CS213
Principles of Database Systems(H)

Chapter 2

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Most contents are from Stéphane Faroult's slides

2.1 Introduction to SQL

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How to manage data in a database?

Special language needed!

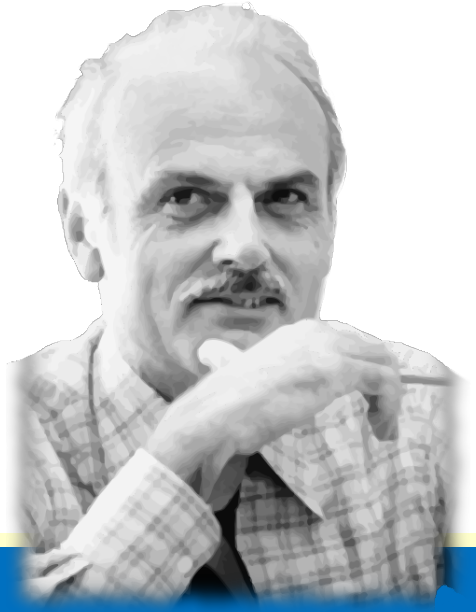
We must be able to use a language to query a database, either interactively or from within a program: a query language.

- Find the supplier names and locations of those suppliers who supply part 15.

$$(r_1[2],\ r_1[3]):\ P_1 r_1 \wedge \exists P_2 r_2 (r_2[2] = 15 \wedge r_2[1] = r_1[1]).$$

- Find the locations of suppliers and the parts being supplied by them (omitting those suppliers who are supplying no parts at this time).

$$(r_1[3],\ r_2[2]):\ P_1 r_1 \wedge P_2 r_2 \wedge (r_1[1] = r_2[1]).$$



ALPHA

Codd worked on a language. It didn't excite enthusiasm at IBM.

SEQUEL: A STRUCTURED ENGLISH QUERY LANGUAGE

by

Donald D. Chamberlin
Raymond F. Boyce

IBM Research Laboratory
San Jose, California

What the IBM management wanted was an "easy" language, with an English-like syntax. Here comes SQL (born SEQUEL)

Don Chamberlin with Ray Boyce (+ 1974)

ABSTRACT: In this paper we present the data manipulation facility for a structured English query language (SEQUEL) which can be used for accessing data in an integrated relational data base. Without resorting to the concepts of bound variables and quantifiers SEQUEL identifies a set of simple operations on tabular structures, which can be shown to be of equivalent power to the first order predicate calculus. A SEQUEL user is presented with a consistent set of keyword English templates which reflect how people use tables to

```
select ...
from ...
where ...
```

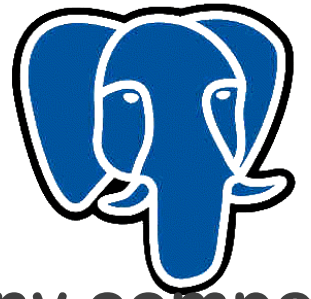
The basic syntax of SQL is very simple. SELECT is followed by the names of the columns you want to return, FROM by the name of the tables that you query, and WHERE by filtering conditions.

```
range of e is employee
retrieve (comp = e.salary / (e.age - 18))
where e.name = "Jones"
```

QUEL

INGRES

PostgreSQL



SQL was just one of many competing languages. QUEL, born at Berkeley, and associated with INGRES, was highly regarded.

Michael Stonebraker

Movies	Movieid	Title	Country	Year_Released
P.			IN	> 1985

QBE

Moshe Zloof

Query By Example (QBE) was a visual querying tool (visual but with characters) also created at IBM. Some descendents of it still exist today.

ORACLE®

Oates Ellison Miner

Those three guys (the founders of Oracle) took SQL and created an SQL-compatible system on other systems than the IBM systems, thus helping turn SQL into a standard.

