Supplemental Material

- What are you installing when you install PostgreSQL?
  - Server-side program: the database management system itself
  - Client-side program: the client tools to manipulate the server via networks
- Search for the keywords after the class:
  - basics in computer networking (IP address, port, client, server, web browser, HTTP)
  - client-server architecture, browser-server architecture

Principles of Database Systems (CS307)

Lecture 3: Basic SQL

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- Most contents are from slides made by Stéphane Faroult and the authors of Database System Concepts (7th Edition).
- Their original slides have been modified to adapt to the schedule of CS307 at SUSTech.

Select

- `select * from` [tablename]
  - The `select` clause lists the attributes desired in the result of a query
  - To display the full content of a table, you can use select *
    - * : all columns

```
select A1, A2, ..., An
 from r1, r2, ..., rm
        where P
```

Select

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  - The `select` clause lists the attributes desired in the result of a query
  - To display the full content of a table, you can use select *
    - * : all columns

```
select A1, A2, ..., An
 from r1, r2, ..., rm
       where P
```

- Such a query is frequently used in interactive tools (especially when you don't remember column names ...)
  - But you should not use it, though, in application programs

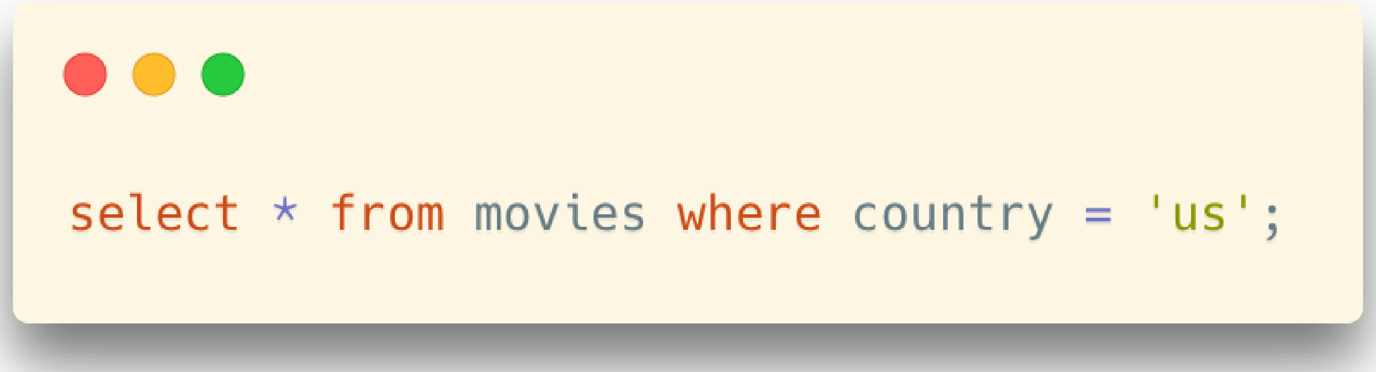
Restrictions

- When tables contains thousands or millions or billions of rows, you are usually interested in only a small subset, and only want to return some of the rows

peopleid	first_name	surname	born	died

Restrictions

- Filtering
  - Performed in the “where” clause
  - Conditions are usually expressed by a column name
    - … followed by a comparison operator and the value to which the content of the column is compared
  - Only rows for which the condition is true will be returned



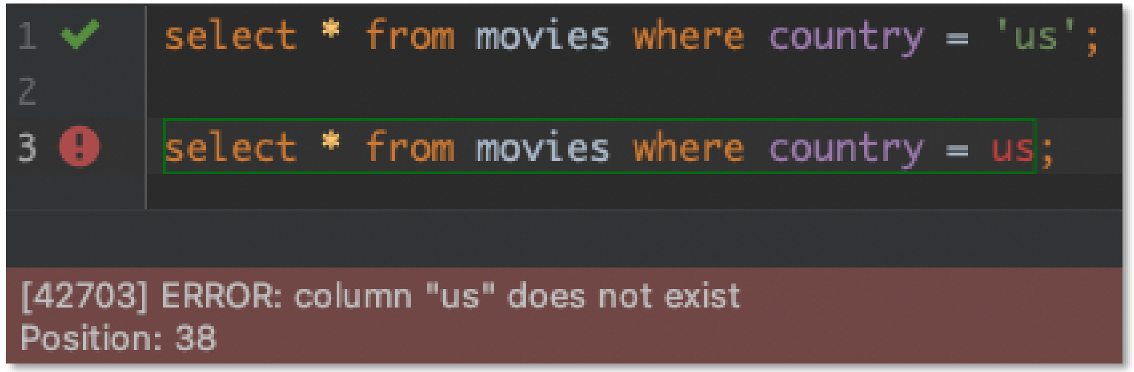
```sql
select * from movies where country = 'us';
```

Comparison

- You can compare to:
  - a number
  - a string constant
  - another column (from the same table or another, we'll see queries involving several tables later)
  - the result of a function (we'll see them soon)

String Constants

- Be aware that string constants must be quoted between single-quotes
  - If they aren't quoted, they will be interpreted as column names
  - * Same thing with Oracle if they are double-quoted



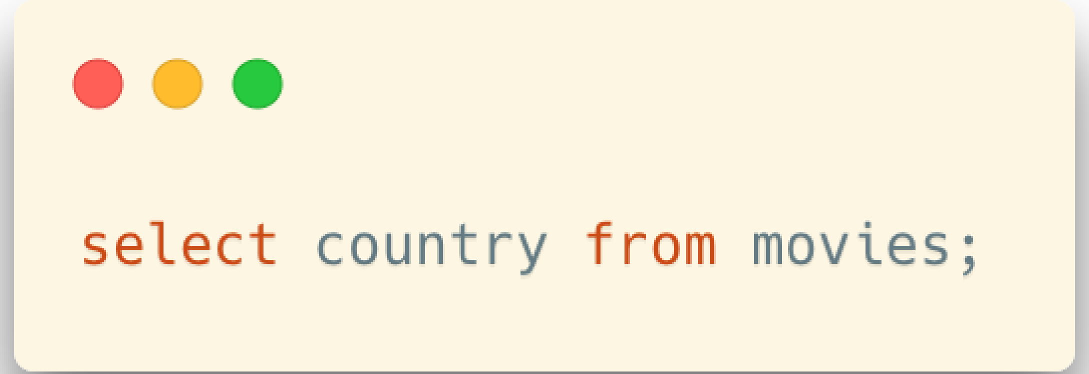
```
select * from movies where country = 'us';

select * from movies where country = us;
```

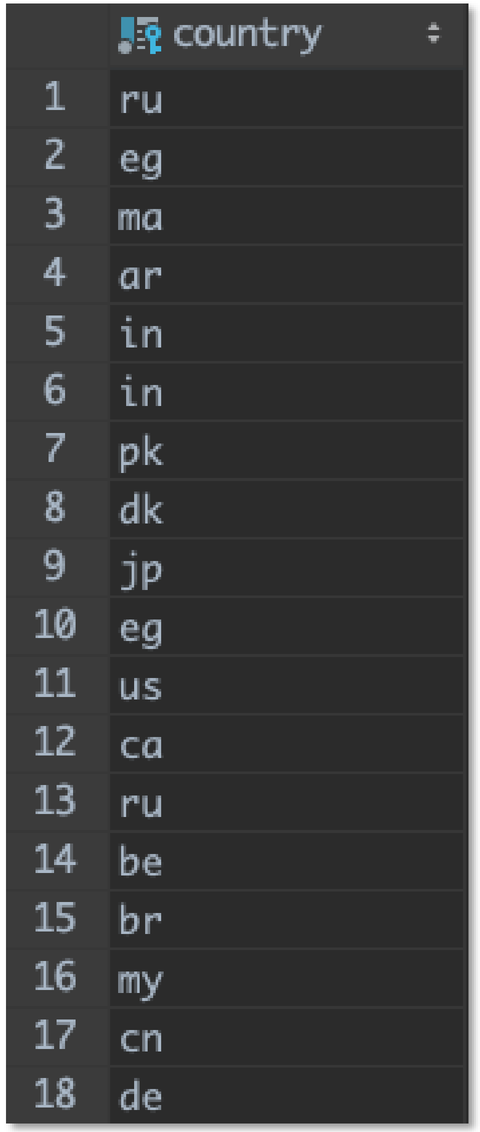
```
[42703] ERROR: column "us" does not exist
Position: 38
```

Filtering

- Note that a filtering condition returns a subset
  - If you return all the columns from a table without duplicates, it won't contain duplicates either and will be a valid "relation"



```sql
select country from movies;
```



	country
1	ru
2	eg
3	ma
4	ar
5	in
6	in
7	pk
8	dk
9	jp
10	eg
11	us
12	ca
13	ru
14	be
15	br
16	my
17	cn
18	de

Select without From or Where

- An attribute can be a literal with no from clause

```
select '437'
```

  - Results is a table with one column and a single row with value “437”
  - Can give the column a name using:

```
select '437' as FOO
```

- An attribute can be a literal with from clause

```
select 'A' from movies
```

  - Result is a table with one column and N rows (number of tuples in the movies table), each row with value “A”

Select without From or Where

- An attribute can be a literal with no from clause

```
select '437'
```

A common way to test expressions

  - Results is a table with one column and a single row with value “437”
  - Can give the column a name using:

```
select '437' as FOO
```

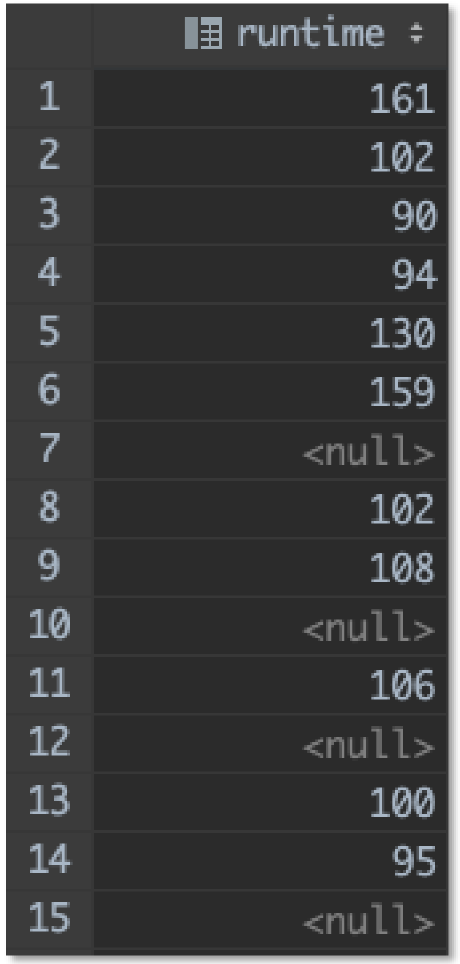
- An attribute can be a literal with from clause

```
select 'A’ from movies
```

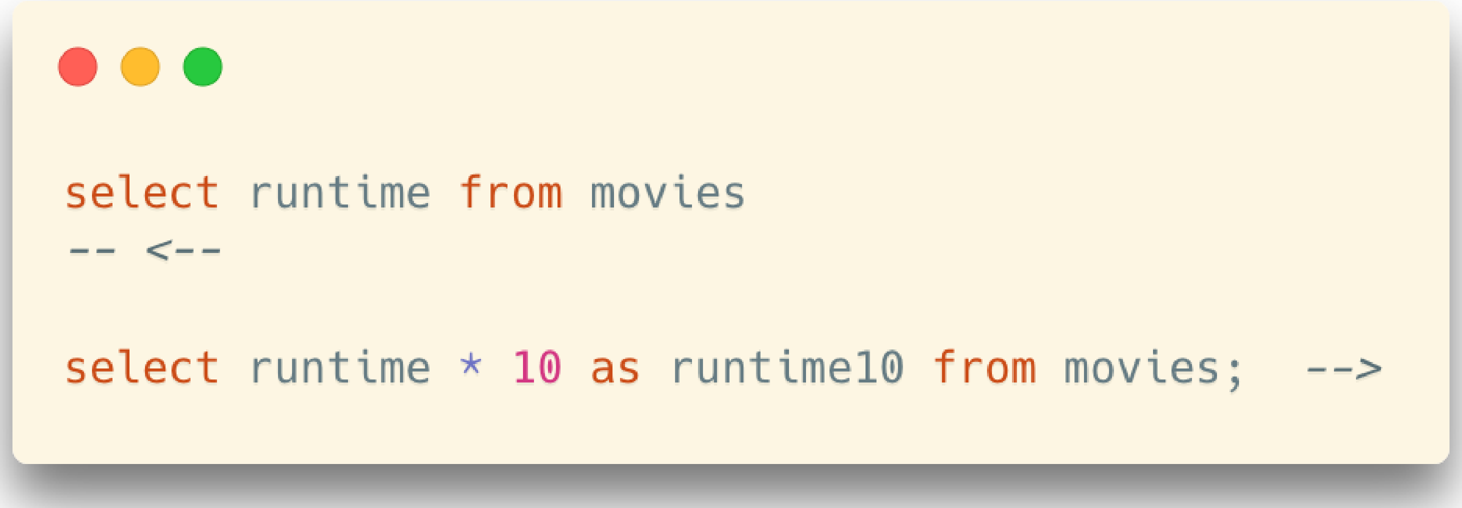
  - Result is a table with one column and N rows (number of tuples in the movies table), each row with value “A”

Arithmetic Expression

- The `select` clause can contain arithmetic expressions involving the operation, +, –, *, and /, and operating on constants or attributes of tuples

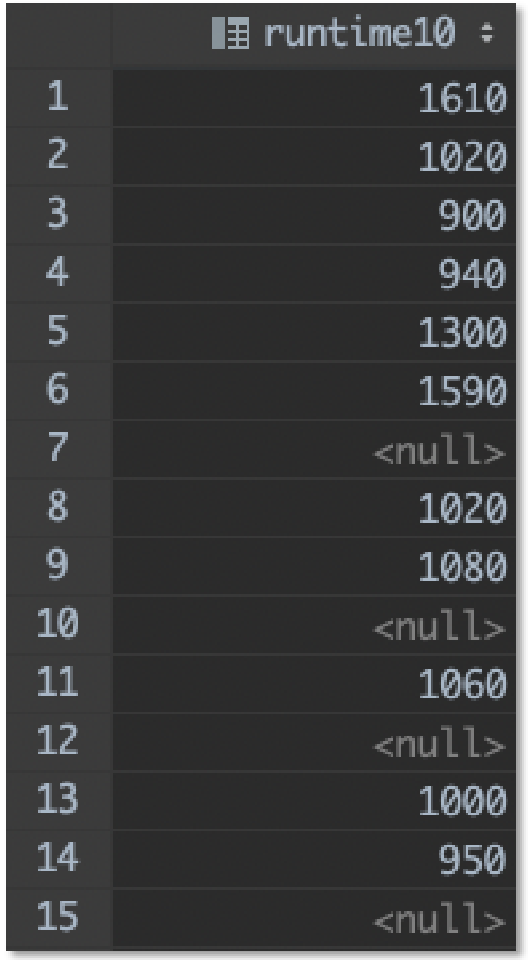


	runtime
1	161
2	102
3	90
4	94
5	130
6	159
7	<null>
8	102
9	108
10	<null>
11	106
12	<null>
13	100
14	95
15	<null>



```
select runtime from movies
-- <--

select runtime * 10 as runtime10 from movies;  -->
```



	runtime10
1	1610
2	1020
3	900
4	940
5	1300
6	1590
7	<null>
8	1020
9	1080
10	<null>
11	1060
12	<null>
13	1000
14	950
15	<null>

Arithmetic Expression

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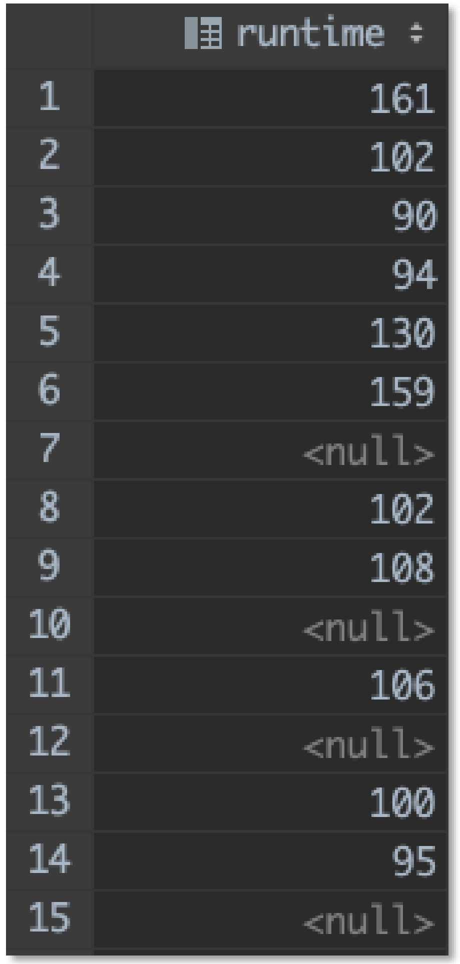

	runtime
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2	102
3	90
4	94
5	130
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10	<null>
11	106
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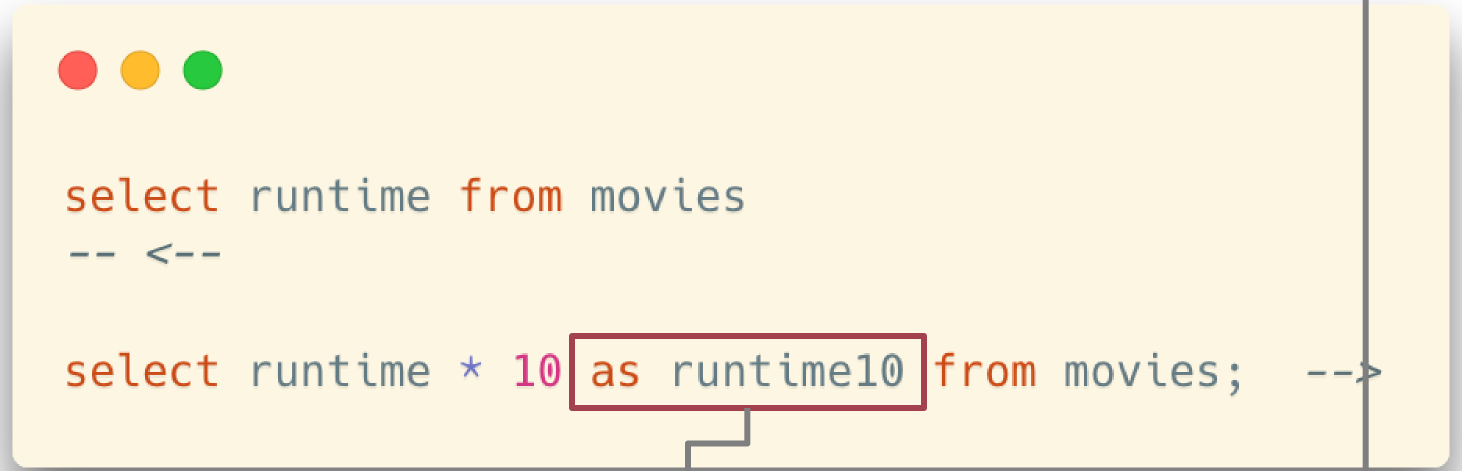
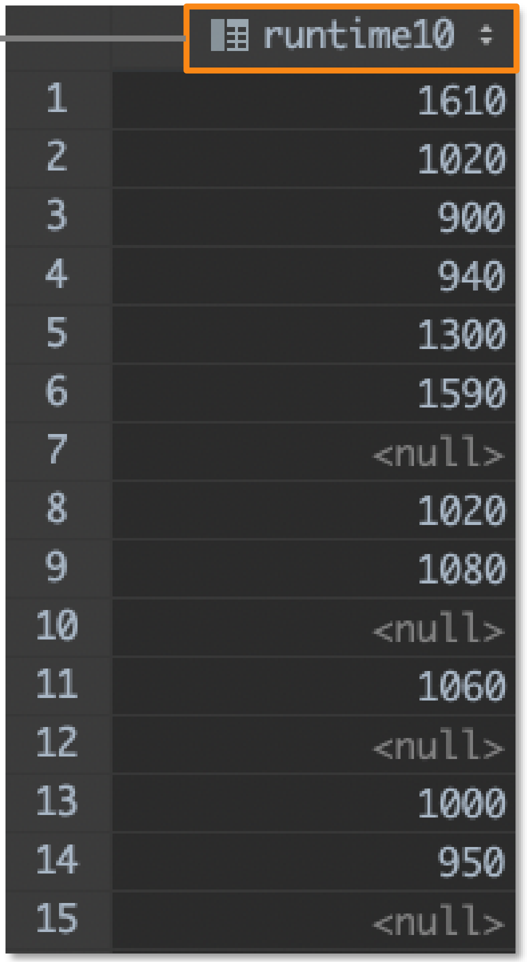


```
select runtime from movies
-- <--

select runtime * 10 as runtime10 from movies;  -->
```

as clause:

- Rename the column



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Logical Connectives

- and, or, not
  - Just like in programming languages
  - All logical operators have different precedence
    - For example, and is “stronger” than or

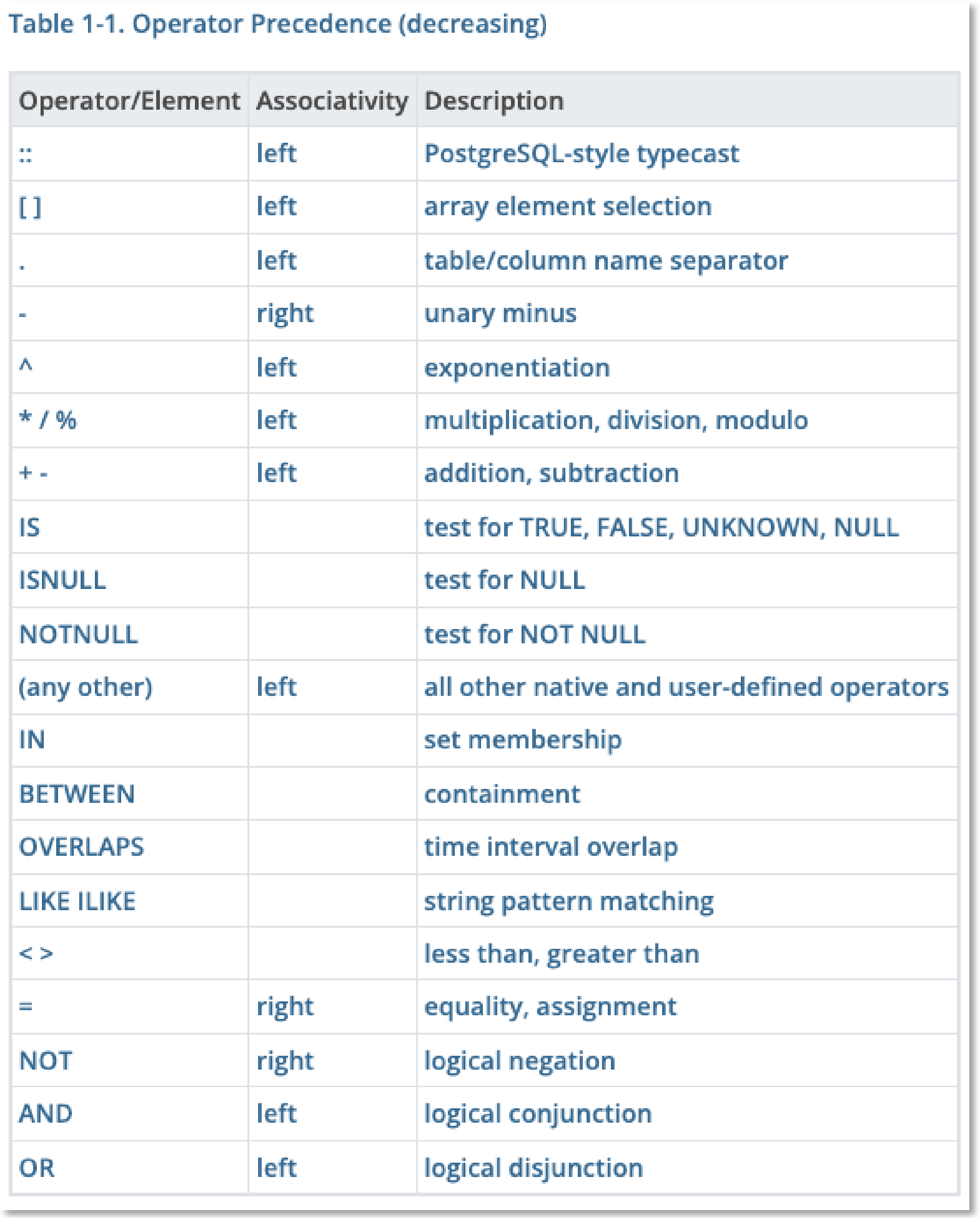

Table 1-1. Operator Precedence (decreasing)

Operator/Element	Associativity	Description
::	left	PostgreSQL-style typecast
[ ]	left	array element selection
.	left	table/column name separator
-	right	unary minus
^	left	exponentiation
* / %	left	multiplication, division, modulo
+ -	left	addition, subtraction
IS		test for TRUE, FALSE, UNKNOWN, NULL
ISNULL		test for NULL
NOTNULL		test for NOT NULL
(any other)	left	all other native and user-defined operators
IN		set membership
BETWEEN		containment
OVERLAPS		time interval overlap
LIKE ILIKE		string pattern matching
< >		less than, greater than
=	right	equality, assignment
NOT	right	logical negation
AND	left	logical conjunction
OR	left	logical disjunction

https://www.postgresql.org/docs/7.2/sql-precedence.html

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  - Just like in programming languages
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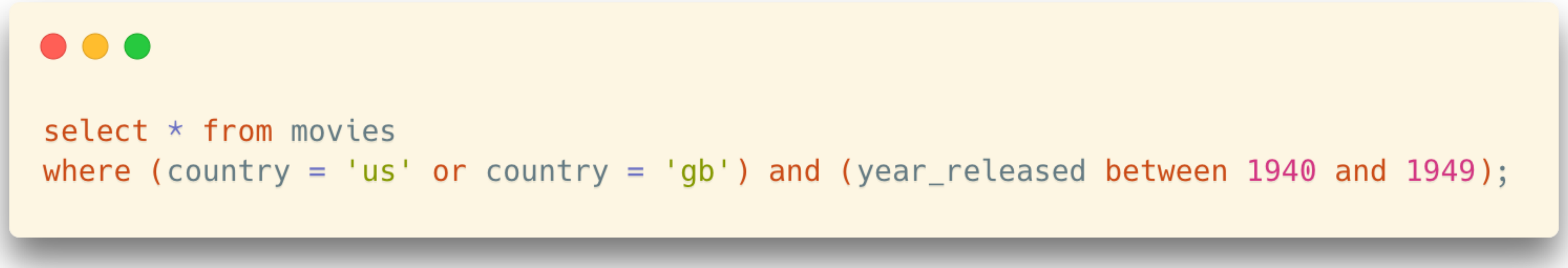
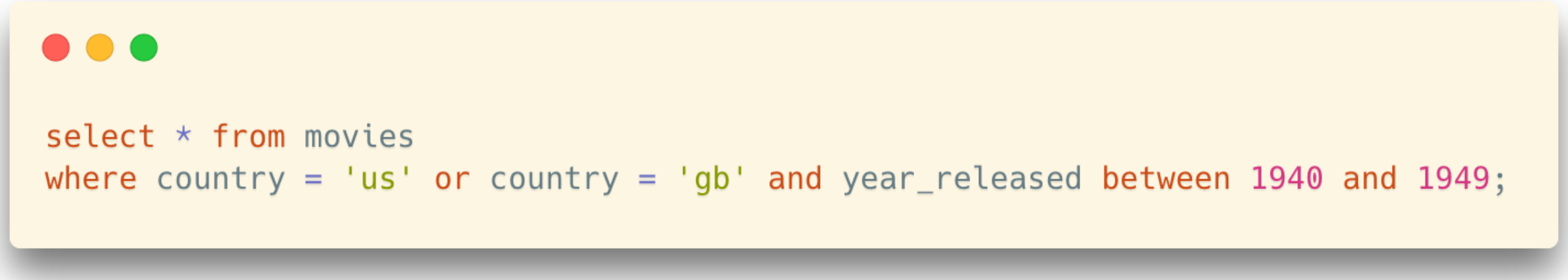


```
select * from movies
where (country = 'us' or country = 'gb') and (year_released between 1940 and 1949);
```

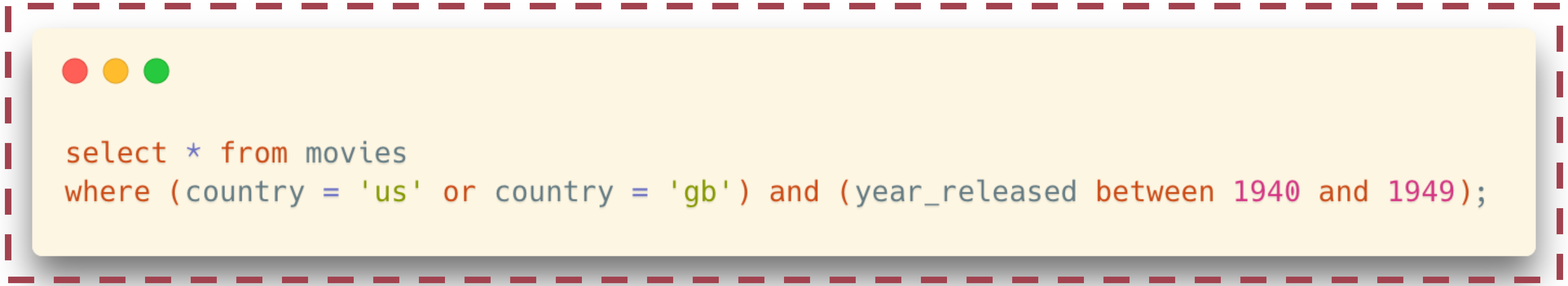


```
select * from movies
where country = 'us' or country = 'gb' and year_released between 1940 and 1949;
```

Differences?

