

MySQL Workbench

Exercises

video(title,director,serial)
customer(name,addr,memberno)
hire(memberno,serial,date)

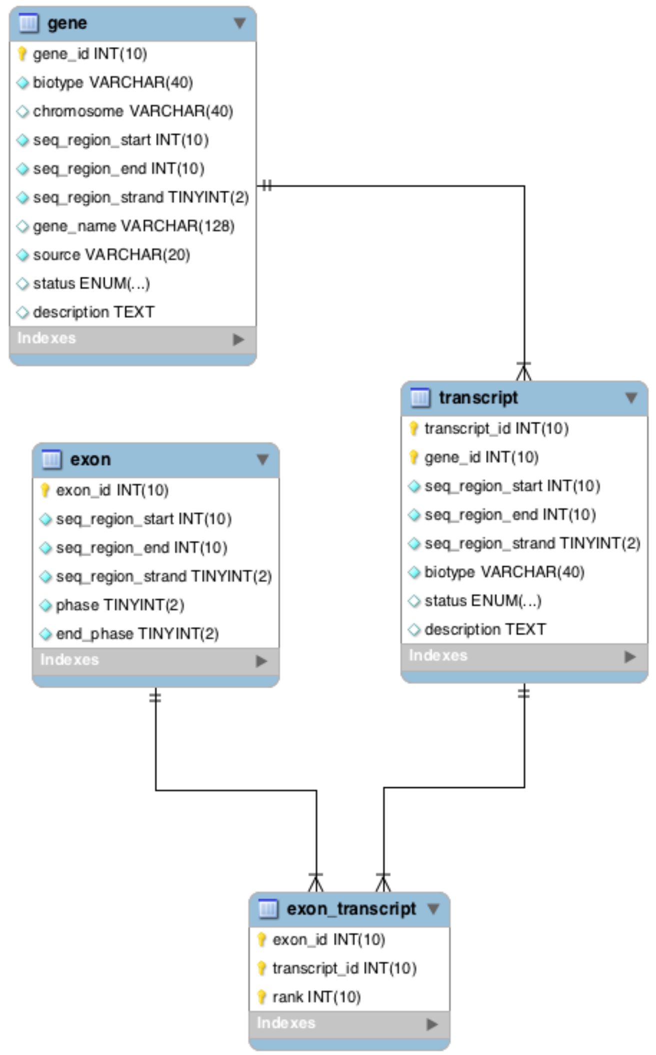
title->director,serial
serial->title serial->director
name,addr -> memberno
memberno -> name,addr
serial,date -> memberno

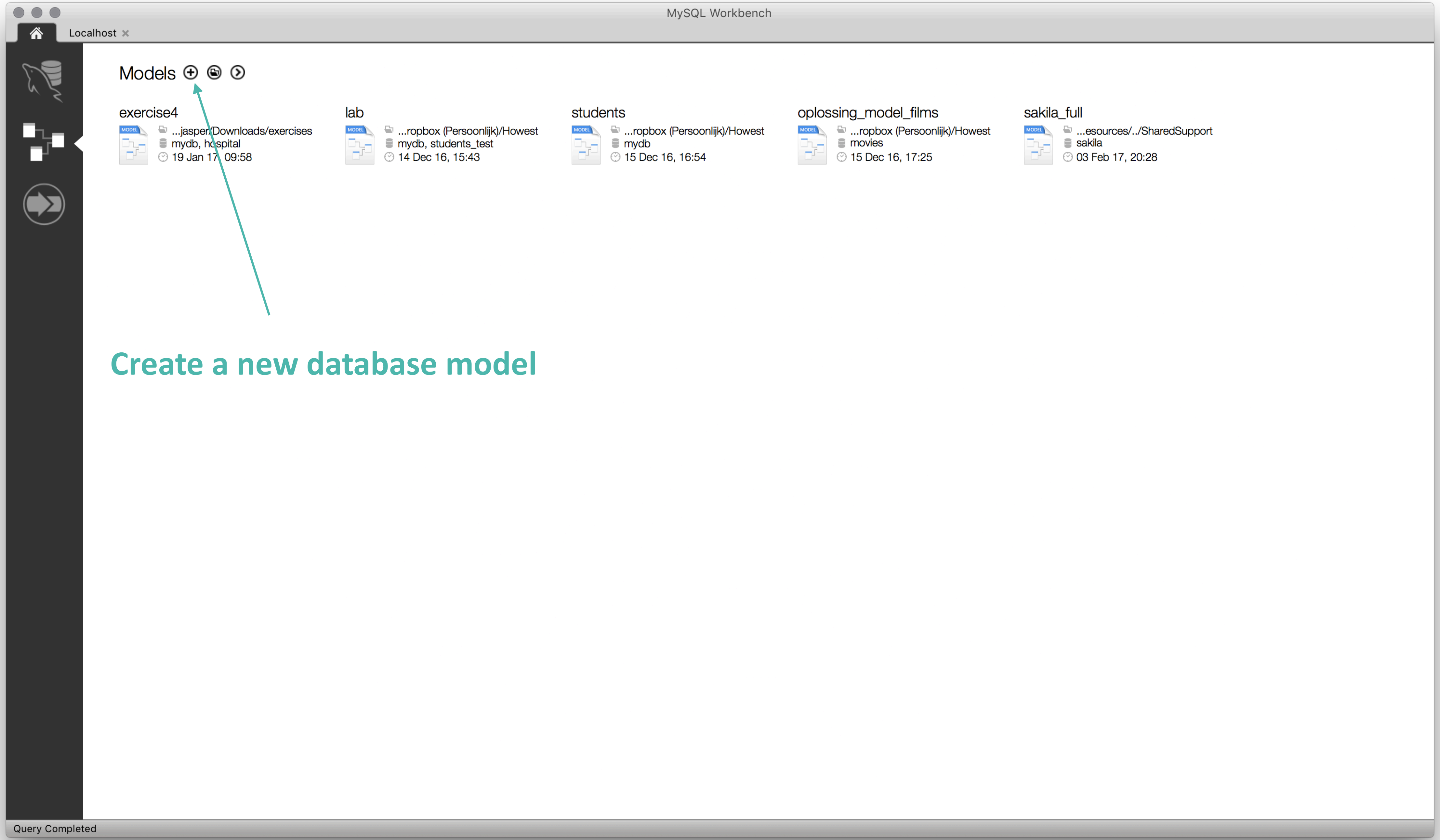
- What normal form is this?
- Convert to BCNF