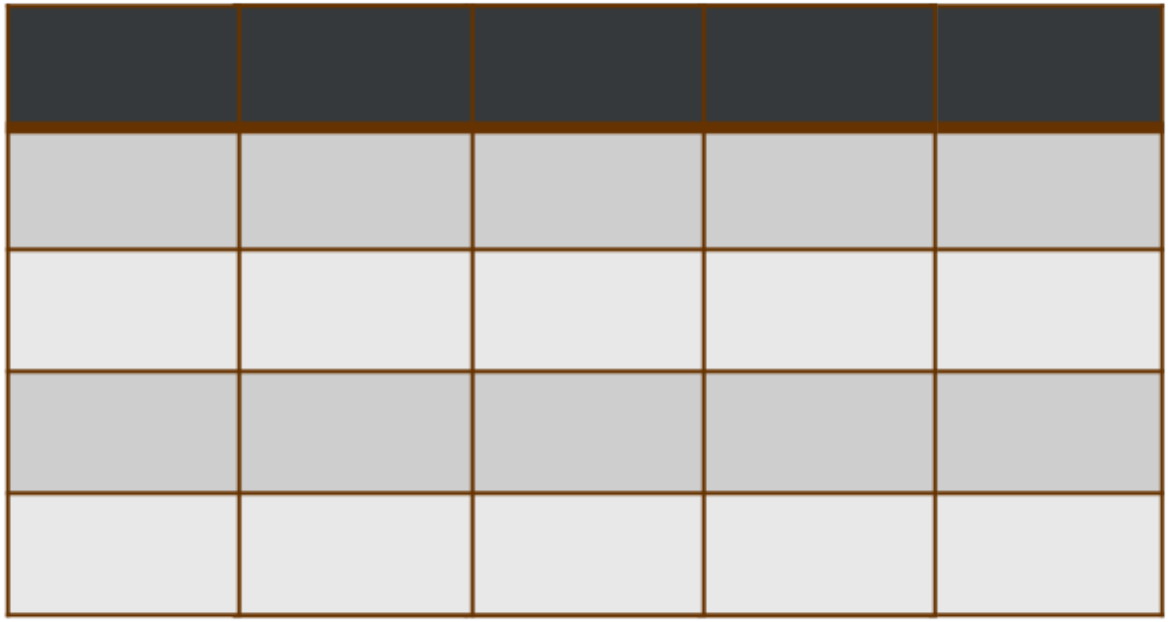
TWO main components

Codd had required in his seminal paper that a good database language should allow to deal as easily with contents (data) as containers (tables), something that SQL does reasonably well.

CREATE

ALTER

DROP



Data Definition Language

The data definition language (usually called DDL) deals with tables (as well as other database "objects" that we'll see later).

Three commands are enough for creating a new table, changing its structure (for instance adding a new column) or deleting it.

INSERT

id	title	country	year_released
1	Casablanca	us	1942
2	Blade Runner	us	1982
3	On The Waterfront	us	1954
4	Lawrence Of Arabia	uk	1962
5	Annie Hall	us	1977
6	Goodfellas	us	1990
7	The Third Man	uk	1949
8	Citizen Kane	us	1941
9	Bicycle Thieves	it	1948
10	The Battleship Potemkin	ru	1925
11	Sholay	in	1975
12	A Better Tomorrow	hk	1986

Data Manipulation Language

UPDATE

id	title	country	year_released
1	Casablanca	us	1942
2	Blade Runner	us	1982
3	On The Waterfront	us	1954
4	Lawrence Of Arabia	gb	1962
5	Annie Hall	us	1977
6	Goodfellas	us	1990
7	The Third Man	gb	1949
8	Citizen Kane	us	1941
9	Bicycle Thieves	it	1948
10	The Battleship Potemkin	ru	1925
11	Sholay	in	1975
12	A Better Tomorrow	hk	1986

Data Manipulation Language

DELETE

id	title	country	year_released
1	Casablanca	us	1942
2	Blade Runner	us	1982
3	On The Waterfront	us	1954
4	Lawrence Of Arabia	gb	1962
6	Goodfellas	us	1990
7	The Third Man	gb	1949
8	Citizen Kane	us	1941
9	Bicycle Thieves	it	1948
10	The Battleship Potemkin	ru	1925
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Data Manipulation Language

DELETE

id	title	country	year_released
1	Casablanca	us	1942
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3	On The Waterfront	us	1954
4	Lawrence Of Arabia	gb	1962
6	Goodfellas	us	1990
7	The Third Man	gb	1949
8	Citizen Kane	us	1941
9	Bicycle Thieves	it	1948
10	The Battleship Potemkin	ru	1925
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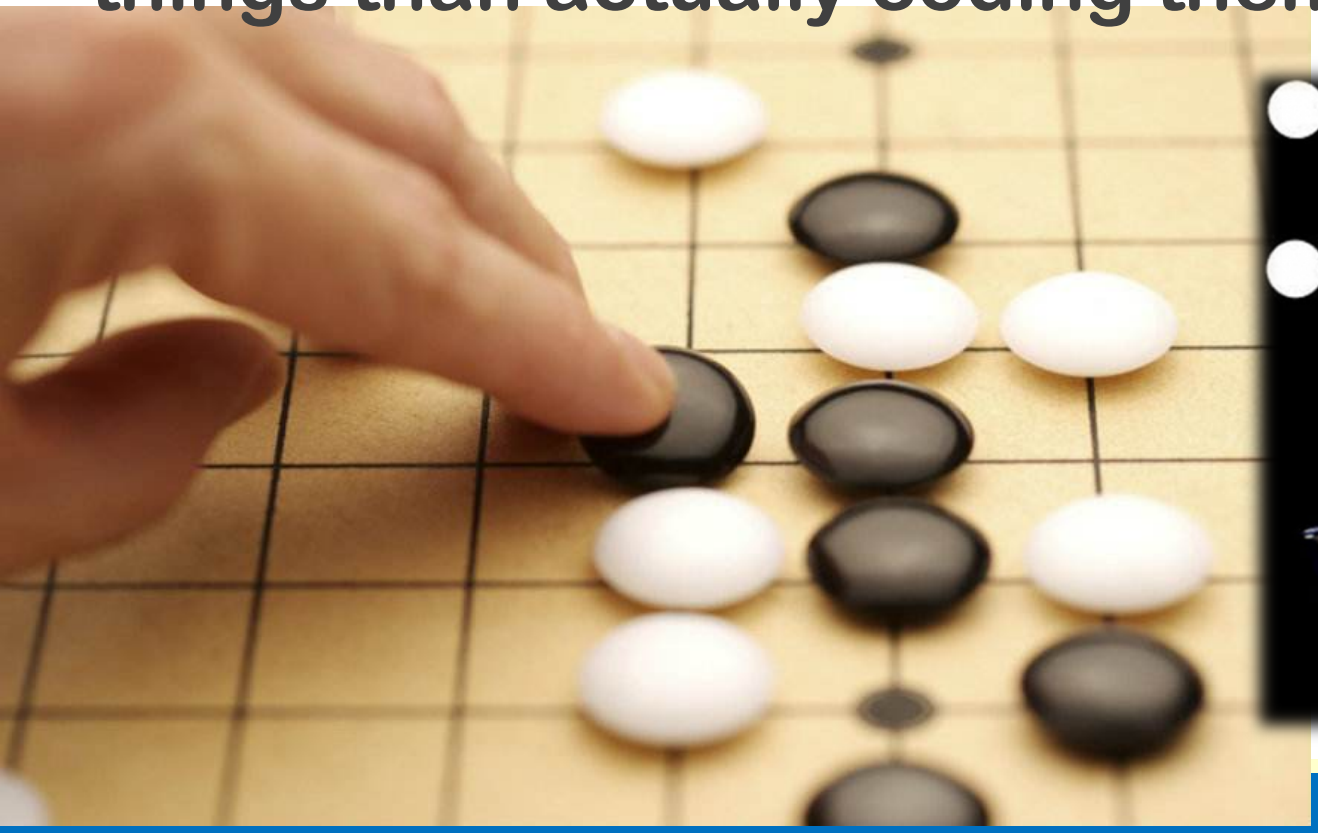
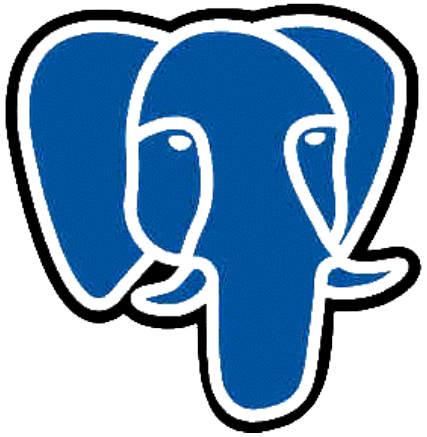
12	A Better Tomorrow	hk	1986