Logical Connectives

- Use parentheses to specify that the “or” should be evaluated before the “and”, and that the conditions filter
  - 1) British or American films
  - 2) that were released in the 1940s



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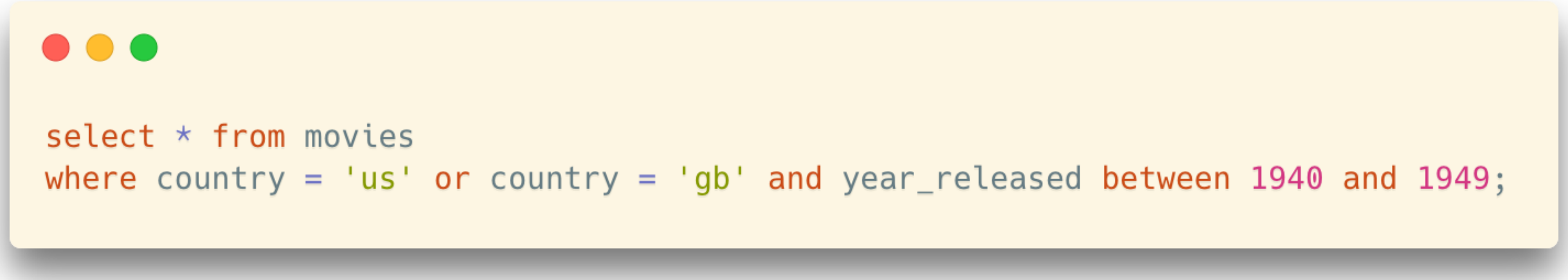

```
select * from movies
where country = 'us' or country = 'gb' and year_released between 1940 and 1949;
```

Logical Connectives

- Question:
  - Find the Chinese movies from the 1940s and American movies from the 1950s

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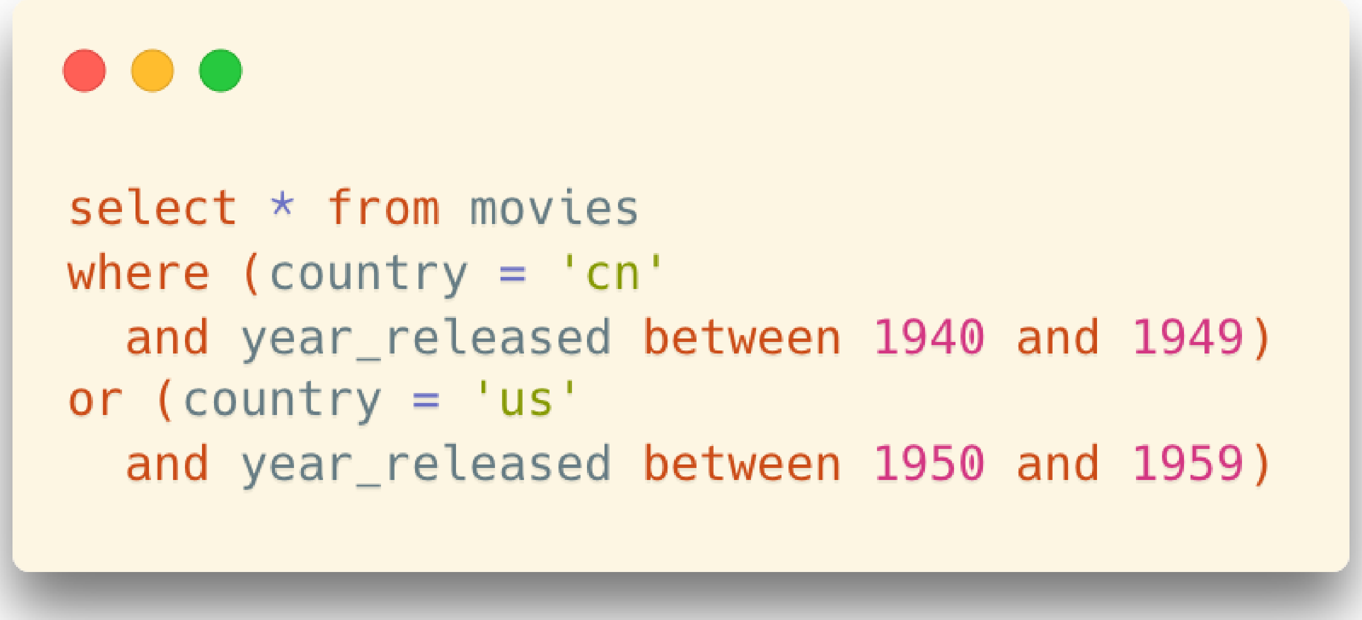


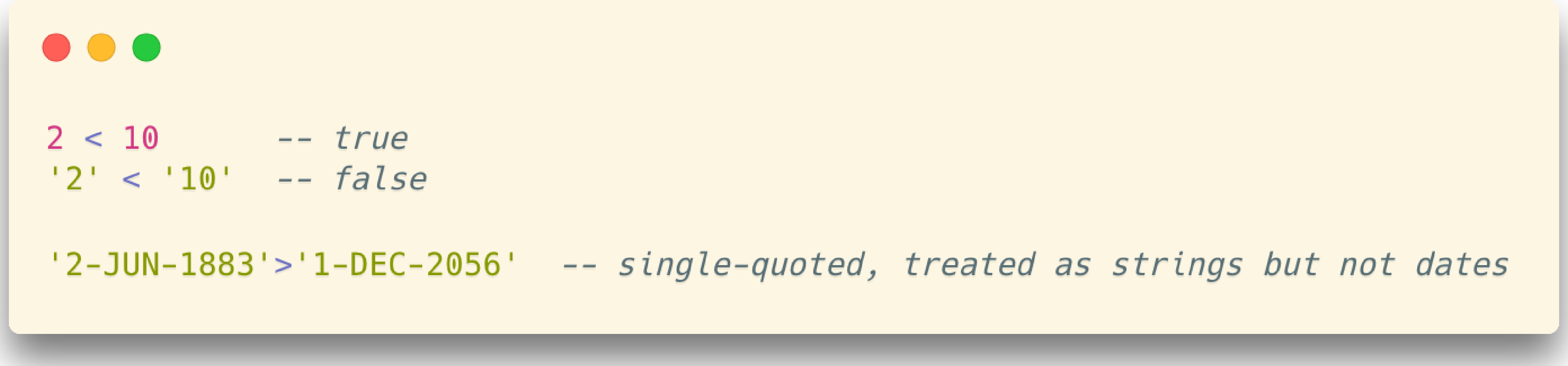
```
select * from movies
where (country = 'cn'
  and year_released between 1940 and 1949)
or (country = 'us'
  and year_released between 1950 and 1959)
```

In this case, parentheses are optional – but they don't hurt

- The parentheses make the statement easier to understand

Logical Connectives

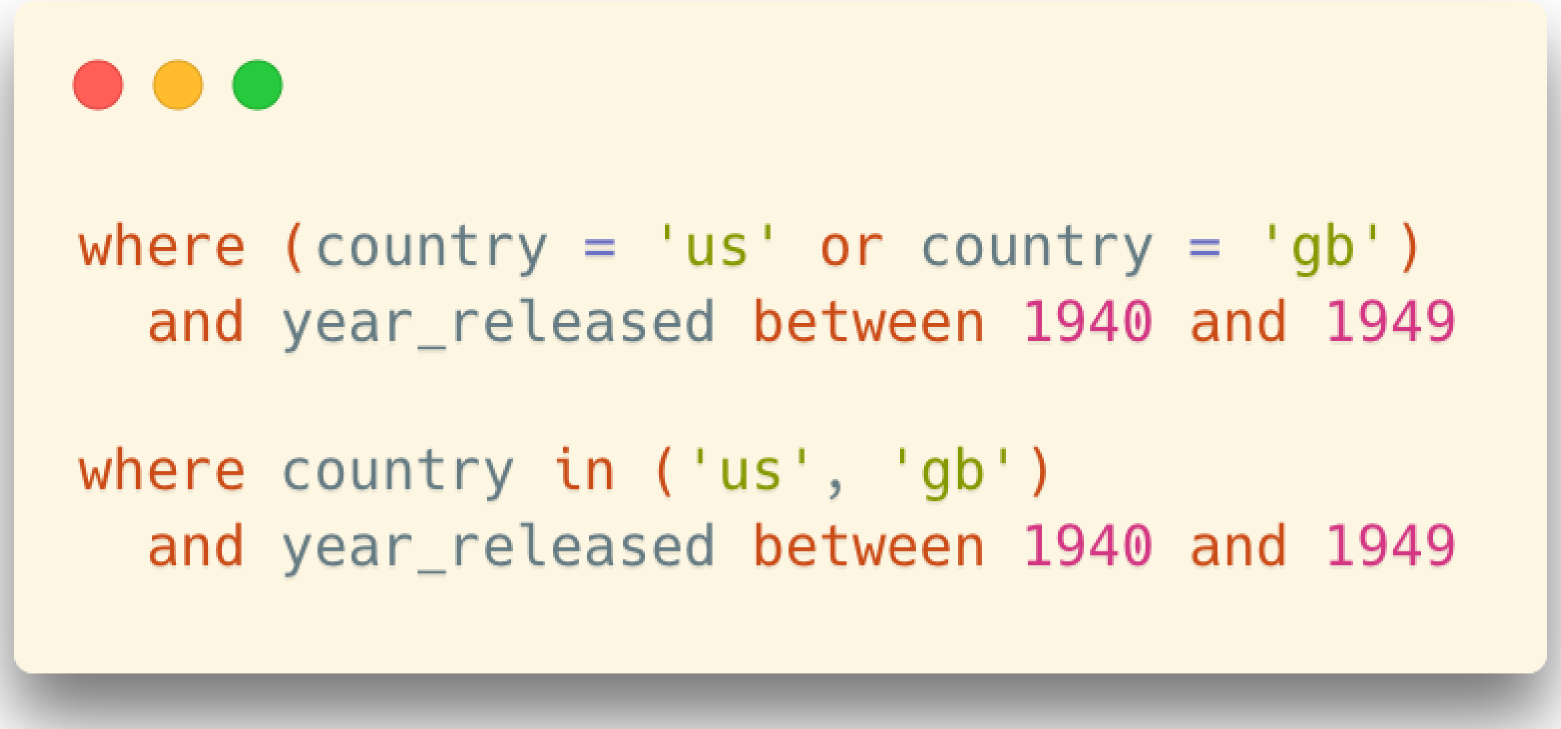
- The operands of the logical connectives can be expressions involving the comparison operators <, <=, >, >=, =, and <>.
  - Note that there are two ways to write “not equal to”: != and <>
  - Comparisons can be applied to results of arithmetic expressions
- Beware that "bigger" and "smaller" have a meaning that depends on the data type
  - It can be tricky because most products implicitly convert one of the sides in a comparison between values of differing types



```
2 < 10      -- true
'2' < '10'  -- false

'2-JUN-1883'>'1-DEC-2056'  -- single-quoted, treated as strings but not dates
```

Logical Connectives

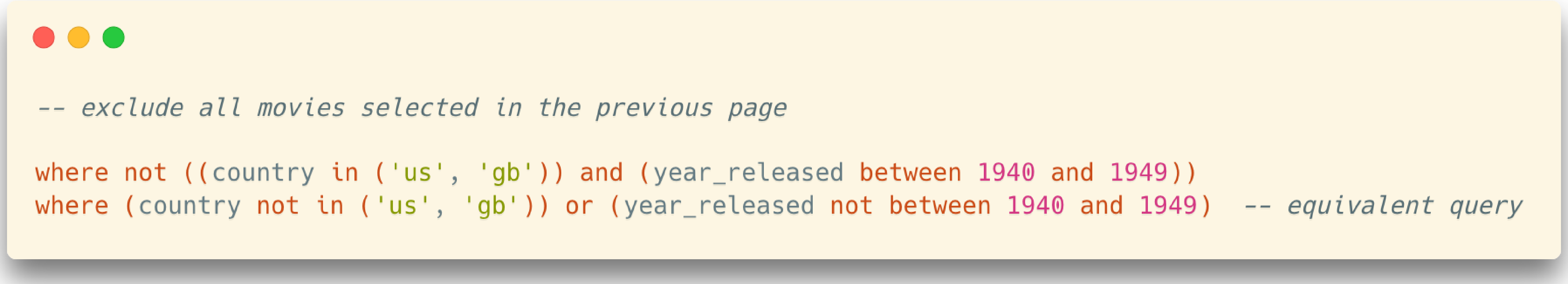
- `in()`
  - It can be used as the equivalent for a series of equalities with `or`
  - It may make a comparison clearer than a parenthesized expression
  - * Some advanced features of `in()` will be introduced when learning subqueries



```
where (country = 'us' or country = 'gb')
  and year_released between 1940 and 1949

where country in ('us', 'gb')
  and year_released between 1940 and 1949
```

Logical Connectives

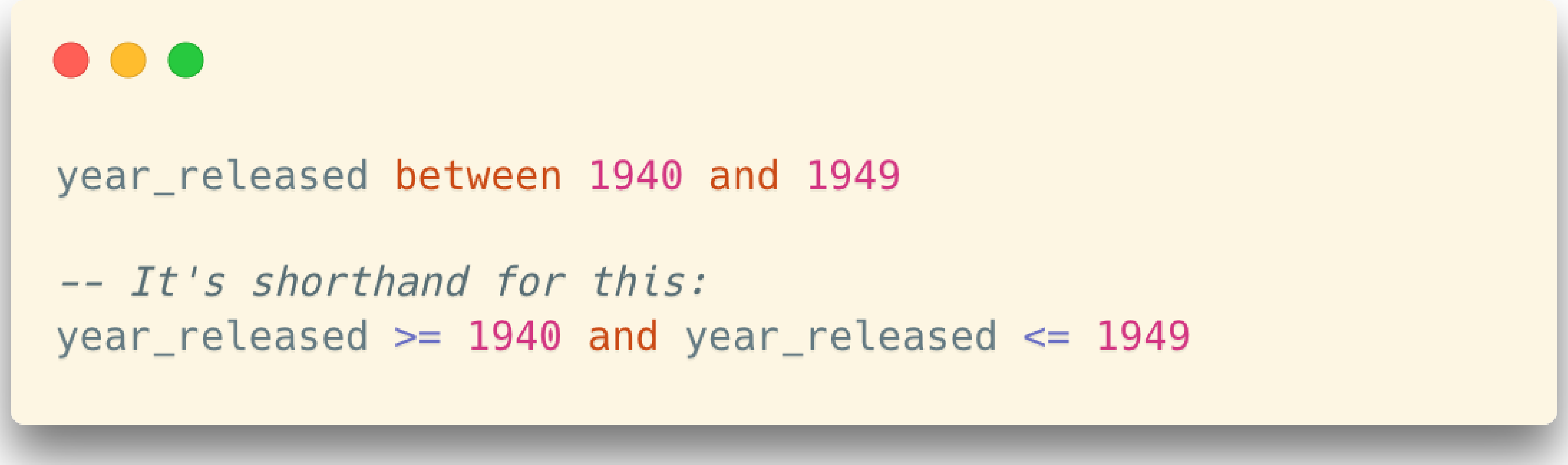
- Negation
  - All comparisons can be negated with `not`



```
-- exclude all movies selected in the previous page

where not ((country in ('us', 'gb')) and (year_released between 1940 and 1949))
where (country not in ('us', 'gb')) or (year_released not between 1940 and 1949)  -- equivalent query
```

between Comparison Operator

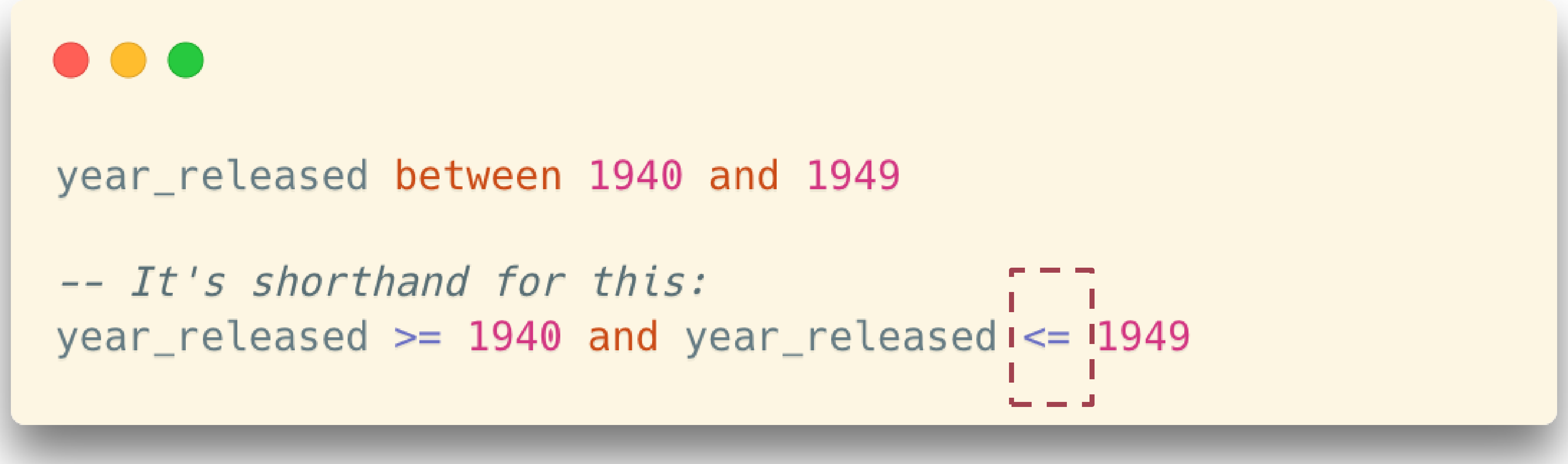
- between … and …
  - shorthand for: >= and <=



```
year_released between 1940 and 1949

-- It's shorthand for this:
year_released >= 1940 and year_released <= 1949
```

between Comparison Operator

- between … and …
  - shorthand for: >= and <=



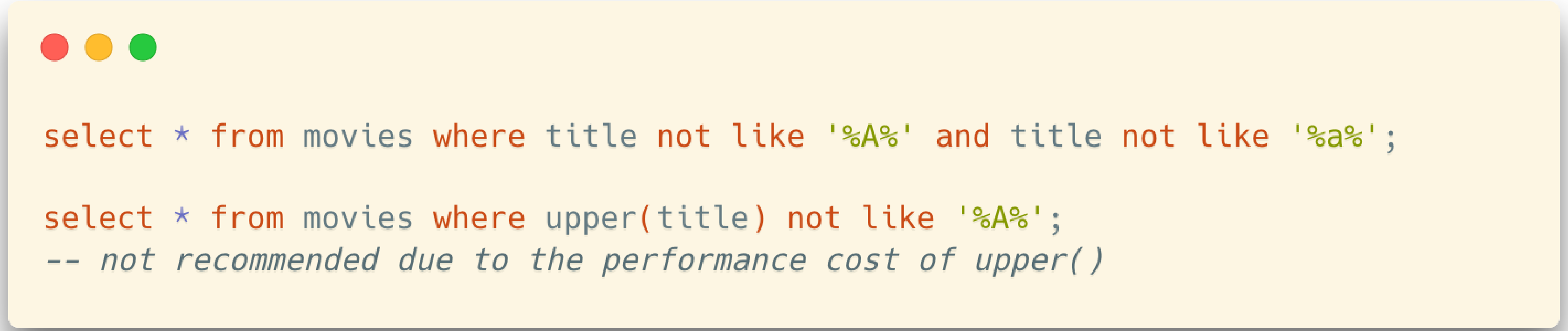
```
year_released between 1940 and 1949

-- It's shorthand for this:
year_released >= 1940 and year_released <= 1949
```

not “<”

like

- For strings, you also have like `which` is a kind of regex (regular expression) for dummies.
- `like` compares a string to a pattern that can contain two wildcard characters:
  - `%` meaning "any number of characters, including none”
  - `_` meaning "one and only one character"

like



```sql
select * from movies where title not like '%A%' and title not like '%a%';

select * from movies where upper(title) not like '%A%';
-- not recommended due to the performance cost of upper()
```

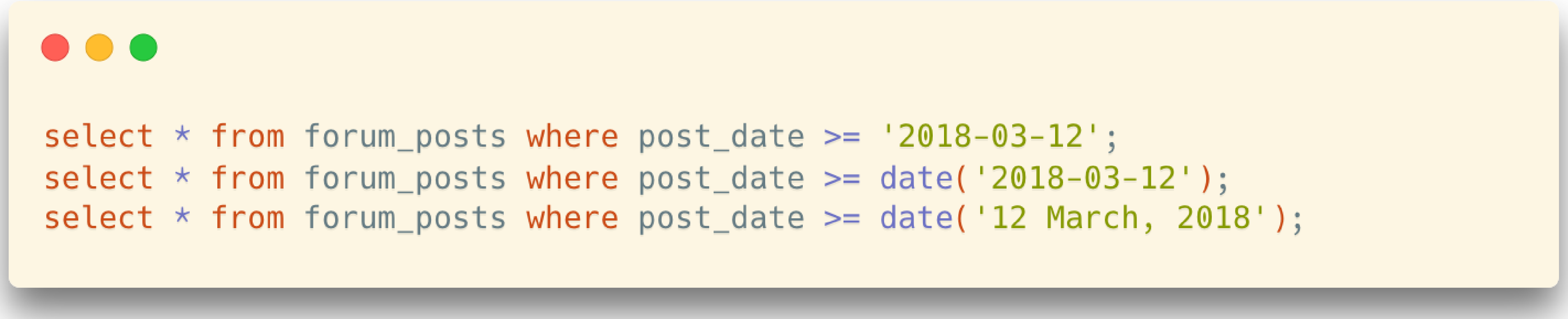
- This expression for instance returns films the title of which doesn't contain any A
  - This A might be the first or last character as well
  - Note that if the DBMS is case sensitive, you need to cater both for upper and lower case
  - Function calls could slow down queries; use with caution

Date

- Date formats
  - Beware also of date formats, and of conflicting European/American formats which can be ambiguous for some dates. Common problem in multinational companies.

```
DD/MM/YYYY
MM/DD/YYYY
YYYY/MM/DD
```

Date

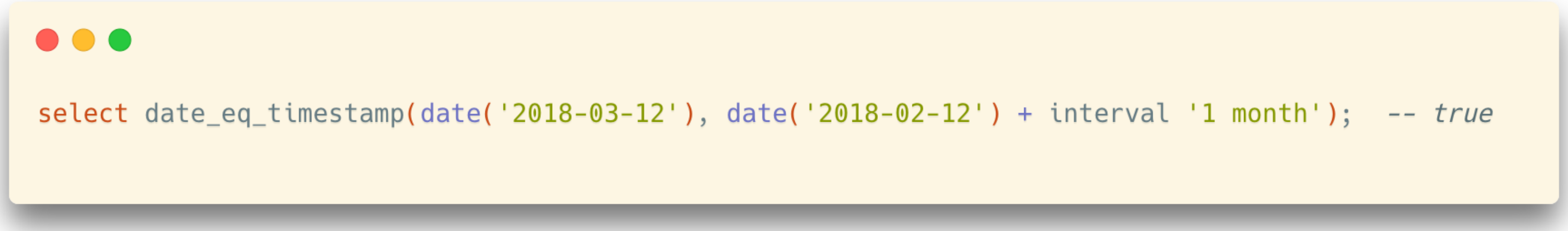


```
select * from forum_posts where post_date >= '2018-03-12';
select * from forum_posts where post_date >= date('2018-03-12');
select * from forum_posts where post_date >= date('12 March, 2018');
```

- Whenever you are comparing data of slightly different types, you should use functions that "cast" data types
  - It will avoid bad surprises
  - The functions don't always bear the same names but exist with all products
- Default formats vary by product, and can often be changed at the DBMS level
  - So, better to use explicit date types and functions other than strings
  - Conversely, you can format something that is internally stored as a date and turn it into a character string that has almost any format you want

Date and Datetime

- If you compare datetime values to a date (without any time component) the SQL engine will not understand that the date part of the datetime should be equal to that date
  - Rather, it will consider that the date that you have supplied is actually a datetime, with the time component that you can read below
    - `date(‘2020-03-20’)` is equal to `datetime(‘2020-03-20 00:00:00’)`
- Date functions
  - Many useful date functions when manipulating date and datetime values
  - However, most of them are DBMS-dependent



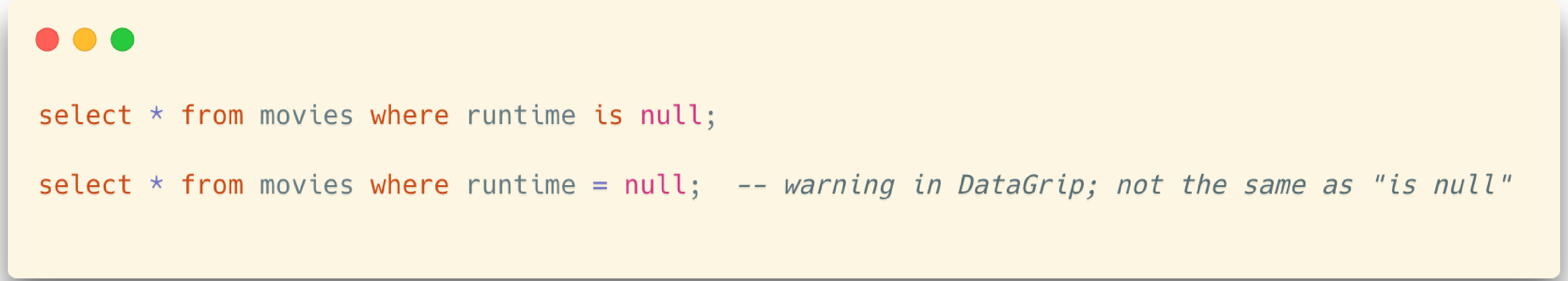
```
select date_eq_timestamp(date('2018-03-12'), date('2018-02-12') + interval '1 month');  -- true
```

NULL

- In a language such as Java, you can compare a reference to `null`, because `null` is defined as the ‘0’ address.
  - In C, you can also compare a pointer to `NULL` (pointer is C-speak for reference)

NULL

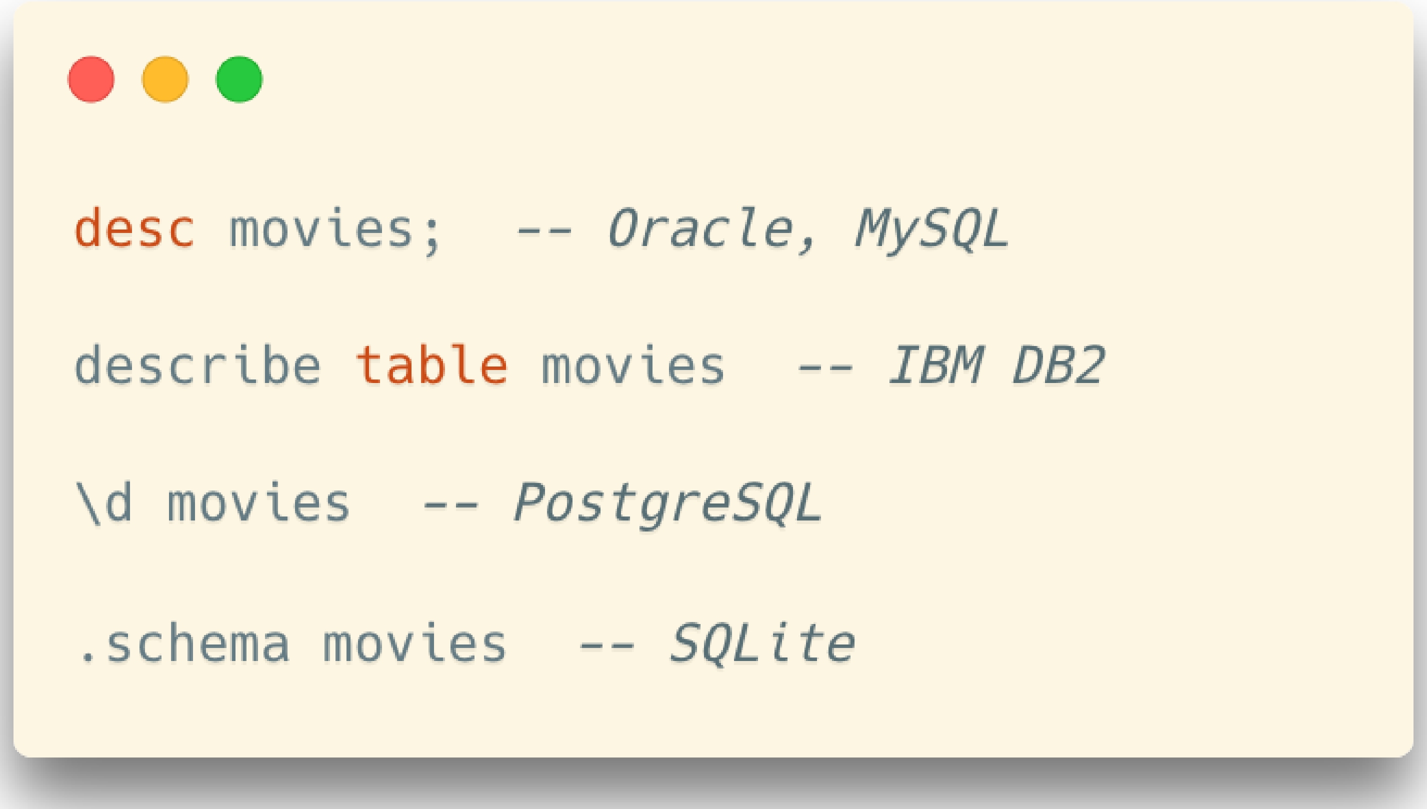
- Not in SQL, where NULL denotes that a value is missing
    - Null in SQL is not a value
        - … and if it's not a value, hard to say if a condition is true.
        - A lot of people talk about "null values", but they have it wrong
    - Most expression with NULL is evaluated to NULL



```sql
select * from movies where runtime is null;

select * from movies where runtime = null;  -- warning in DataGrip; not the same as "is null"
```

Some Functions

- Show DDL of a table



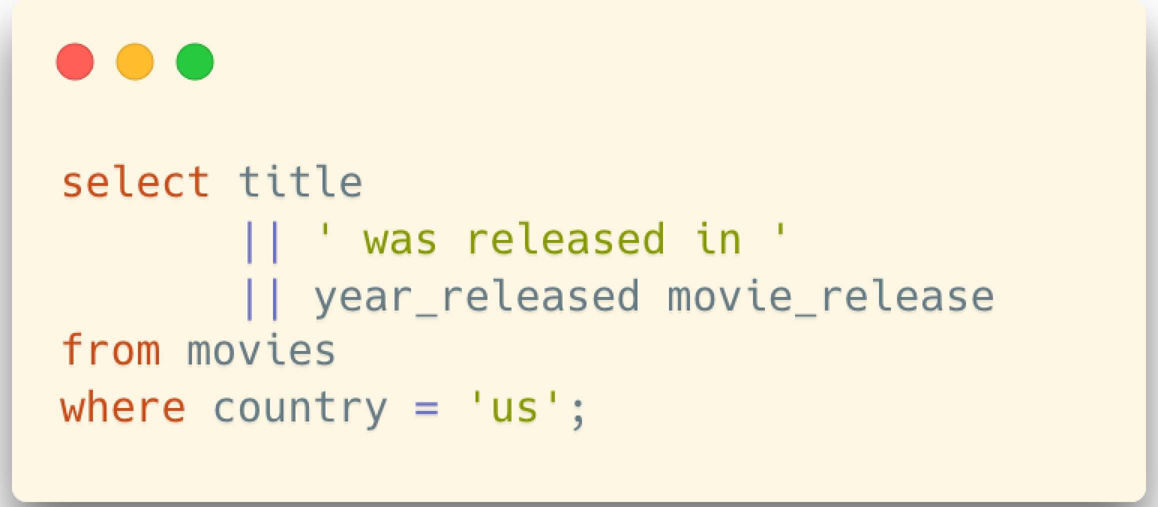
```
desc movies;  -- Oracle, MySQL

describe table movies  -- IBM DB2

\d movies  -- PostgreSQL

.schema movies  -- SQLite
```

