SQL Examples

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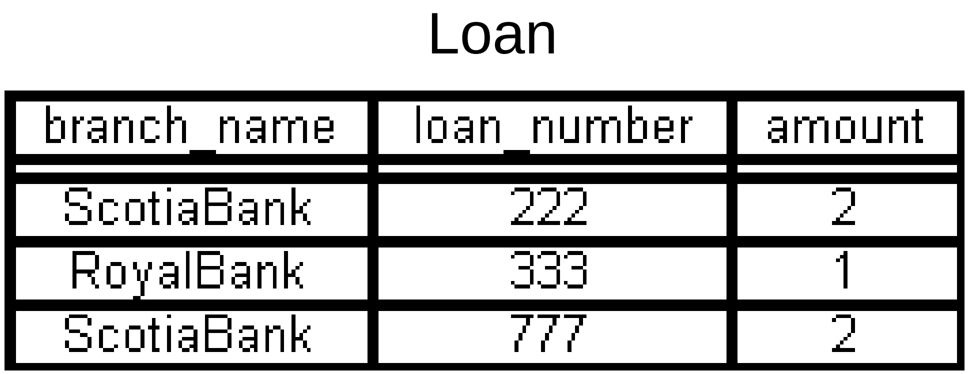
```
SELECT      [DISTINCT]  target-list
FROM        relation-list
WHERE       qualification
```

- *qualification*
  - Comparisons (***Attr op const*** or ***Attr1 op Attr2***, where op is one of $<, >, =, \leq, \geq, \neq$) combined using *AND*, *OR* and *NOT*.
- *DISTINCT*
  - an optional keyword indicating that the answer should not contain duplicates. Default is that duplicates are ***<u>not</u>*** eliminated.

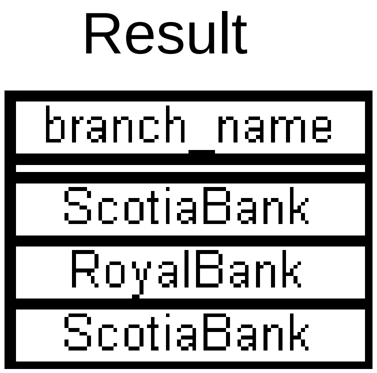
- Example: Find the names of all branches in the loan relation.

```
SELECT branch-name
FROM Loan
```



Loan

branch_name	loan_number	amount
ScotiaBank	222	2
RoyalBank	333	1
ScotiaBank	777	2



Result

branch_name
ScotiaBank
RoyalBank
ScotiaBank

- To remove duplications

```
SELECT DISTINCT branch-name
FROM Loan
```

Loan

branch_name	loan_number	amount
ScotiaBank	222	2
RoyalBank	333	1
ScotiaBank	777	2

Result

branch_name
ScotiaBank
RoyalBank

- Example (Q1, p.137): Find the names of sailors who have reserved boat number 103.

sid	bid	day
22	101	10/10/96
58	103	11/12/96

Instance R3 of Reserves

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

Instance S4 of Sailors

Find names of the sailors who have reserved boot number 103

Sailors

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

Reserves

sid	bid	day
22	101	10/10/96
58	103	11/12/96

```
SELECT  S.sname
FROM    Sailors S, Reserves R
WHERE   S.sid=R.sid AND R.bid=103
```

sid	sname	rating	age	sid	bid	day
22	dustin	7	45.0	22	101	10/10/96
22	dustin	7	45.0	58	103	11/12/96
31	lubber	8	55.5	22	101	10/10/96
31	lubber	8	55.5	58	103	11/12/96
58	rusty	10	35.0	22	101	10/10/96
58	rusty	10	35.0	58	103	11/12/96

Row remains after selection.

Result

S4 X R3

More Examples

- Given the following schema:

Sailors(*sid*; integer, *sname*: string, *rating*:integer, *age*: real)

Boats(*bid*: integer, *bname*; string, *color*: string)

Reserves(*sid*: integer, *bid*: integer, *day*: date)

sailors

sid	sname	rating	age

Boats

bid	bname	color

Reserves

sid	bid	day

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

Example: Find the sids of sailors who have reserved a red boat.

```
SELECT  R.sid
FROM  Boat B, Reserves R
WHERE  B.bid = R.bid AND B.color = ‘red’
```

Example: Find the names of sailors who have reserved a red boat.

```
SELECT  S.sname
FROM  Sailors S, Reserves R, Boat B
WHERE  S.sid = R.sid AND R.bid = B.bid AND
  B.color = ‘red’
```

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

Example: Find the colors of boats reserved by Lubber.

```
SELECT  B.color
FROM  Sailors S, Reserves R, Boat B
WHERE  S.sid = R.sid AND R.bid = B.bid AND
  S.name = ‘Lubber’.
```

(In general, there may be more than one sailor called Lubber. In this case, it will return the colors of boats reserved by some Lubber).

