Principles of Database Systems (CS307)

Lecture 6: More about NULL; Ordering; Window Function

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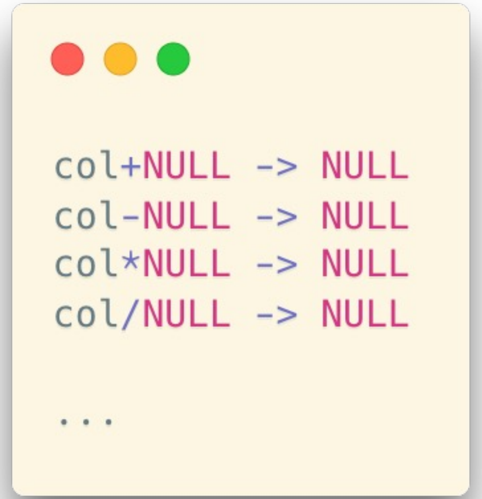
- Most contents are from slides made by Stéphane Faroult and the authors of Database System Concepts (7th Edition).
- Their original slides have been modified to adapt to the schedule of CS307 at SUSTech.

More about NULL

Expressions with NULL Values

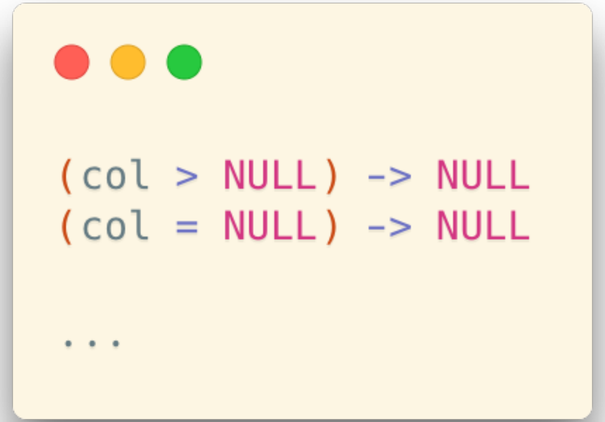
- Most expressions with `NULL` will be evaluated into `NULL`
  - Arithmetic operations:



```
col+NULL -> NULL
col-NULL -> NULL
col*NULL -> NULL
col/NULL -> NULL

...
```

  - Comparison operations:

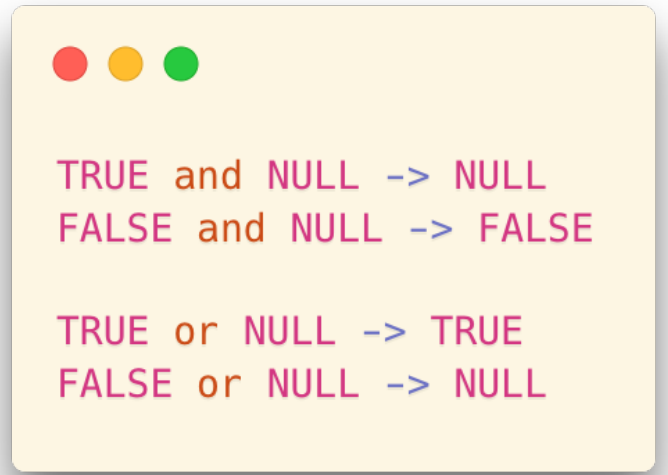


```
(col > NULL) -> NULL
(col = NULL) -> NULL

...
```

Expressions with NULL Values

- Most expressions with `NULL` will be evaluated into `NULL`
  - But, there are some conditions where the values are not `NULL`



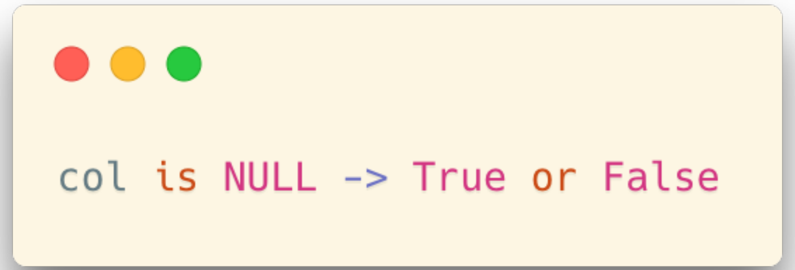
```
TRUE and NULL -> NULL
FALSE and NULL -> FALSE

TRUE or NULL -> TRUE
FALSE or NULL -> NULL
```

Logical operators (or, and):

- Three-valued logic (true, false, and unknown)

More on this: Three-valued logic and its application in SQL
`https://en.wikipedia.org/wiki/Three-valued_logic#SQL`



```
col is NULL -> True or False
```

The way we use to check a `NULL` value: use `is`, not `=`

Recall: Subquery after Where

- Some important points for `in()`
  - `in()` means an implicit distinct in the subquery
    - `in('cn', 'us', 'cn', 'us', 'us')` is equal to `in('cn', 'us')`
  - null values in `in()`
    - Be extremely cautious if you are using `not in(...)` with a null value in it

```
value not in(2, 3, null)
⇒not (value=2 or value=3 or value=null)
⇒value<>2 and value<>3 and value<>null
⇒false  -- always false or null, never true
```

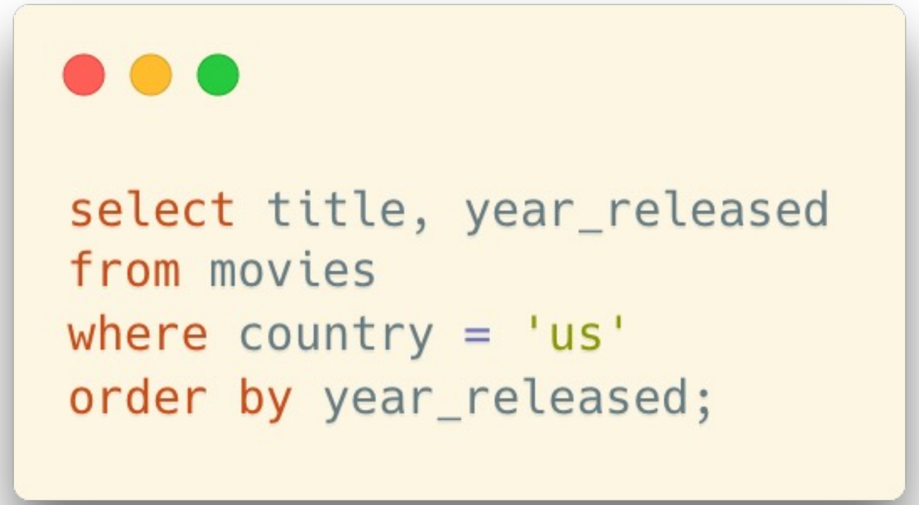
$\boxed{\texttt{value<>null}}$

- If value is 2, the result is:
  `TRUE and FALSE and NULL -> FALSE`
- if value is 5, the result is:
  `TRUE and TRUE and NULL -> NULL`
- if value is NULL, the result is :
  `NULL and NULL and NULL -> NULL`

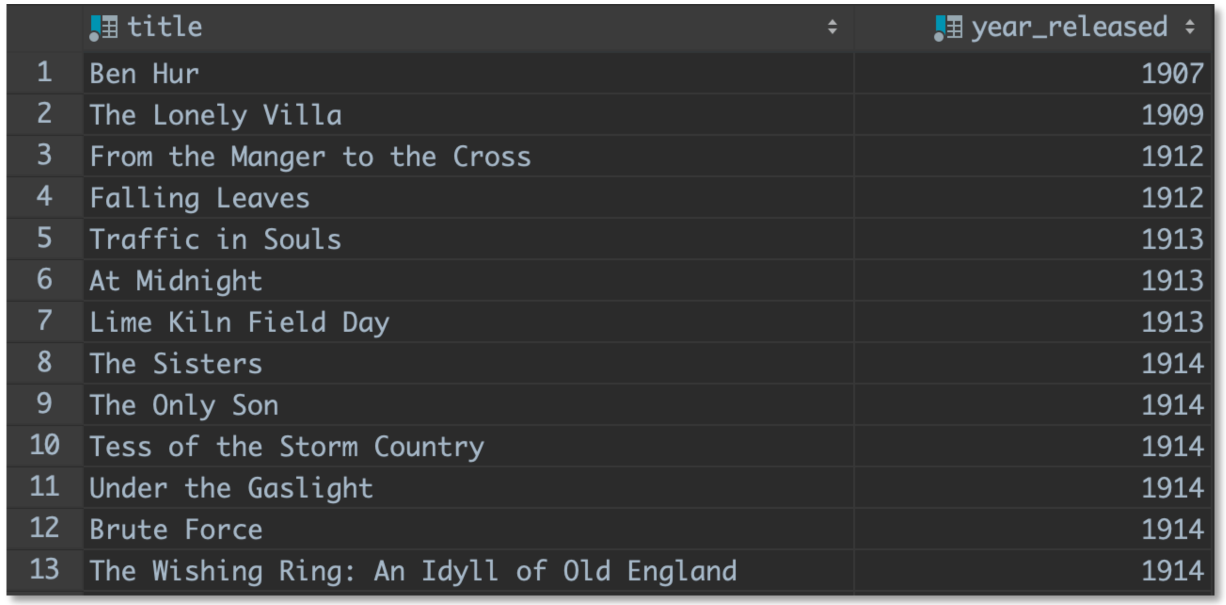
Ordering

Ordering in SQL

- `order by`
  - A simple expression in SQL to order a result set
  - It comes at the end of a query
    - ... and, you can have it in subqueries, definitely
  - Followed by the list of columns used as sort columns



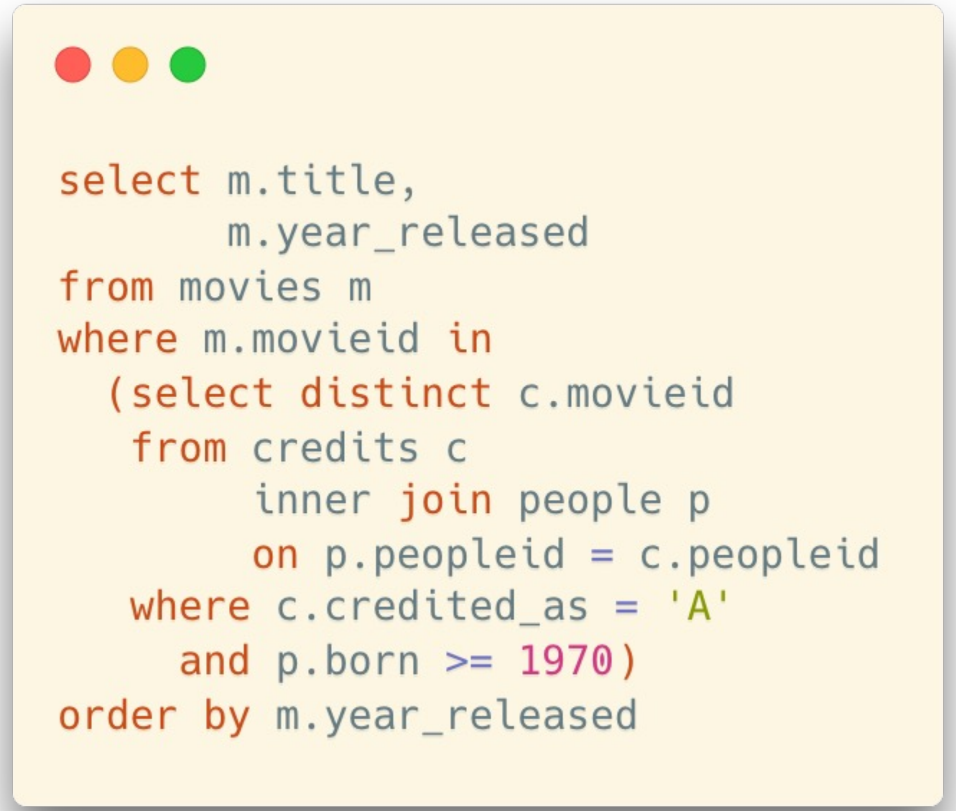
```
select title, year_released
from movies
where country = 'us'
order by year_released;
```