MySQL Workbench

Creating tables

- Use the ”model” interface in MySQL Workbench
  - DDL statements will be auto-generated
- Tables can be placed anywhere and dragged around
- Foreign keys will be displayed as lines and arrows





exercise4
...jasper/Downloads/exercises
mydb, hospital
19 Jan 17, 09:58

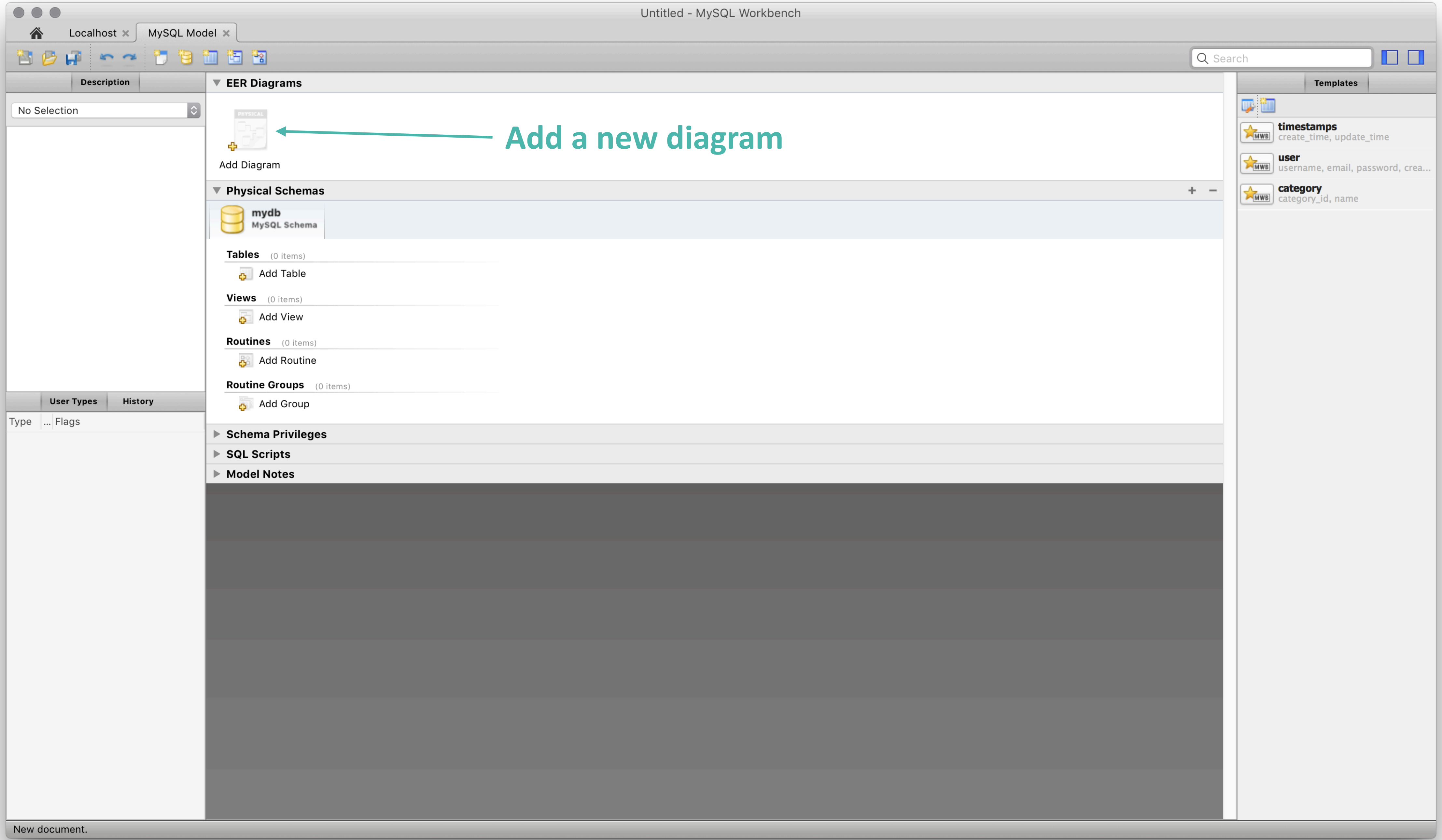
lab
...ropbox (Persoonlijk)/Howest
mydb, students_test
14 Dec 16, 15:43