Some Functions – Compute and Derive

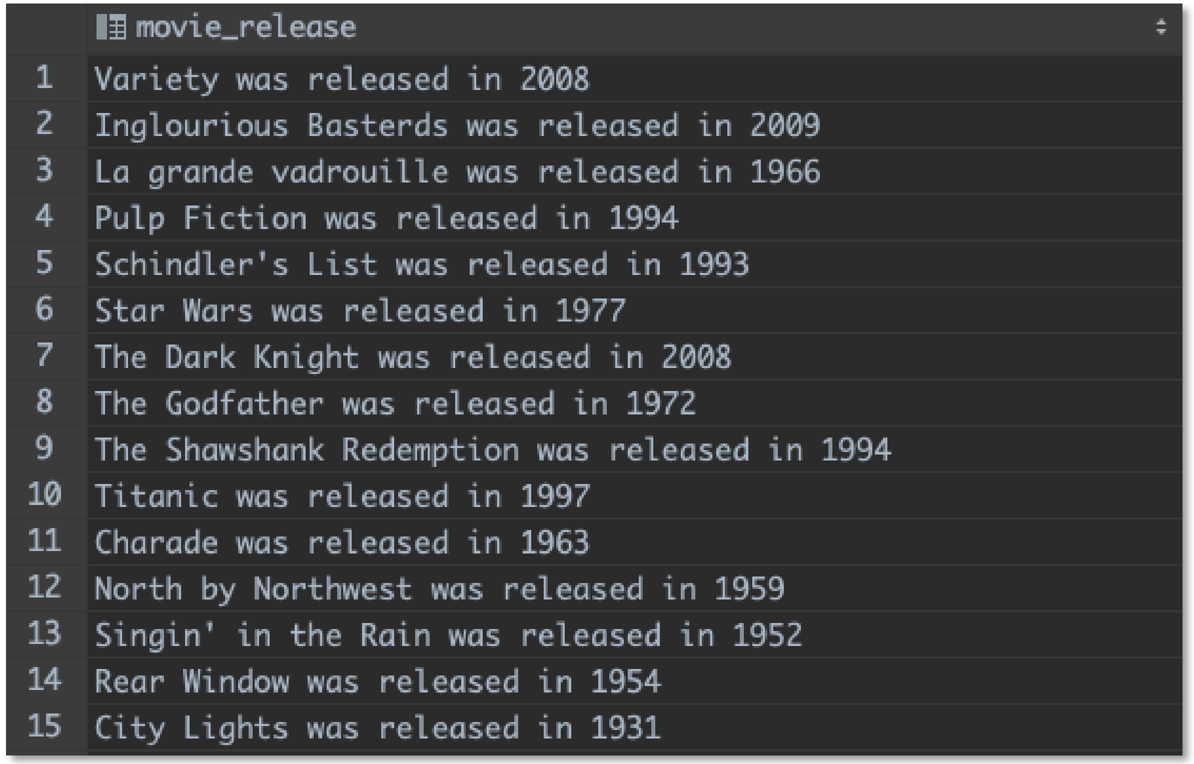
- One important feature of SQL is that you don’t need to return data exactly as it was stored
  - Operators, and many (*mostly DBMS specific*) functions allow to return transformed data

Some Functions

- A simple transformation is concatenating two strings together
  - Most products use || (two vertical bars) to indicate string concatenation
  - SQL Server, though, uses +, and MySQL a special `concat()` function that also exists in some other products



```
select title
       || ' was released in '
       || year_released movie_release
from movies
where country = 'us';
```



	movie_release
1	Variety was released in 2008
2	Inglourious Basterds was released in 2009
3	La grande vadrouille was released in 1966
4	Pulp Fiction was released in 1994
5	Schindler's List was released in 1993
6	Star Wars was released in 1977
7	The Dark Knight was released in 2008
8	The Godfather was released in 1972
9	The Shawshank Redemption was released in 1994
10	Titanic was released in 1997
11	Charade was released in 1963
12	North by Northwest was released in 1959
13	Singin' in the Rain was released in 1952
14	Rear Window was released in 1954
15	City Lights was released in 1931

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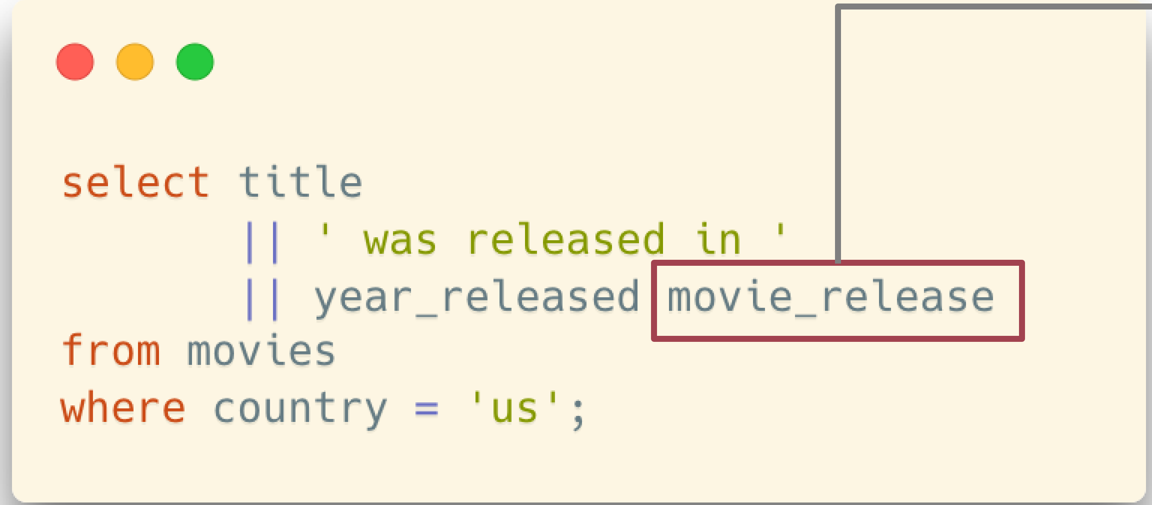

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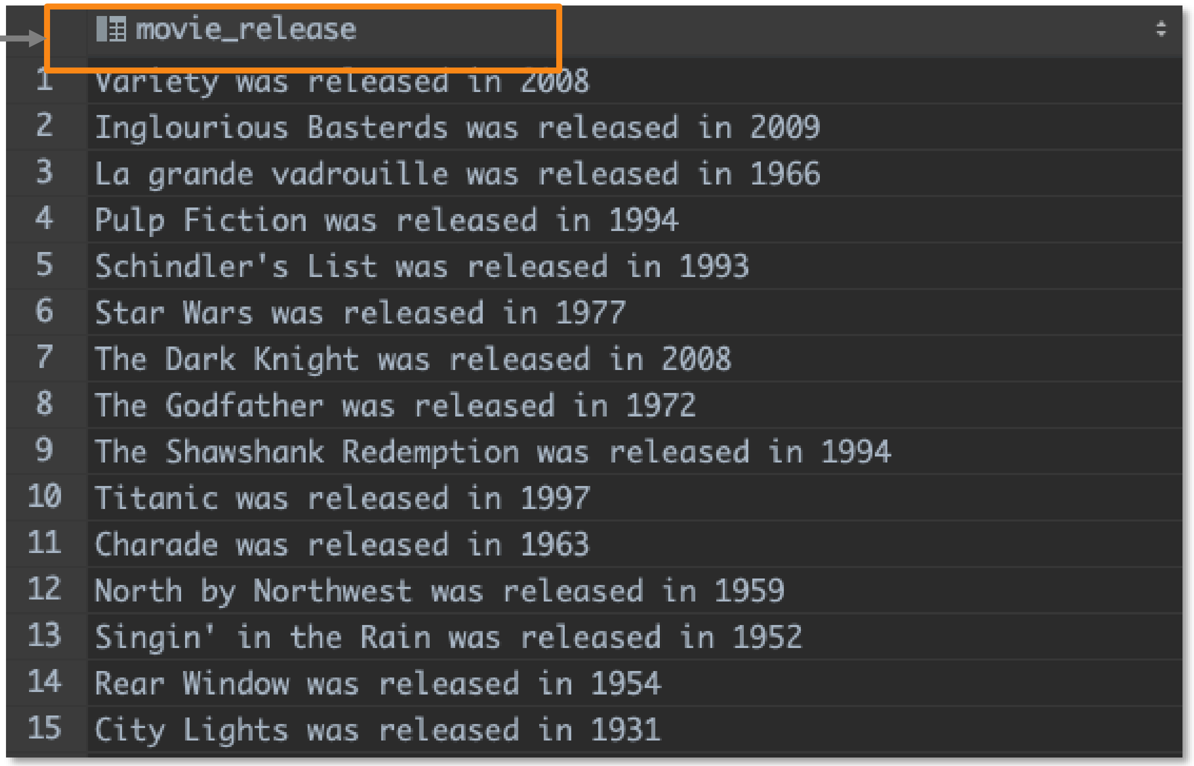
```



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11 Charade was released in 1963
12 North by Northwest was released in 1959
13 Singin' in the Rain was released in 1952
14 Rear Window was released in 1954
15 City Lights was released in 1931
```

Note that you can give a name to an expression

- This will be used as column header
- It also becomes a "virtual column" if you turn the query into a "virtual table"

Some Functions

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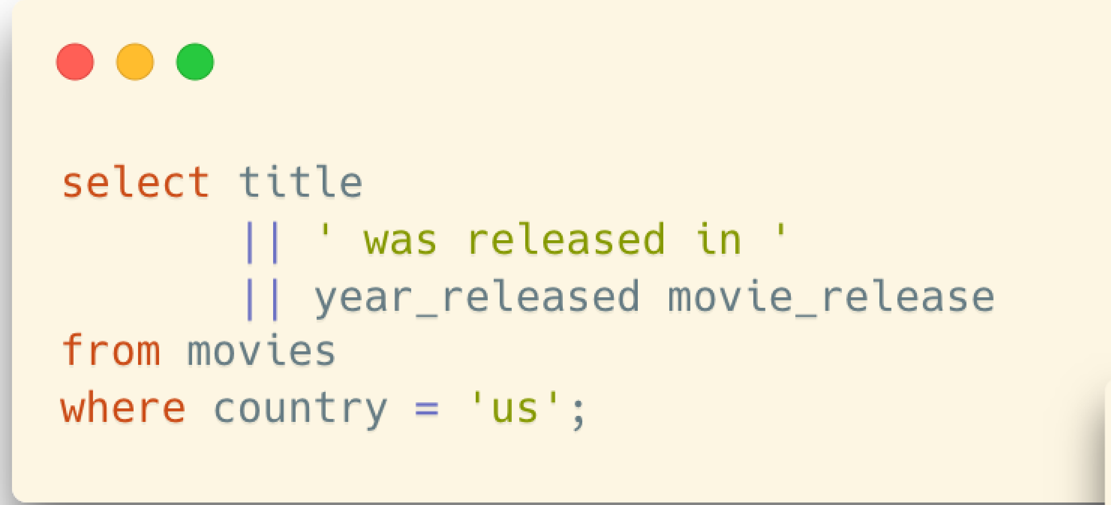
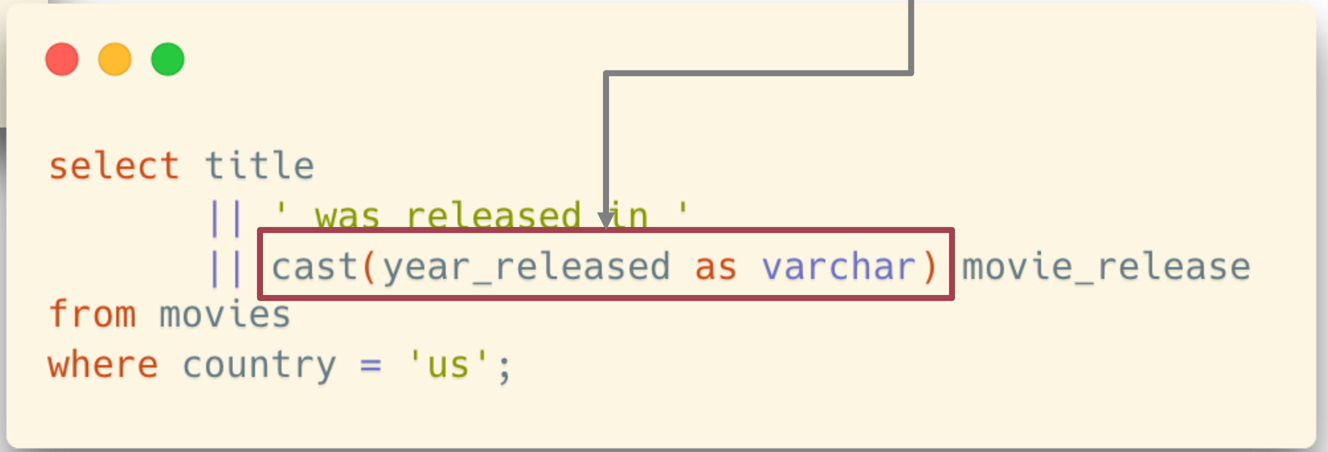


```
select title
       || ' was released in '
       || year_released movie_release
from movies
where country = 'us';
```

Although YEAR_RELEASED is actually a number, it's implicitly turned into a string by the DBMS.

- In that case it's not a big issue, but it would be better to use a function to convert explicitly.



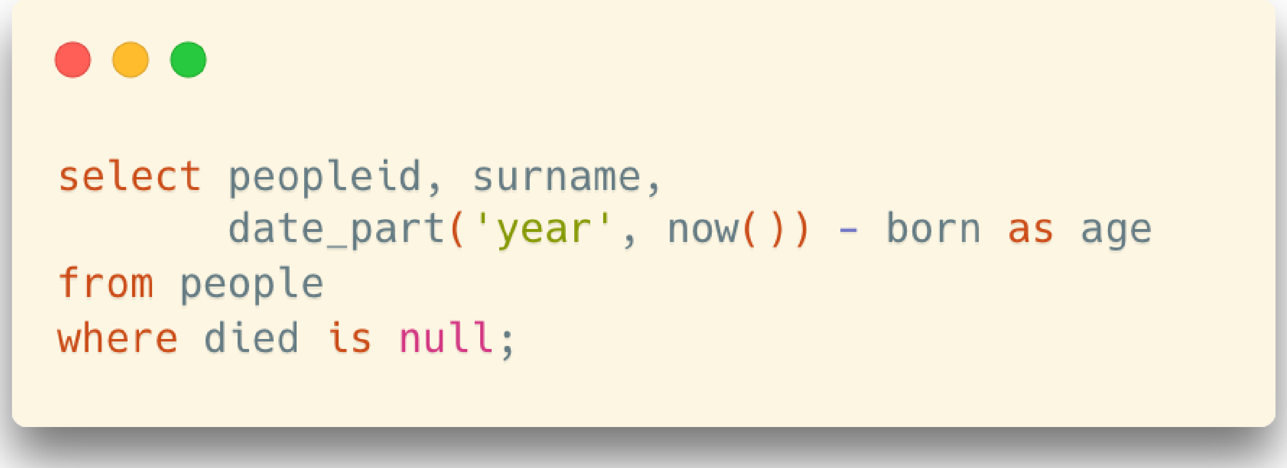
```
select title
       || ' was released in '
       || cast(year_released as varchar) movie_release
from movies
where country = 'us';
```

Some Functions

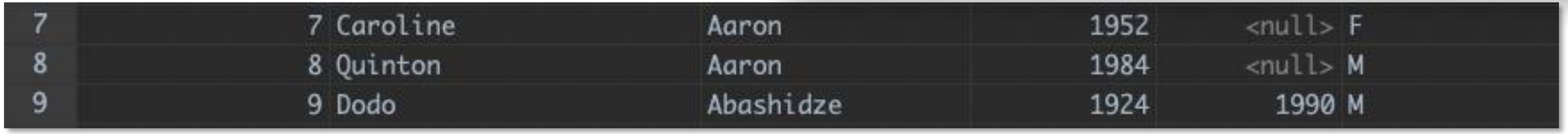
- When to use functions
  - An example of showing a result that isn't stored as such is computing an age
    - You should never store an age; it changes all the time!
    - If you want to display the age of people who are alive, you must compute their age by subtracting the year when they were born from the current year.

Some Functions

- When to use functions
  - An example of showing a result that isn't stored as such is computing an age
    - You should never store an age; it changes all the time!
    - If you want to display the age of people who are alive, you must compute their age by subtracting the year when they were born from the current year.
  - In the table people:
    - Alive – died is `null`
    - Age: `<this year> - born`



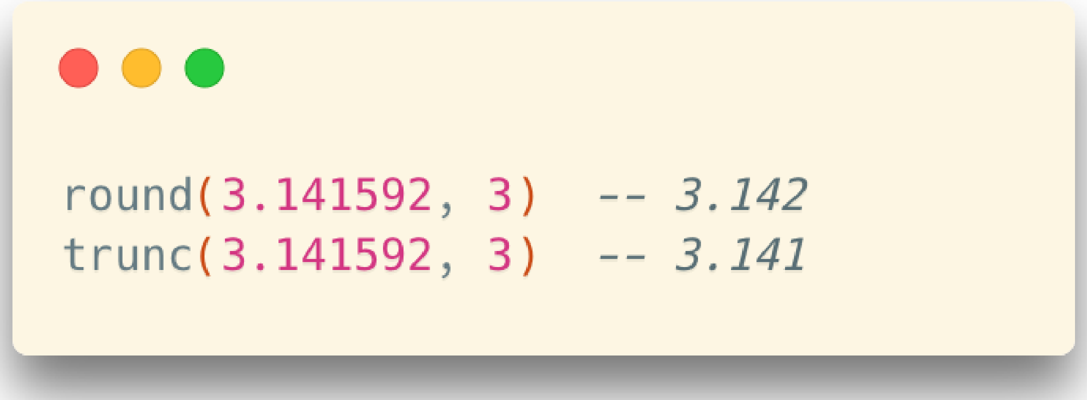
```
select peopleid, surname,
       date_part('year', now()) - born as age
from people
where died is null;
```



7	7	Caroline	Aaron	1952	<null>	F
8	8	Quinton	Aaron	1984	<null>	M
9	9	Dodo	Abashidze	1924	1990	M

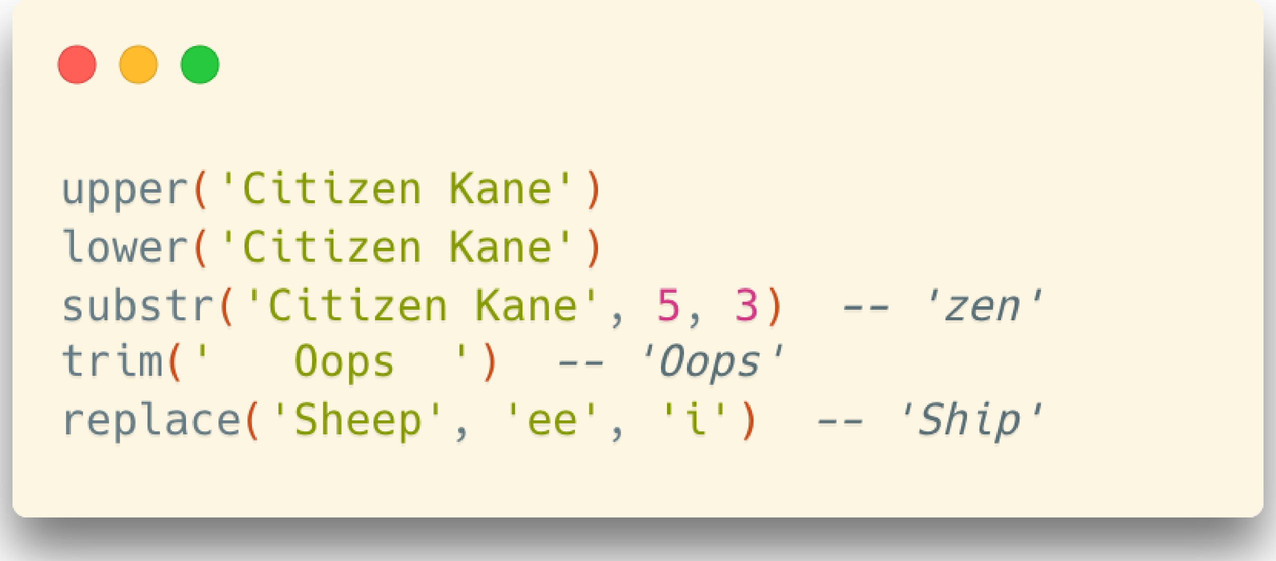
Some Functions

- Numerical functions



```
round(3.141592, 3)  -- 3.142
trunc(3.141592, 3)  -- 3.141
```

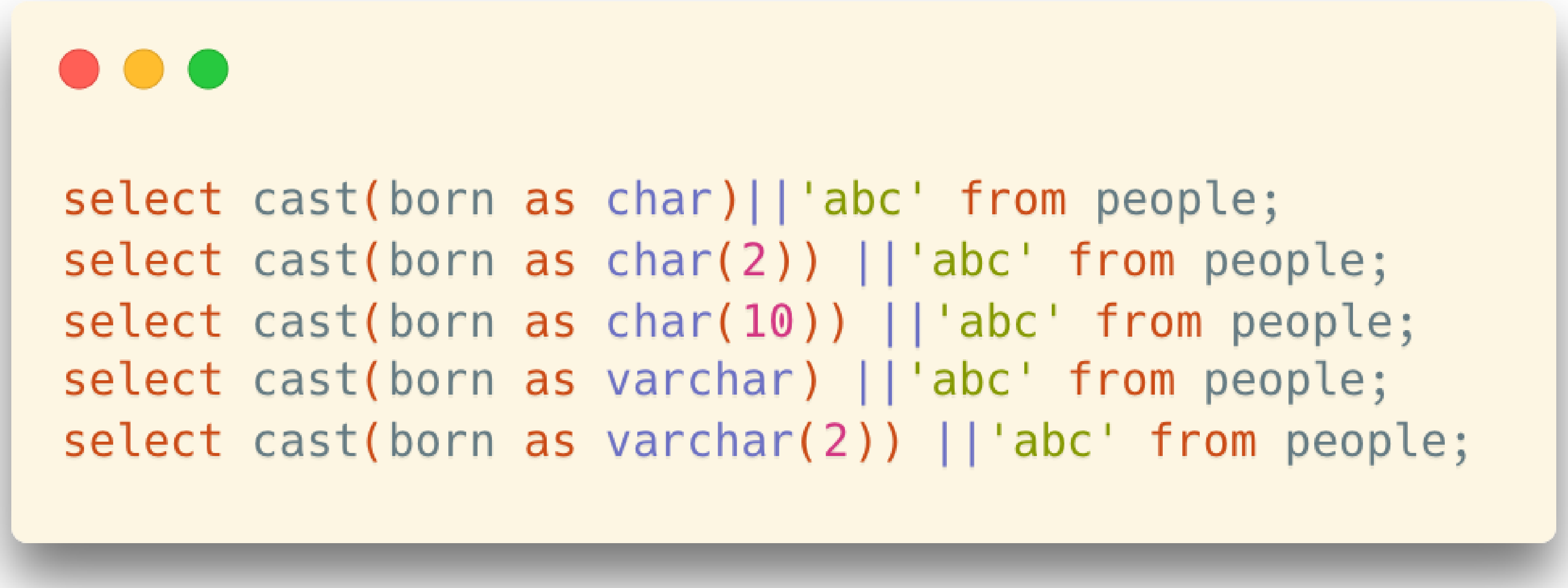
- More string functions



```
upper('Citizen Kane')
lower('Citizen Kane')
substr('Citizen Kane', 5, 3)  -- 'zen'
trim('   Oops  ')  -- 'Oops'
replace('Sheep', 'ee', 'i')  -- 'Ship'
```

Some Functions

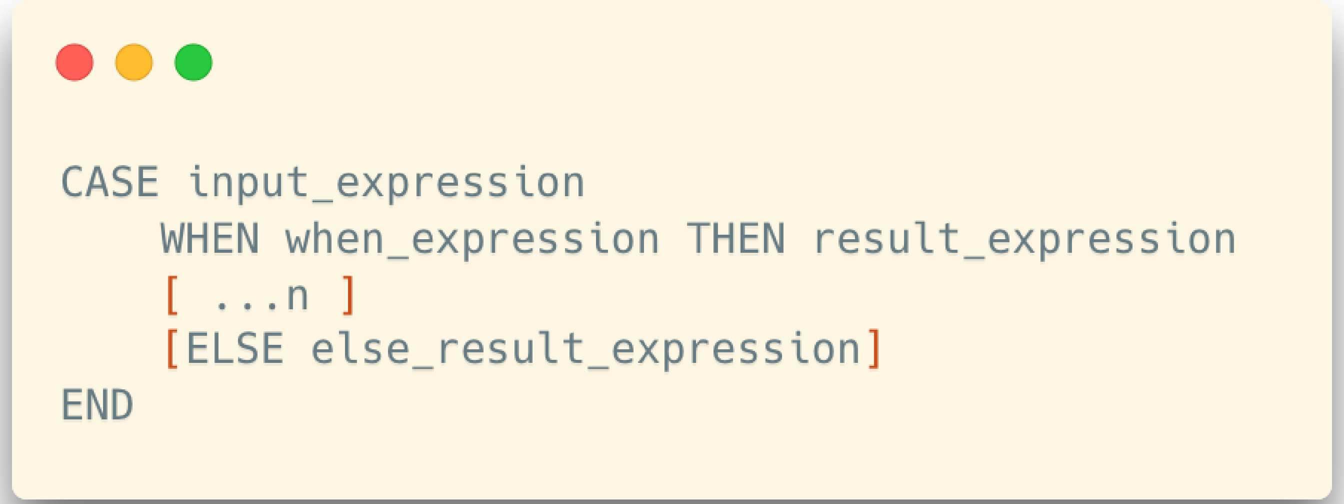
- Type casting
  - `cast(column as type)`



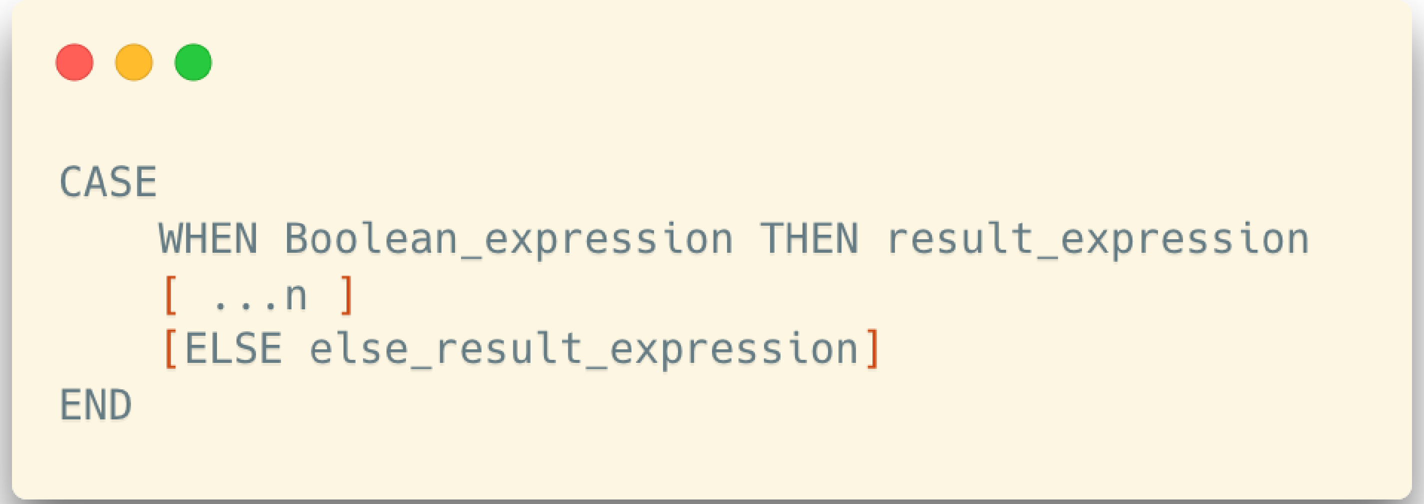
```
select cast(born as char)||'abc' from people;
select cast(born as char(2)) ||'abc' from people;
select cast(born as char(10)) ||'abc' from people;
select cast(born as varchar) ||'abc' from people;
select cast(born as varchar(2)) ||'abc' from people;
```

Case

- A very useful construct is the CASE … END construct that is similar to IF or SWITCH statements in a program



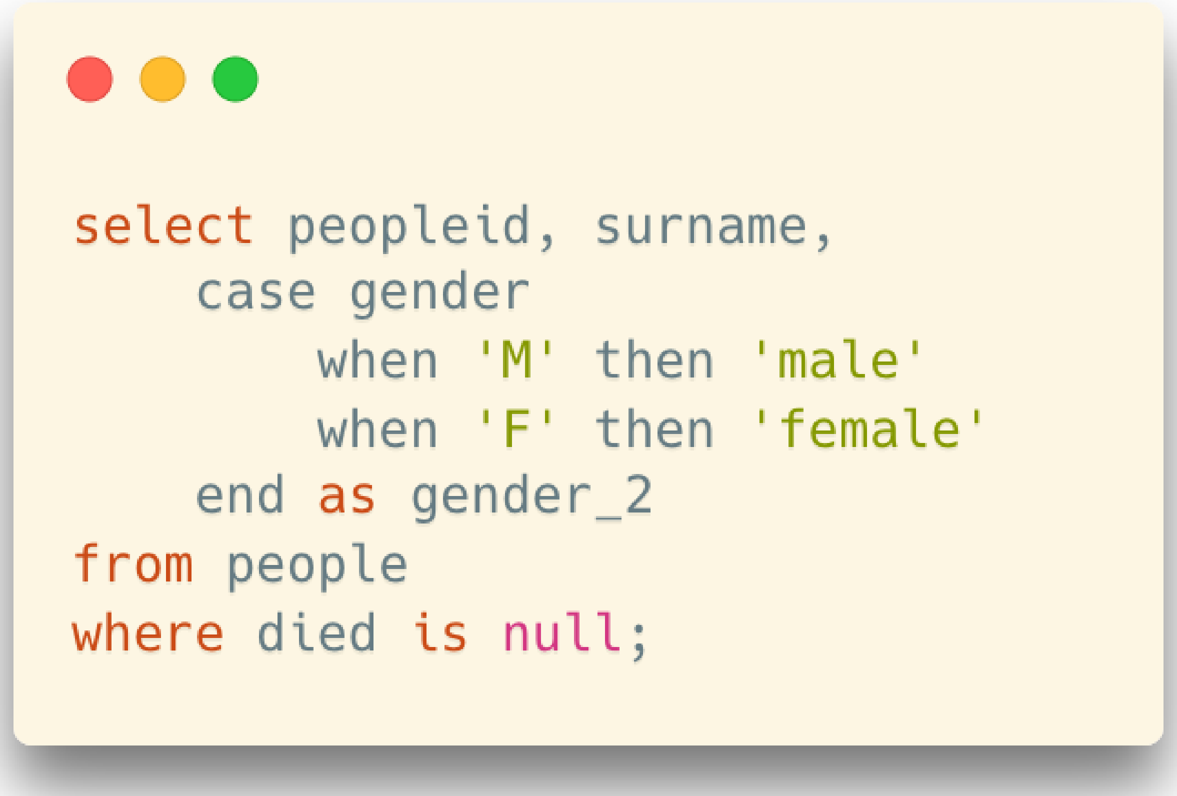
```
CASE input_expression
    WHEN when_expression THEN result_expression
    [ ...n ]
    [ELSE else_result_expression]
END
```



```
CASE
    WHEN Boolean_expression THEN result_expression
    [ ...n ]
    [ELSE else_result_expression]
END
```