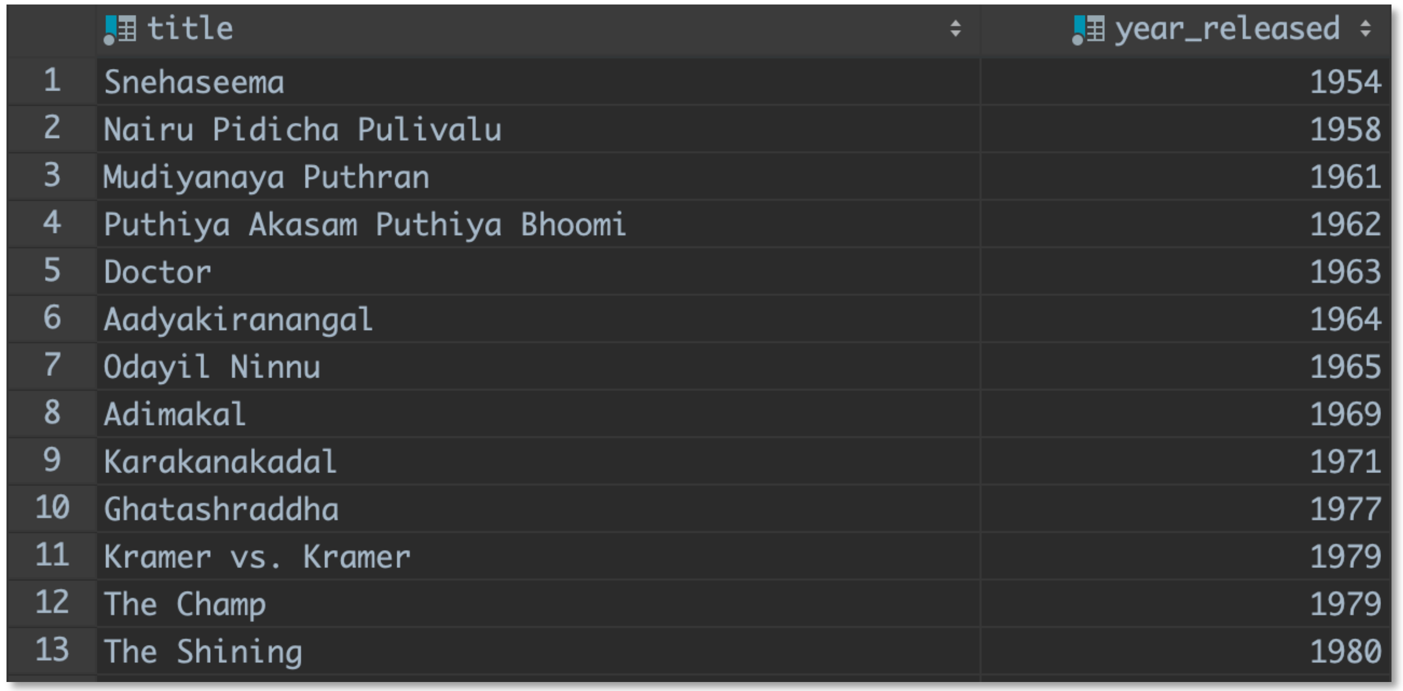
	title	year_released
1	Ben Hur	1907
2	The Lonely Villa	1909
3	From the Manger to the Cross	1912
4	Falling Leaves	1912
5	Traffic in Souls	1913
6	At Midnight	1913
7	Lime Kiln Field Day	1913
8	The Sisters	1914
9	The Only Son	1914
10	Tess of the Storm Country	1914
11	Under the Gaslight	1914
12	Brute Force	1914
13	The Wishing Ring: An Idyll of Old England	1914

Ordering in SQL

- No matter how difficult the query is, you can apply order by to any result set



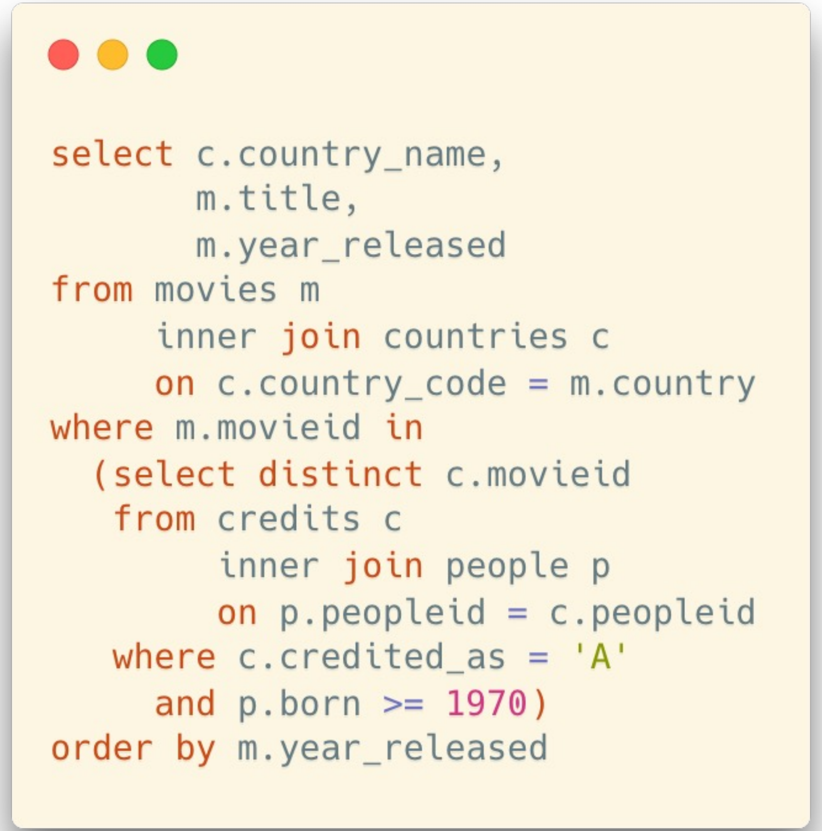
```
select m.title,
       m.year_released
from movies m
where m.movieid in
  (select distinct c.movieid
   from credits c
        inner join people p
        on p.peopleid = c.peopleid
   where c.credited_as = 'A'
     and p.born >= 1970)
order by m.year_released
```



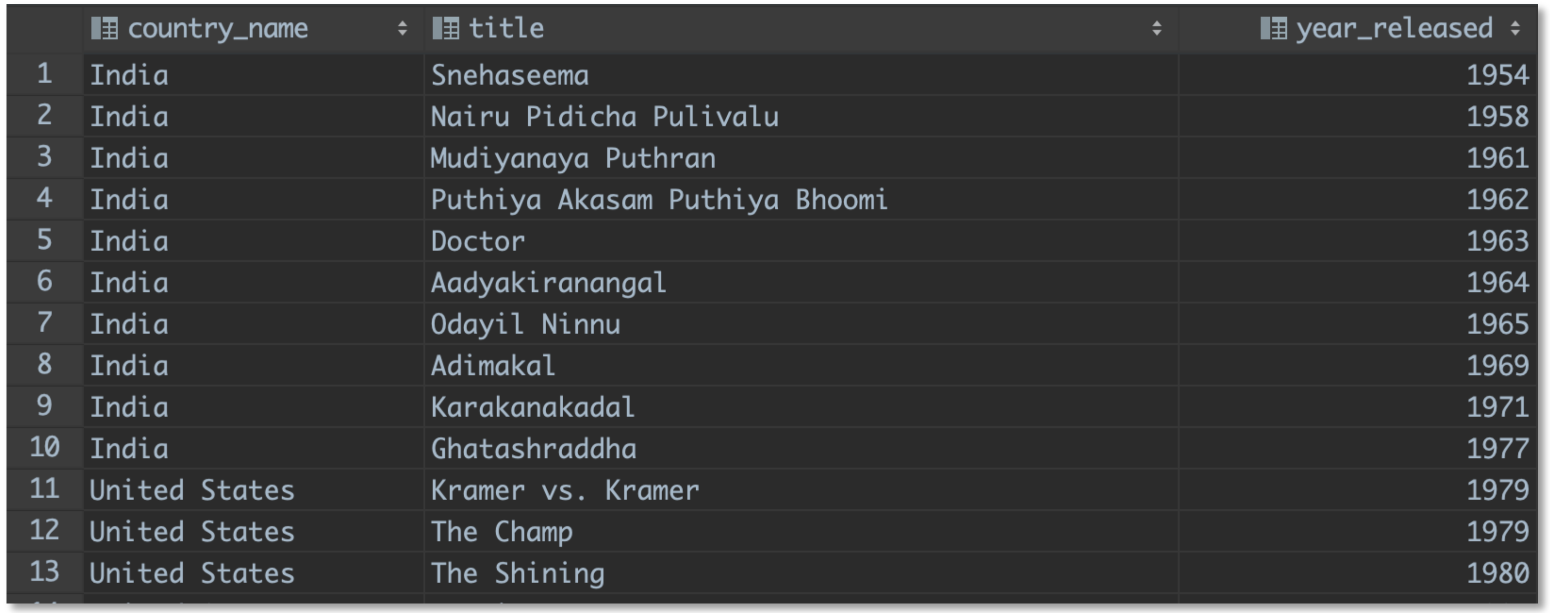
	title	year_released
1	Snehaseema	1954
2	Nairu Pidicha Pulivalu	1958
3	Mudiyanaya Puthran	1961
4	Puthiya Akasam Puthiya Bhoomi	1962
5	Doctor	1963
6	Aadyakiranangal	1964
7	Odayil Ninnu	1965
8	Adimakal	1969
9	Karakanakadal	1971
10	Ghatashraddha	1977
11	Kramer vs. Kramer	1979
12	The Champ	1979
13	The Shining	1980

Ordering in SQL

- Ordering with joins
  - We can sort by any column of any table in the join (remember the super wide table with all the columns from all tables involved)



```
select c.country_name,
       m.title,
       m.year_released
from movies m
     inner join countries c
     on c.country_code = m.country
where m.movieid in
   (select distinct c.movieid
    from credits c
         inner join people p
         on p.peopleid = c.peopleid
    where c.credited_as = 'A'
      and p.born >= 1970)
order by m.year_released
```



	country_name	title	year_released
1	India	Snehaseema	1954
2	India	Nairu Pidicha Pulivalu	1958
3	India	Mudiyanaya Puthran	1961
4	India	Puthiya Akasam Puthiya Bhoomi	1962
5	India	Doctor	1963
6	India	Aadyakiranangal	1964
7	India	Odayil Ninnu	1965
8	India	Adimakal	1969
9	India	Karakanakadal	1971
10	India	Ghatashraddha	1977
11	United States	Kramer vs. Kramer	1979
12	United States	The Champ	1979
13	United States	The Shining	1980