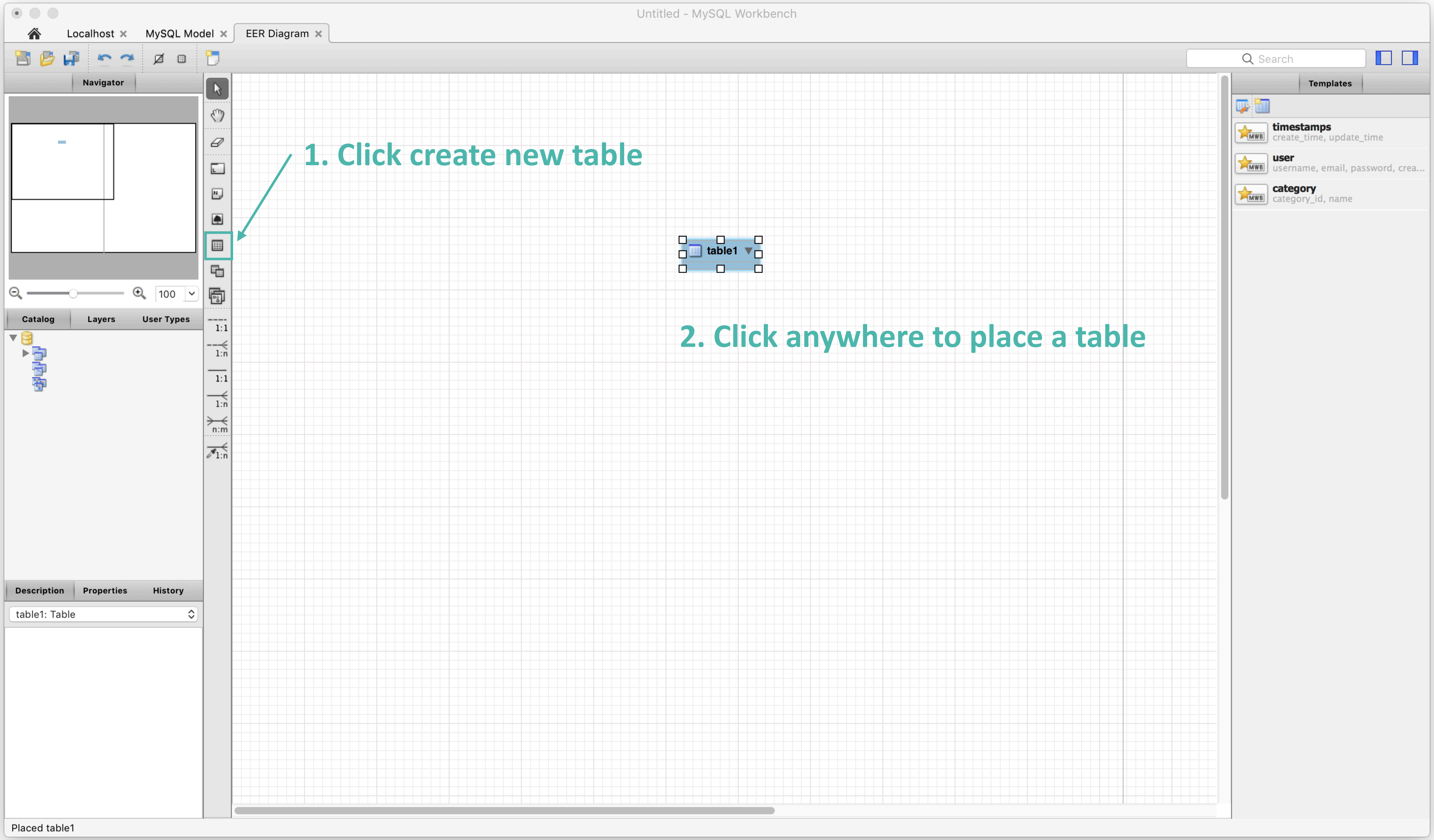
students
...ropbox (Persoonlijk)/Howest
mydb
15 Dec 16, 16:54

oplossing_model_films
...ropbox (Persoonlijk)/Howest
movies
15 Dec 16, 17:25

sakila_full
...esources/../SharedSupport
sakila
03 Feb 17, 20:28

Create a new database model


Untitled - MySQL Workbench
Localhost
MySQL Model
Search
Description
No Selection
EER Diagrams
Add Diagram
Add a new diagram
Physical Schemas
mydb
MySQL Schema
Tables (0 items)
Add Table
Views (0 items)
Add View
Routines (0 items)
Add Routine
Routine Groups (0 items)
Add Group
Schema Privileges
SQL Scripts
Model Notes
User Types
History
Type
... Flags
Templates
timestamps
create_time, update_time
user
username, email, password, crea...
category
category_id, name
New document.