Data Manipulation Language

SIMPLE or NOT SIMPLE?

As you can see it's simple. Like chess, it becomes complicated when you COMBINE operations .
SQL is one of a few languages where you spend more time thinking about how you are going to do things than actually coding them.





There is an official SQL standard that no product fully implements, and many subtly and sometimes irritatingly different dialects. We'll see the main variants of SQL.

It must be stressed that although for most people SQL is synonym with "relational database", SQL wasn't designed as a "relationally correct" language, but as an "easy language" that anybody could use. It implements features that are heretical for a database purist. More importantly, it's, in some respects, very lax. As a result, it's very easy to misuse, using it well is difficult, and there have been performance issues with SQL since circa 1974.

SQL

a BIG

misunderstanding

```c
#include <stdio.h>
int main() {
    float a = 7.0;
    float b = 3.0;
    int c;
    c = (a / b) % 2;
    printf("c = %d\n", c);
    return 0;
}
```

To give an analogy, if in a C program you try to apply an operator (here the modulo operator, %) to variable types that don't support it (floats), the compiler won't let you go scot-free.

```
yushiqi@Shiqi-Yu-SurfacePro:~$ gcc hello.c  -o hello
hello.c: In function ‘main’:
hello.c:6:16: error: invalid operands to binary % (have ‘float’ and ‘int’)
    c = (a / b) % 2;
        ~~~~~~~ ^
```

Codd's operations, like the modulo, are only valid with certain types of "table variables". Contrary to the C compiler, an SQL engine won't complain when your tables don't fit the requirements of the theory. As a result, if you aren't rigorous enough, you may get wrong results without any warning.

Key propriety of relations (Codd's original paper):

ALL ROWS ARE DISTINCT

CAN BE enforced for tables in SQL

But you have to create your tables well.

NOT enforced for query results in SQL

You have to be extra-careful if the result of a query is the starting point for another query, which happens often.

2.2 Create Tables

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Most contents are from Stéphane Faroult's slides

```
CREATE TABLE  table_name
    (                                   ,
                                        ,
        …
    )
```

This is the syntax (simplified, some products can take a lot of additional options) for creating a table. The weird capitalization here is only to explain that SQL keywords (words that have a special meaning in SQL) are NOT case sensitive and can be typed in any case you want. I mostly use lowercase but some people have different habits.

tablename

=

TABLENAME

=

tABleNamE

Same story with identifiers, the names you give to tables or, as you will soon see, columns, aren't case-sensitive.

Some classic rules apply though: table (and column) names must start with a letter (PostgreSQL tolerates an underscore) and only contain letters, digits, or underscores. The $ sign is also accepted, and some products allow #.

~~4ME~~

MY_TABLE2

~~MY TABLE~~

Because names are not case-sensitive, CamelCaps aren't often used and underscores are preferred to separate words. Note that names can sometimes be quoted between double quotes or square brackets, in which case spaces are allowed AND names become case-sensitive. Better to avoid it.

```
create table  table_name
    (column_name        datatype ,
                                 ,
        …
    )
```

A comma-separated list of a column-name followed by spaces and a datatype specifies the columns in the table.

Text

Number

Date

Binary

That's basically what you find in a database; nothing fancy. Some products allow user defined types, but they aren't much used. Dates are quite important in databases.

plus some specific types or variants

Text datatypes

```
char(length)  char char(1)
varchar(max length)
varchar2(max length)
clob
```

ORACLE®

Datatype names vary with the DBMS. char() is for fixed-size columns (data is padded with spaces if shorter). Used for codes. Oracle understands varchar() and transforms it into its own varchar2(), but it's slightly different (an empty varchar2() is the same as nothing, not an empty varchar()). varchars don't pad. They are limited in length (a few thousand bytes). CLOB (called TEXT in MySQL) allows to store much bigger text (Gb).