Ordering in SQL

- Ordering with joins
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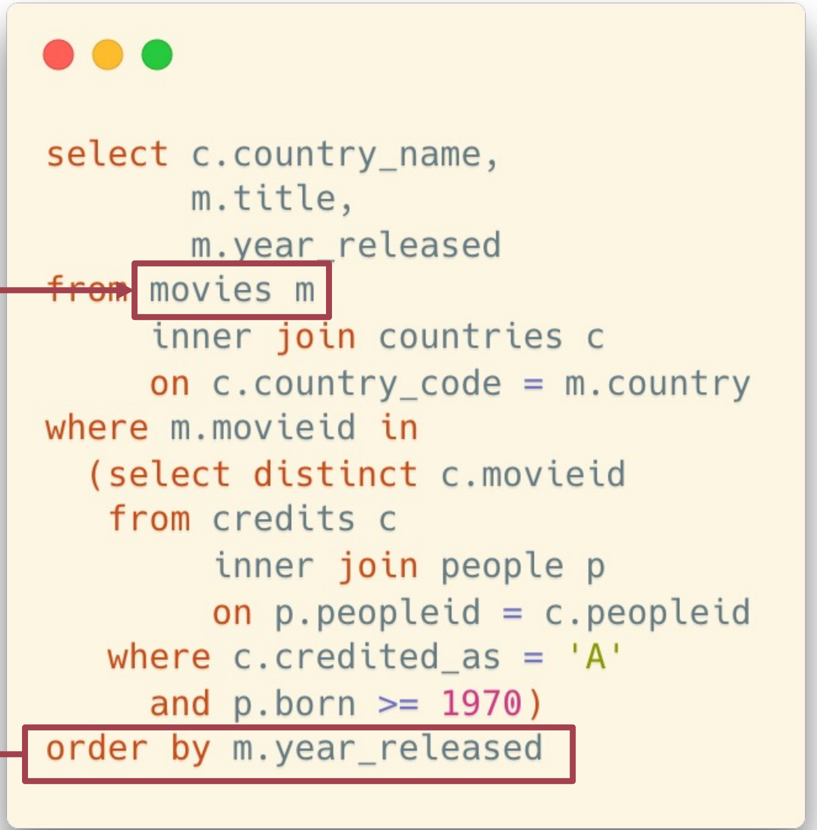
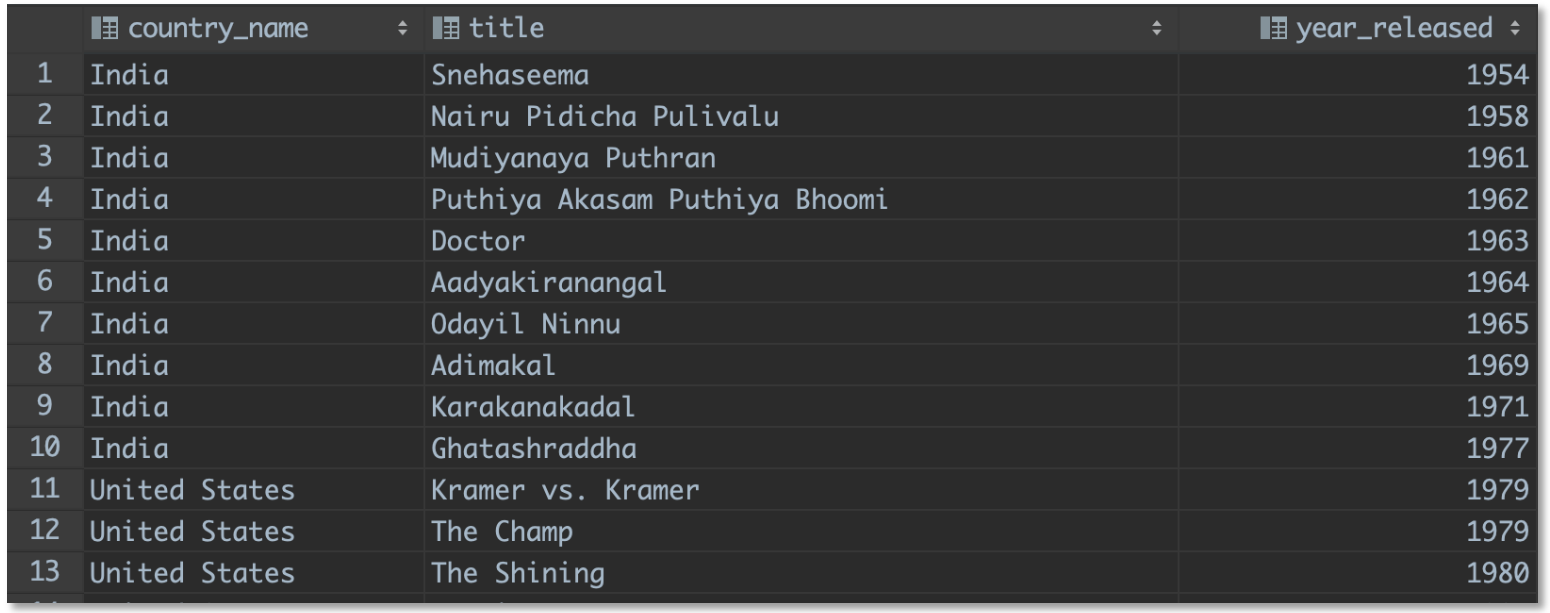


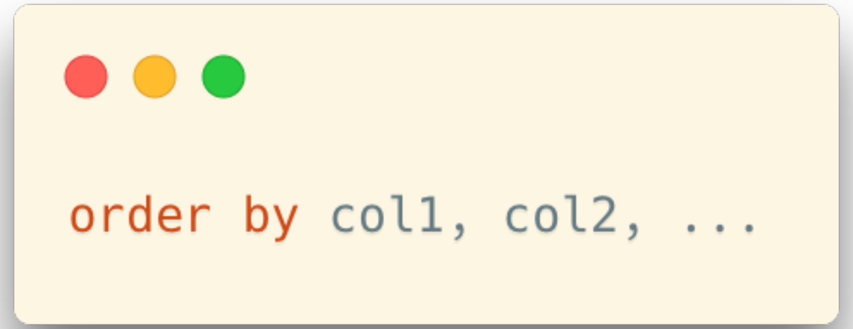
```
select c.country_name,
       m.title,
       m.year_released
from movies m
     inner join countries c
     on c.country_code = m.country
where m.movieid in
  (select distinct c.movieid
   from credits c
        inner join people p
        on p.peopleid = c.peopleid
   where c.credited_as = 'A'
     and p.born >= 1970)
order by m.year_released
```



	country_name	title	year_released
1	India	Snehaseema	1954
2	India	Nairu Pidicha Pulivalu	1958
3	India	Mudiyanaya Puthran	1961
4	India	Puthiya Akasam Puthiya Bhoomi	1962
5	India	Doctor	1963
6	India	Aadyakiranangal	1964
7	India	Odayil Ninnu	1965
8	India	Adimakal	1969
9	India	Karakanakadal	1971
10	India	Ghatashraddha	1977
11	United States	Kramer vs. Kramer	1979
12	United States	The Champ	1979
13	United States	The Shining	1980

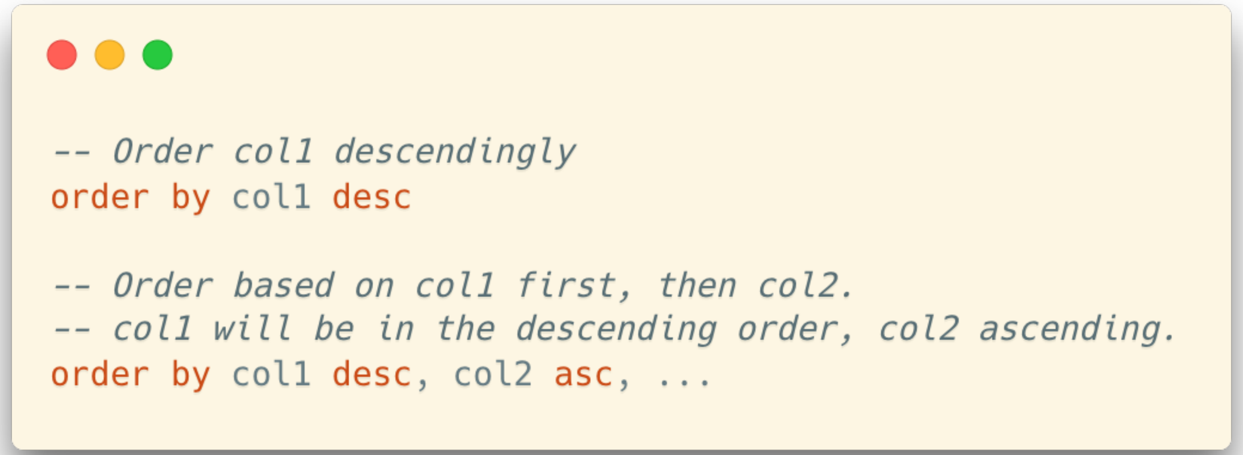
Advanced Ordering

- Multiple columns
  - For example:
    - The result set will be order by `col1` first
    - If there are rows with the same value on `col1`, these rows will be ordered by `col2`.



```sql
order by col1, col2, ...
```

- Ascending or descending order
  - Add `desc` or `asc` after the column
    - However, `asc` is the <u>default option</u> and thus <u>always omitted</u>

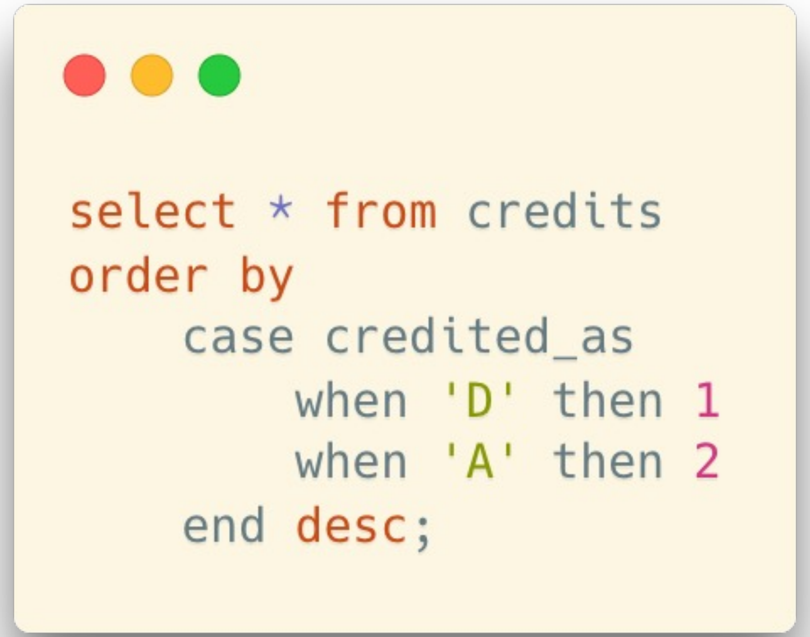


```sql
-- Order col1 descendingly
order by col1 desc

-- Order based on col1 first, then col2.
-- col1 will be in the descending order, col2 ascending.
order by col1 desc, col2 asc, ...
```