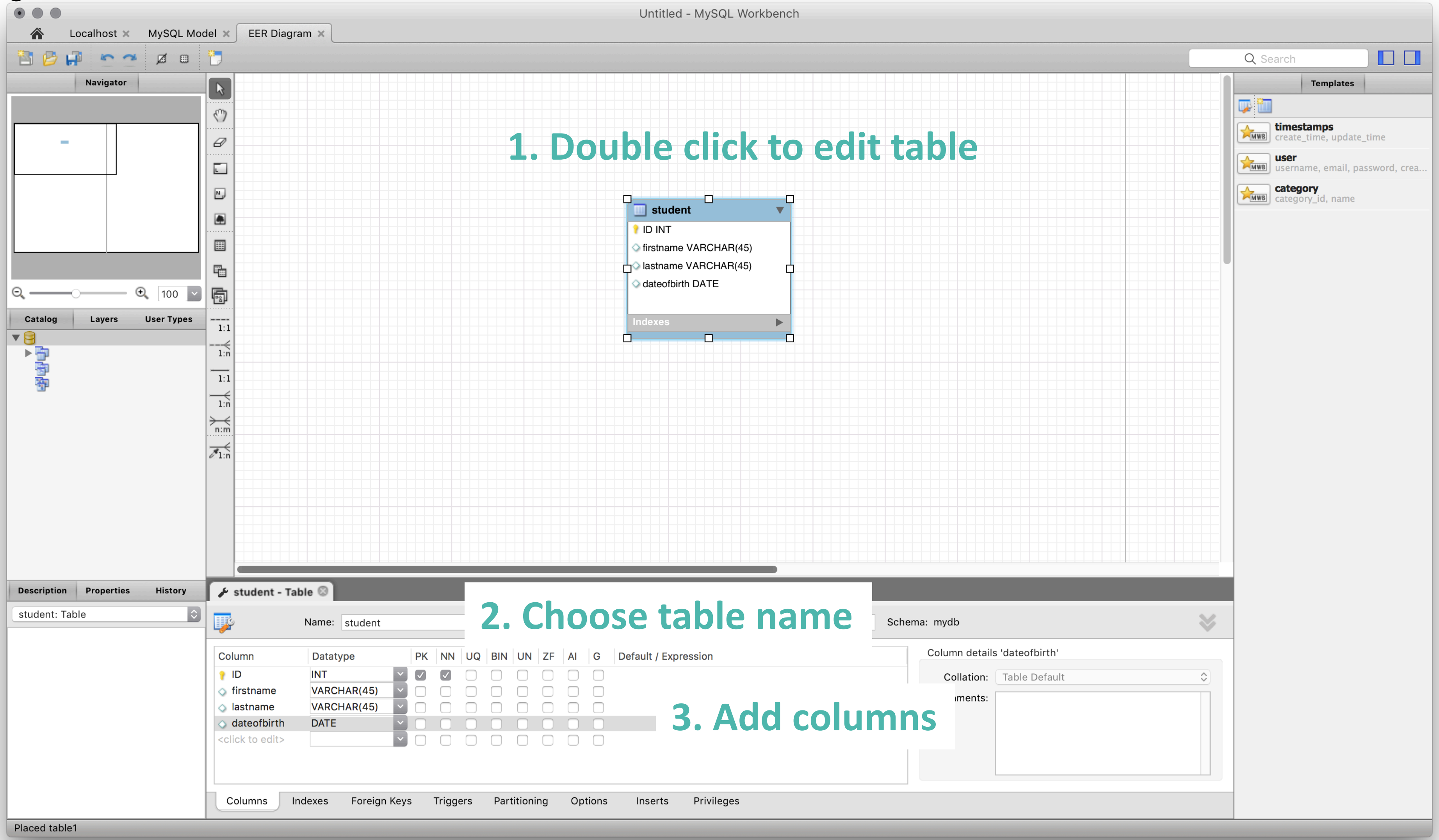


1. Click create new table

2. Click anywhere to place a table

MySQL Workbench

Creating tables



1. Double click to edit table

student
- ID INT
- firstname VARCHAR(45)
- lastname VARCHAR(45)
- dateofbirth DATE

Indexes

student - Table

2. Choose table name

Name: student Schema: mydb

Column	Datatype	PK	NN	UQ	BIN	UN	ZF	AI	G	Default / Expression
ID	INT	✓	✓							
firstname	VARCHAR(45)									
lastname	VARCHAR(45)									
dateofbirth	DATE									
<click to edit>										