Case

- Example 1: Show the corresponding words of the gender abbreviations



```
select peopleid, surname,
    case gender
        when 'M' then 'male'
        when 'F' then 'female'
    end as gender_2
from people
where died is null;
```

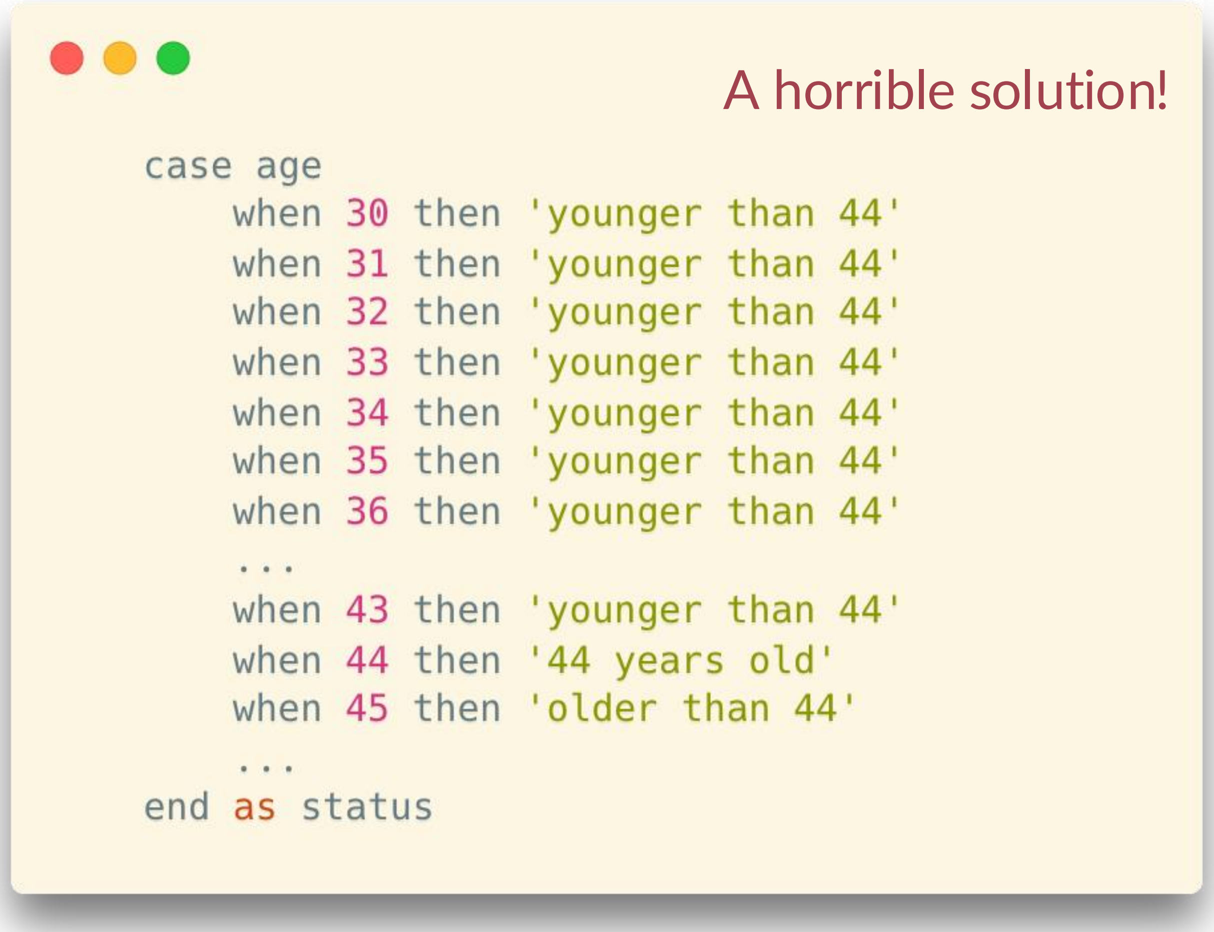
*Similar to the switch-case statement in Java and C

Case

- Example 2: Decide whether someone’s age is older/younger than a pivot

Case

- Example 2: Decide whether someone's age is older/younger than a pivot

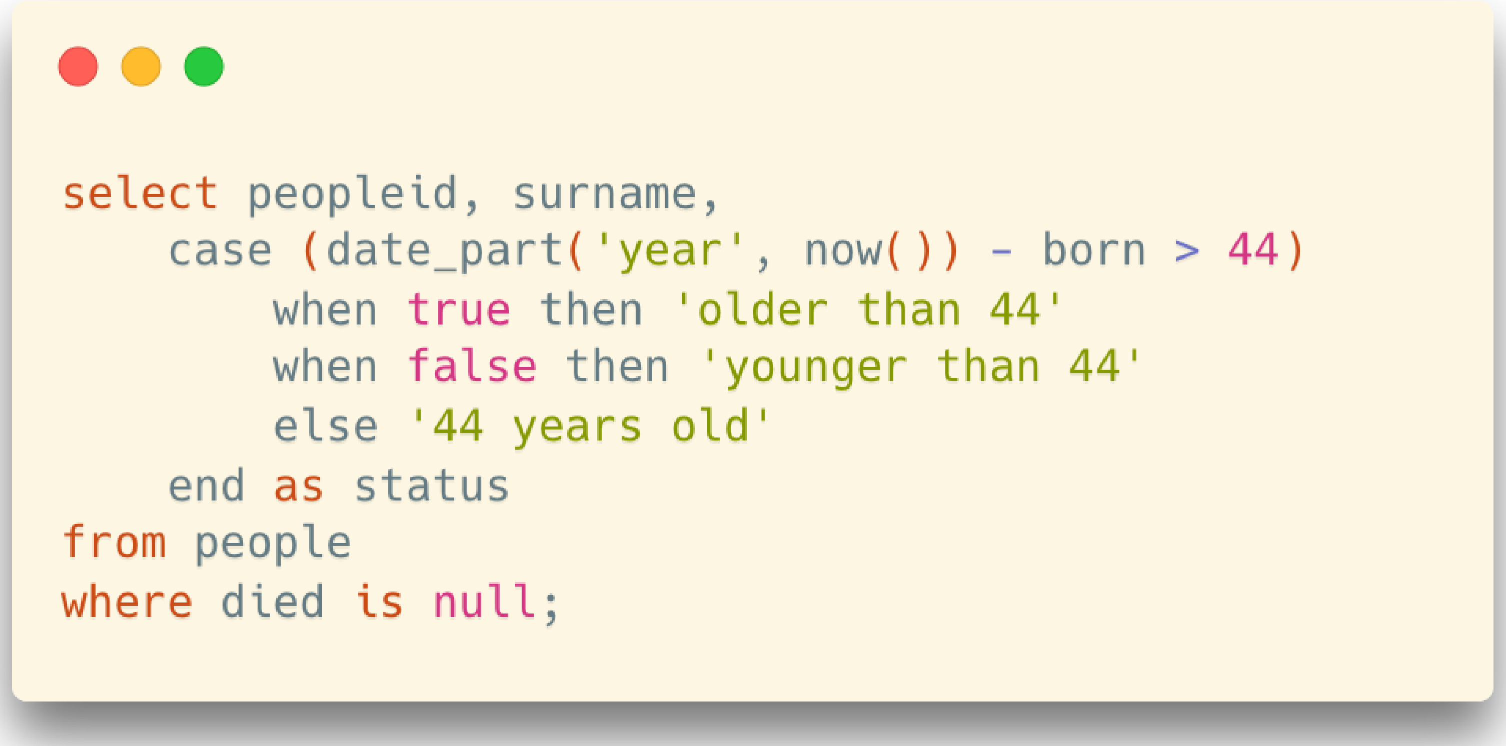


A horrible solution!

```
case age
    when 30 then 'younger than 44'
    when 31 then 'younger than 44'
    when 32 then 'younger than 44'
    when 33 then 'younger than 44'
    when 34 then 'younger than 44'
    when 35 then 'younger than 44'
    when 36 then 'younger than 44'
    ...
    when 43 then 'younger than 44'
    when 44 then '44 years old'
    when 45 then 'older than 44'
    ...
end as status
```

Case

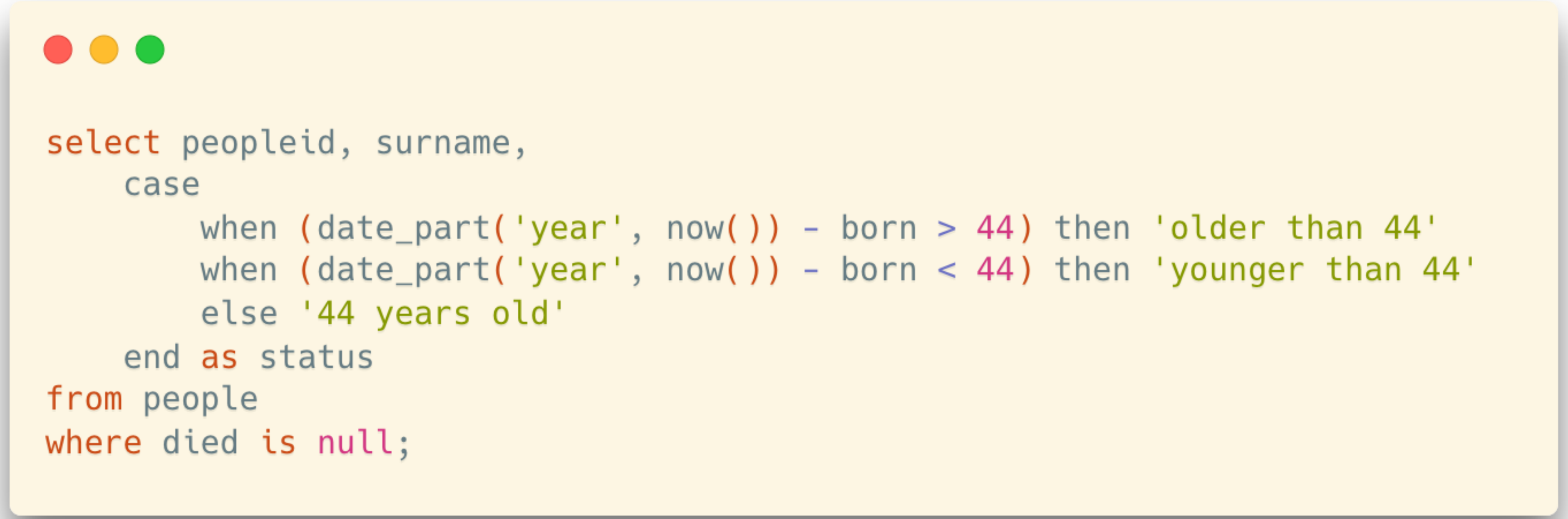
- Example 2: Decide whether someone's age is older/younger than a pivot
    - CASE



```
select peopleid, surname,
    case (date_part('year', now()) - born > 44)
        when true then 'older than 44'
        when false then 'younger than 44'
        else '44 years old'
    end as status
from people
where died is null;
```

Case

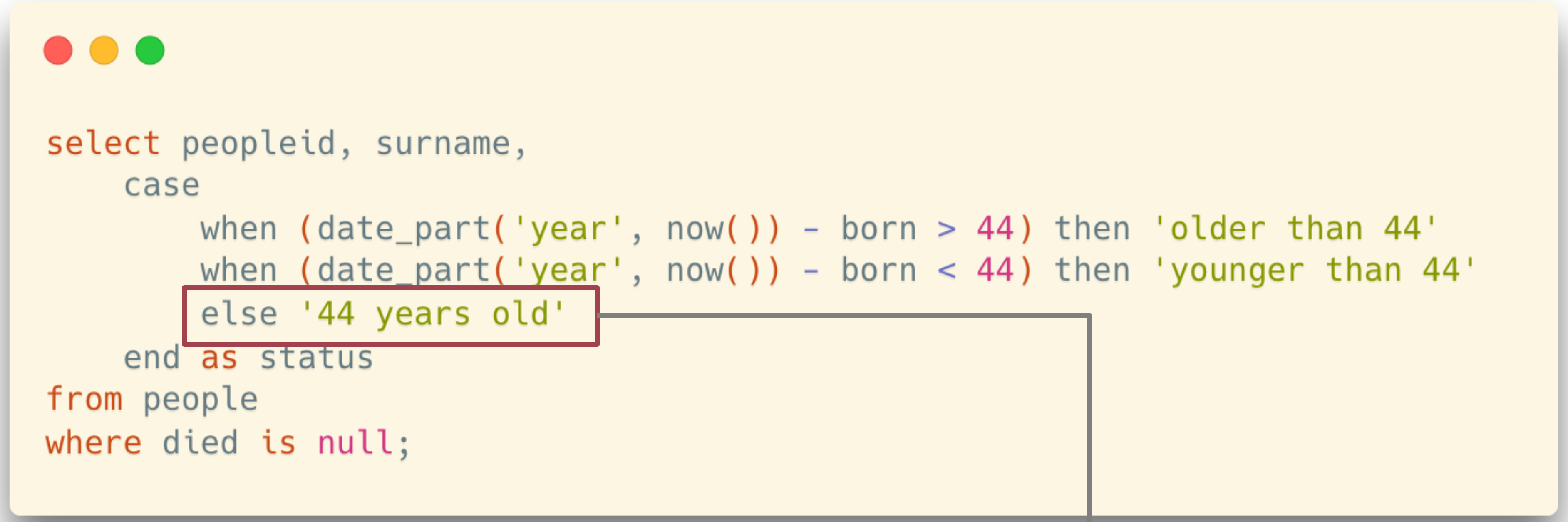
- Example 2: Decide whether someone’s age is older/younger than a pivot
  - CASE
  - CASE WHEN



```
select peopleid, surname,
    case
        when (date_part('year', now()) - born > 44) then 'older than 44'
        when (date_part('year', now()) - born < 44) then 'younger than 44'
        else '44 years old'
    end as status
from people
where died is null;
```

Case

- Example 2: Decide whether someone’s age is older/younger than a pivot
  - CASE
  - CASE WHEN



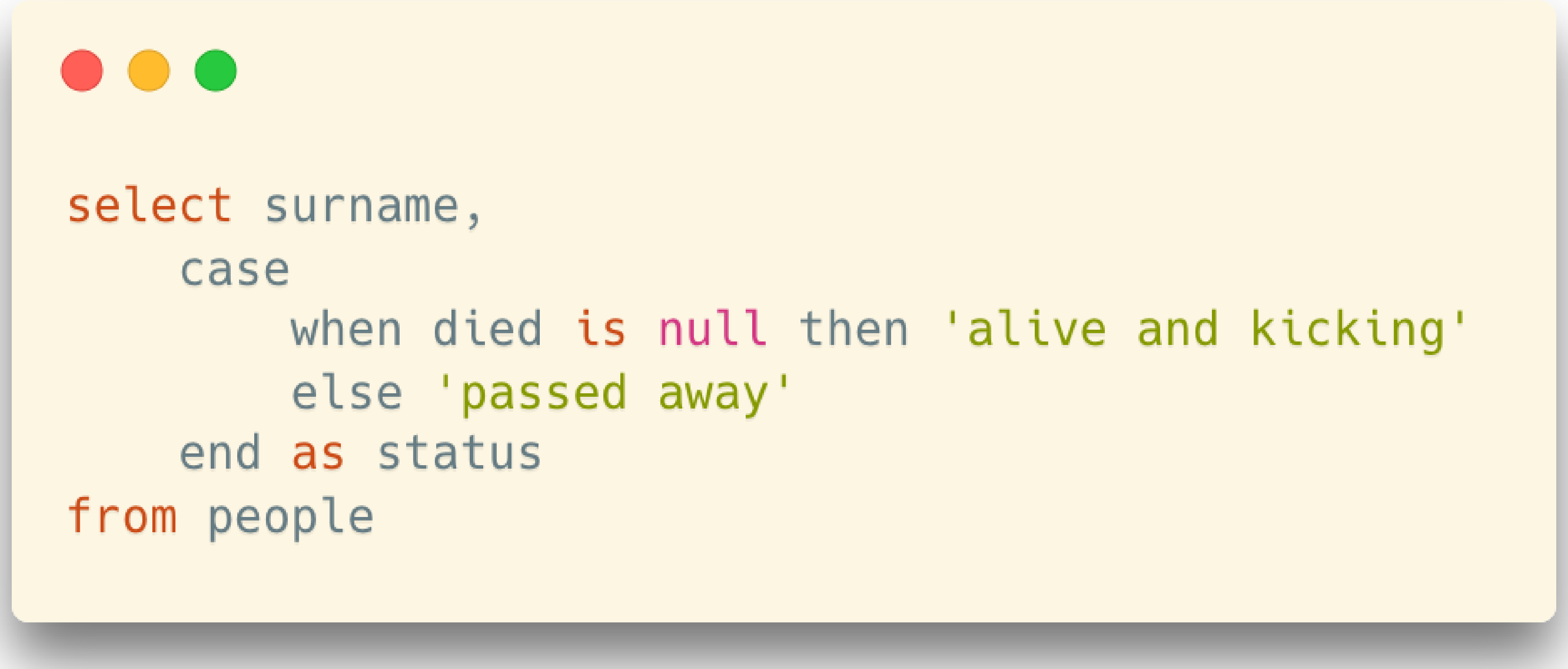
```
select peopleid, surname,
    case
        when (date_part('year', now()) - born > 44) then 'older than 44'
        when (date_part('year', now()) - born < 44) then 'younger than 44'
        else '44 years old'
    end as status
from people
where died is null;
```

The ELSE branch

- Return a default value when all `when` criteria are not met
- If no else, `NULL` will be returned

Case

- About the `NULL` value
  - Use the "`is null`" criteria



```
select surname,
    case
        when died is null then 'alive and kicking'
        else 'passed away'
    end as status
from people
```

More on Retrieving Data

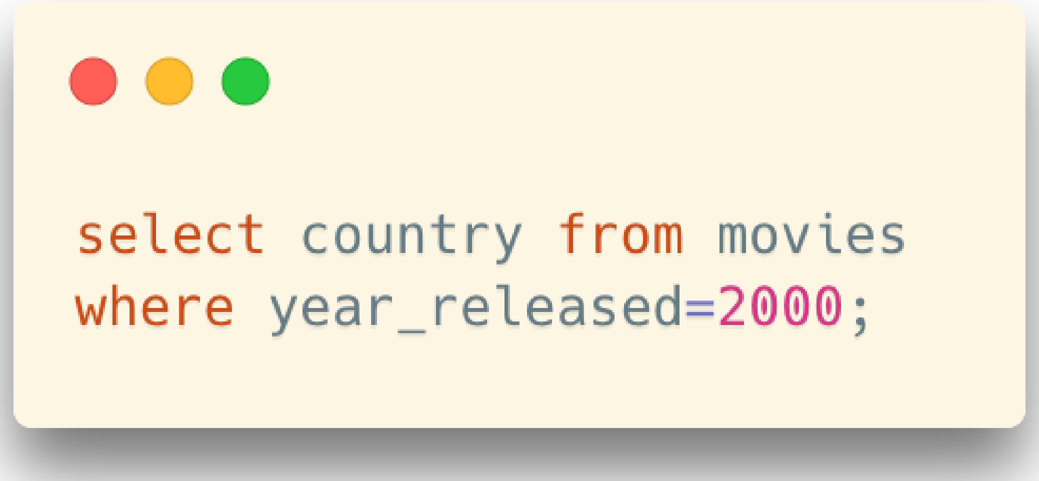
Distinct

Distinct

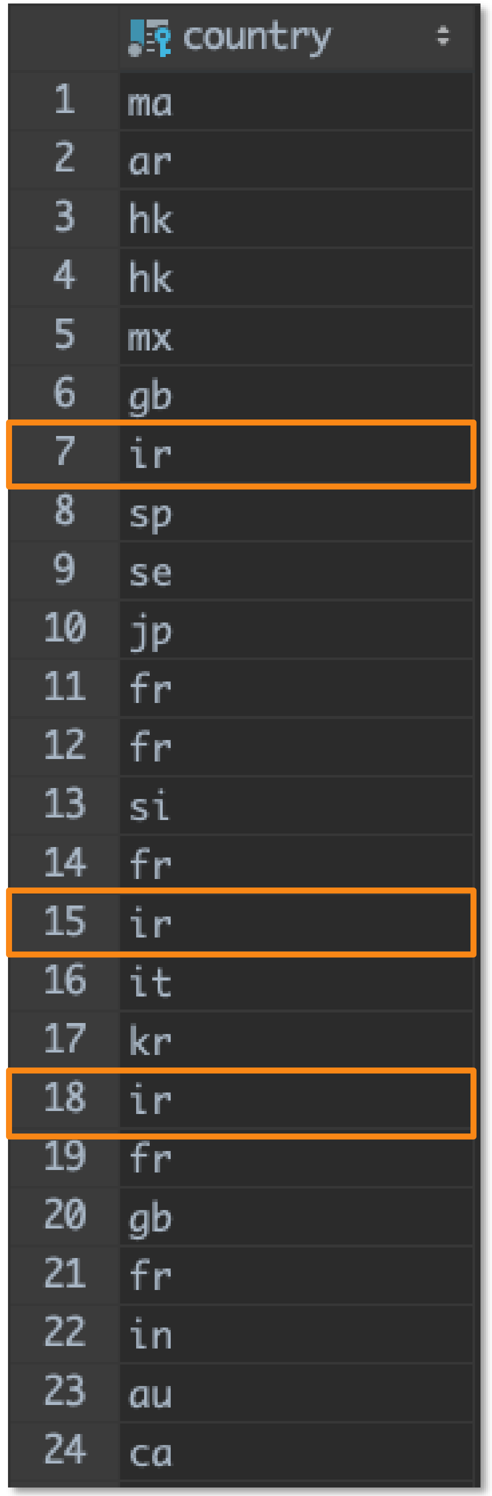
- No duplicated identifier
    - **Some rules** must be respected if you want to obtain valid results when you apply new operations to result sets
        - They must be mathematical sets, i.e., no duplicates

Distinct

- If we run a query such as the one below
  - Many identical rows
    - In other words, we may be obtaining a table, but it's not a relation because many rows cannot be distinguished



```
select country from movies
where year_released=2000;
```



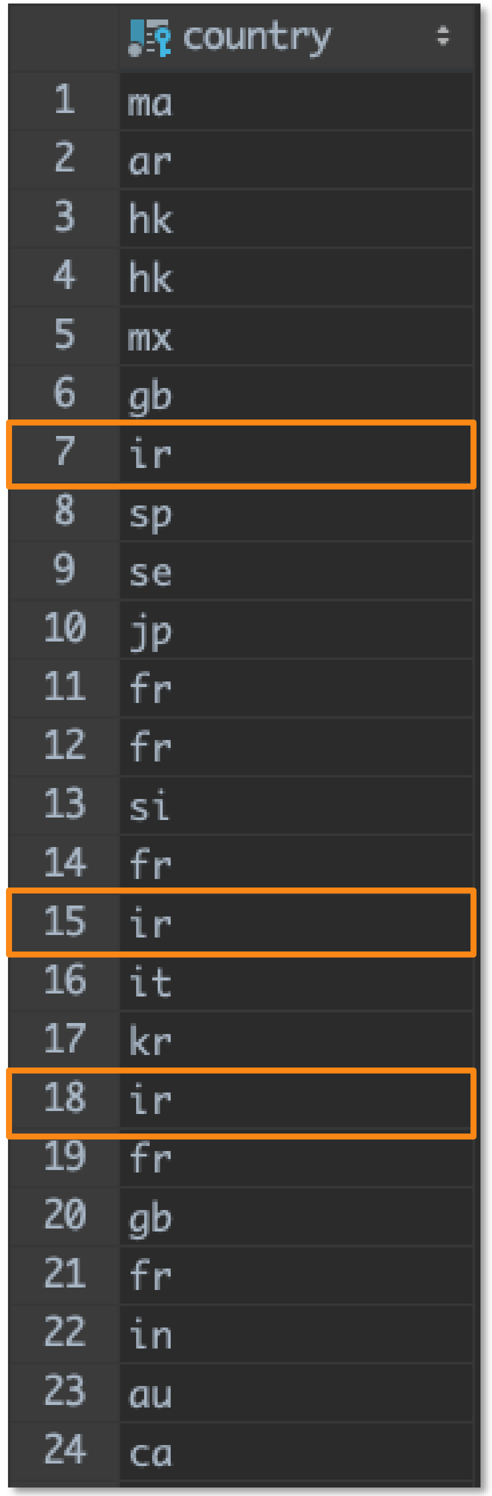
	country
1	ma
2	ar
3	hk
4	hk
5	mx
6	gb
7	ir
8	sp
9	se
10	jp
11	fr
12	fr
13	si
14	fr
15	ir
16	it
17	kr
18	ir
19	fr
20	gb
21	fr
22	in
23	au
24	ca

Duplicated country codes in the query result

- But their original rows are not considered duplicated tuples

Distinct

- The result of the query is in fact completely uninteresting
  - Whenever we are only interested in countries in table movies, it can only be for one of two reasons:
    - See a list of countries that have movies
    - Or, for instance, see which countries appear most often



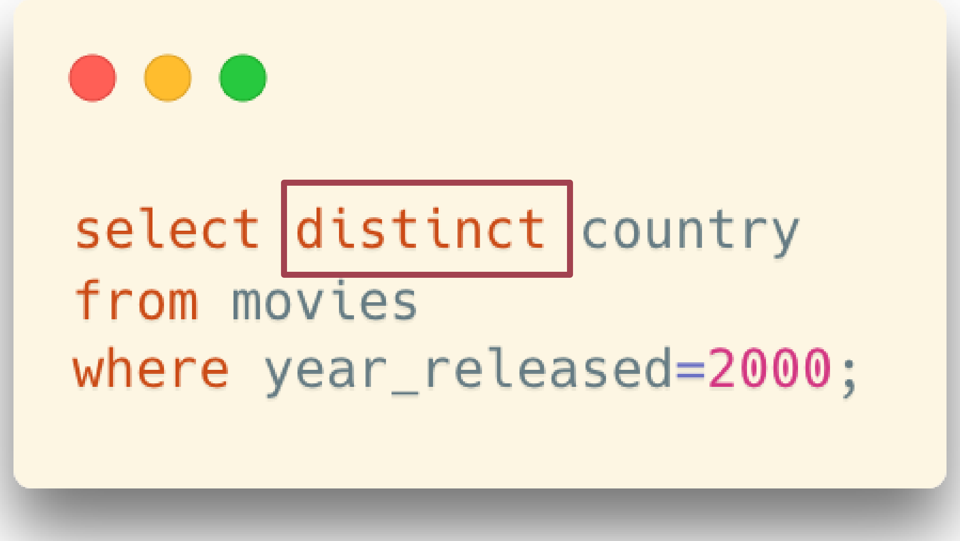
	country
1	ma
2	ar
3	hk
4	hk
5	mx
6	gb
7	ir
8	sp
9	se
10	jp
11	fr
12	fr
13	si
14	fr
15	ir
16	it
17	kr
18	ir
19	fr
20	gb
21	fr
22	in
23	au
24	ca

Duplicated country codes in the query result

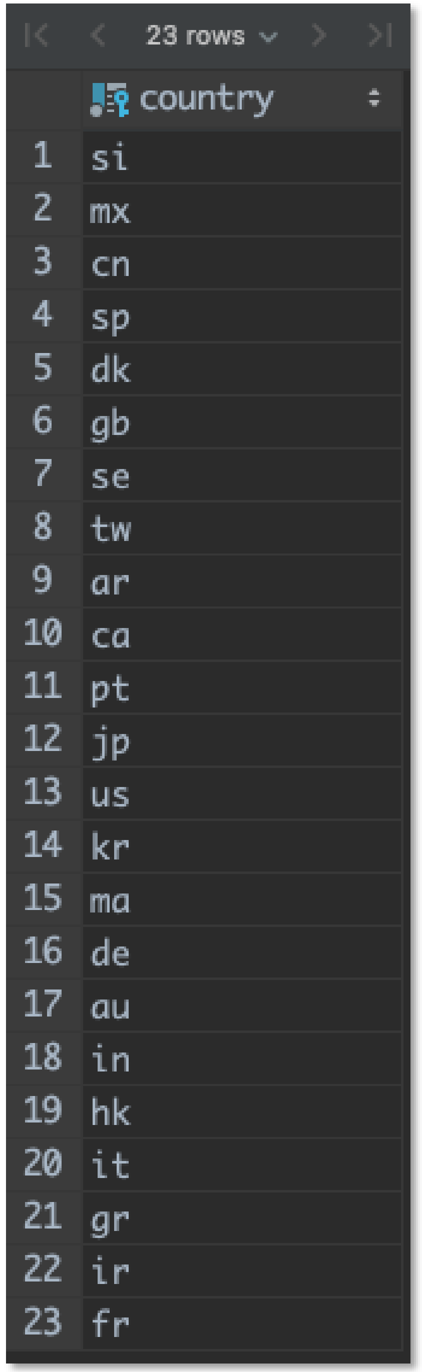
- But their original rows are not considered duplicated tuples

Distinct

- If we only are interested in the different countries, there is the special keyword `distinct`.



```sql
select distinct country
from movies
where year_released=2000;
```



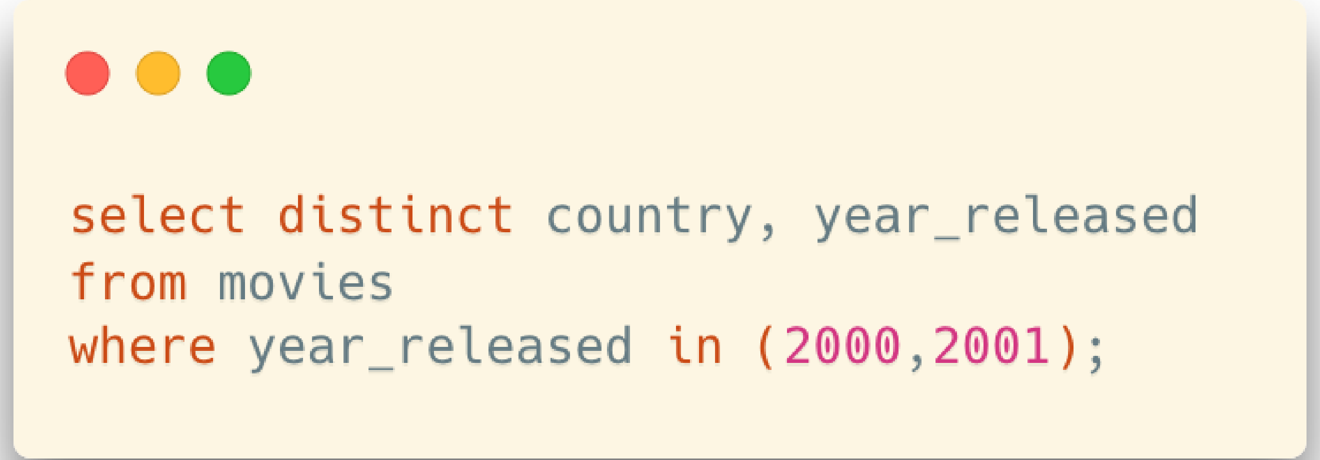
```
   country
1  si
2  mx
3  cn
4  sp
5  dk
6  gb
7  se
8  tw
9  ar
10 ca
11 pt
12 jp
13 us
14 kr
15 ma
16 de
17 au
18 in
19 hk
20 it
21 gr
22 ir
23 fr
```

No duplicated results in the country code list now

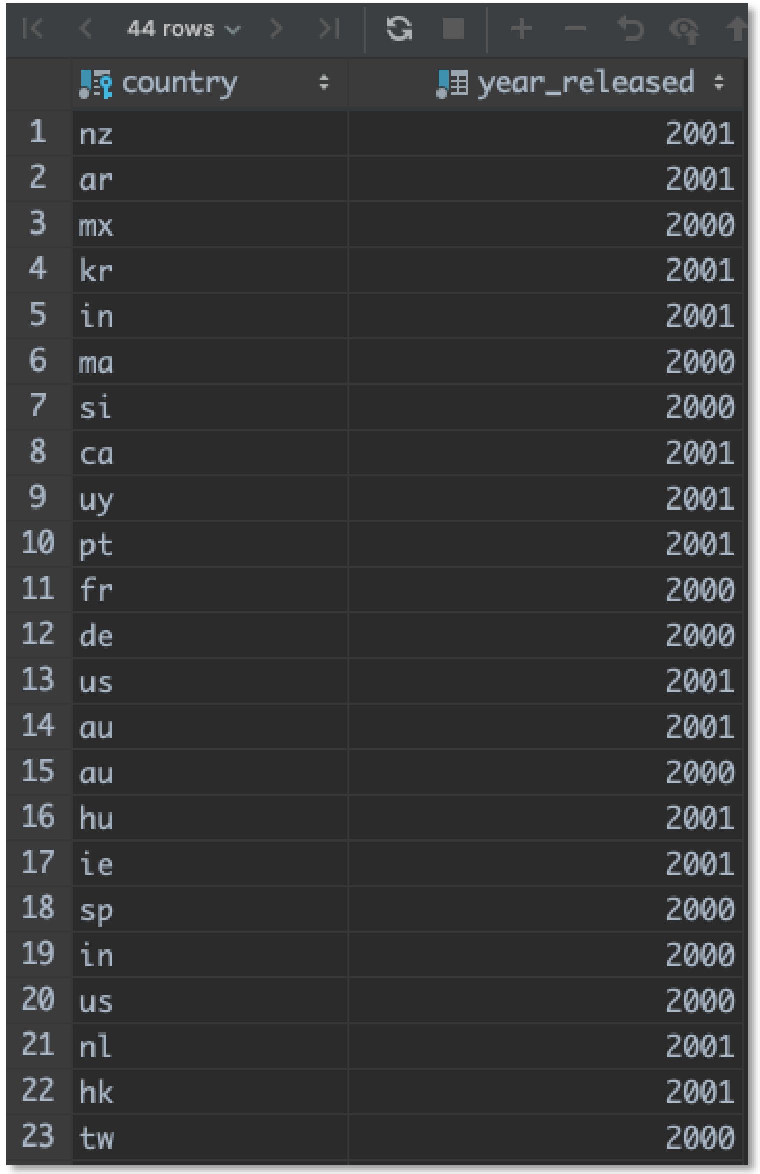
- All of them are different now, and hence it is a relation!