Advanced Ordering

- Self-defined ordering
  - Use "`case` ... `when`" in `order by` to define criteria on how to order the rows



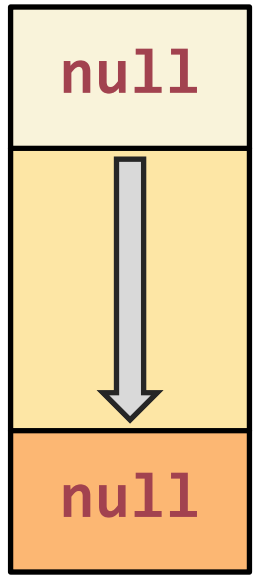
```
select * from credits
order by
    case credited_as
        when 'D' then 1
        when 'A' then 2
    end desc;
```

Data Types in Ordering

- Ordering depends on the data type
  - Strings: alphabetically,
  - Numbers: numerically
  - Dates and times: chronologically

Data Types in Ordering

- What about `NULL`?
  - It is implementation-dependent
  - SQL Server, MySQL and SQLite:
    - "nothing" is smaller than everything
  - Oracle and PostgreSQL:
    - "nothing" is greater than anything



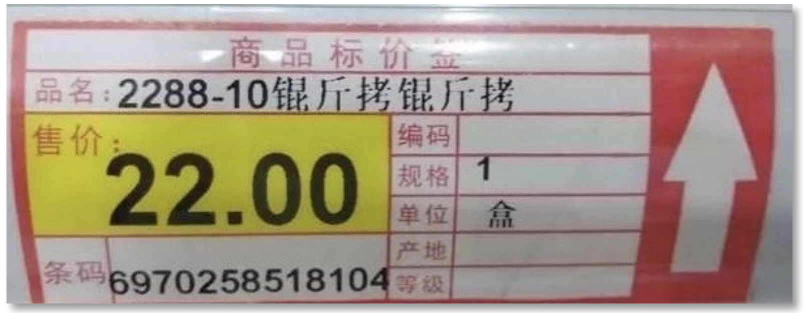
Ordering in Text Data

- Remember, we have many different languages other than English
  - "Alphabetical order" in different languages means different things
    - Mandarin: Pinyin? Number of strokes?
    - Swedish and German
      - "ö" is considered the last letter in Swedish, while in German it is ordered after "o".
  - Collation

Self Study: Text Encoding

- Key Question: How does characters represented in a computer?
  - Wikipedia – Character encoding: `https://en.wikipedia.org/wiki/Character_encoding`
  - A video on Bilibili: `https://www.bilibili.com/video/BV1xP4y1J7CS`

Self Study: Text Encoding



商品标价签

品名：2288-10锟斤拷锟斤拷

售价：22.00

编码

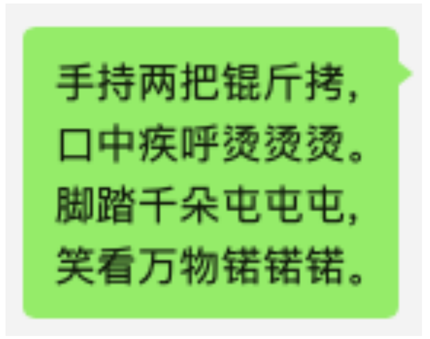
规格 1

单位 盒

产地

等级

条码 6970258518104



手持两把锟斤拷，
口中疾呼烫烫烫。
脚踏千朵屯屯屯，
笑看万物锘锘锘。

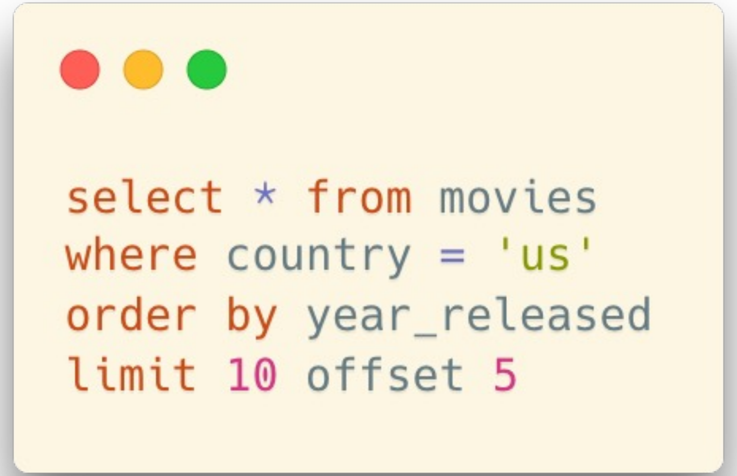
- Try to answer the following questions:
  - What are ASCII, Unicode, UTF-8, and UTF-16? What are the relationships between them?
  - What are GB2312, GB18030, and GBK? What are “锟斤拷” and “烫烫烫”? How can you make it (not) happen?
  - Given a string with several characters, can you print the bitmap of this string?
  - Are emojis characters? How can you insert an emoji in a text editor?
  - What are the default character encodings in different platforms?
    - OS: Windows, MacOS, Linux
    - DBMS: PostgreSQL, etc.
    - Programming Languages: Java, C, C++, Python, etc.
  - How can we translate strings from one encoding to another?
    - E.g., with text editors (Windows Notepad, VSCode, Sublime Text, etc.); in programming languages; in DBMS

Limit and Offset

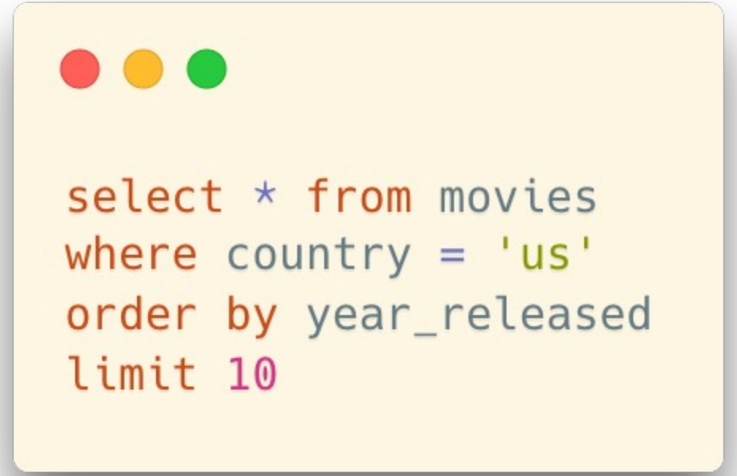
- Get a slice of the long query result
  - `limit k offset p`
    - Return the top-k rows in the result set and skip the first p rows
    - `offset` is optional (which means “`offset 0`”)

  - Always used together with order by
    - E.g., get the top-k query results under a certain ordering criteria

  - * In some DBMS, the syntax can be different
    - Always refer to the software manual for specific features



```
select * from movies
where country = 'us'
order by year_released
limit 10 offset 5
```

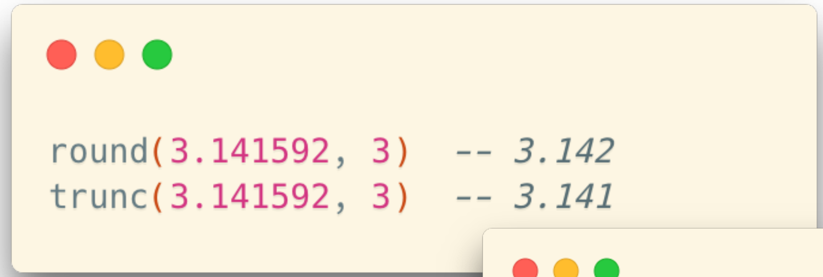


```
select * from movies
where country = 'us'
order by year_released
limit 10
```

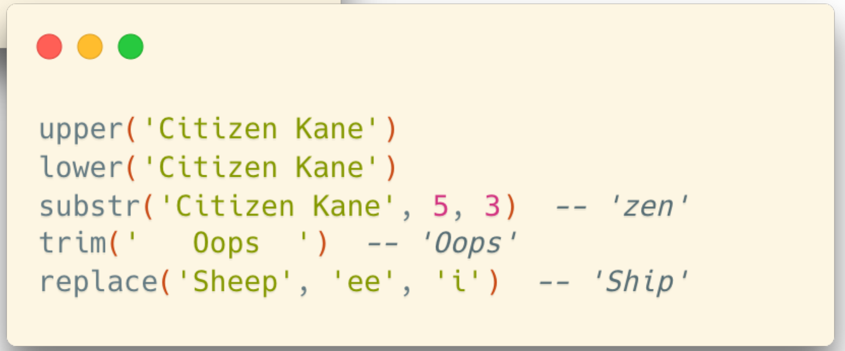
Window Function

Scalar Functions and Aggregation Functions

- Scalar function
  - Functions that operate on values in the current row
    - Recall: "Some Functions", Lecture 3

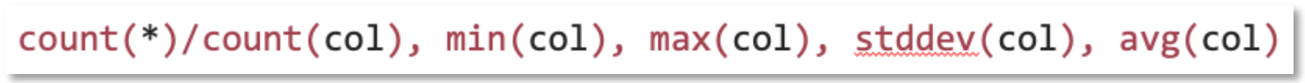


```
round(3.141592, 3)  -- 3.142
trunc(3.141592, 3)  -- 3.141
```



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

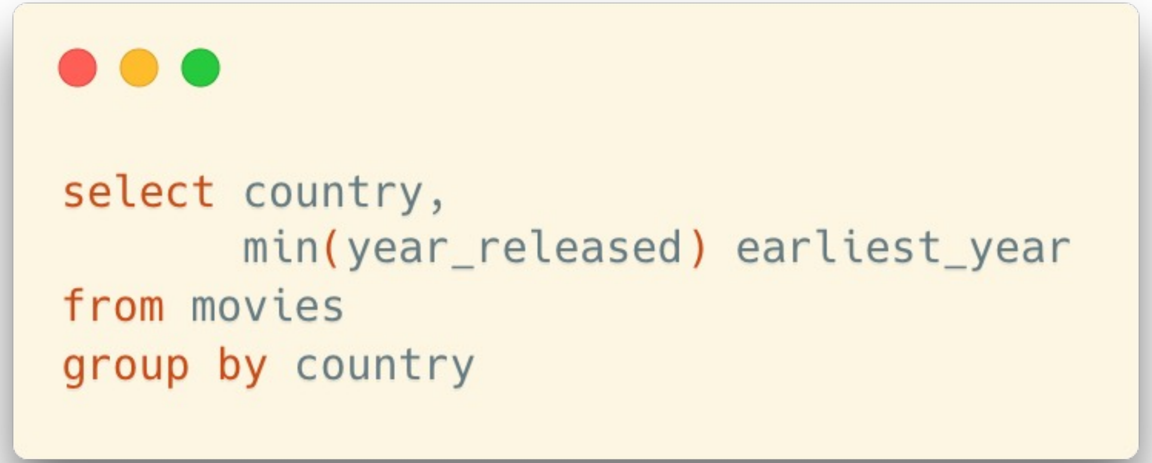
- Aggregation function
  - Functions that operate on sets of rows and return an aggregated value
    - Recall: "Aggregate Functions", Lecture 4



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

Issues with Aggregate Functions

- A Problem: In aggregated functions, the details of the rows are vanished
    - For example: If we ask for the year of the oldest movie per country,
        - … we get a country, a year, and nothing else.