3. Add columns

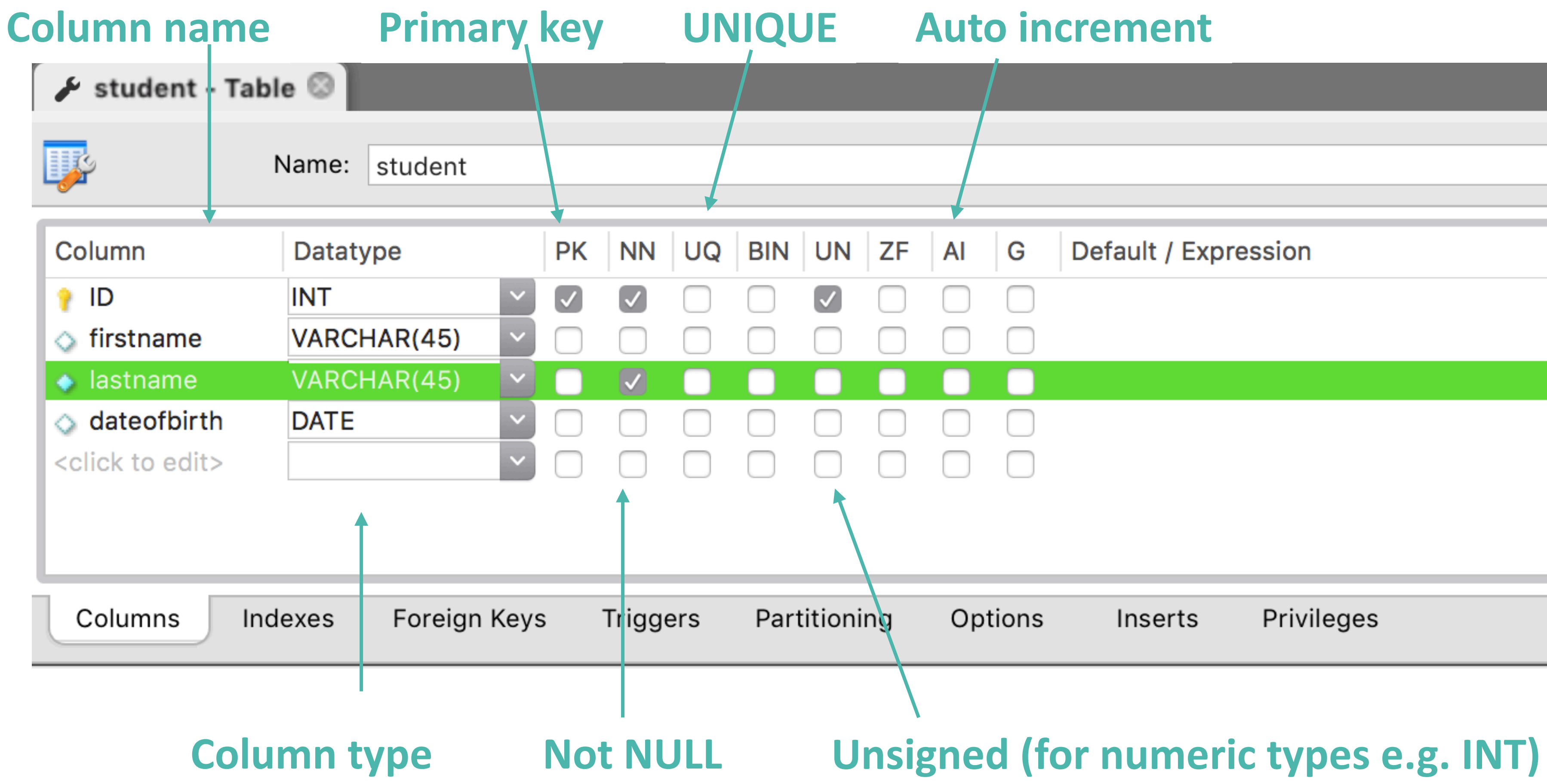
Column details 'dateofbirth'

Collation: Table Default

Columns | Indexes | Foreign Keys | Triggers | Partitioning | Options | Inserts | Privileges

MySQL Workbench

Add columns to table



student - Table

Name: student

Schema: mydb

Column	Datatype	PK	NN	UQ	BIN	UN	ZF	AI	G	Default / Expression
ID	INT	✓	✓			✓				
firstname	VARCHAR(45)									
lastname	VARCHAR(45)		✓							
dateofbirth	DATE									
<click to edit>										