Distinct

- Multiple columns after the keyword `distinct`
  - It will eliminate those rows where all the selected fields are identical
  - The selected combination `(country, year_released)` will be identical



```
select distinct country, year_released
from movies
where year_released in (2000,2001);
```



	country	year_released
1	nz	2001
2	ar	2001
3	mx	2000
4	kr	2001
5	in	2001
6	ma	2000
7	si	2000
8	ca	2001
9	uy	2001
10	pt	2001
11	fr	2000
12	de	2000
13	us	2001
14	au	2001
15	au	2000
16	hu	2001
17	ie	2001
18	sp	2000
19	in	2000
20	us	2000
21	nl	2001
22	hk	2001
23	tw	2000

More on Retrieving Data

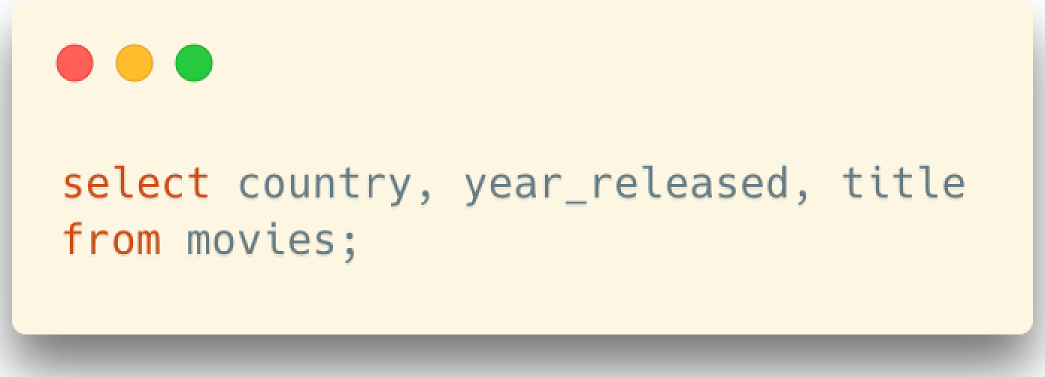
Aggregate Functions

Aggregate Functions

- Statistical functions
  - When we are interested in what we might call countrywide characteristics, such as how many movies released, we use Aggregate Functions.
  - Aggregate function will
    - aggregate all rows that share a feature (such as being movies from the same country)
    - … and return a characteristic of each group of aggregated rows

Aggregate Functions

- To compute an aggregated result, we'll first retrieve data
  - Here, all rows are in the table



```
select country, year_released, title
from movies;
```

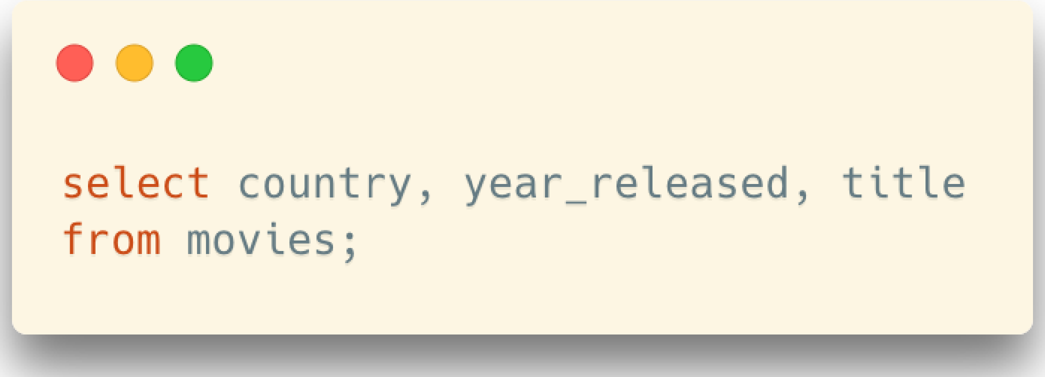
country	year_released	title
de	1985	Das Boot
fr	1997	Le cinquième élément
fr	1946	La belle et la bête
fr	1942	Les Visiteurs du Soir
gb	1962	Lawrence Of Arabia
gb	1949	The Third Man
in	1975	Sholay
in	1955	Pather Panchali
jp	1954	Shichinin no Samurai

Note: Just for demonstration purpose, not the real data in the table `movie`

Aggregate Functions

- To compute an aggregated result, we'll first retrieve data
  - Here, all rows are in the table

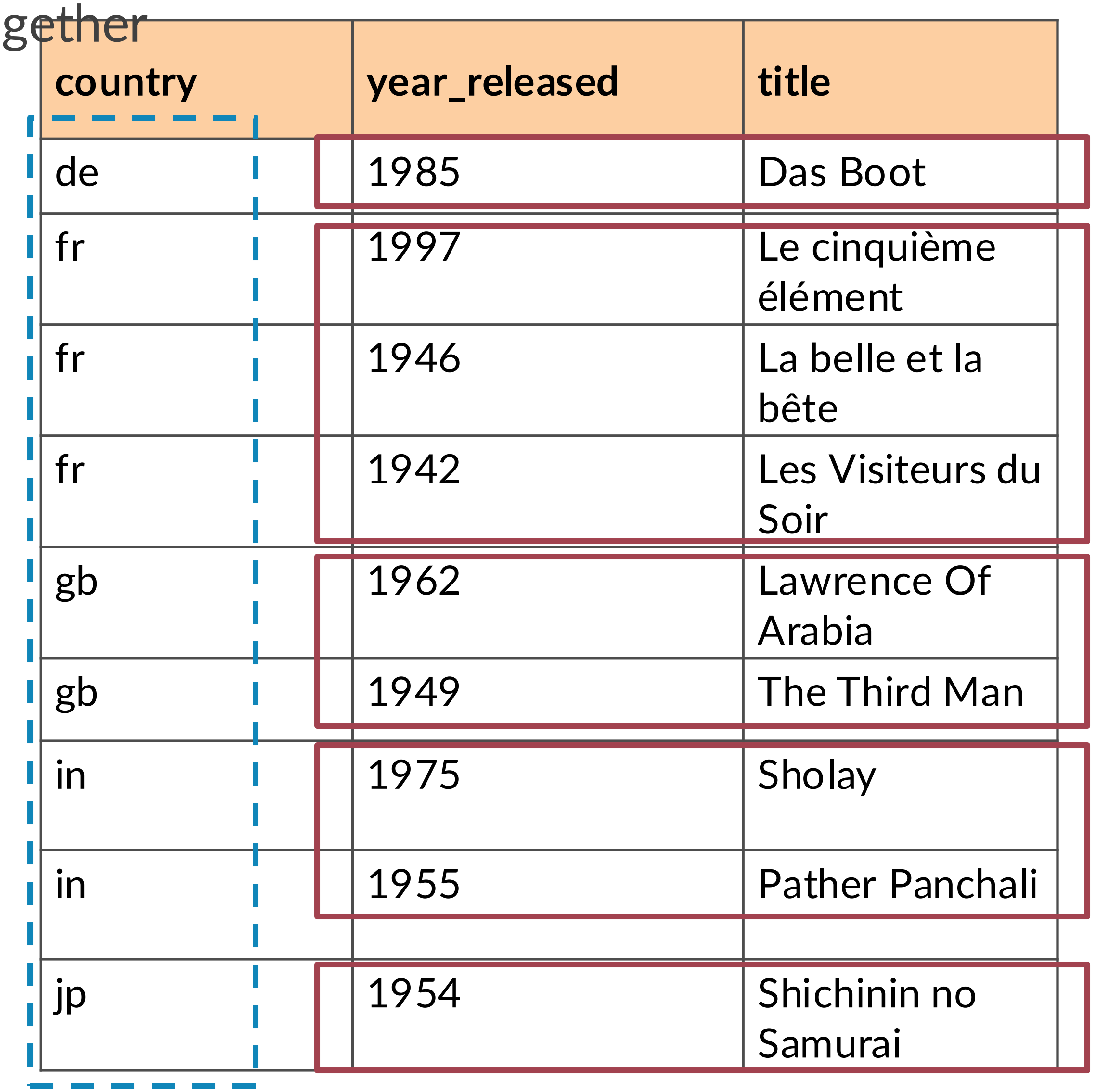
- Then, data will be regrouped according to the value in one or several columns



```
select country, year_released, title
from movies;
```

Grouped according to country

- Rows with the same value will be grouped together

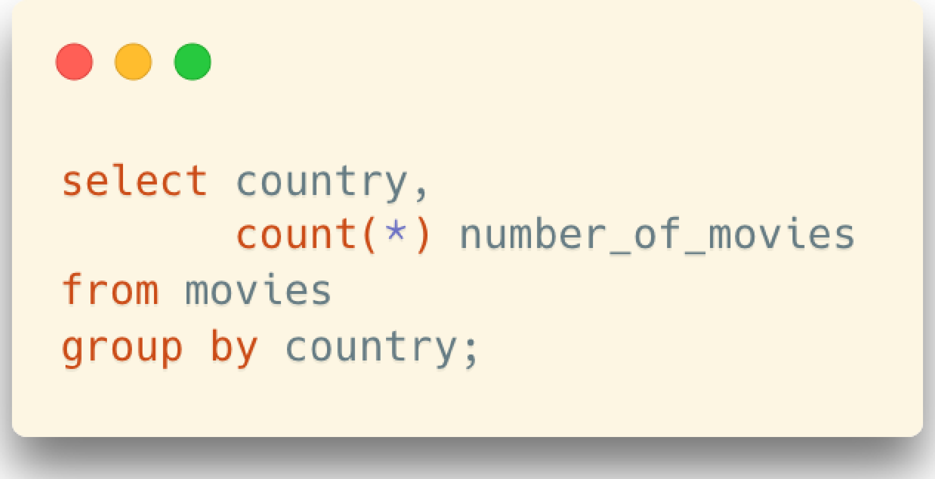


country	year_released	title
de	1985	Das Boot
fr	1997	Le cinquième élément
fr	1946	La belle et la bête
fr	1942	Les Visiteurs du Soir
gb	1962	Lawrence Of Arabia
gb	1949	The Third Man
in	1975	Sholay
in	1955	Pather Panchali
jp	1954	Shichinin no Samurai

Note: Just for demonstration purpose, not the real data in the table `movie`

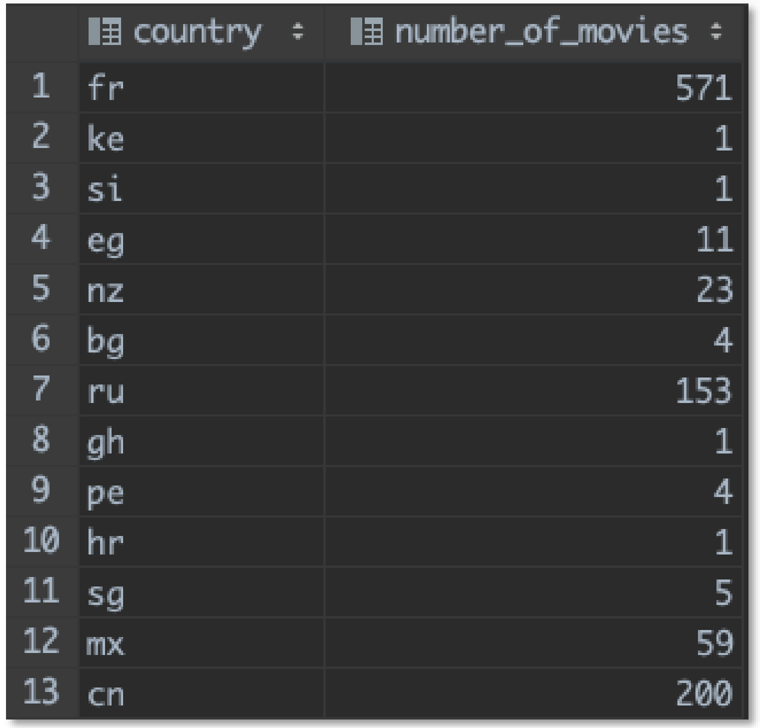
Aggregate Functions

- We say that we want to "group by country"
  - … and, for each country, the aggregate function `count(*)` says <u>how many movies we have</u>
    - "how many movies" = "how many rows"



```
select country,
       count(*) number_of_movies
from movies
group by country;
```

- The query result
  - One row for each group
  - The statistical value is attached in another column

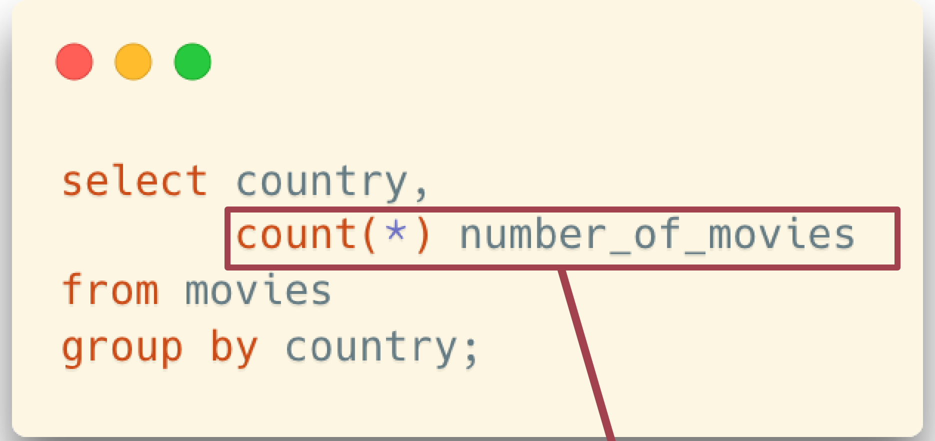


	country	number_of_movies
1	fr	571
2	ke	1
3	si	1
4	eg	11
5	nz	23
6	bg	4
7	ru	153
8	gh	1
9	pe	4
10	hr	1
11	sg	5
12	mx	59
13	cn	200

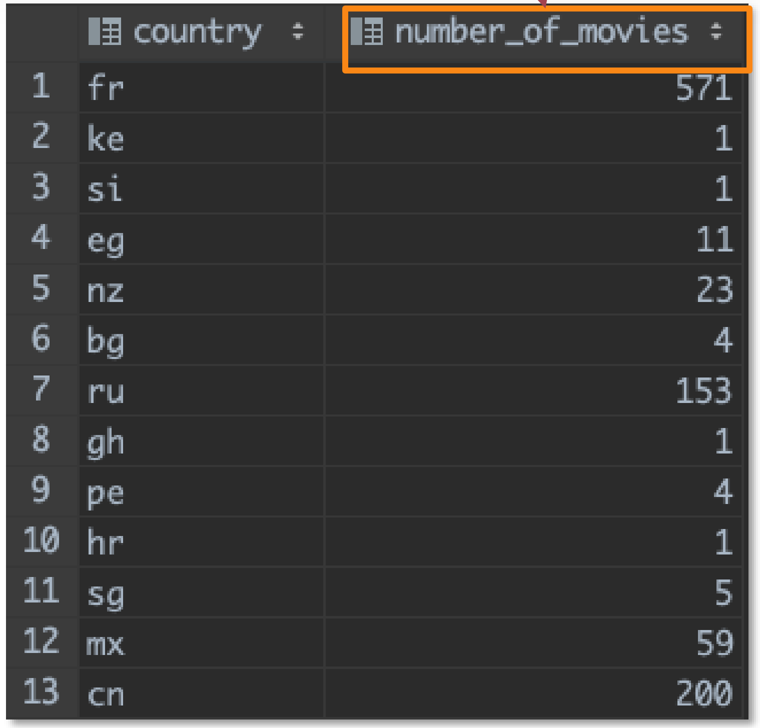
Aggregate Functions

- We say that we want to "group by country"
  - … and, for each country, the aggregate function `count(*)` says how many movies we have
    - "how many movies" = "how many rows"

By the way, we can **rename** the column of the aggregate function, like below



```
select country,
       count(*) number_of_movies
from movies
group by country;
```



	country	number_of_movies
1	fr	571
2	ke	1
3	si	1
4	eg	11
5	nz	23
6	bg	4
7	ru	153
8	gh	1
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- The query result
  - One row for each group
  - The statistical value is attached in another column

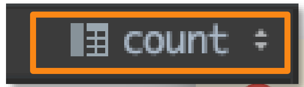
Aggregate Functions

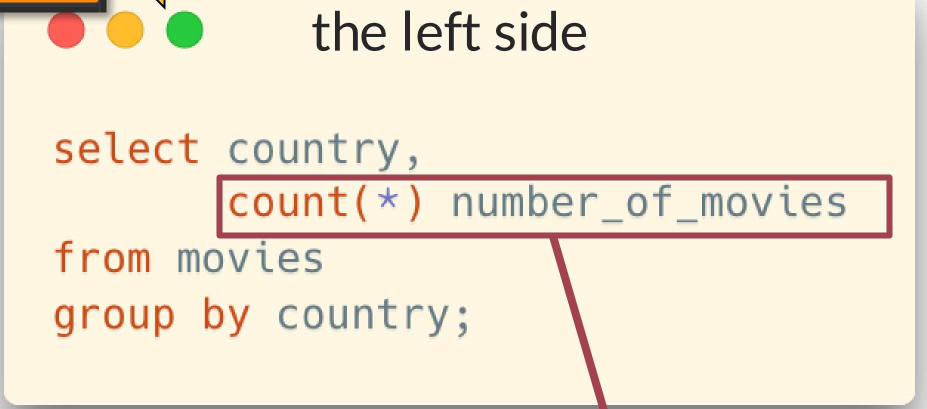
- We say that we want to "group by country"
  - … and, for each country, the aggregate function `count(*)` says how many movies we have
    - "how many movies" = "how many rows"

- The query result
  - One row for each group
  - The statistical value is attached in another column

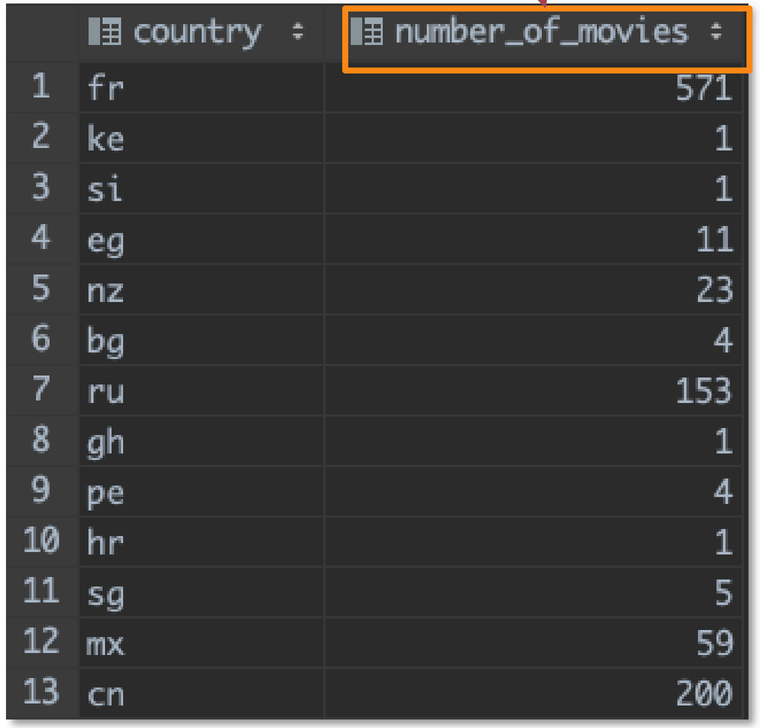
By the way, we can **rename** the column of the aggregate function, like below

- … or, the client will generate a temporary name shown on the left side





```
select country,
       count(*) number_of_movies
from movies
group by country;
```



	country	number_of_movies
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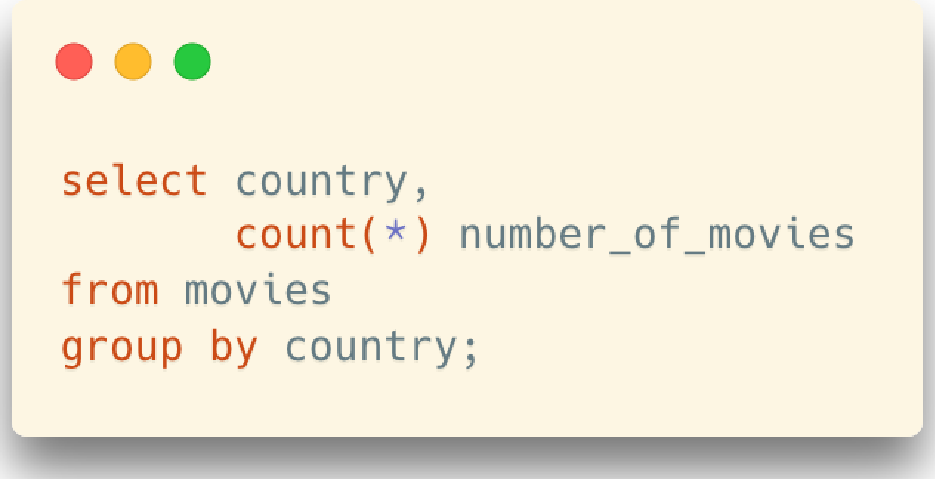
Aggregate Functions

- We say that we want to "group by country"
  - … and, for each country, the aggregate function `count(*)` says <u>how many movies we have</u>
    - "how many movies" = "how many rows"

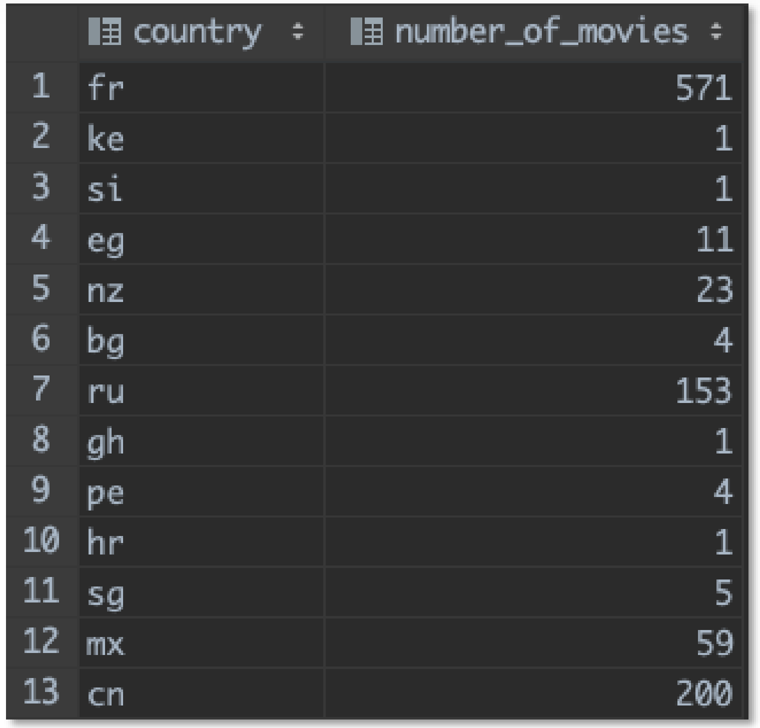
Caution: The table `movie` must be a relation (no duplicated movie records)

- … or, the counting result will not reflect the actual number of movies

- The query result
  - One row for each group
  - The statistical value is attached in another column



```
select country,
       count(*) number_of_movies
from movies
group by country;
```



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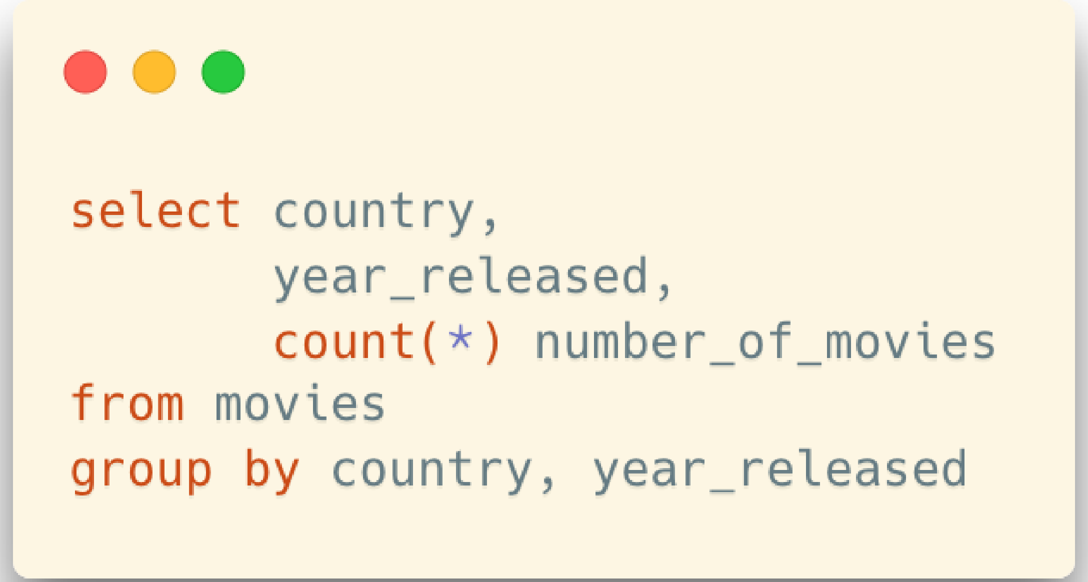
5	nz	23
6	bg	4
7	ru	153
8	gh	1
9	pe	4
10	hr	1
11	sg	5
12	mx	59
13	cn	200

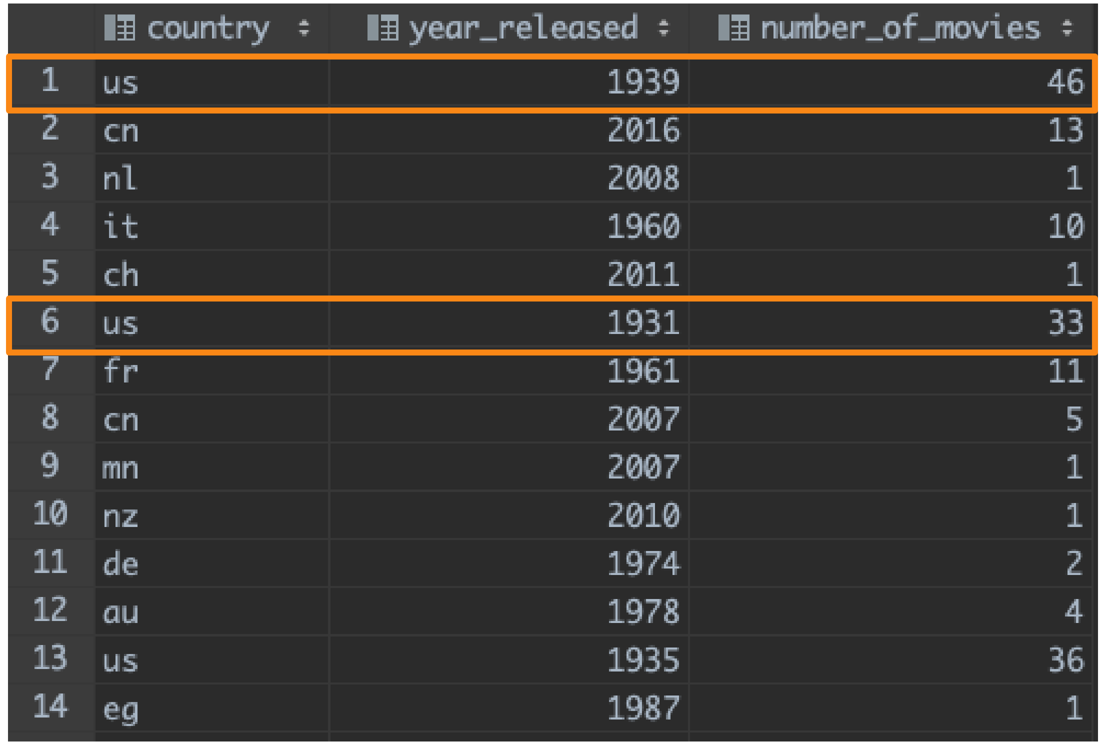
Aggregate Functions

- Group on several columns
  - Every column that isn't an aggregate function and appears after `select` must also appear after `group by`



```
select country,
       year_released,
       count(*) number_of_movies
from movies
group by country, year_released
```