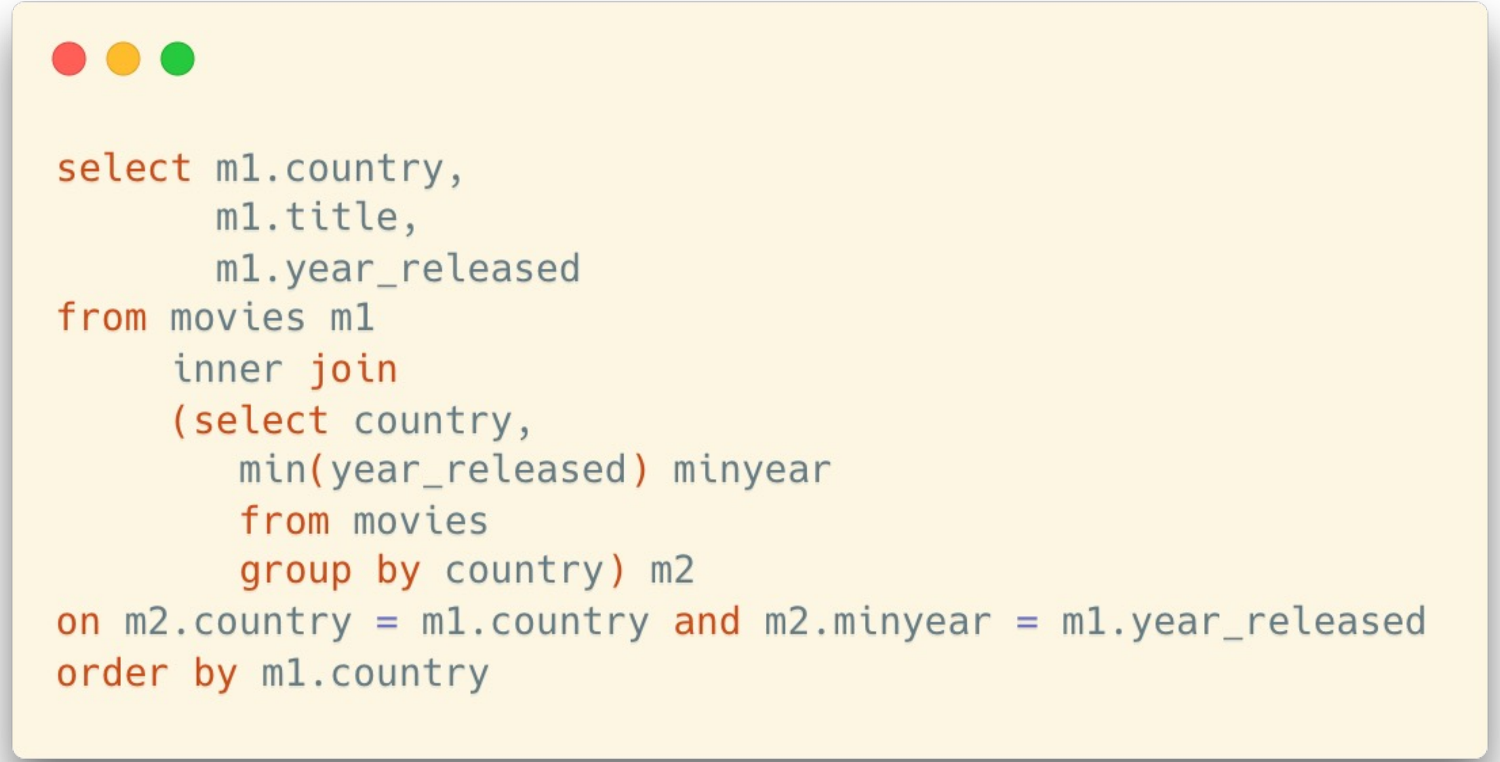
```sql
select country,
       min(year_released) earliest_year
from movies
group by country
```

Issues with Aggregate Functions

- A Problem: In aggregated functions, the details of the rows are vanished
  - For example: If we ask for the year of the oldest movie per country,
    - … we get a country, a year, and nothing else.

If we want some more details, like the title of the oldest movies for each country, we can only use self-join to keep the columns

- And there is also one more problem in the query on the right side. Can you find it?



```
select m1.country,
       m1.title,
       m1.year_released
from movies m1
     inner join
     (select country,
        min(year_released) minyear
        from movies
        group by country) m2
on m2.country = m1.country and m2.minyear = m1.year_released
order by m1.country
```

Issues with Aggregate Functions

- A Problem: In aggregated functions, the details of the rows are vanished
  - Another example: How can we rank the movies in each country separately based on the released year?
    - “order by” for subgroups
  - One more example: Get the top-3 oldest movies for each country.
    - How can we implement it?

Window Function

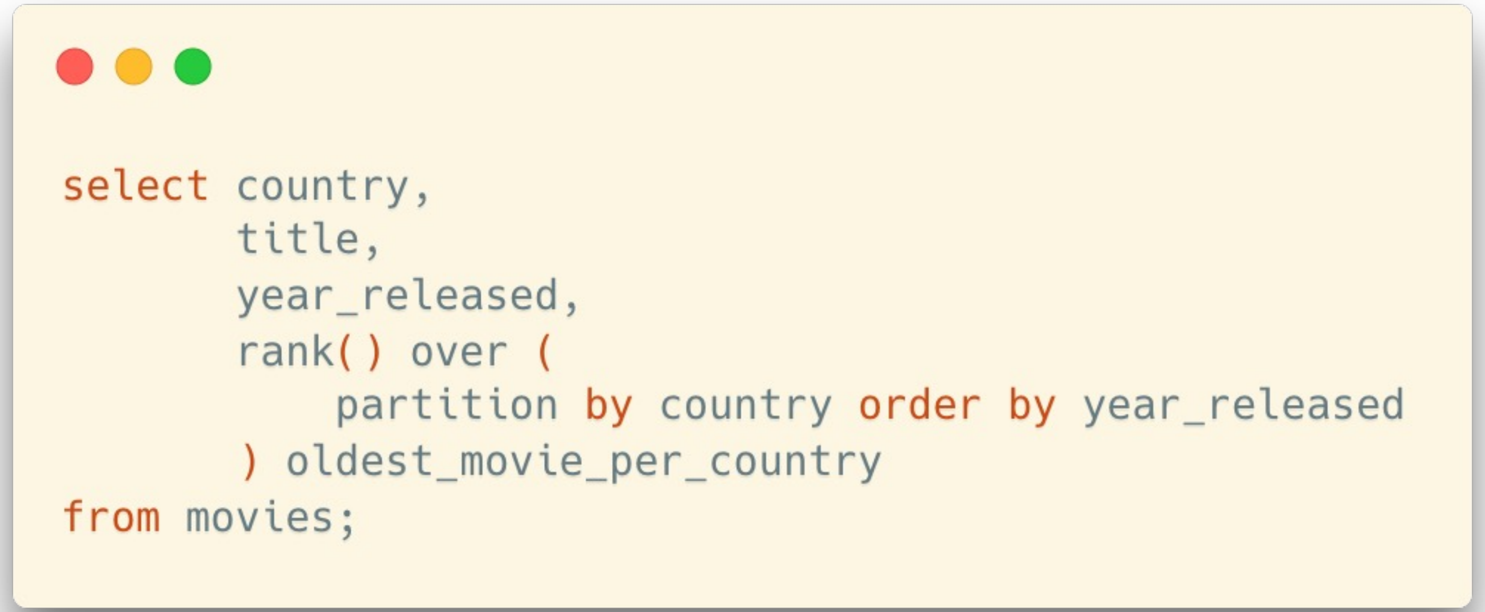
- Syntax:

```
<function> over (partition by <col_p> order by <col_o1, col_o2, …>)
```

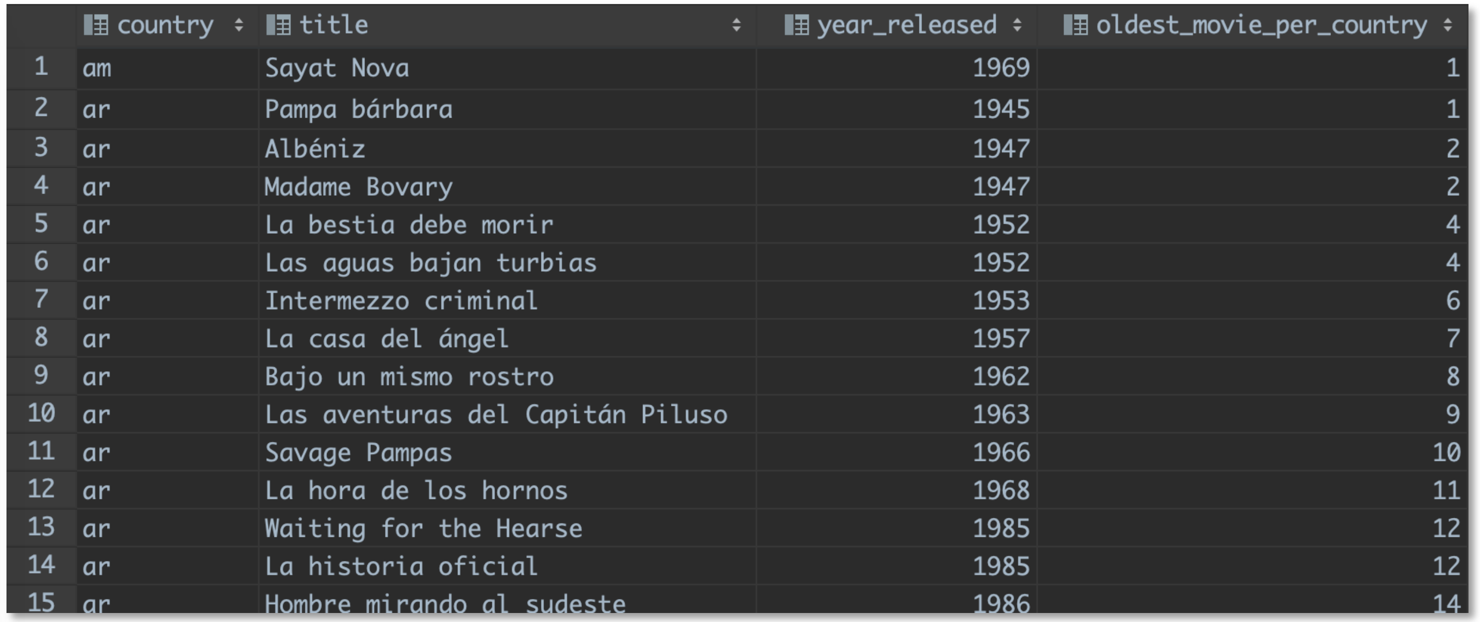
  - `<function>`: we can apply (1) ranking window functions, or (2) aggregation functions
  - `partition by`: specify the column for grouping
  - `order by`: specify the column(s) for ordering in each group