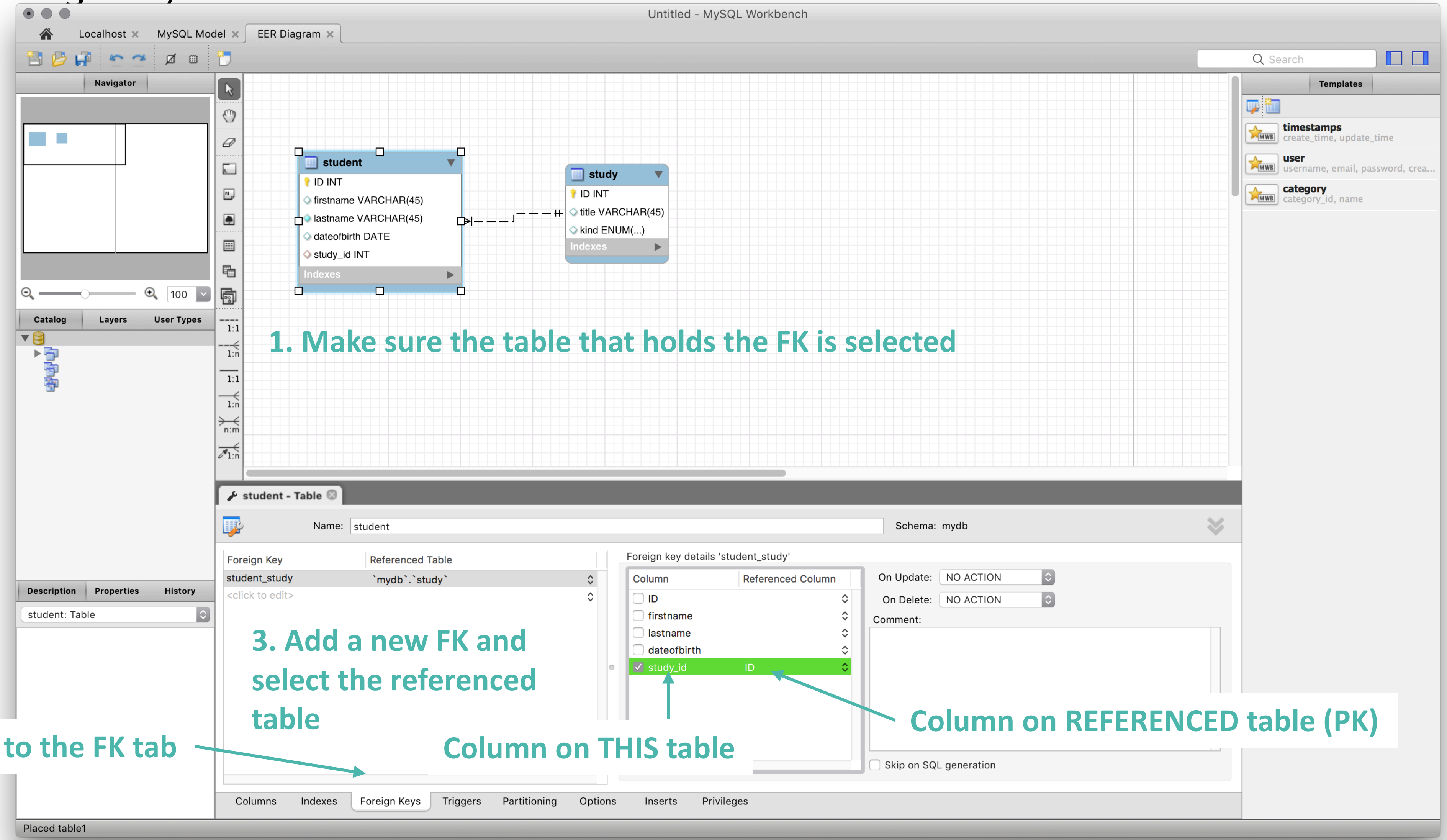
Column detai

Collation:

Comments:

MySQL Workbench

Add foreign keys to table



Untitled - MySQL Workbench

student: ID INT, firstname VARCHAR(45), lastname VARCHAR(45), dateofbirth DATE, study_id INT

study: ID INT, title VARCHAR(45), kind ENUM(...)

student - Table

Name: student

Schema: mydb

Foreign Key	Referenced Table
student_study	`mydb`.`study`
<click to edit>	

Foreign key details 'student_study'

Column	Referenced Column
☐ ID	
☐ firstname	
☐ lastname	
☐ dateofbirth	
✓ study_id	ID

On Update: NO ACTION

On Delete: NO ACTION

Comment:

Skip on SQL generation

1. Make sure the table that holds the FK is selected

2. Switch to the FK tab

3. Add a new FK and select the referenced table

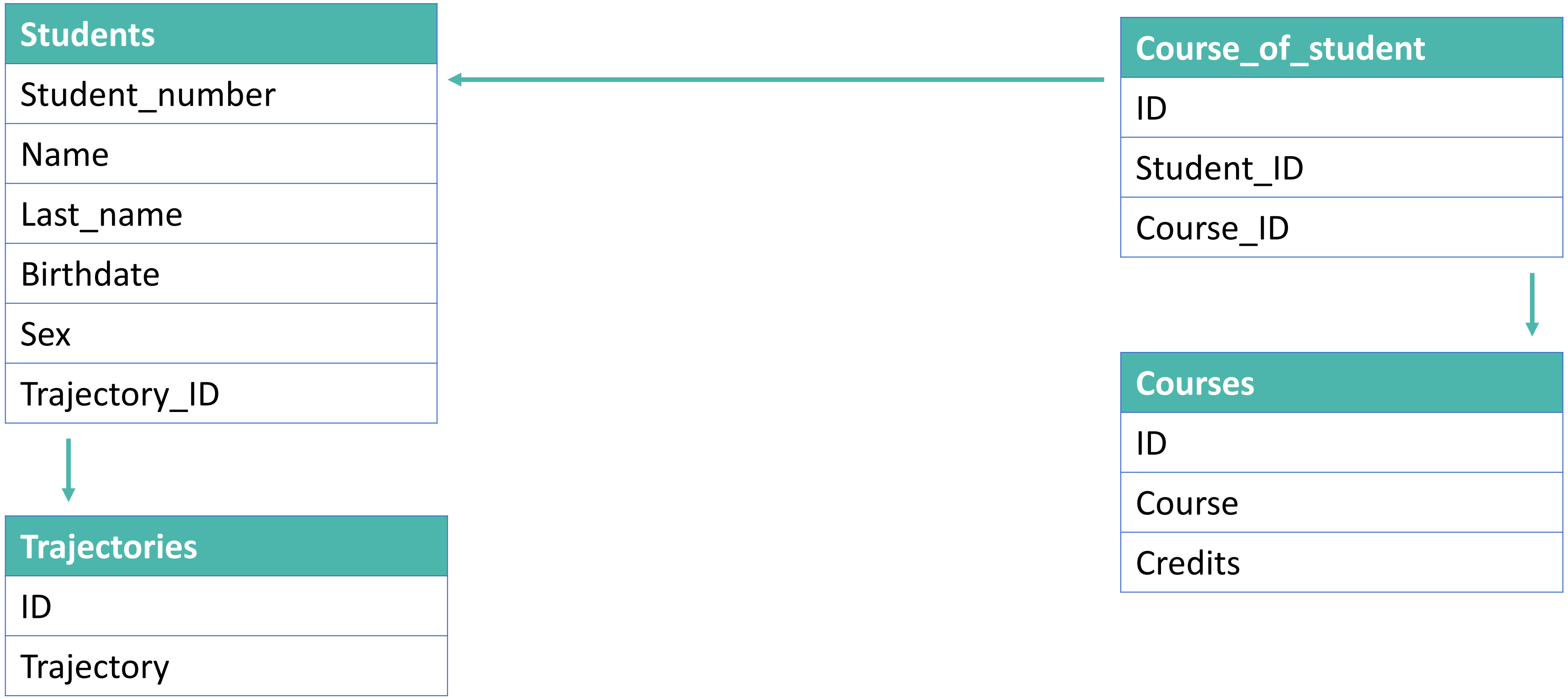
Column on THIS table

Column on REFERENCED table (PK)