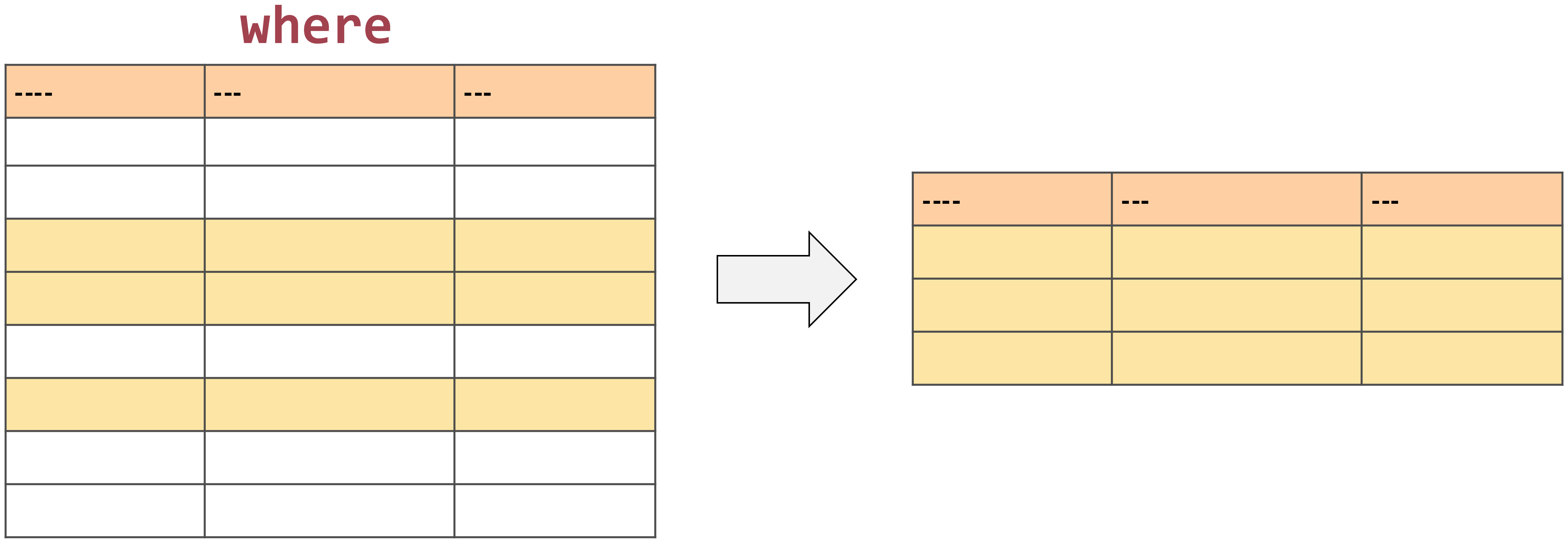
The combination of the countries and released years will appear in the result



	country	year_released	number_of_movies
1	us	1939	46
2	cn	2016	13
3	nl	2008	1
4	it	1960	10
5	ch	2011	1
6	us	1931	33
7	fr	1961	11
8	cn	2007	5
9	mn	2007	1
10	nz	2010	1
11	de	1974	2
12	au	1978	4
13	us	1935	36
14	eg	1987	1

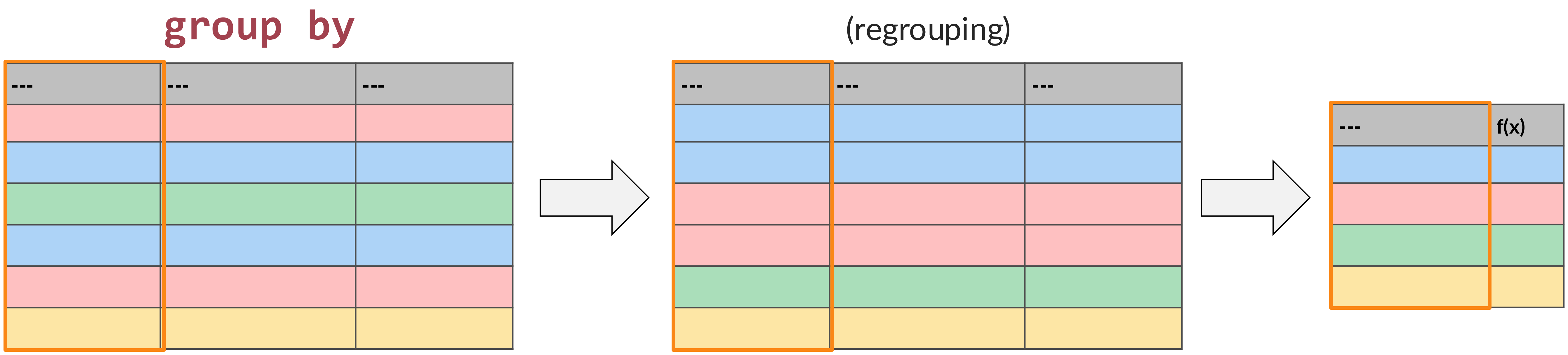
Aggregate Functions

- Beware of some performance implications
  - When you apply a simple `where` filter, you can start returning rows as soon as you have found a match.



Aggregate Functions

- Beware of some performance implications
  - With a group by, you must regroup rows before you can aggregate them and return results.
    - In other words, you have a preparatory phase that may take time, even if you return few rows in the end.
    - In interactive applications, end-users don't always understand it well.



Aggregate Functions

`count(*)/count(col), min(col), max(col), stddev(col), avg(col)`

- These aggregate function examples exist in almost all products
  - Most products implement other functions
  - Some work with any datatype, others only work with numerical columns

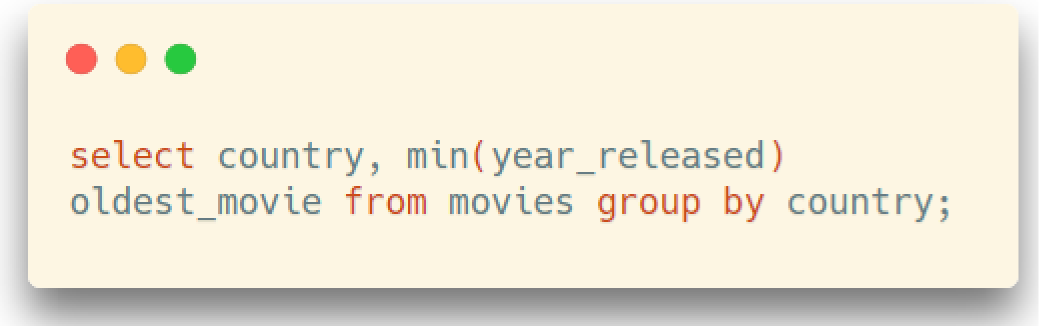
  - It is strongly recommended to refer to the database manual for details
    - For example, SQLite doesn't have `stddev()` which computes the standard deviation

Aggregate Functions

- *Earliest release year by country?*

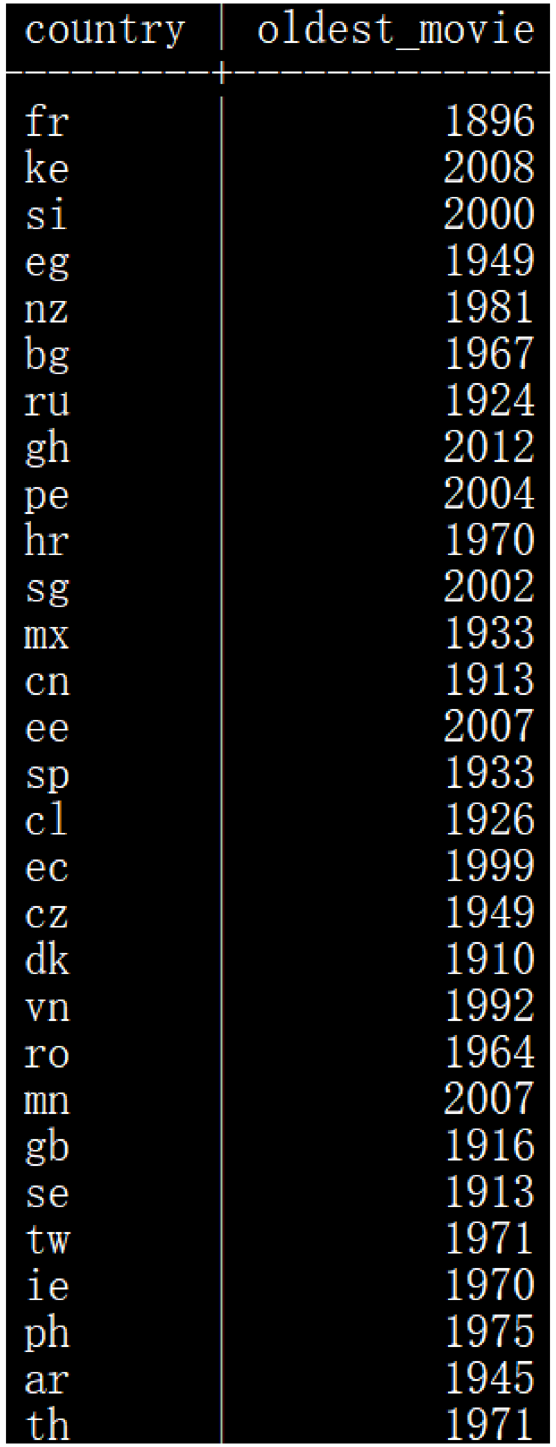
Aggregate Functions

- *Earliest release year by country?*



```
select country, min(year_released)
oldest_movie from movies group by country;
```

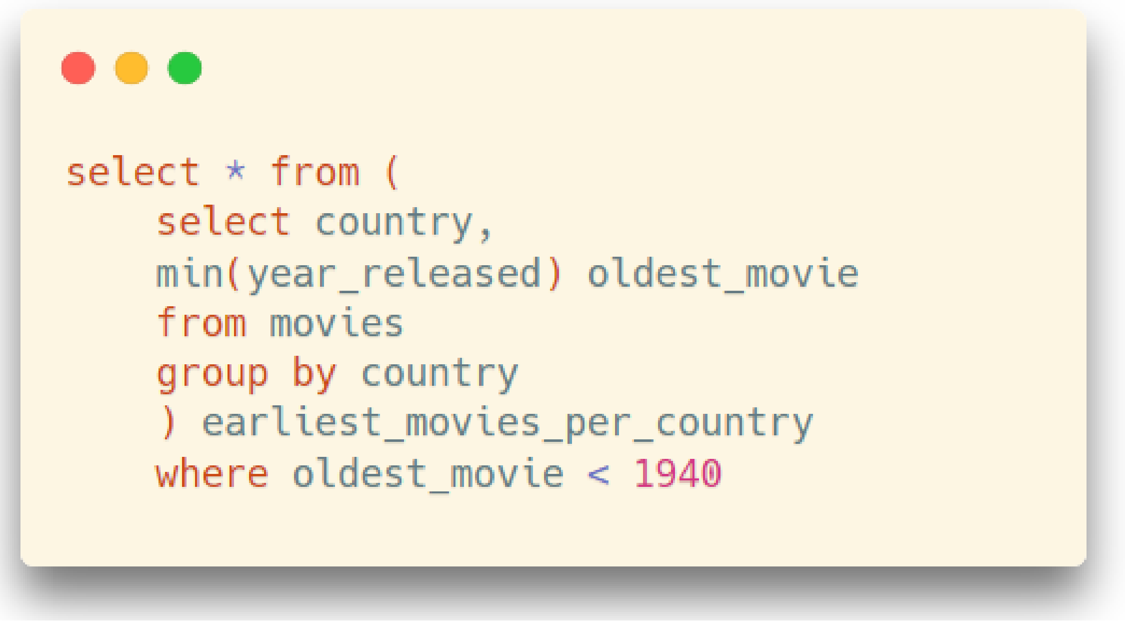
- Such a query answers the question
  - Note that in the demo database years are simple numerical values, but generally speaking min() applied to a date logically returns the earliest one.
  - The result will be a relation: no duplicates, and the key that identifies each row will be the country code (generally speaking, what follows GROUP BY).



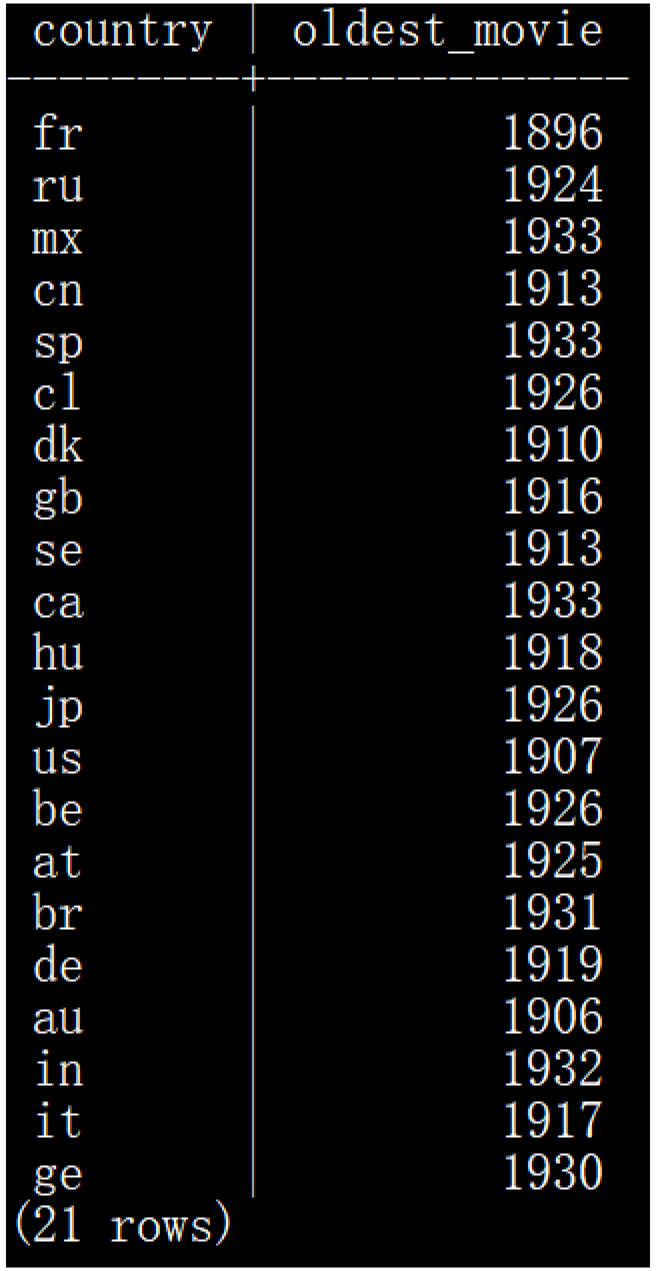
```
 country | oldest_movie
---------+--------------
 fr      |         1896
 ke      |         2008
 si      |         2000
 eg      |         1949
 nz      |         1981
 bg      |         1967
 ru      |         1924
 gh      |         2012
 pe      |         2004
 hr      |         1970
 sg      |         2002
 mx      |         1933
 cn      |         1913
 ee      |         2007
 sp      |         1933
 cl      |         1926
 ec      |         1999
 cz      |         1949
 dk      |         1910
 vn      |         1992
 ro      |         1964
 mn      |         2007
 gb      |         1916
 se      |         1913
 tw      |         1971
 ie      |         1970
 ph      |         1975
 ar      |         1945
 th      |         1971
```

Aggregate Functions

- Therefore, we can validly apply another relational operation such as the “select” operation (row filtering) and only return countries for which the earliest movie was released before 1940.



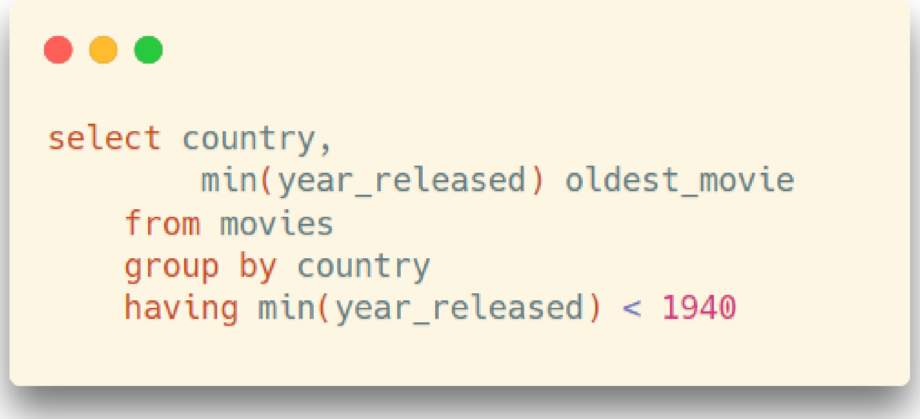
```
select * from (
    select country,
    min(year_released) oldest_movie
    from movies
    group by country
    ) earliest_movies_per_country
    where oldest_movie < 1940
```



```
 country | oldest_movie
---------+--------------
 fr      |         1896
 ru      |         1924
 mx      |         1933
 cn      |         1913
 sp      |         1933
 cl      |         1926
 dk      |         1910
 gb      |         1916
 se      |         1913
 ca      |         1933
 hu      |         1918
 jp      |         1926
 us      |         1907
 be      |         1926
 at      |         1925
 br      |         1931
 de      |         1919
 au      |         1906
 in      |         1932
 it      |         1917
 ge      |         1930
(21 rows)
```

Aggregate Functions

- There is a short-hand that makes nesting queries unnecessary (in the same way as AND allows multiple filters). You can have a condition on the result of an aggregate with **having.**



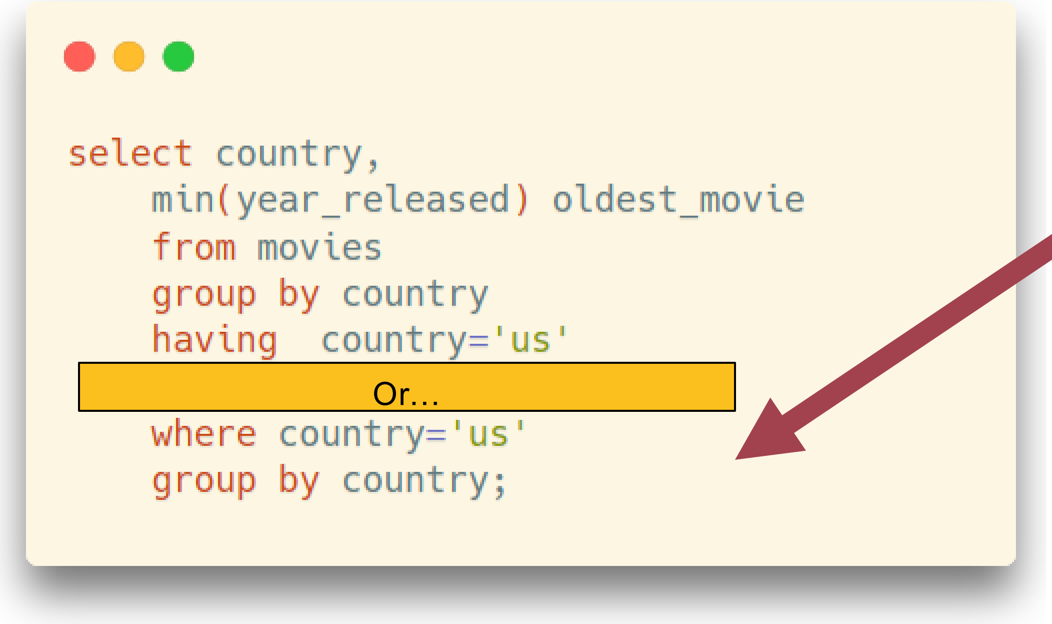
```
select country,
        min(year_released) oldest_movie
    from movies
    group by country
    having min(year_released) < 1940
```

- Now, keep in mind that aggregating rows requires sorting them in a way or another, and that sorts are always costly operations that don't scale well (cost increases faster than the number of rows sorted).

Aggregate Functions

SORT：<u>Time complexity</u> of sorting algorithms: O(n*log(n))

- The following query is perfectly valid in SQL. What you are doing is aggregating movies for all countries, then discarding everything that isn't American:



```
select country,
    min(year_released) oldest_movie
    from movies
    group by country
    having  country='us'
```

Or...

```
    where country='us'
    group by country;
```

The efficient way to proceed is of course to select American movies first, and only aggregate them.

- SQL Server will do the right thing behind your back.
- Oracle will assume that you have some obscure reason for writing your query that way and will do as told. It can hurt.

Aggregate Functions

- All database management systems have a highly important component that we'll see again, called the "query optimizer".
  - It takes your query and tries to find the most efficient way to run it.
  - Sometimes it tries to outsmart you, with from time to time unintended consequences
  - Sometimes it optimistically assumes that you know what you are doing
  - ... In all, optimizers don't all behave the same.

Aggregate Functions

- *Nulls?*

- When you apply a function or operators to a null, with very few exceptions the result is null because the result of a transformation applied to something unknown is an unknown quantity. What happens with aggregates?

- known + unknown = unknown

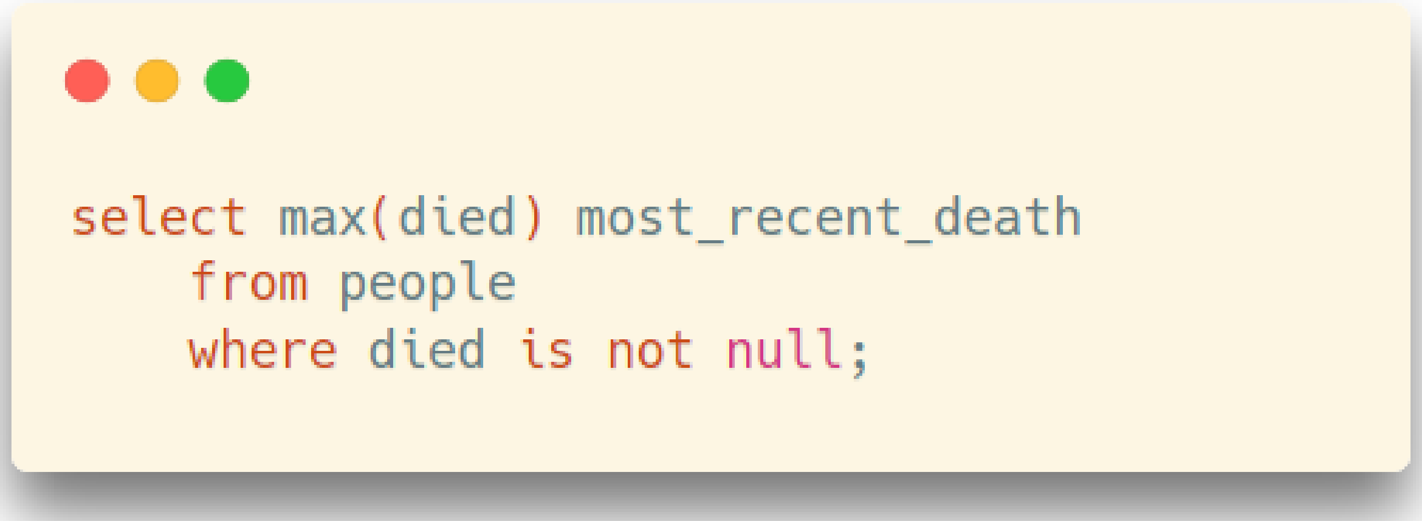
Aggregate Functions

- ***Nulls?***

- Aggregate functions **ignore** Nulls.

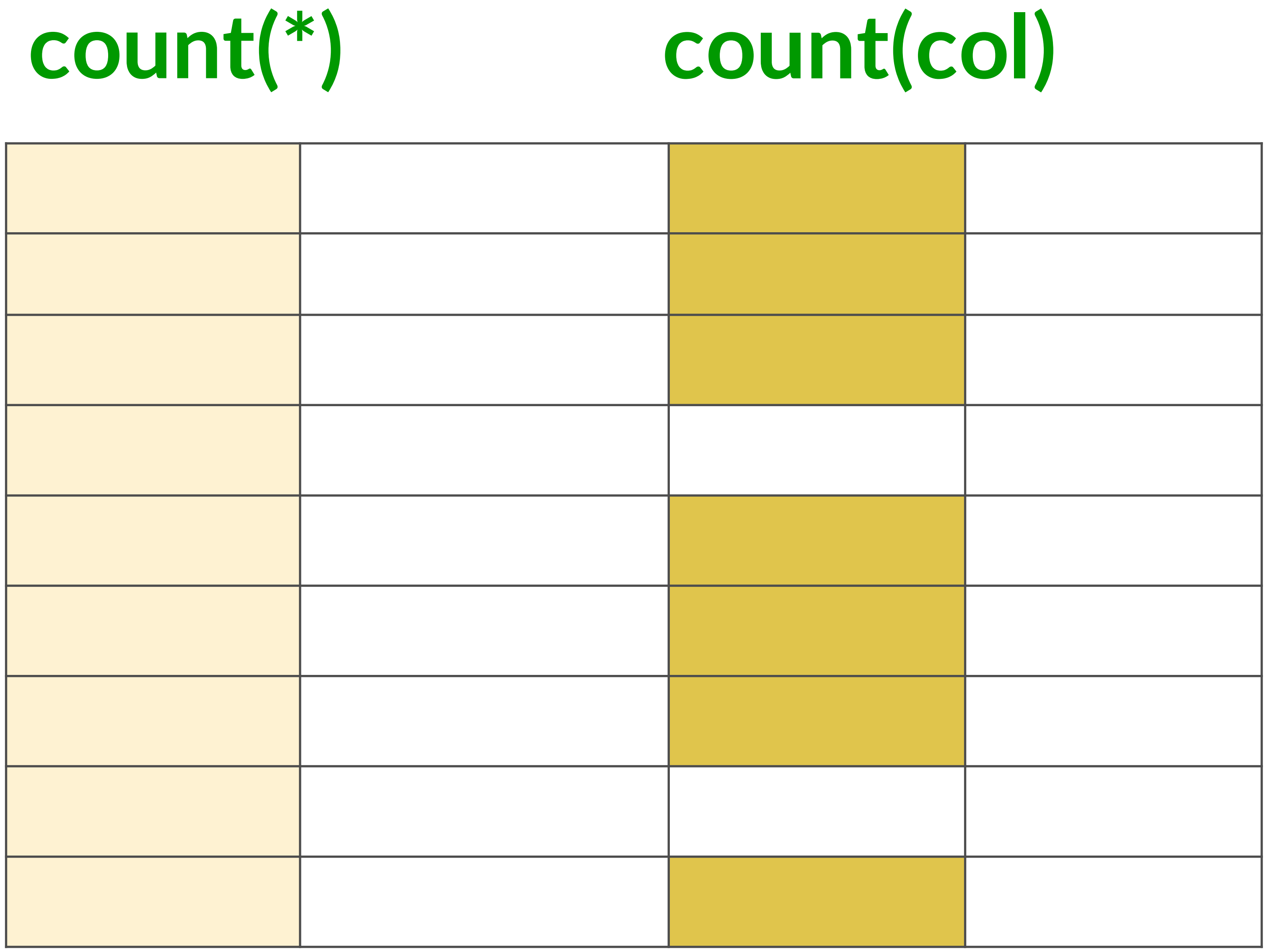
Aggregate Functions

- In this query, the `where` condition changes nothing to the result
    - Perhaps it makes more obvious that we are dealing with dead people only, but for the SQL engine it's implicit.



```
select max(died) most_recent_death
    from people
    where died is not null;
```

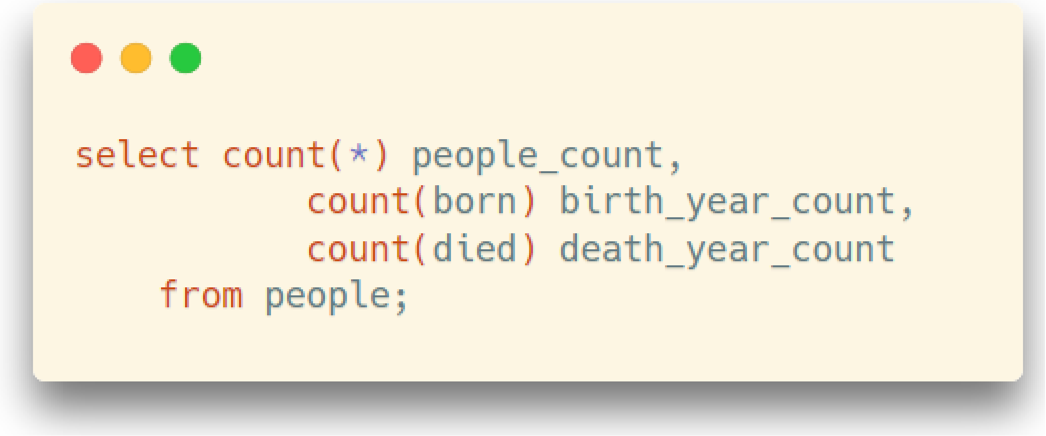
Aggregate Functions



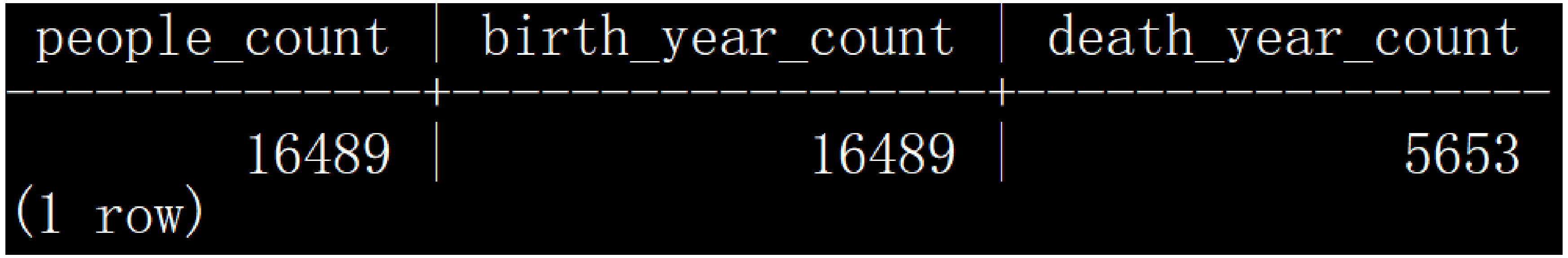
- Depending on the column you count, the function can therefore return different values. count(*) will always return the number of rows in the result set, because there is always one value that isn't null in a row (otherwise you wouldn't have a row in the first place)

Aggregate Functions

- Counting a mandatory column such as BORN will return the same value as COUNT(*)
  - The third count, though, will only return the number of dead people in the table.



```
select count(*) people_count,
           count(born) birth_year_count,
           count(died) death_year_count
    from people;
```



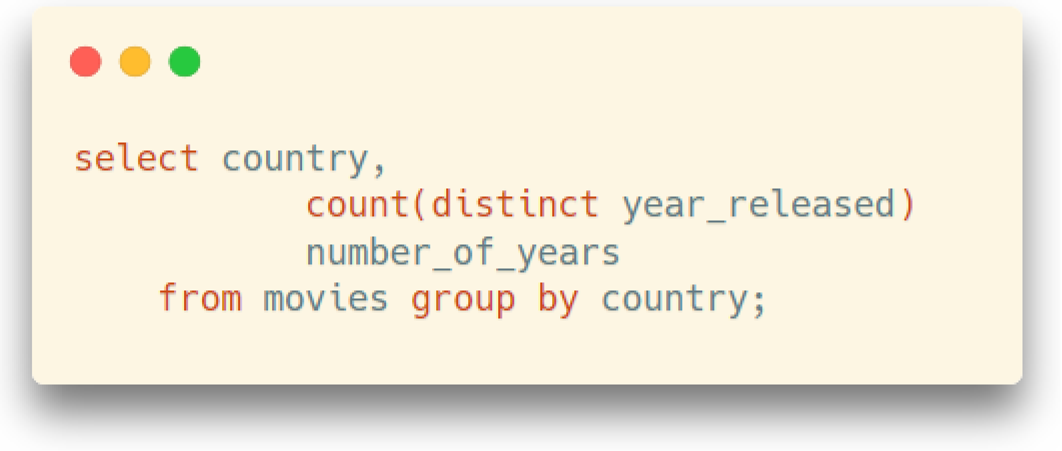
```
 people_count | birth_year_count | death_year_count
--------------+------------------+------------------
        16489 |            16489 |             5653
(1 row)
```

Aggregate Functions

- `select count(colname)`
- `select count(distinct colname)`

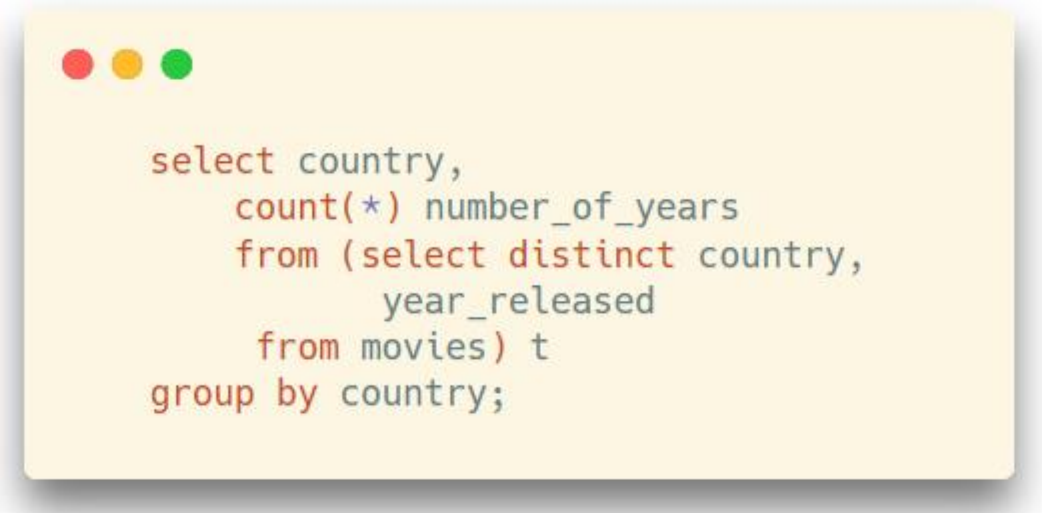
- In some cases, you only want to count distinct values
  - For instance, you may want to count how many different surnames start with a Q instead of how many people have a surname that starts with a Q.