Ranking Window Function

- Example
  - How can we rank the movies in each country separately based on the released year?
    - "order by" for subgroups



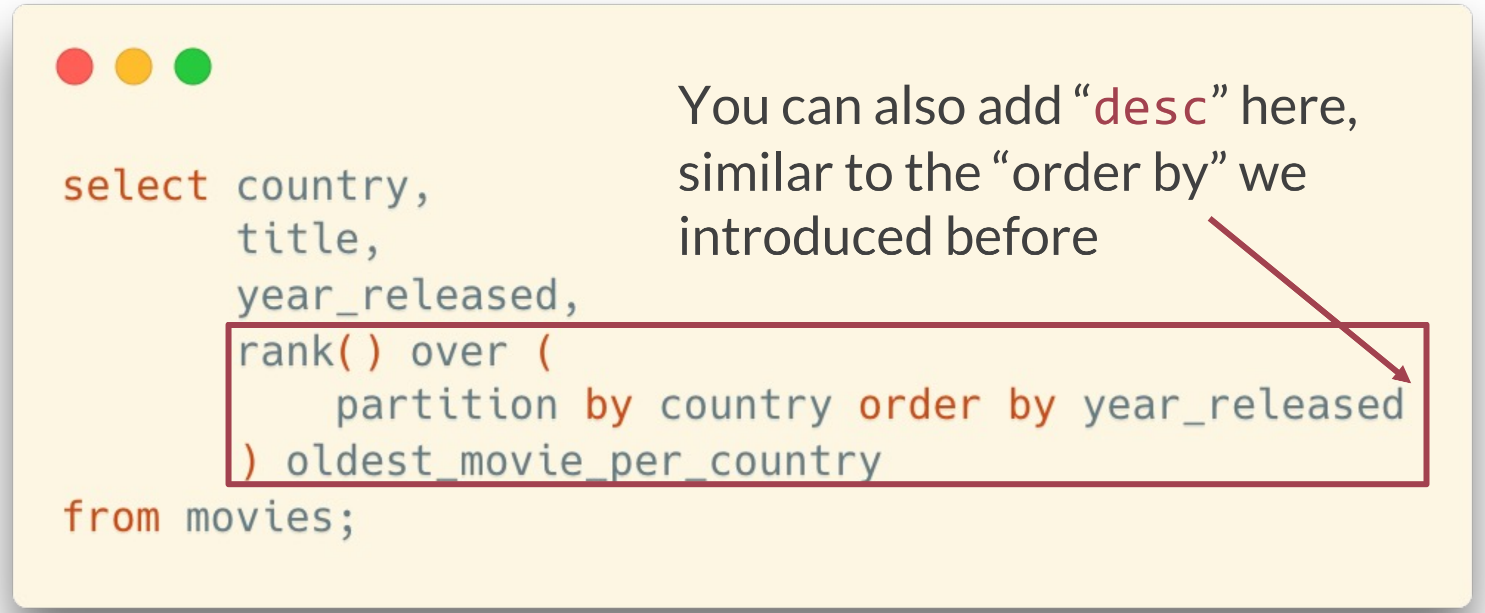
```sql
select country,
       title,
       year_released,
       rank() over (
          partition by country order by year_released
       ) oldest_movie_per_country
from movies;
```



	country	title	year_released	oldest_movie_per_country
1	am	Sayat Nova	1969	1
2	ar	Pampa bárbara	1945	1
3	ar	Albéniz	1947	2
4	ar	Madame Bovary	1947	2
5	ar	La bestia debe morir	1952	4
6	ar	Las aguas bajan turbias	1952	4
7	ar	Intermezzo criminal	1953	6
8	ar	La casa del ángel	1957	7
9	ar	Bajo un mismo rostro	1962	8
10	ar	Las aventuras del Capitán Piluso	1963	9
11	ar	Savage Pampas	1966	10
12	ar	La hora de los hornos	1968	11
13	ar	Waiting for the Hearse	1985	12
14	ar	La historia oficial	1985	12
15	ar	Hombre mirando al sudeste	1986	14

Ranking Window Function

- Example
  - How can we rank the movies in each country separately based on the released year?
    - "order by" for subgroups



```
select country,
       title,
       year_released,
       rank() over (
          partition by country order by year_released
       ) oldest_movie_per_country
from movies;
```

You can also add "desc" here, similar to the "order by" we introduced before

country	title	year_released	oldest_movie_per_country
ar	some title	1948	1
ar	some title	1959	2
ar	some title	1980	3
cn	some title	1987	1
cn	some title	2002	2
uk	some title	1985	1
uk	some title	1992	2
uk	some title	2010	3

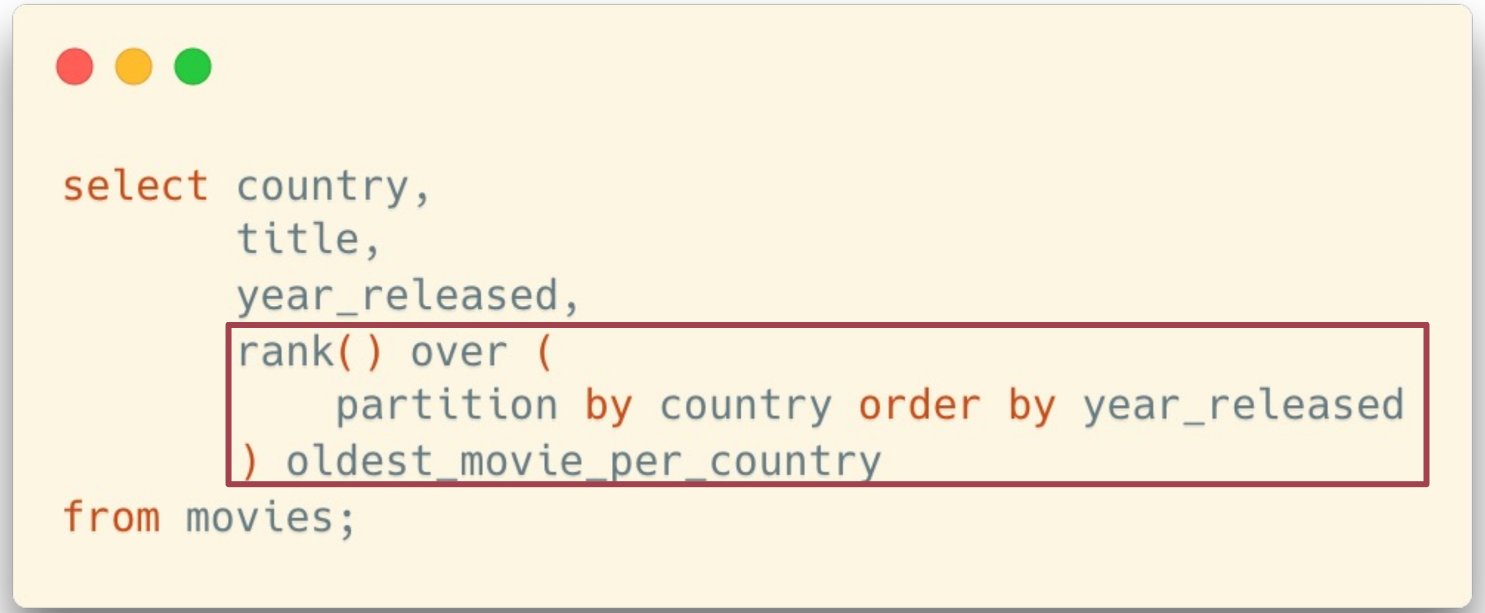
`partition by country`
- the selected rows will be grouped (partitioned) according to the values in the column country

`rank()`
- A function to say that "I want to order the rows in each partition"
- No parameters in the parentheses

`order by year_released`
- In each group (partition), the rows will be ordered by the column "year_released"

Ranking Window Function

- Example
  - How can we rank the movies in each country separately based on the released year?
    - “order by” for subgroups



```
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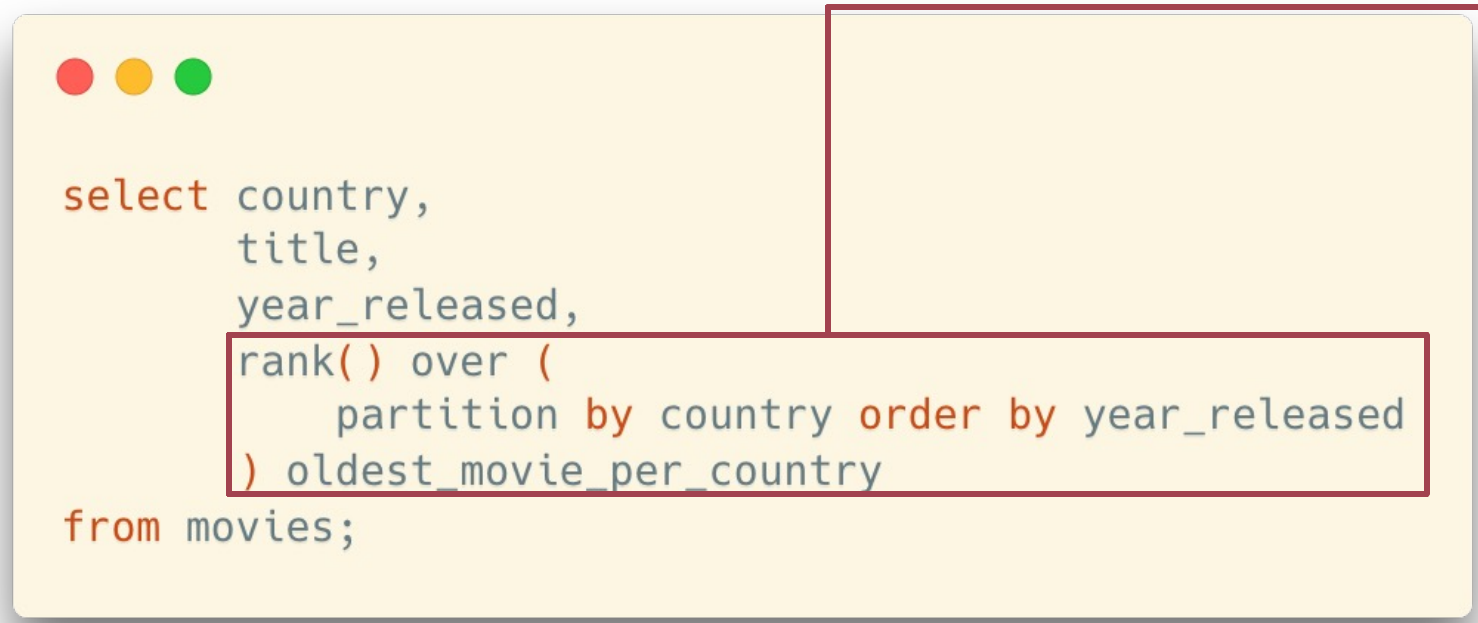
uk	some title	1985	1
uk	some title	1992	2
uk	some title	2010	3

Note: partition functions can only be used in the `select` clause

- … since it is designed to work on the query result

Ranking Window Function

- Example
  - How can we rank the movies in each country separately based on the released year?
    - “order by” for subgroups