MySQL Workbench

Exercises

- Create the following database schema

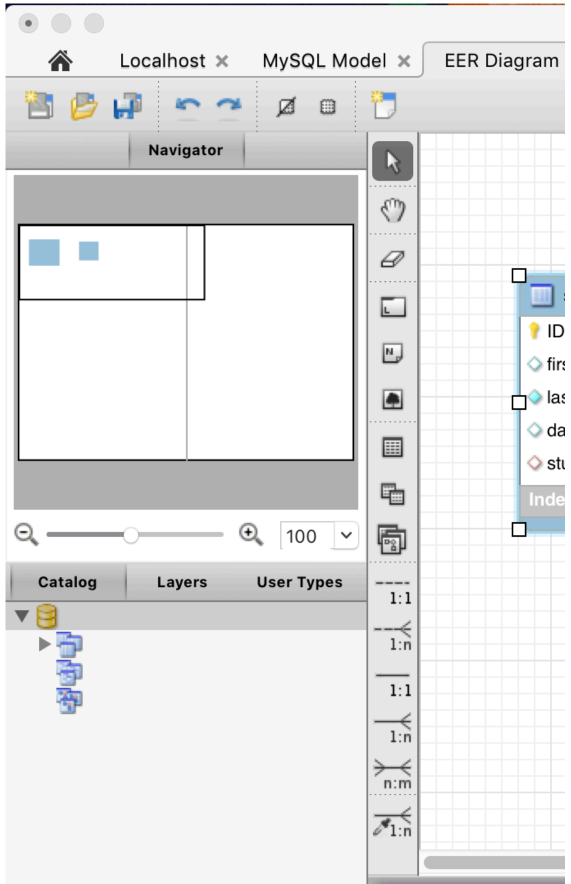


MySQL Workbench

Forward engineering

- Function in MySQL Workbench
  - Generates SQL code to create/modify a database based on your model
- Make sure the name of your database is correct!
  - Located under *Database > Forward engineer*
  - Check in the database browser (Refresh)

Double click to change $\longrightarrow$



MySQL Workbench

Exercises

- Create a MySQL table to track the movies you have watched:
  - Movie title
  - Genre: action, comedy, drama, horror, science fiction
  - Date you watched to movie
  - Score: 0-10
  - Comments
- Create a table to store your favourite directors and link it with the movie table
- Create a table to store your favourite actors and link it with the movie table
- Forward engineer your tables to your database
- Add some rows to the table you have created

MySQL Workbench

Creating a database

- Important questions
  - Which data?
  - Constraints?
  - Application?
  - Relations between data?