Aggregate Functions



```
select country,
           count(distinct year_released)
           number_of_years
    from movies group by country;
```

- These two queries are equivalent



```
select country,
    count(*) number_of_years
    from (select distinct country,
           year_released
     from movies) t
group by country;
```

Here we'll only get one row per country and year

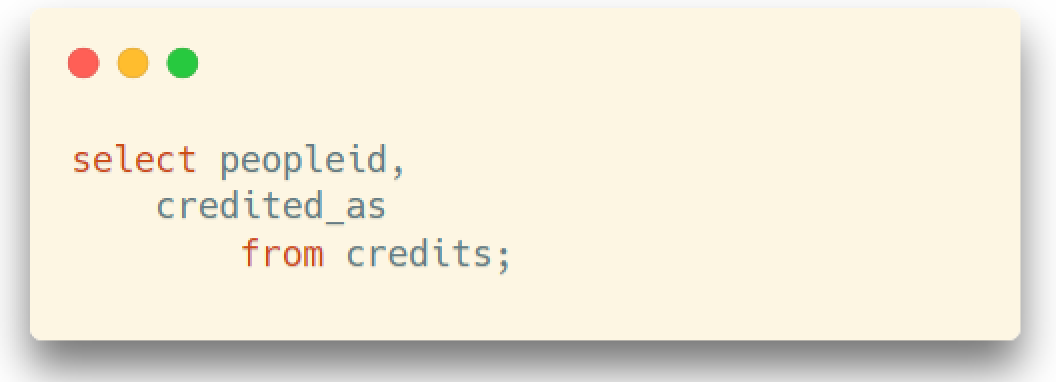
Aggregate Functions

- How many people are both actors and directors?

credits

Aggregate Functions

~~movie_id~~	people_id	credited_as
~~8~~	37	D
~~8~~	38	A
~~8~~	39	A
~~8~~	40	A
~~10~~	11	A
~~10~~	12	A
~~10~~	15	D
~~10~~	16	A
~~10~~	17	A

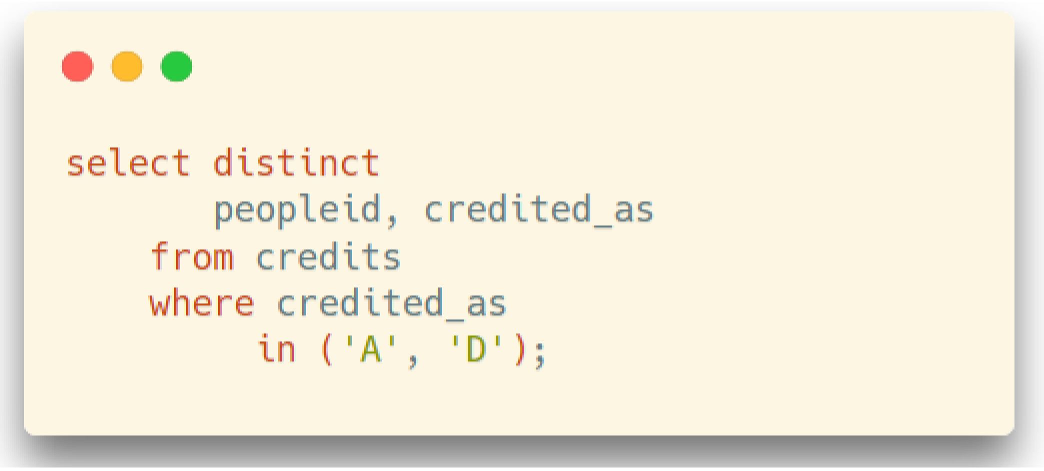


```
select peopleid,
    credited_as
        from credits;
```

- There is no restriction such as “that have played in a movie that they have directed”, so the `movie_id` is irrelevant.
- But if we remove the `movie_id`, we have tons of duplicates. Not a relation!

Aggregate Functions

- People who appear twice are the ones we want.



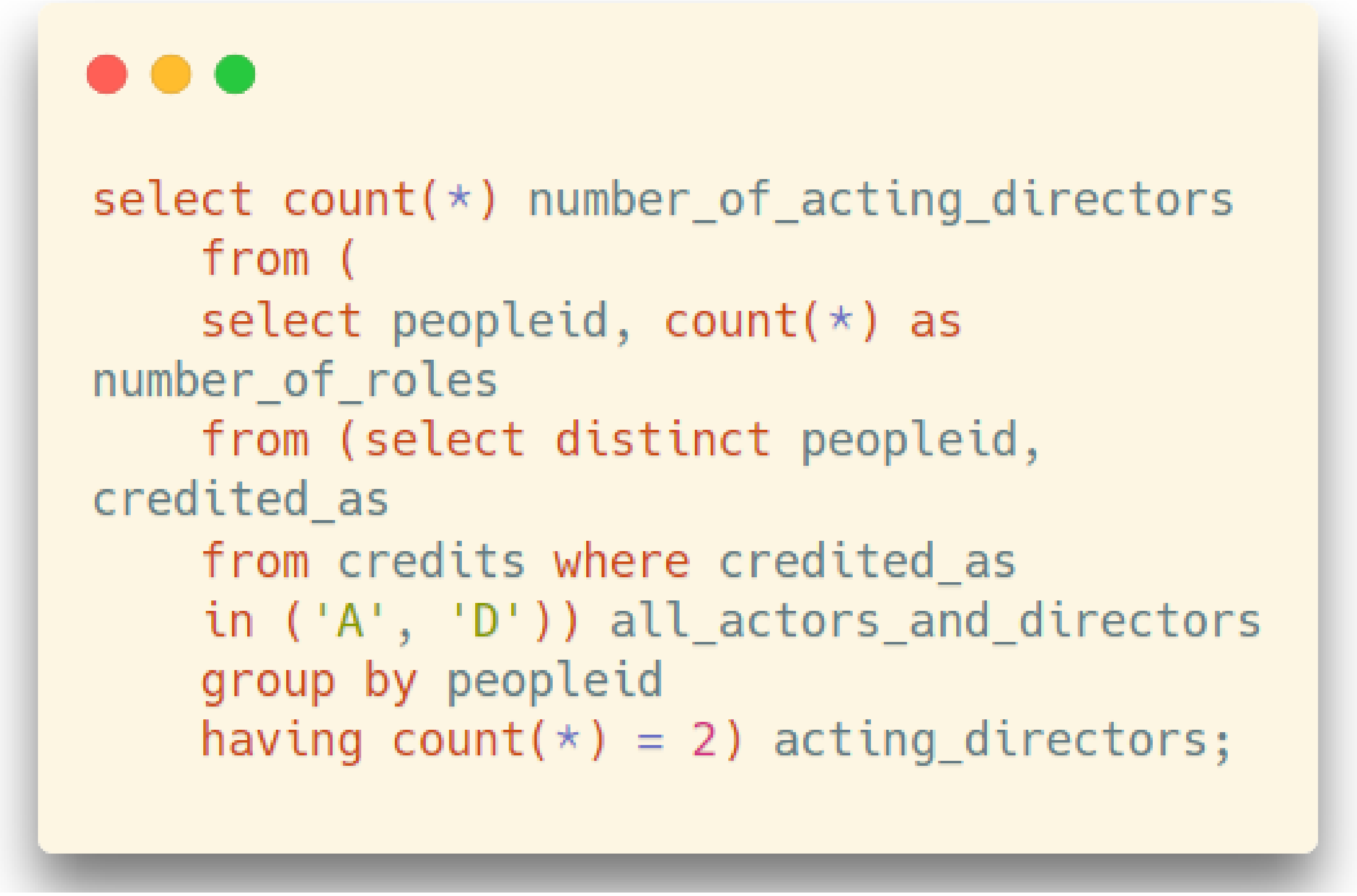
```
select distinct
       peopleid, credited_as
    from credits
    where credited_as
         in ('A', 'D');
```

  - distinct will remove duplicates and provide a true relation.
  - We specify the values for credited_as
    - There are no other values now
    - but you can't predict the future. Someday there may be producers or directors of photography (cinematographer).

people_id	credited_as
11	D
11	A
12	A
15	A
16	A
17	A
37	D
38	A
39	A

Aggregate Functions

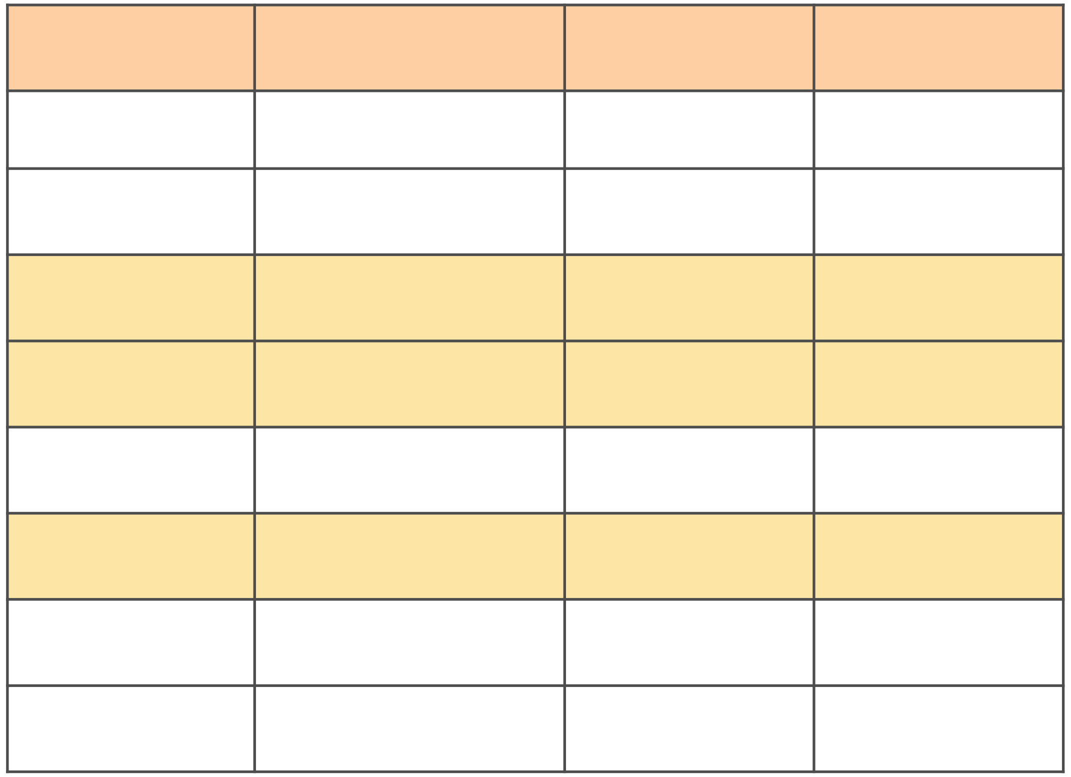
- The `having` selects only people who appear twice … and we just have to count them. Mission accomplished.



```
select count(*) number_of_acting_directors
    from (
    select peopleid, count(*) as
number_of_roles
    from (select distinct peopleid,
credited_as
    from credits where credited_as
    in ('A', 'D')) all_actors_and_directors
    group by peopleid
    having count(*) = 2) acting_directors;
```

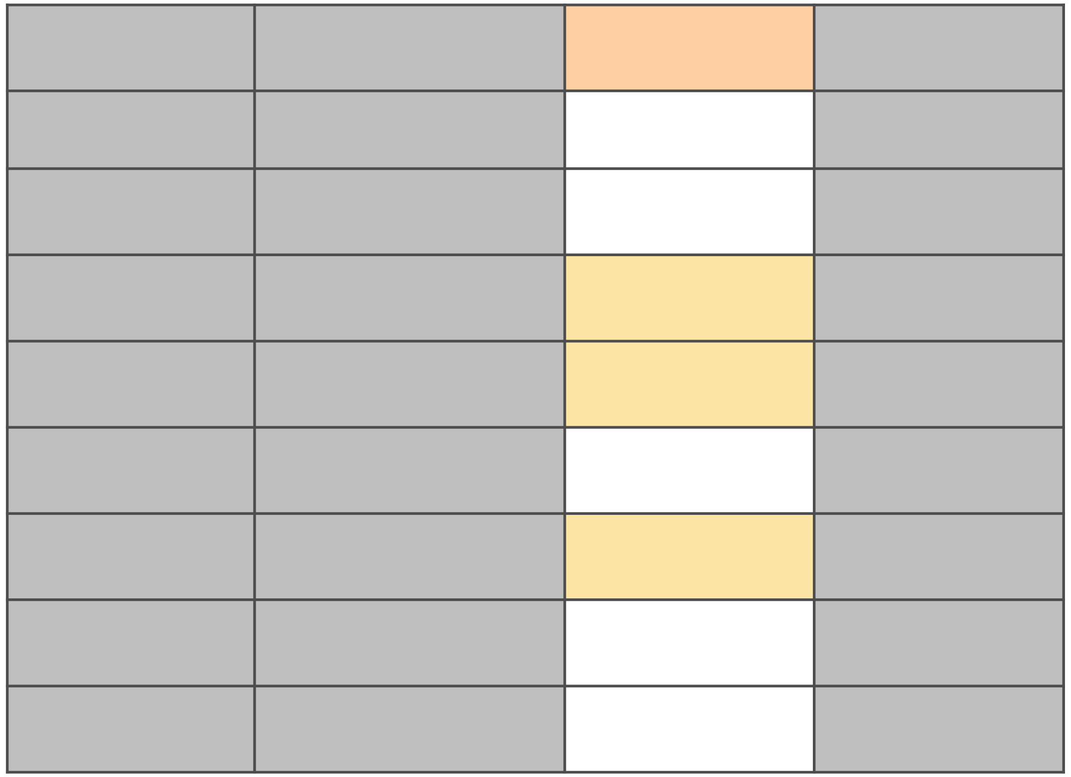
Join

Retrieving Data from Multiple Tables



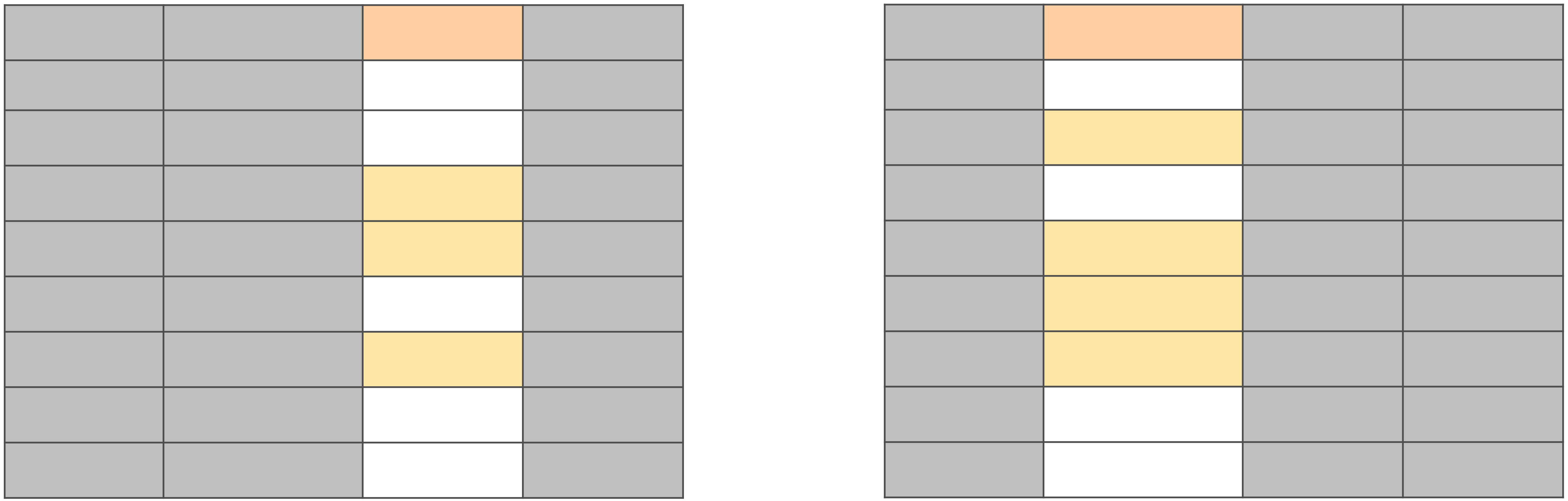
- We have seen the basic operation consisting in filtering rows (an operator called SELECT by Codd)

Retrieving Data from Multiple Tables



- We have seen how we can only return some columns (called PROJECT by Codd), and that we must be careful not to return duplicates when we aren't returning a full key.

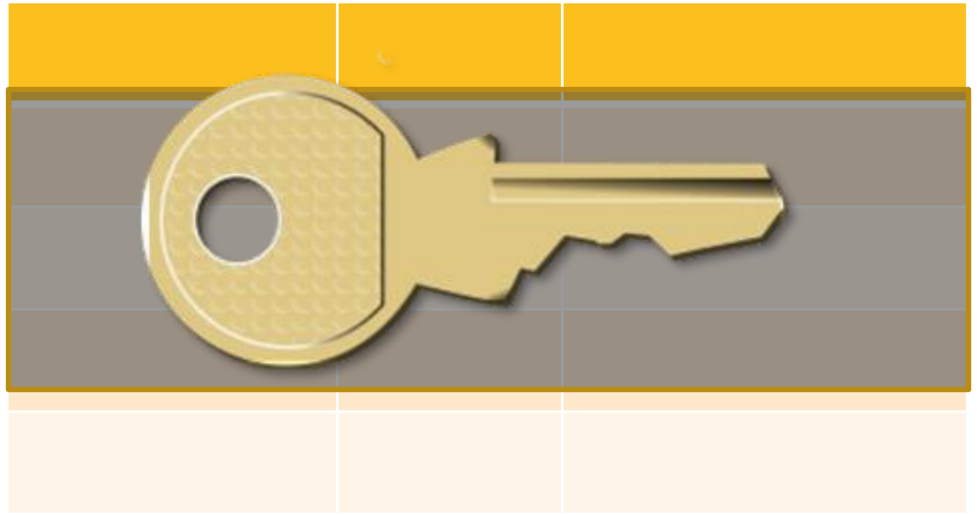
Retrieving Data from Multiple Tables



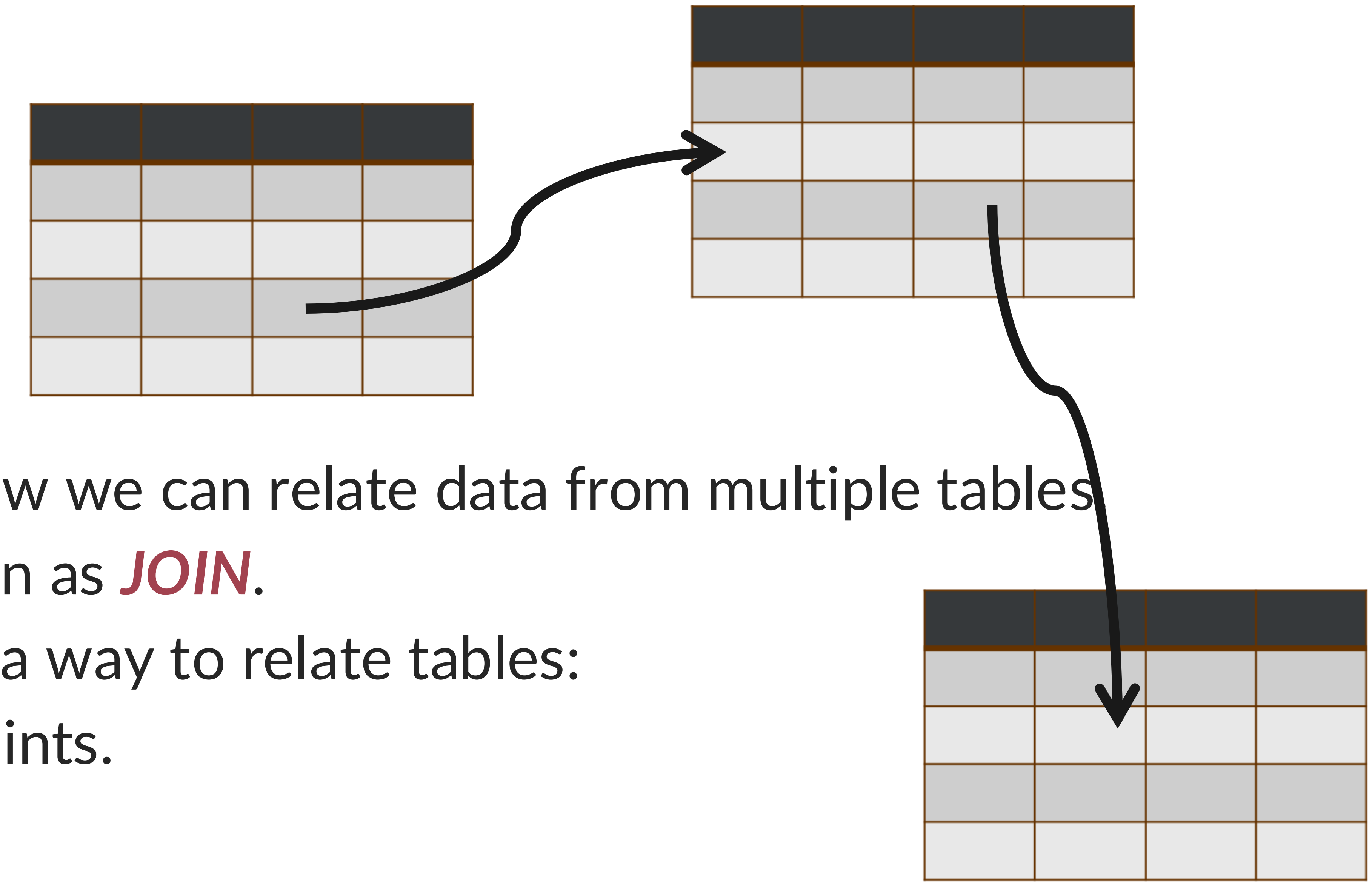
- We have also seen how we can return data that doesn't exist as such in tables by applying functions to columns.

Retrieving Data from Multiple Tables

- What is Important is that in all cases our result set looks like a clean table, with no duplicates and a column (or combination of columns) that could be used as a key
  - If this is the case, we are safe. This must be true at every stage in a complex query built by successive layers.



Retrieving Data from Multiple Tables



- It's time now to see how we can relate data from multiple tables.
- This operation is known as ***JOIN***.
- We have already seen a way to relate tables:

  foreign key constraints.

Retrieving Data from Multiple Tables

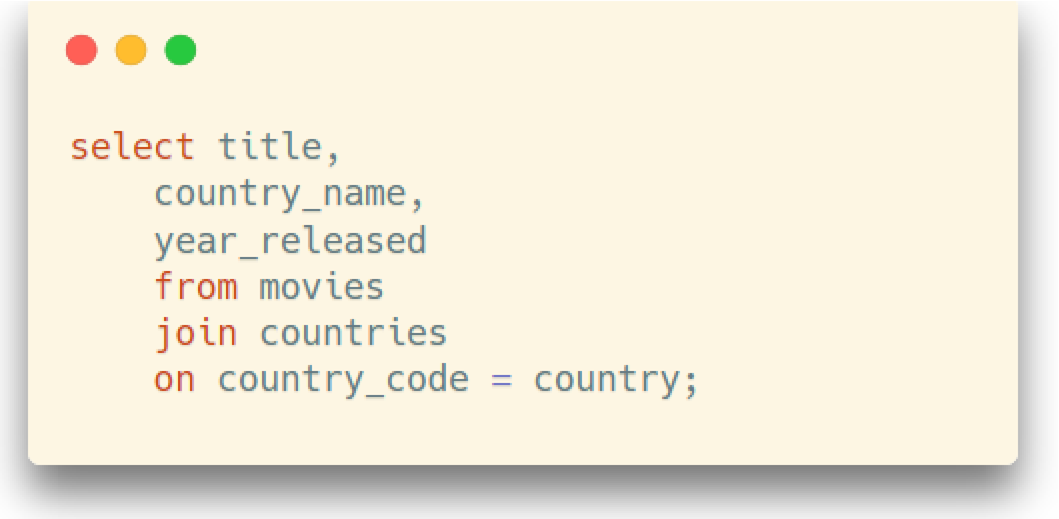
movieid	title	country	year_released
1	Casab	us	1942
2	Goodfellas	us	1990
3	Bronenosets Potyomkin	ru	1925
4	Blade Runner	us	1982
5	Annie Hall	us	1977

country_code	country_name	continent
ru	Russia	Europe
us	United States	America
in	India	Asia
gb	United Kingdom	Europe

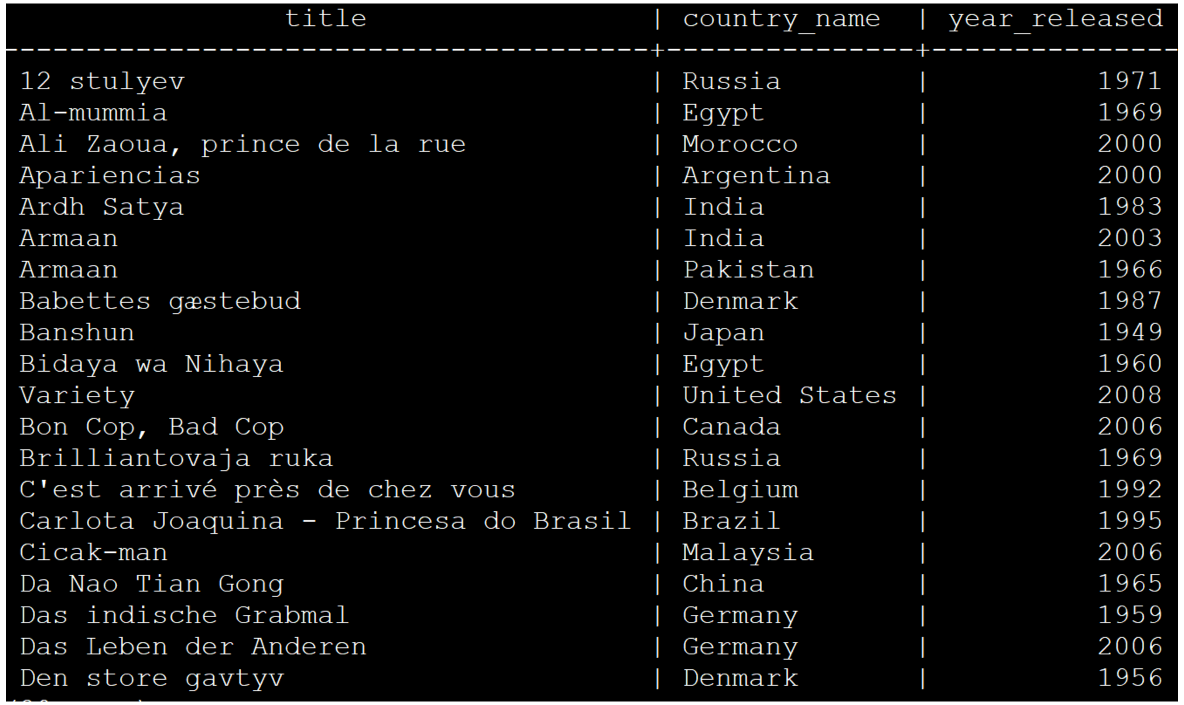
- The “country” column in “movies” can be used to retrieve the country name from “countries”.