```
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       year_released,
       rank() over (
          partition by country order by year_released
       ) oldest_movie_per_country
from movies;
```

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ar	some title	1980	3
cn	some title	1987	1
cn	some title	2002	2
uk	some title	1985	1
uk	some title	1992	2
uk	some title	2010	3

Partitioned by country

- i.e., a country in a group

An order value is computed for each row in a partition.

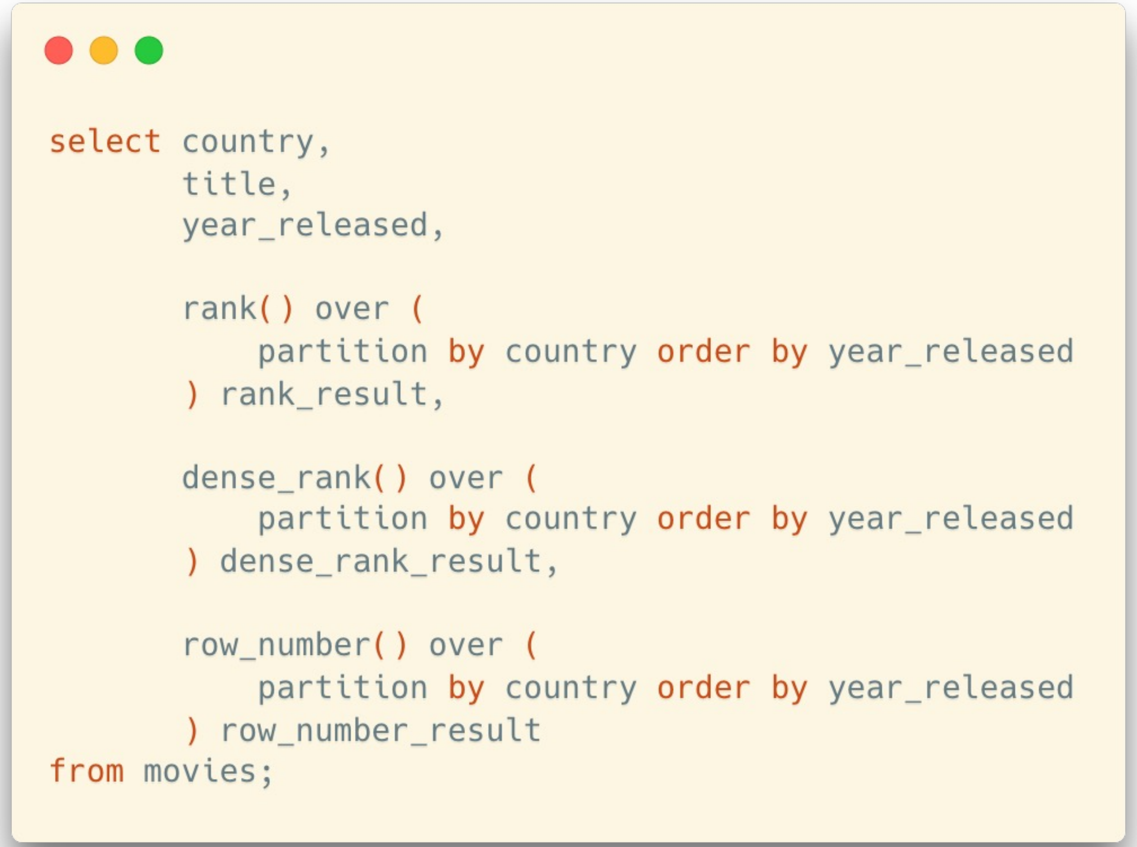
- Only inside the partition, not across the entire result set

Ranking Window Function

- Why window function, not group by?
  - “Group by” reduces the rows in a group (partition) into one result, which is the meaning of “aggregation”
    - Then, the values in non-aggregating columns are vanished
  - Window functions do not reduce the rows
    - Instead, they attach computed values next to the rows in a group (partition) and keep the details
    - Actually, the partition here means “window”: an affective range for statistics

Ranking Window Function

- Some more ranking window functions
  - Besides `rank()`, we also have `dense_rank()` and `row_number()`
  - The difference is about how they treat rows with the same rank



```
select country,
       title,
       year_released,

       rank() over (
           partition by country order by year_released
       ) rank_result,

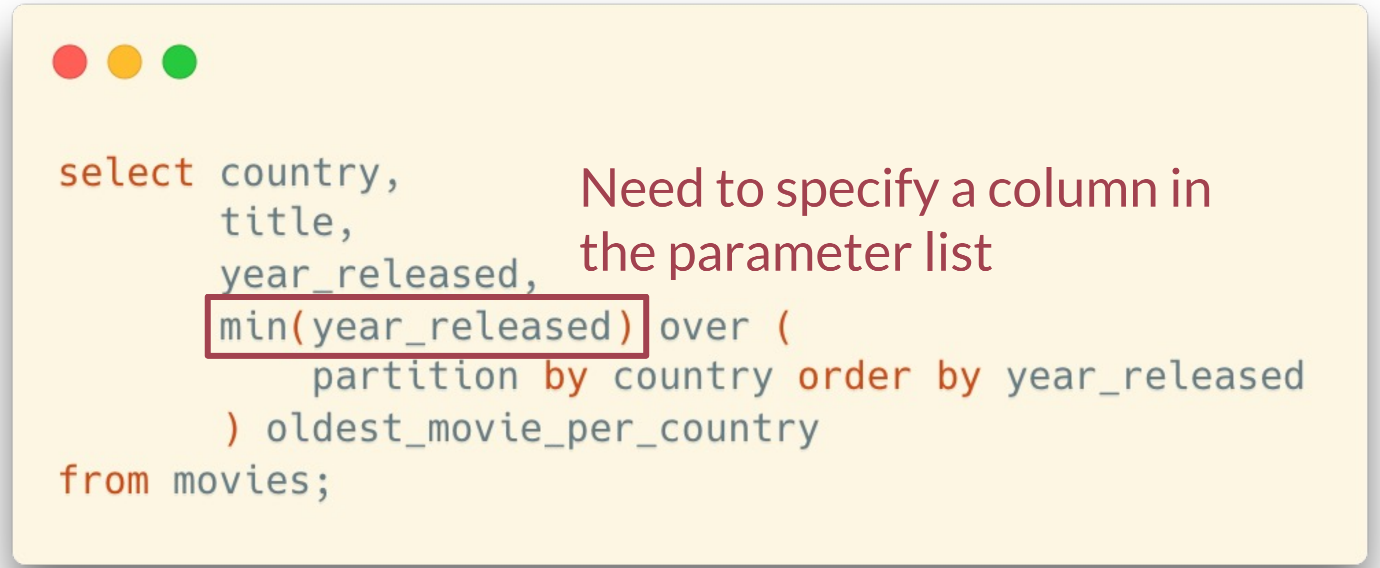
       dense_rank() over (
           partition by country order by year_released
       ) dense_rank_result,

       row_number() over (
           partition by country order by year_released
       ) row_number_result
from movies;
```

country	title	year_released	rank_result	dense_rank_result	row_number_result
cn	some title	1948	1	1	1
cn	some title	1959	2	2	2
cn	some title	1959	2	2	3
cn	some title	1987	4	3	4
cn	some title	2002	5	4	5
uk	some title	1985	1	1	1
uk	some title	1992	2	2	2
uk	some title	2010	3	3	3

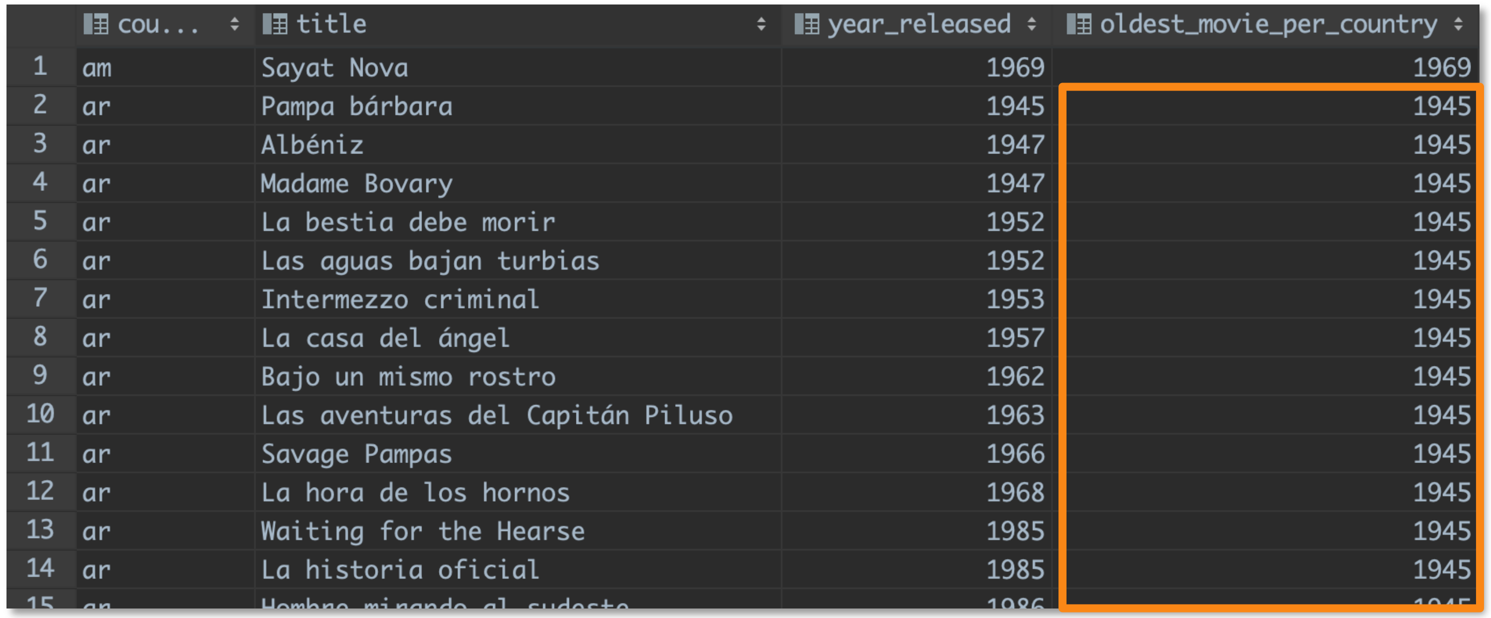
Aggregation Functions as Window Functions

- `max(col)` and `min(col)`