Number datatypes

```
int

float

numeric(precision, scale)
```

8 2

99999999

Oracle knows mostly one number datatype, NUMBER, which can optionally take a precision (number of digits) and a scale (number of these digits after the decimal point). Something equivalent is called NUMERIC (sometimes DECIMAL) with other products, but other products also use INT and FLOAT far more.

Date datatypes

`date` includes time, down to second with Oracle, not with other products

`datetime` down to second (other than Oracle, DB2 and PostreSQL

`timestamp` down to 0.000001 second, Replace datetime in DB2/PostgreSQL

Same kind of mess with date and time datatypes. You also find a datetime2 type with SQL Server. Some subtle differences in ranges of acceptable values, precision, etc. Some products also implement a distinct TIME datatype, or datatypes that represent time intervals.

Binary datatypes

```
raw(max length)
varbinary(max length)
blob,bytea
```

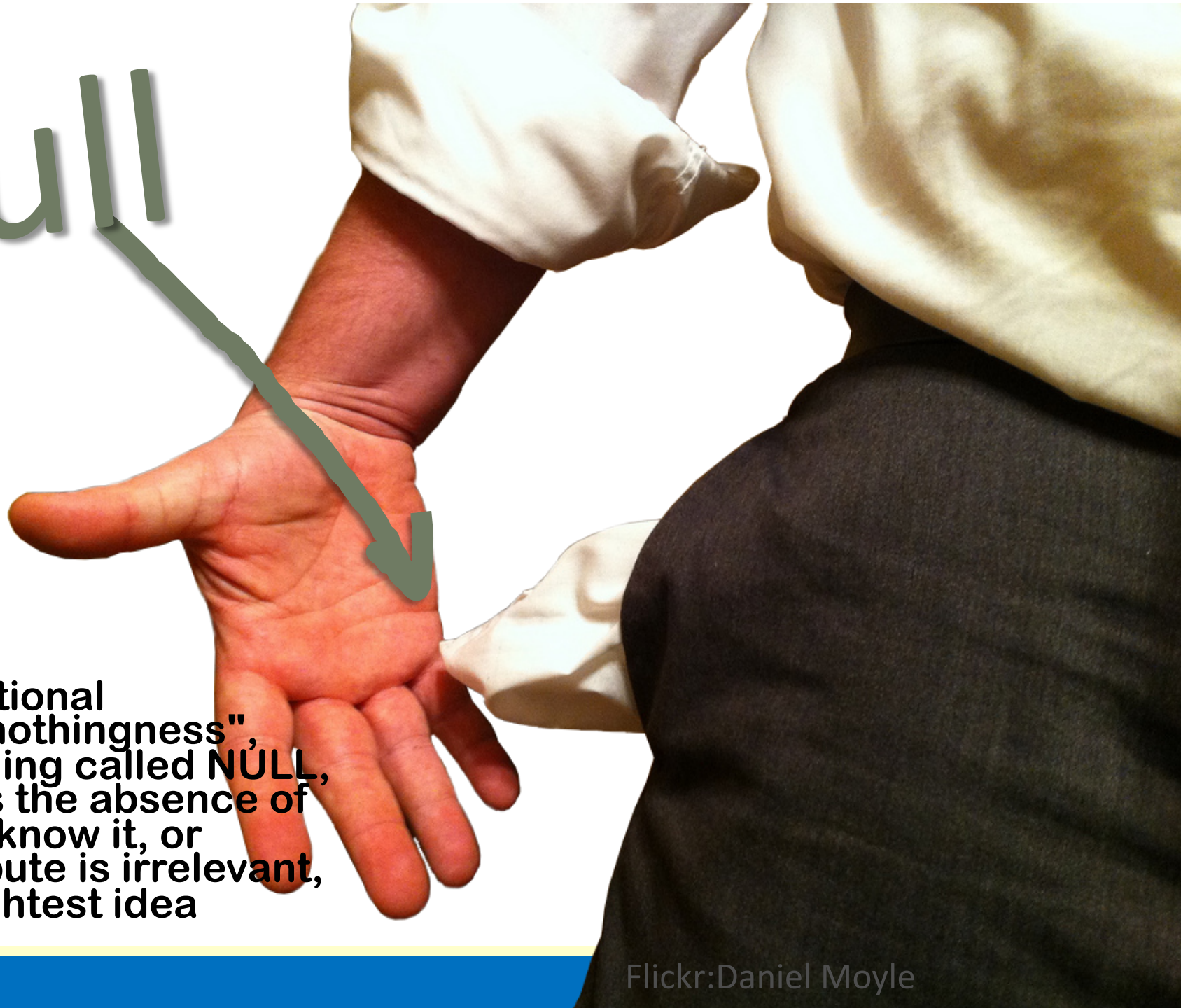
RAW in Oracle, and VARBINARY (SQL Server) are the binary equivalent of VARCHAR. BLOB is the binary equivalent of CLOB (BLOB means Binary Large Object). PostgreSQL calls the binary datatype BYTEA, don't ask me why.

```
create table people ( peopleid   int,
                      first_name varchar(30),
                      surname    varchar(30),
                      born       numeric(4),
                      Died       numeric(4)
                                   )
```

This CREATE TABLE statement would be accepted as perfectly valid by most DBMS product (Oracle would automatically convert INT into NUMBER(38), VARCHAR into VARCHAR2 and NUMERIC into NUMBER). However, this is a VERY BAD CREATE TABLE statement because it does nothing to enforce that we have a valid "relation" in Codd's sense.