Retrieving Data from Multiple Tables

- This is done with this type of query. We retrieve, and display as a single set, pieces of data coming from two different tables.



```
select title,
    country_name,
    year_released
    from movies
    join countries
    on country_code = country;
```



```
                 title                 | country_name  | year_released
---------------------------------------+---------------+---------------
 12 stulyev                            | Russia        |          1971
 Al-mummia                             | Egypt         |          1969
 Ali Zaoua, prince de la rue           | Morocco       |          2000
 Apariencias                           | Argentina     |          2000
 Ardh Satya                            | India         |          1983
 Armaan                                | India         |          2003
 Armaan                                | Pakistan      |          1966
 Babettes gæstebud                     | Denmark       |          1987
 Banshun                               | Japan         |          1949
 Bidaya wa Nihaya                      | Egypt         |          1960
 Variety                               | United States |          2008
 Bon Cop, Bad Cop                      | Canada        |          2006
 Brilliantovaja ruka                   | Russia        |          1969
 C'est arrivé près de chez vous        | Belgium       |          1992
 Carlota Joaquina - Princesa do Brasil | Brazil        |          1995
 Cicak-man                             | Malaysia      |          2006
 Da Nao Tian Gong                      | China         |          1965
 Das indische Grabmal                  | Germany       |          1959
 Das Leben der Anderen                 | Germany       |          2006
 Den store gavtyv                      | Denmark       |          1956
```

Retrieving Data from Multiple Tables

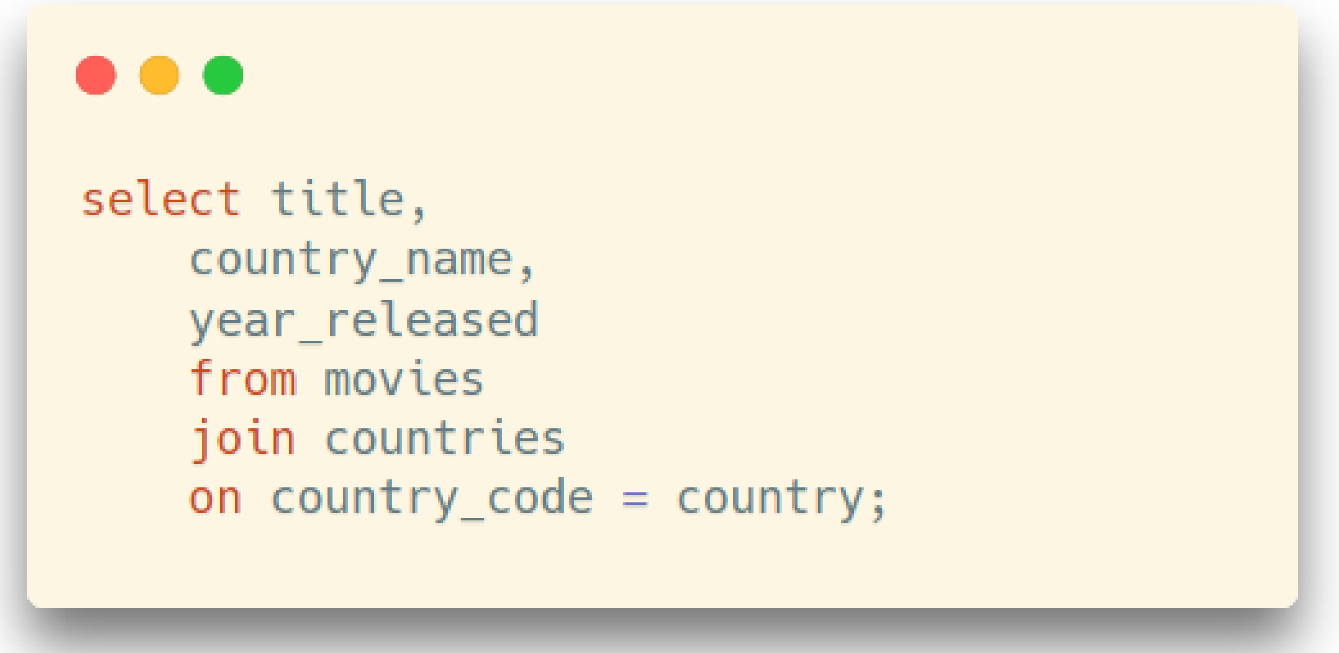
- The join operation will create a virtual table with all combinations between rows in Table1 and rows in Table2.
- If Table1 has R1 rows, and Table2 has R2, the huge virtual table has R1xR2 rows.

movies join countries

movieid	title	country	year_released	country_code	country_name	continent
1	Casablanca	us	1942	ru	Russia	Europe
1	Casablanca	us	1942	us	United States	America
1	Casablanca	us	1942	in	India	Asia
1	Casablanca	us	1942	gb	United Kingdom	Europe
1	Casablanca	us	1942	ru	Russia	Europe

Retrieving Data from Multiple Tables

- The join condition says which values in each table must match for our associating the other columns



```
select title,
    country_name,
    year_released
    from movies
    join countries
    on country_code = country;
```

Retrieving Data from Multiple Tables

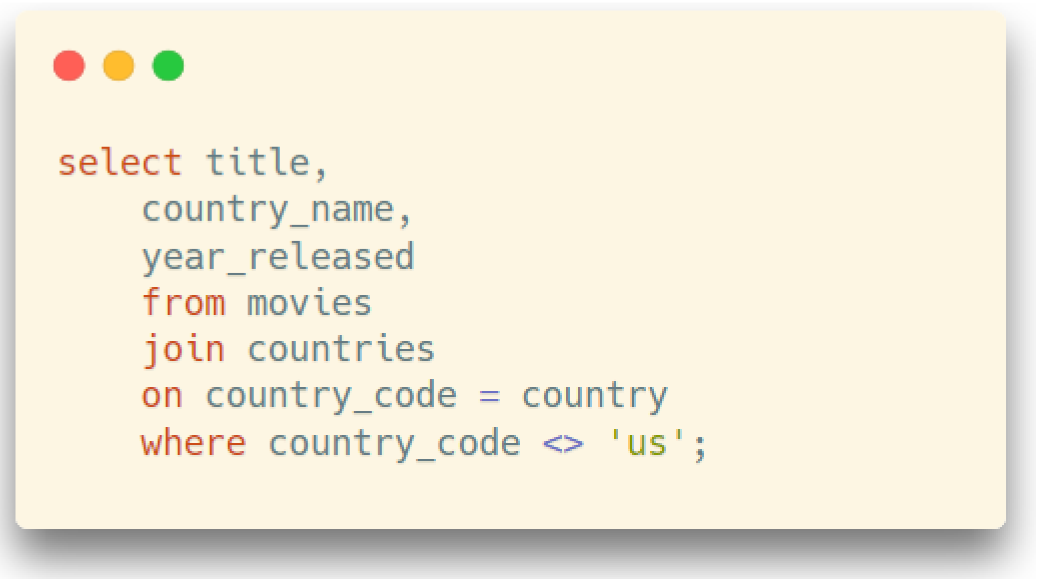
`movies join countries`

movieid	title	country	year_released	country_code	country_name	continent
1	Casablanca	us	1942	ru	Russia	Europe
1	Casablanca	us	1942	us	United States	America
1	Casablanca	us	1942	in	India	Asia
1	Casablanca	us	1942	gb	United Kingdom	Europe
1	Casablanca	us	1942	ru	Russia	Europe

- We use on country_code = country to filter out unrelated rows to make a much smaller virtual table.

Retrieving Data from Multiple Tables

- From this virtual table
    - Retrieve some columns and apply filtering conditions to any column

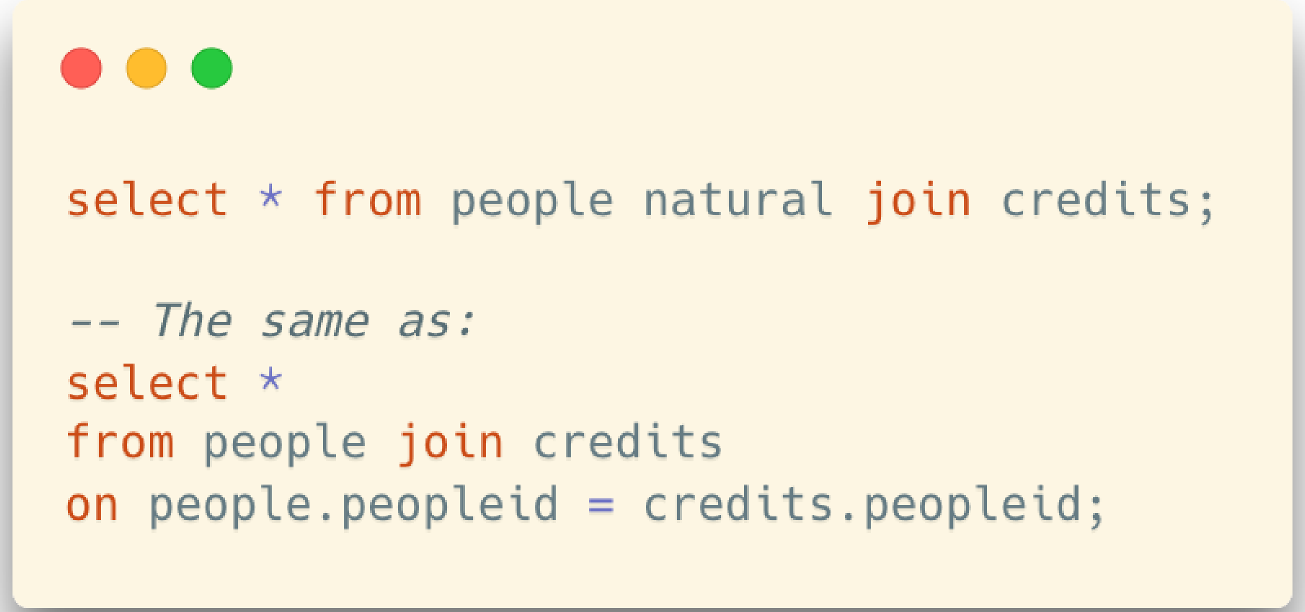


```
select title,
    country_name,
    year_released
    from movies
    join countries
    on country_code = country
    where country_code <> 'us';
```

movieid	title	country	year_released	country_code	country_name	continent
1	Casablanca	us	1942	us	United States	America
2	Goodfellas	us	1990	us	United States	America
3	Bronenosets Potyomkin	ru	1925	ru	Russia	Europe
4	Blade Runner	us	1982	us	United States	America

Natural Join

- What if we don’t specify the column?
  - Natural join

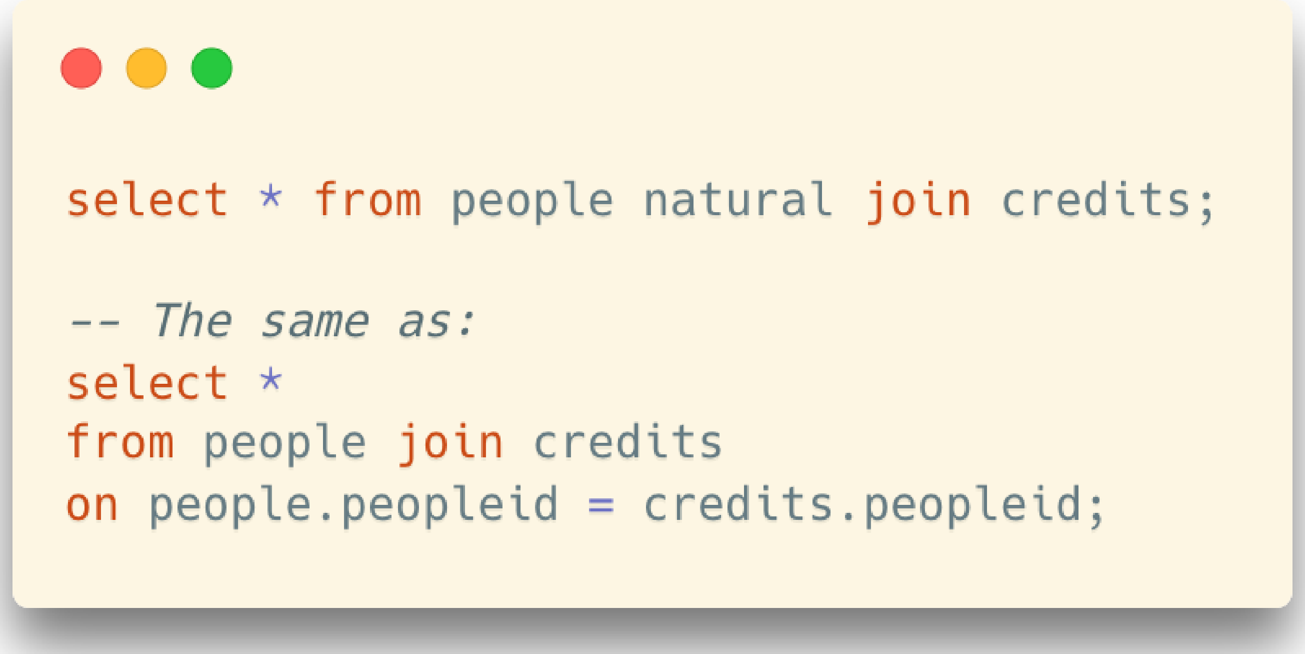


```
select * from people natural join credits;

-- The same as:
select *
from people join credits
on people.peopleid = credits.peopleid;
```

Natural Join

- What if we don’t specify the column?
  - Natural join
- *“If a column has the same name, then we should join on it”*
  - Bad idea!
  - Same name != Same meaning



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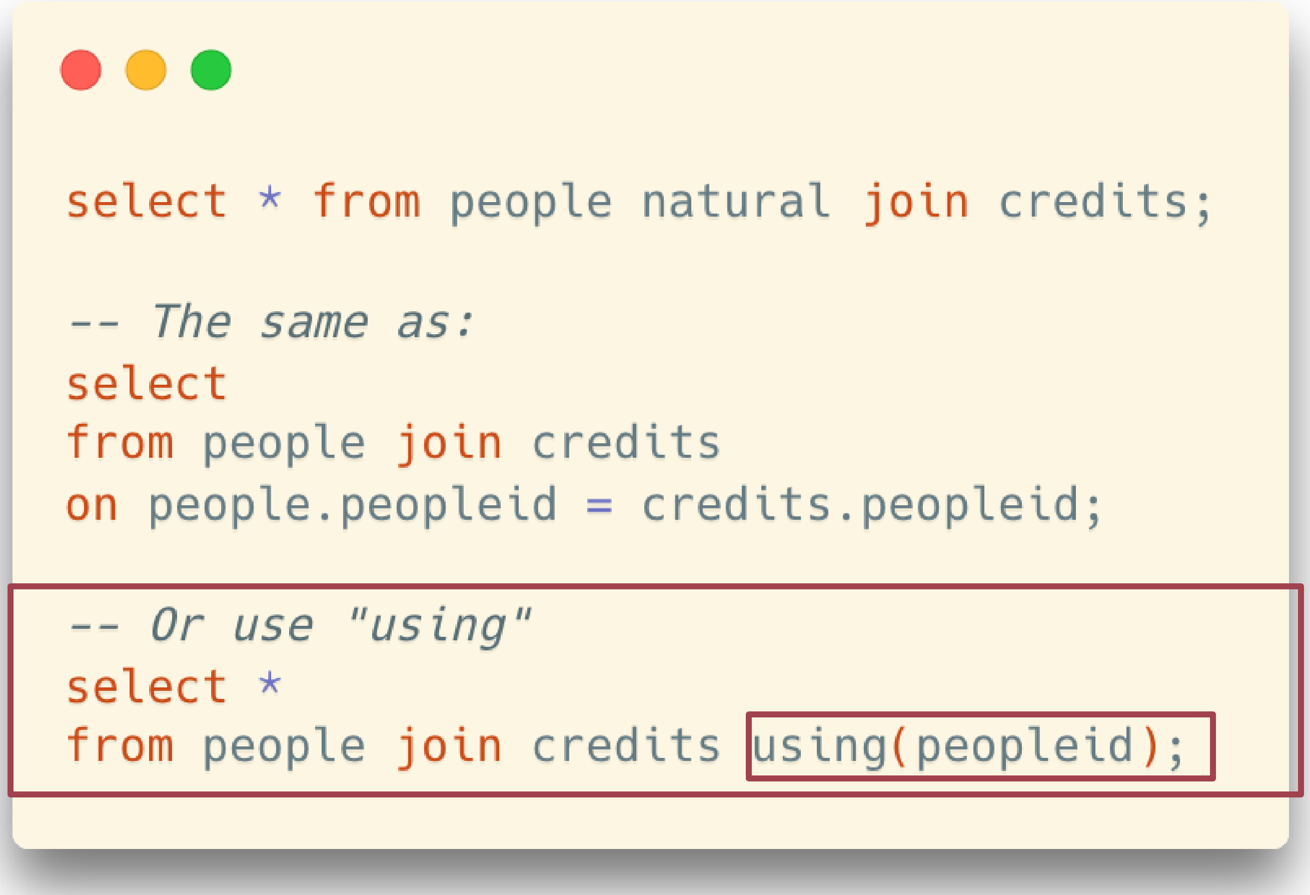
```

Natural Join

- What if we don’t specify the column?
  - Natural join
- *“If a column has the same name, then we should join on it”*
  - Bad idea!
  - Same name != Same semantic
- In join (not natural join):
  - Use `using` to specify the column with the same name



```
select * from people natural join credits;

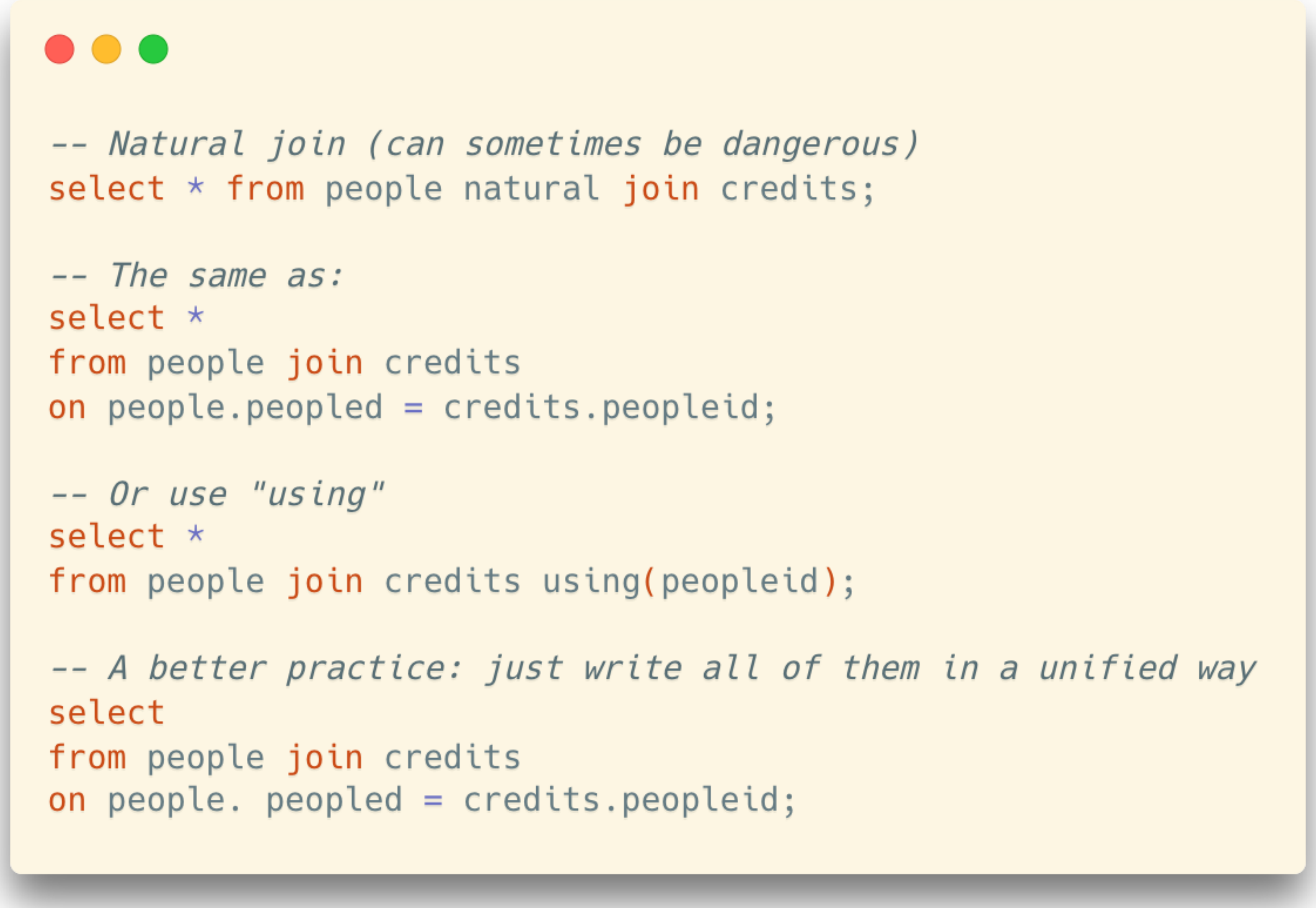
-- The same as:
select
from people join credits
on people.peopleid = credits.peopleid;

-- Or use "using"
select *
from people join credits using(peopleid);
```

(Maybe) A Good Practice in Writing Queries

- It is preferred not to depend on how database designers name their columns
    - It can be a good practice to use a single (and sometimes straightforward) syntax that works all the time

Keep it simple stupid



```
-- Natural join (can sometimes be dangerous)
select * from people natural join credits;

-- The same as:
select *
from people join credits
on people.peopled = credits.peopleid;

-- Or use "using"
select *
from people join credits using(peopleid);

-- A better practice: just write all of them in a unified way
select
from people join credits
on people. peopled = credits.peopleid;
```

Self Join

- Join the same table together
  - For example: How can we find all the pairs of people with the same first name?

Self Join

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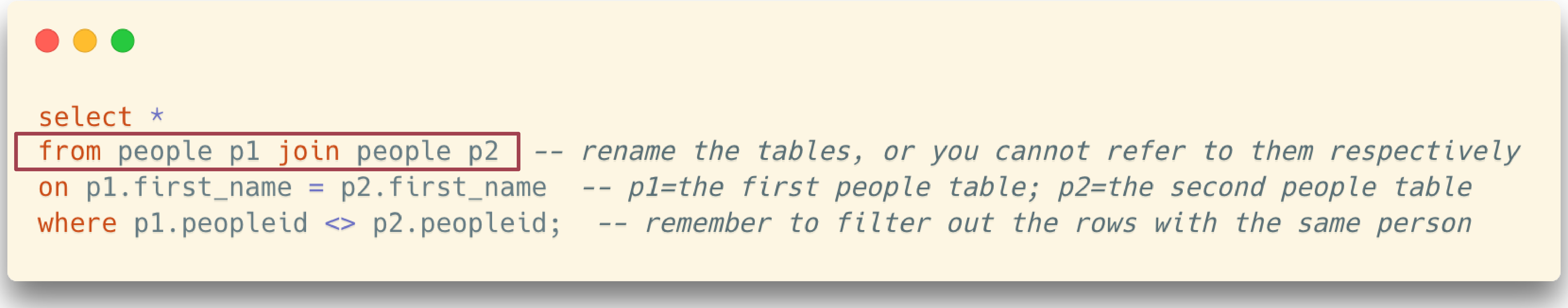
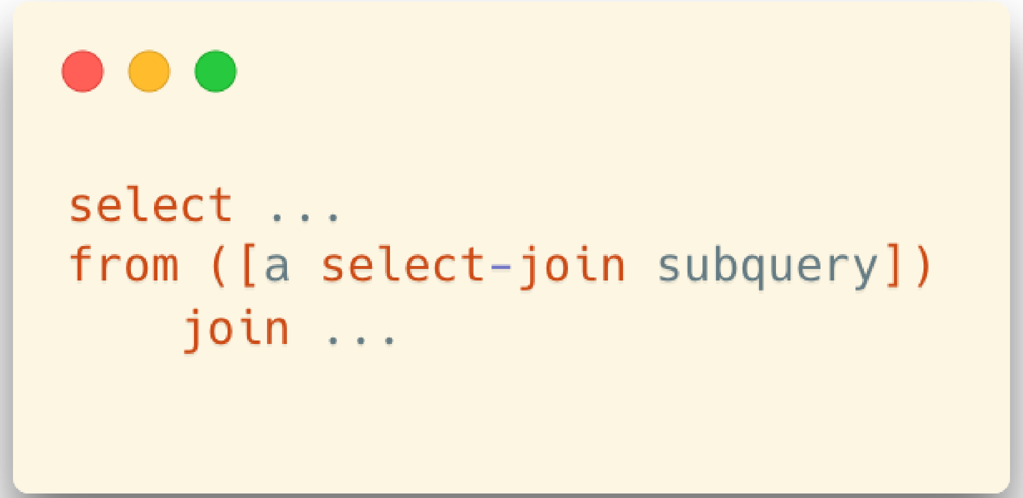


```sql
select *
from people p1 join people p2  -- rename the tables, or you cannot refer to them respectively
on p1.first_name = p2.first_name  -- p1=the first people table; p2=the second people table
where p1.peopleid <> p2.peopleid;  -- remember to filter out the rows with the same person
```

Join in a Subquery

- A join can as well be applied to a subquery seen as a virtual table
  - … as long as the result of this subquery is a valid relation in Codd's sense



```
select ...
from ([a select-join subquery])
    join ...
```

Chaining Joins Together

- We can also chain joins the same way we chain filtering conditions with AND.
  - Joins between 10 or 15 tables aren’t uncommon, and queries generated by programs often do much worse.

Chaining Joins Together

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  - Example: Show names of actors and directors for Chinese movies

Chaining Joins Together

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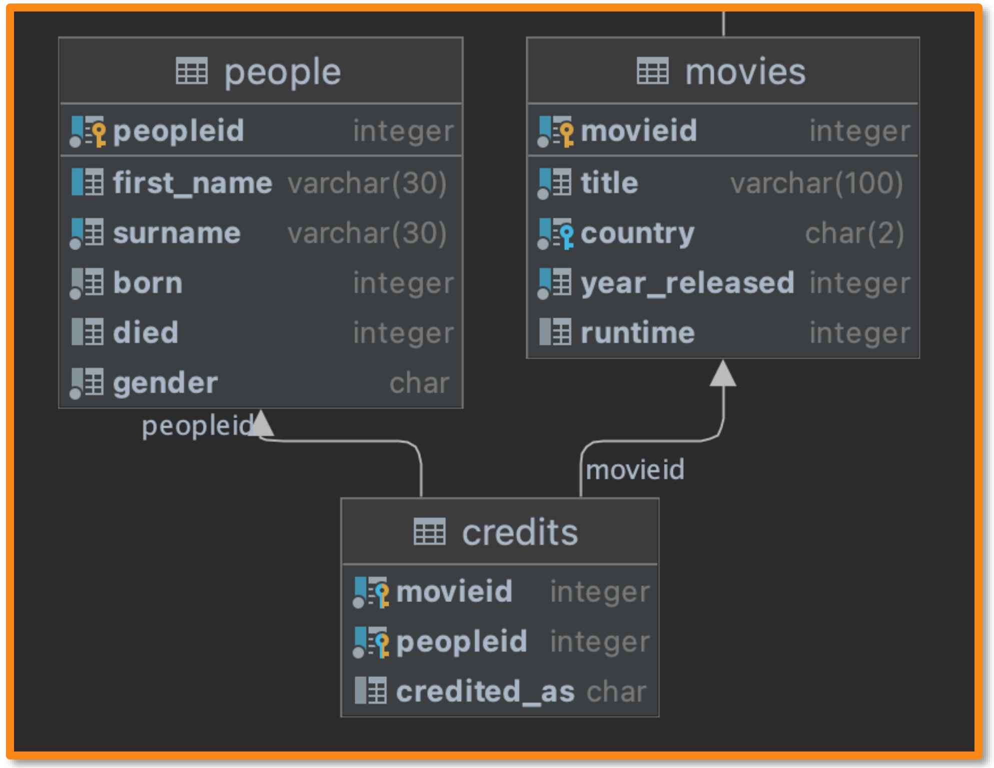
  - Joins between 10 or 15 tables aren’t uncommon, and queries generated by programs often do much worse.
  - Example: Show names of actors and directors for Chinese movies



people

peopleid	integer
first_name	varchar(30)
surname	varchar(30)
born	integer
died	integer
gender	char

movies

movieid	integer
title	varchar(100)
country	char(2)
year_released	integer
runtime	integer

credits

movieid	integer
peopleid	integer
credited_as	char

Chaining Joins Together

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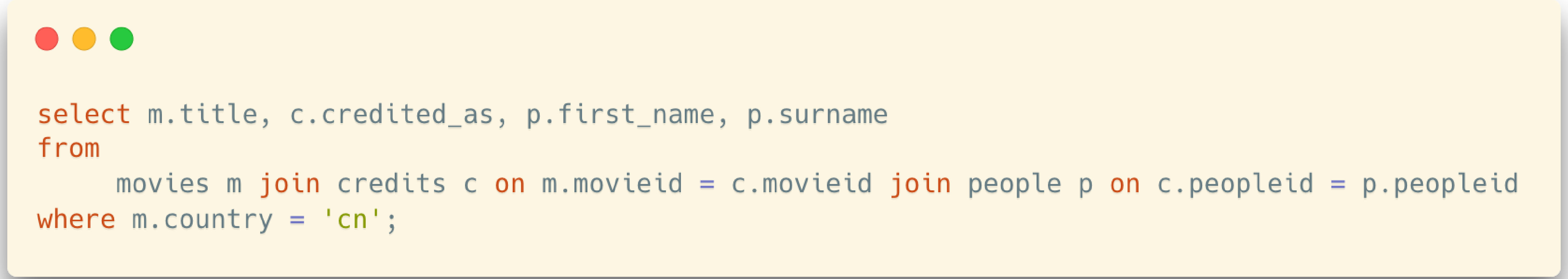
    - Joins between 10 or 15 tables aren't uncommon, and queries generated by programs often do much worse.
    - Example: Show names of actors and directors for Chinese movies



```sql
select m.title, c.credited_as, p.first_name, p.surname
from
     movies m join credits c on m.movieid = c.movieid join people p on c.peopleid = p.peopleid
where m.country = 'cn';
```