```sql
select country,
       title,
       year_released,
       min(year_released) over (
         partition by country order by year_released
       ) oldest_movie_per_country
from movies;
```

Need to specify a column in the parameter list

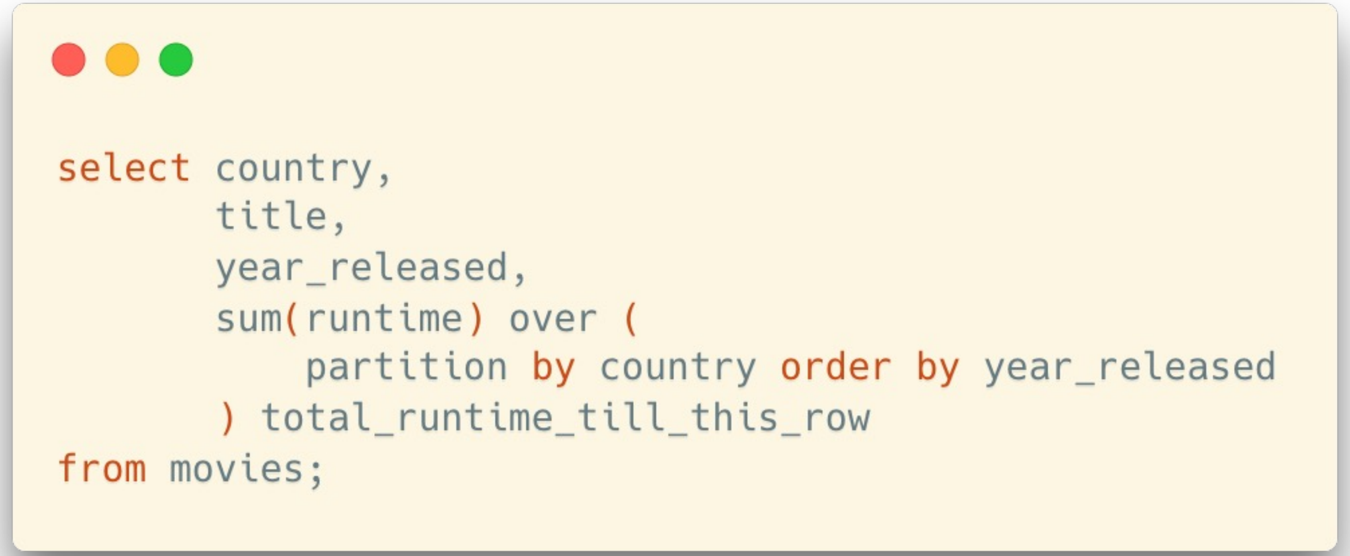


	cou...	title	year_released	oldest_movie_per_country
1	am	Sayat Nova	1969	1969
2	ar	Pampa bárbara	1945	1945
3	ar	Albéniz	1947	1945
4	ar	Madame Bovary	1947	1945
5	ar	La bestia debe morir	1952	1945
6	ar	Las aguas bajan turbias	1952	1945
7	ar	Intermezzo criminal	1953	1945
8	ar	La casa del ángel	1957	1945
9	ar	Bajo un mismo rostro	1962	1945
10	ar	Las aventuras del Capitán Piluso	1963	1945
11	ar	Savage Pampas	1966	1945
12	ar	La hora de los hornos	1968	1945
13	ar	Waiting for the Hearse	1985	1945
14	ar	La historia oficial	1985	1945
15	ar	Hombre mirando al sudeste	1986	1945

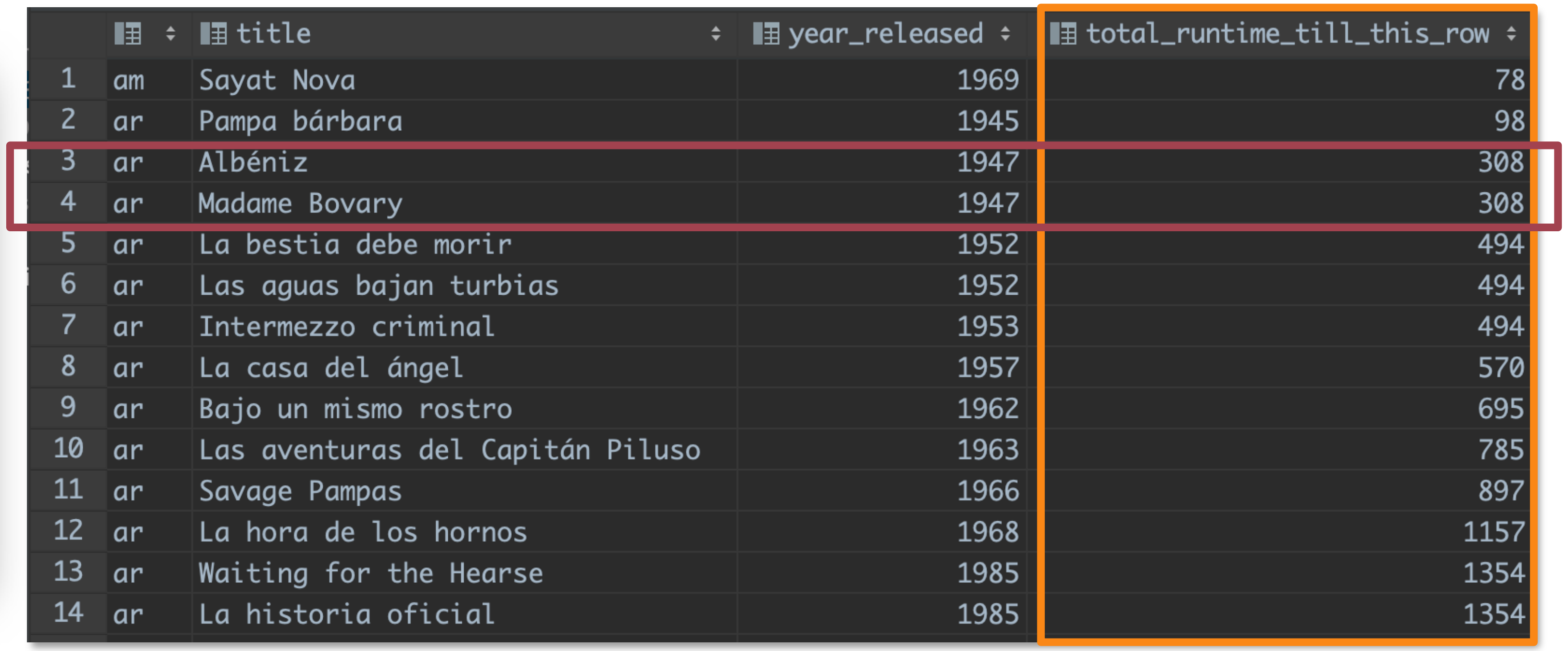
The min/max value for each partition is assigned for all the rows inside this partition

Aggregation Functions as Window Functions

- `sum(col)`, `count(col)`, `avg(col)`, `stddev(col)`, etc.
  - Different from min/max: for these aggregation functions, it means the **aggregation value** from the first row to the current row in its partition when `order by` is specified



```
select country,
       title,
       year_released,
       sum(runtime) over (
           partition by country order by year_released
       ) total_runtime_till_this_row
from movies;
```



		title	year_released	total_runtime_till_this_row
1	am	Sayat Nova	1969	78
2	ar	Pampa bárbara	1945	98
3	ar	Albéniz	1947	308
4	ar	Madame Bovary	1947	308
5	ar	La bestia debe morir	1952	494
6	ar	Las aguas bajan turbias	1952	494
7	ar	Intermezzo criminal	1953	494
8	ar	La casa del ángel	1957	570
9	ar	Bajo un mismo rostro	1962	695
10	ar	Las aventuras del Capitán Piluso	1963	785
11	ar	Savage Pampas	1966	897
12	ar	La hora de los hornos	1968	1157
13	ar	Waiting for the Hearse	1985	1354
14	ar	La historia oficial	1985	1354

However, if there is no `order by`, the behavior will be similar to `min()` and `max()`
- One result for all rows

Pay attention to the behavior on rows with the same rank:
- They are "treated like the same row" here

Exercise

- Question: How can we get the top-5 most recent movies for each country?
  - Hint: Use a subquery in the "`from`" clause

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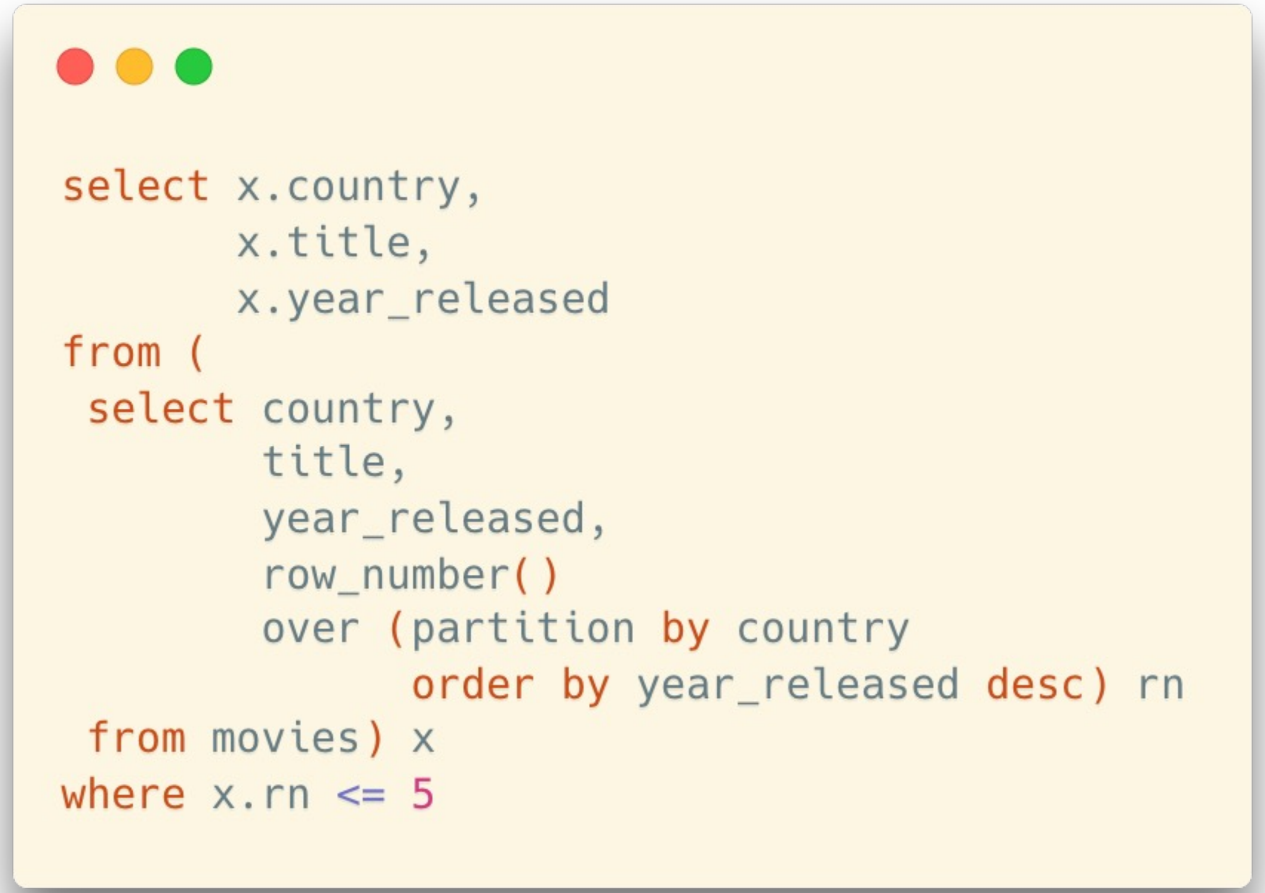

```sql
select x.country,
       x.title,
       x.year_released
from (
 select country,
        title,
        year_released,
        row_number()
        over (partition by country
              order by year_released desc) rn
 from movies) x
where x.rn <= 5
```