A first question to ask ourselves is what should be mandatory? Do we really want rows about people we don't even know the name of? Obviously not.

Null



One important concept in relational databases is the concept of "nothingness", represented in SQL by something called NULL, which isn't a value. It indicates the absence of a value, because we don't yet know it, or because in that case the attribute is irrelevant, or because we haven't the slightest idea about what this should be.

Flickr:Daniel Moyle

```
create table people (peopleid   int   ,not null,
                     first_name varchar(30),
                     surname    varchar(30)   ,not null,
                     born       numeric(4),
                     died       numeric(4))
```

We indicate that a column is mandatory by saying that NULL isn't acceptable for this column, which is indicated by NOT NULL after the data type. The more NOT NULL columns, the better, because saying "I don't know" everywhere isn't very interesting. Surname and people identifier are columns that MUST have a value. Unless we only want dead people in our database, we should allow column DIED to take unknown values (we all know it will take a value one day, but we don't know it now). What about first_name?

Lady Gaga

```
filmdb=# select * from people where surname like '%Gaga%';
 peopleid | first_name |  surname   | born | died | gender
----------+------------+------------+------+------+--------
     8105 |            | Lady Gaga  | 1986 |      | F
(1 row)
```

Stored in the database

```
comment on column people.surname is 'Surname or stage name';
```

Not usually stored in the database

```
-- comments in an SQL statement start with a double dash
```

In that case the surname will be either the surname or a stage name. We can document it inside the database with the COMMENT statement available with SOME DBMS products, or we may document it in the CREATE STATEMENT itself (usually saved to a file) with a comment that extends from a double dash to the end of the line.

```
create table people (peopleid   int not null,
                     first_name varchar(30),
                     surname    varchar(30) not null,
                     born       numeric(4),
                     died       numeric(4))
```

For column BORN, we can either accept that a row is created for a person before we have the information when that person was born, or we may consider that people who enter data should do their homework and find the information before they create a row for a person. This is the option taken in the demo database.

```
create table people (peopleid   int not null,
                     first_name varchar(30),
                     surname    varchar(30) not null,
                     born       numeric(4)  ,not null,
                     died       numeric(4))
```

2.3 Constraints

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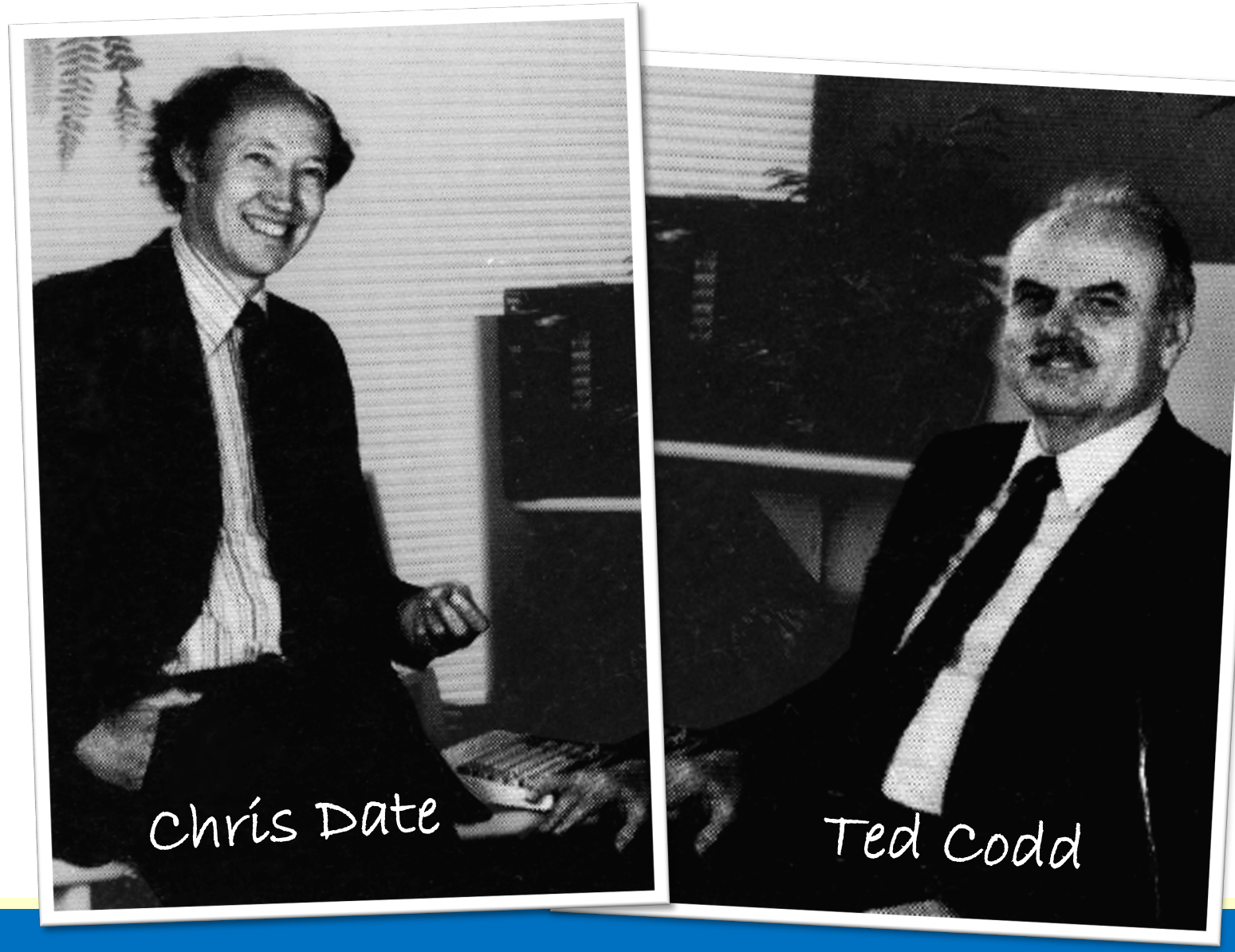
```
create table people (peopleid   int not null,
                     first_name varchar(30),
                     surname    varchar(30) not null,
                     born       numeric(4)  ,
                     died       numeric(4))
```