⇒ Entity relationship diagram

MySQL Workbench

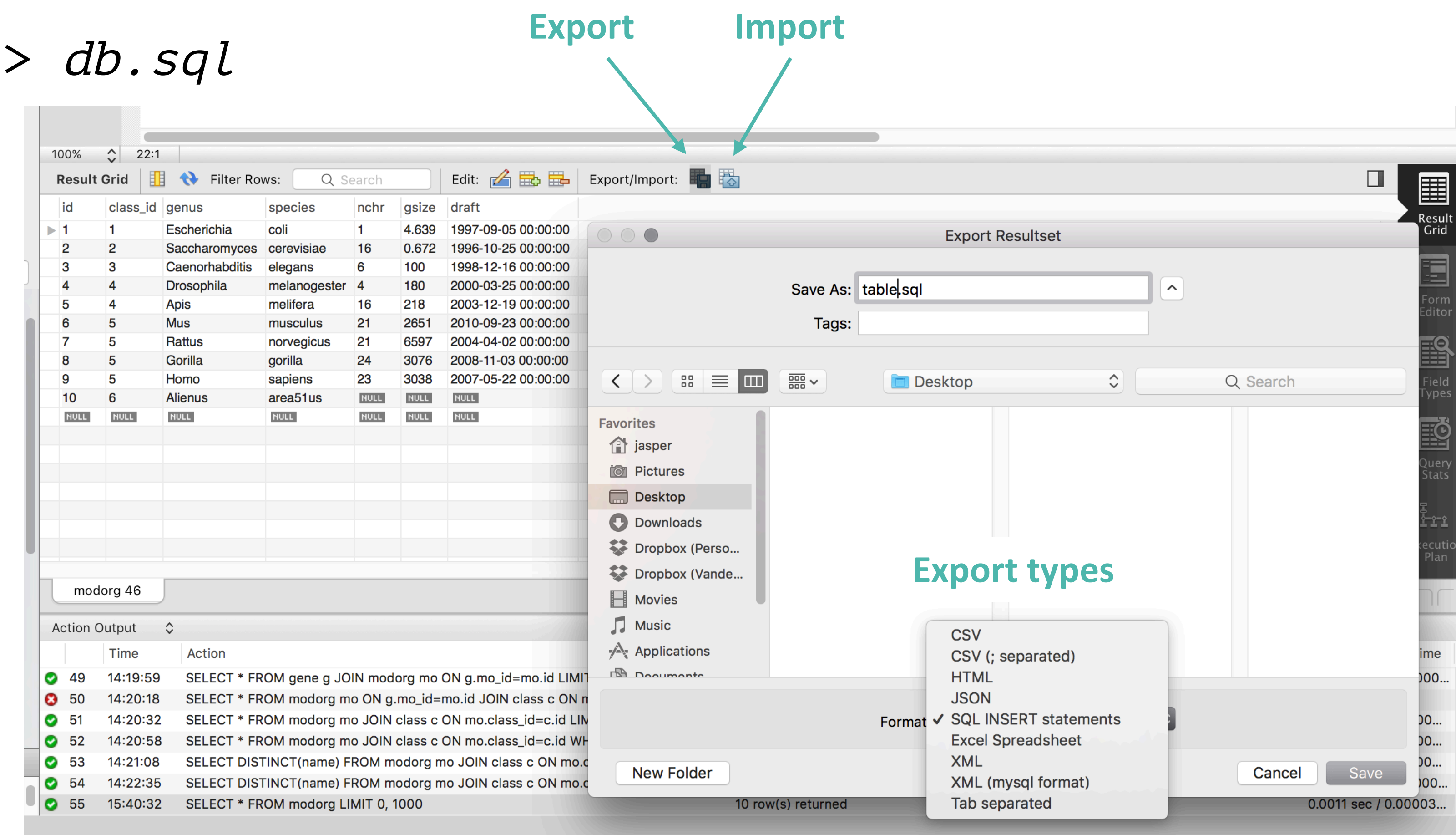
Exercises

- Reverse engineer the model of the bioinf_testdb
    - Check out the relationships between the different tables
    - Give the names of all the keys used

MySQL Workbench

Exporting data

- Remember
  `$ mysqldump [opt] db > db.sql`
- Dump your database
  - Structure, data or both
  - Useful for backup
- Ability to export part of results (JSON, CSV, HTML, XML, …)



id	class_id	genus	species	nchr	gsize	draft
1	1	Escherichia	coli	1	4.639	1997-09-05 00:00:00
2	2	Saccharomyces	cerevisiae	16	0.672	1996-10-25 00:00:00
3	3	Caenorhabditis	elegans	6	100	1998-12-16 00:00:00
4	4	Drosophila	melanogester	4	180	2000-03-25 00:00:00
5	4	Apis	melifera	16	218	2003-12-19 00:00:00
6	5	Mus	musculus	21	2651	2010-09-23 00:00:00
7	5	Rattus	norvegicus	21	6597	2004-04-02 00:00:00
8	5	Gorilla	gorilla	24	3076	2008-11-03 00:00:00
9	5	Homo	sapiens	23	3038	2007-05-22 00:00:00
10	6	Alienus	area51us	NULL	NULL	NULL
NULL	NULL	NULL	NULL	NULL	NULL	NULL

modorg 46

Save As: table.sql
Tags:
Desktop

Format:
- CSV
- CSV (; separated)
- HTML
- JSON
- ✓ SQL INSERT statements
- Excel Spreadsheet
- XML
- XML (mysql format)
- Tab separated

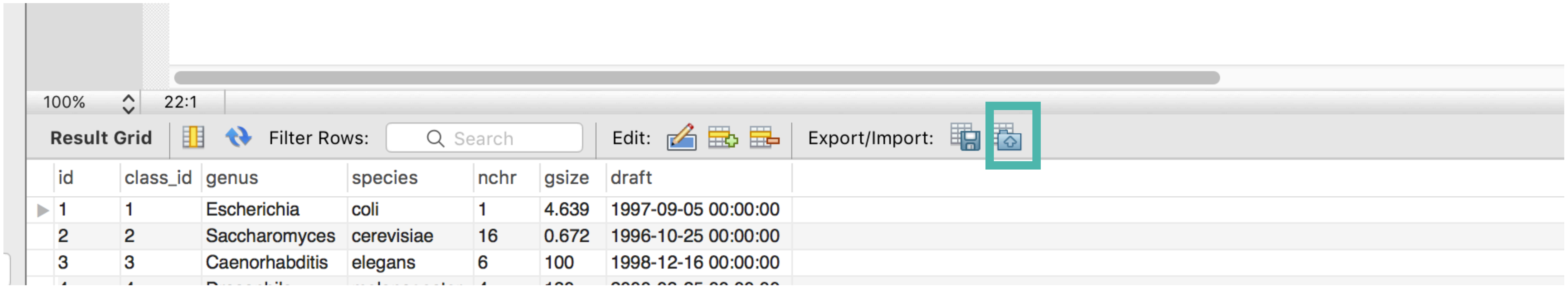
Action Output

```
    Time      Action
49  14:19:59  SELECT * FROM gene g JOIN modorg mo ON g.mo_id=mo.id LIMIT
50  14:20:18  SELECT * FROM modorg mo ON g.mo_id=mo.id JOIN class c ON m
51  14:20:32  SELECT * FROM modorg mo JOIN class c ON mo.class_id=c.id LIM
52  14:20:58  SELECT * FROM modorg mo JOIN class c ON mo.class_id=c.id WH
53  14:21:08  SELECT DISTINCT(name) FROM modorg mo JOIN class c ON mo.c
54  14:22:35  SELECT DISTINCT(name) FROM modorg mo JOIN class c ON mo.c
55  15:40:32  SELECT * FROM modorg LIMIT 0, 1000         10 row(s) returned         0.0011 sec / 0.00003...
```

MySQL Workbench

Import data

- Import entire dump file
- Import data from file (CSV, existing table, SQL, JSON)



id	class_id	genus	species	nchr	gsize	draft
1	1	Escherichia	coli	1	4.639	1997-09-05 00:00:00
2	2	Saccharomyces	cerevisiae	16	0.672	1996-10-25 00:00:00
3	3	Caenorhabditis	elegans	6	100	1998-12-16 00:00:00

MySQL Workbench

Excercises

- Export the data from the `modorg` table in your `biodb` database
- Empty your table (`TRUNCATE`)
- Import data into the `modorg` table using your export file