Our CREATE TABLE statement is better, but still doesn't prevent us for entering two strictly identical rows.

Surname	*Firstname*	*Birthdate*	*Picture*
Hepburn	Audrey	4-May-1929	
Hepburn	Audrey	4-May-1929	

Problem ...

Ted Codd was soon joined by another Briton, Chris Date, about 20 years his junior, who became his close friend, evangelist, and also worked on improving the relational theory.



Chris Date's work was mostly about ensuring first that only correct data that fits the theory can enter the database, and that data inside the database remains correct. Whenever programs retrieve data, they shouldn't have to double-check it and should be able to rely on the database management system. This is ensured through

CONSTRAINTS

Constraints are declarative rules that the DBMS will check every time new data will be added, when data is changed, or even when data is deleted, in order to prevent any inconsistency. Any operation that violates a constraint fails and returns an error.

```
create table people (peopleid    int not null     ,
                     first_name  varchar(30),
                     surname     varchar(30) not null,
                     born        numeric(4) not null,
                     died        numeric(4))
```

NOT NULL is a constraint. But there are many others. For instance, PRIMARY KEY tells which is the main key for the table, and indicates two things:

1) that the value is mandatory (the additional NOT NULL doesn't hurt but is redundant), and

2) that the values are unique (no duplicates allowed in the column)

```
create table people (peopleid   int not null
                                primary key,
                     first_name varchar(30),
                     surname    varchar(30) not null,
                     born       numeric(4) not null,
                     died       numeric(4) ,)
                      unique (first_name, surname))
```

So far, nothing would prevent us from entering two Audrey Hepburns with different ids. To ensure we only have one, we must say that the combination (first_name, surname) is unique (for actors ...). Constraints on several columns at once (same story with primary keys) are specified at the end of the list of columns with a comma-delimited list of column names.

For Oracle, PostgreSQL and DB2 ...

Beware that with many products data IS case sensitive, and different capitalization mean different values that wouldn't violate a uniqueness constraint. You MUST standardize case.

'audrey'

≠

'AUDREY'

≠

'Audrey'

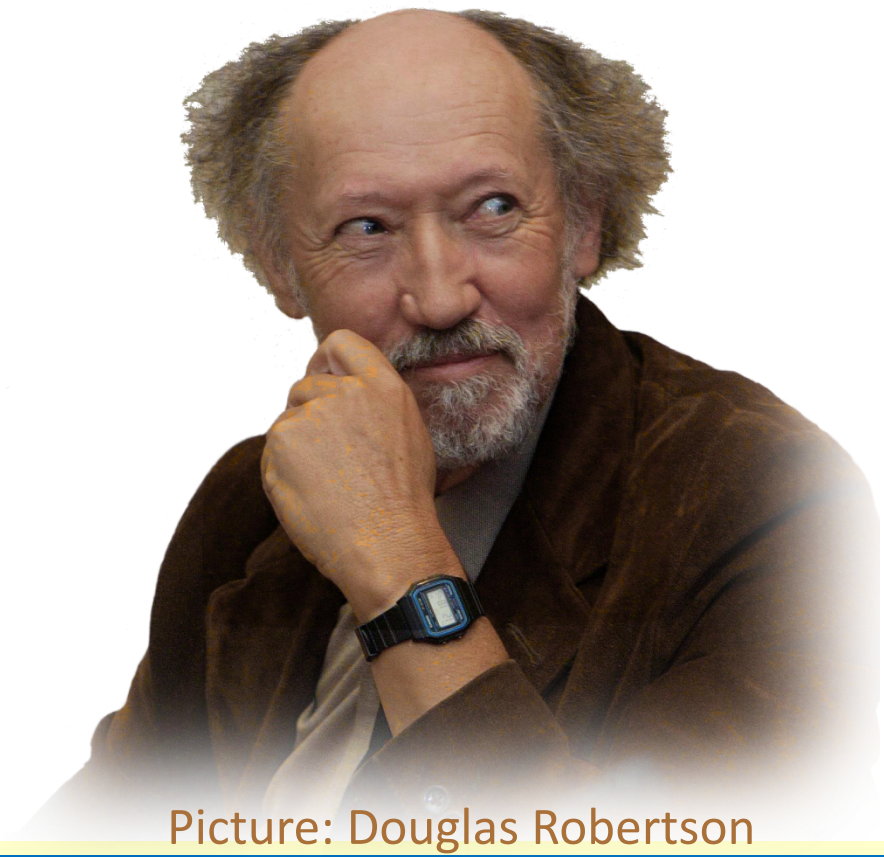
... not for SQL Server, MySQL or SQLite ...

```
create table people (peopleid   int not null
                                primary key,
                     first_name varchar(30),
                      surname    varchar(30) not null,
                      born       numeric(4) not null,
                      died       numeric(4),
                      unique (first_name, surname))
```

```
create table people (peopleid   int not null
                                 primary key,
                     first_name varchar(30)  ,
                     check (first_name = upper(first_name)),
                     surname    varchar(30) not null   ,
                     check (surname = upper(surname)),
                     born       numeric(4) not null,
                     died       numeric(4),
                     unique (first_name, surname))
```

One way to guarantee that case is, for instance, uppercase, would be to use the CHECK constraint, which isn't much used and that's a pity. CHECK is also useful for checking discrete values (e.g. only Y and N are accepted), ranges (percentage is a number between 0 and 100) or date validity (not born after being dead). MySQL accepts CHECK but doesn't enforce it.

Chris Date



Picture: Douglas Robertson

But there is far better than CHECK, which is a fairly static control: Referential Integrity

```
create table movies (movieid        int not null primary key,
                     title          varchar(60) not null,
                     country        char(2) not null,
                     year_released  numeric(4) not null
                                    check(year_released >= 1895),
                     unique (title, country, year_released))
```

In the MOVIES table, COUNTRY is a column that can take a LOT of different values, and listing all of them in a CHECK constraint would be clumsy. Besides, countries disappear (USSR, Yugoslavia) and new countries appear (South Sudan, Croatia, Slovakia). If we have no control, any typo would allow non-existing country codes to slip into the database.

COUNTRIES

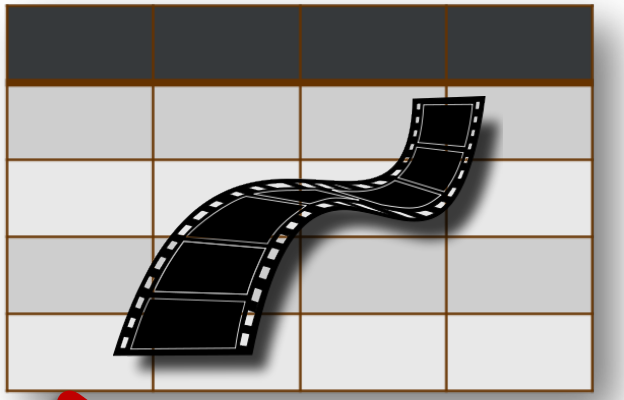
country_code	country_name	continent
us	United States	AMERICA
cn	China	ASIA
in	India	ASIA
br	Brazil	AMERICA
uk	United Kingdom	EUROPE
ru	Russia	EUROPE
mx	Mexico	AMERICA
it	Italy	EUROPE
de	Germany	EUROPE

The solution is referential integrity, and what is known as a reference table: a country that stores all country codes, and corresponding country names (all codes don't immediately ring a bell), with the code as primary key (and the country name declared as unique). We'll only accept a country code if we find it in this table (which can be modified, with new codes added)

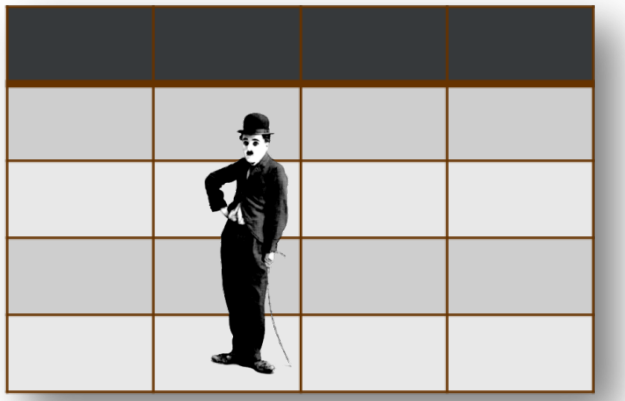
```
create table movies (movieid        int not null primary key,
                     title          varchar(60) not null,
                     country        char(2) not null,
                     year_released  numeric(4) not null
                                    check(year_released >= 1895),
                     unique (title, country, year_released)   );
                      foreign key(country)
                              references countries(country_code))
```

We'll declare in MOVIES that column COUNTRY is a FOREIGN KEY, which means that we must be able to find it as a key of the table that is referenced. Only primary keys and columns declared as UNIQUE can be referenced. A foreign key can be composed of a combination of columns (rare). Note that the constraint works both ways: we won't be able to delete a country if movies reference it, because we would get "orphaned rows" and the database would become inconsistent.

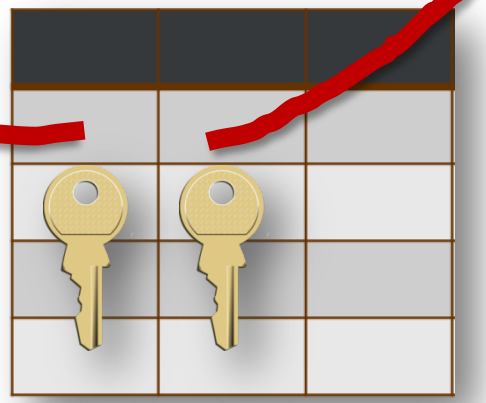
movies



people



credits



foreign key

foreign key

Primary and foreign keys are fairly independent notions. In table CREDITS, the movie id and the person id are foreign keys, because we cannot give credits for a non-existing film or person. Both foreign keys are part of the primary key of credits, which is composed of all three columns for this table.

Foreign Key

However, in some cases, foreign key can be a problem

- Especially in big data processing applications
  - E.g., Alibaba Java Coding Guideline (阿里巴巴Java开发手册)

（三）SQL 语句

6. 【强制】不得使用外键与级联，一切外键概念必须在应用层解决。

说明：以学生和成绩的关系为例，学生表中的 student_id 是主键，那么成绩表中的 student_id 则为外键。如果更新学生表中的 student_id，同时触发成绩表中的 student_id 更新，即为级联更新。外键与级联更新适用于单机低并发，不适合分布式、高并发集群；级联更新是强阻塞，存在数据库更新风暴的风险；外键影响数据库的插入速度。

https://ucc.alicdn.com/download/%E9%98%BF%E9%87%8C%E5%B7%B4%E5%B7%B4Java%E5%BC%80%E5%8F%91%E6%89%8B%E5%86%8C1.4.0.pdf

Reminder

Creating tables requires:

- Proper modelling
- Defining keys
- Determining correct data types
- Defining constraints

When all these are done, you can be sure that data that enters the database will be correct, and will remain so.

The preparatory work may seem (and sometimes is) a bit boring, but the rewards are huge: when programs no longer have to thoroughly check data but only check return codes, they become leaner and are far easier (and cheaper) to maintain. It also ensures, when several applications access the database, that controls are centralized and that one sloppily written small application won't corrupt data for other well written programs.

2.4 Insert

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Most contents are from Stéphane Faroult's slides

INSERT

SOME_TABLE

column1	column2

INSERT enters data into a table; if you consider tables as a special kind of variables, INSERT is very much like an assignment (often more like '+=' in C and derived languages). It changes the contents of the tables.

```
insert into table_name
       (list of columns)
values (list of values)
```

"lists" are comma-separated lists.

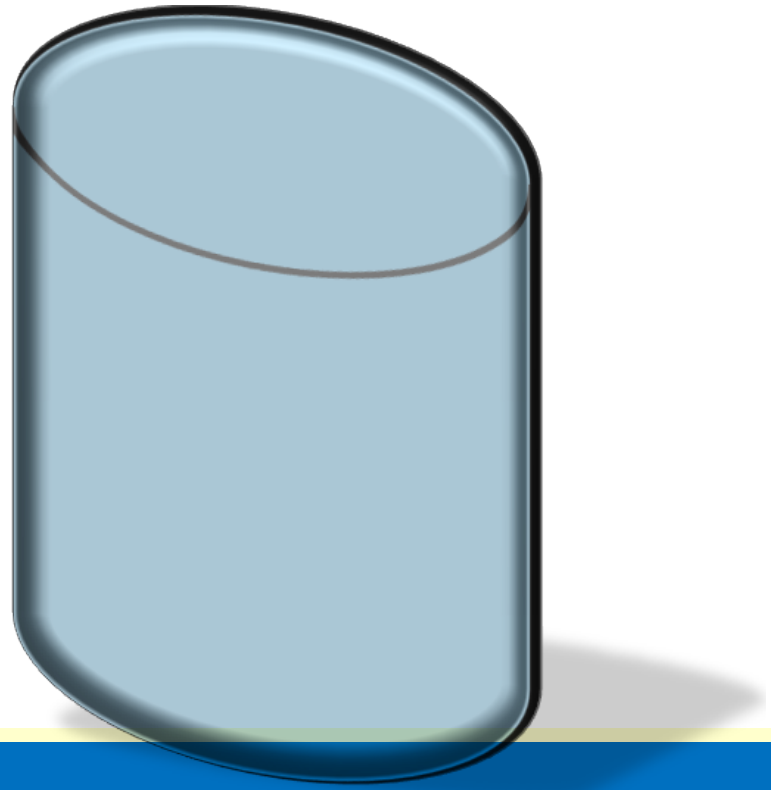
Values must match column-names one by one. What happens if you omit a column name from the list? Nothing is entered into it. If the column is mandatory, the INSERT statement fails and nothing at all is done.

```
insert into countries(country_code,
country_name, continent)
values('us', 'United States', 'AMERICA')
```

Note that strings are given between SINGLE quotes. Some products (MySQL, SQLite) also accept double quotes but SINGLE quotes is the standard and what works everywhere. You should use them.

Reminder

HELLO WORLD



I've stressed that case should be tightly controlled when inserting data. It's possible to use functions in INSERT statements to this effect.

1960

What happens when the data contains a quote?

You must escape it.

```
insert into movies(movieid,
        title,
        country,
        year_released)
values (123,
        'L''Avventura',
        'it',
        1960)
```

The standard SQL way to escape a quote is to double it. Only one is stored. MySQL also accepts a backslash as an escape character.

Flickr: Jason Dgreat

Entering a date?

Entering a date in a table is a common task that demands some care, there are only two ways to enter a date, as a string or as the result of a function or computation.

Most products support a default date format, and are able to automatically translate text that is inserted into a date or datetime column if this text matches the default format. You shouldn't rely on this and always specify the format, as here with Oracle:

```
to_date('07/20/1969',
        'MM/DD/YYYY')
```

The reason is that firstly a database administrator CAN change the default format, and secondly that dates can be ambiguous: an American may read **11/05 as November 5th**, for a European it will be **May 11th**.

SYSDATE

CURDATE()

GETDATE()

The current date is often used. CURRENT_DATE (no time) and CURRENT_TIMESTAMP (time included) are recognized by all products. For historical reasons, all products also have their, still frequently used, own functions.