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

Example: Find the names of sailors who have reserved at least one boat.

```
SELECT  S.name
FROM  Sailors S, Reserves R
WHERE  S.sid = R.sid
```

(If a sailor has not made a reservation, the second step in the conceptual evaluation strategy would eliminate all rows in the cross-product that involve this sailor).

Expressions and Strings

```
SELECT  S.age, age1=S.age-5, 2*S.age AS age2
FROM  Sailors S
WHERE  S.sname LIKE ‘B_%B’
```

- Illustrates use of arithmetic expressions and string pattern matching: *Find triples (of ages of sailors and two fields defined by expressions) for sailors whose names begin and end with B and contain at least three characters.*
- AS and = are two ways to name fields in result.
- LIKE is used for string matching. `_’ stands for any one character and `%’ stands for 0 or more arbitrary characters.

Union, Intersect, and Except

- SQL provides three set-manipulation constructs that extend the basic query form presented earlier.
  - Union ($\cup$)
  - Intersection ($\cap$)
  - Except (–)

(many systems recognize the keyword MINUS for EXCEPT)

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

Example: Find sid's of sailors who've reserved a red or a green boat

- UNION: Can be used to compute the union of any two *union-compatible* sets of tuples (which are themselves the result of SQL queries).
- If we replace OR by AND in the first version, what do we get?
- Also available: EXCEPT (What do we get if we replace UNION by EXCEPT?)

```
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid
  AND (B.color='red' OR B.color='green')
```

```
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid
            AND B.color='red'
UNION
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid
            AND B.color='green'
```

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

Example: Find sid's of sailors who've reserved a red and a green boat

```
SELECT  S.sid
FROM  Sailors S, Boats B1, Reserves R1,
          Boats B2, Reserves R2
WHERE  S.sid=R1.sid AND R1.bid=B1.bid
  AND  S.sid=R2.sid AND R2.bid=B2.bid
  AND (B1.color='red' AND B2.color='green')
```

- INTERSECT: Can be used to compute the intersection of any two *union-compatible* sets of tuples.

- Included in the SQL/92 standard, but some systems don't support it.

```
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid
            AND B.color='red'
INTERSECT
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid
            AND B.color='green'
```

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

Example: Find sid's of all sailors who've reserved red boat but not green boat.

```
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid
           AND B.color='red'
EXCEPT
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid
           AND B.color='green'
```

Indeed, since the Reserves relation contains sid information, there is no need to look at the Sailors relation.

```
SELECT  R.sid
FROM  Boats B, Reserves R
WHERE  R.bid=B.bid AND B.color='red'
EXCEPT
SELECT  R.sid
FROM  Boats B, Reserves R
WHERE  R.bid=B.bid AND B.color='green'
```

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

Example: Find sid's of all sailors who have a rating of 10 or reserved boat 104

```
SELECT  S.sid
FROM  Sailor S
WHERE  S.rating = 10
UNION
SELECT  R.sid
FROM  Reserves R
WHERE  R.bid=104
```

Nested Queries

- A nested query is a query that has another query embedded within it.
- The embedded query is called a subquery.
- The embedded query can be a nested query itself.
  - Queries may have very deeply nested structures.

Example: Find names of sailors who've reserved boat #103:

```
SELECT  S.sname
FROM     Sailors S, Reserves R
WHERE  S.sid=R.sid AND R.bid=103
```

alternative:

```
SELECT  S.sname
FROM  Sailors S
WHERE  S.sid IN  (SELECT  R.sid
                  FROM  Reserves R
                  WHERE  R.bid=103)
```

A very powerful feature of SQL: a WHERE clause can itself contain an SQL query! (Actually, so can FROM and HAVING clauses.)

Consider: Find names of sailors who've not reserved boat #103:

```
SELECT  S.sname
FROM     Sailors S, Reserves R
WHERE  S.sid=R.sid AND R.bid≠103
```

correct?

correct answer:

```
SELECT  S.sname
FROM  Sailors S
WHERE  S.sid NOT IN  (SELECT  R.sid
                      FROM  Reserves R
                      WHERE  R.bid=103)
```

- To understand semantics of nested queries, think of a *nested loops* evaluation: *For each Sailors tuple, check the qualification by computing the subquery.*

Correlated Nested Queries

- In the previous example, the inner subquery has been completely independent of the outer query.
- In general, the inner subquery could depend on the row currently being examined in the outer query.

Example: Find names of sailors who've reserved boat #103:

```
SELECT  S.sname
FROM  Sailors S
WHERE   EXISTS  (SELECT  *
                 FROM  Reserves R
                 WHERE  R.bid=103 AND S.sid=R.sid)
```

EXISTS is another ***set comparison*** operator, which allows us to test whether a set is nonempty.

Sailors

	sid	sname	rating	age
S →	22	dustin	7	45.0
S →	31	lubber	8	55.5
S →	58	rusty	10	35.0

Reserves

	sid	bid	day
R →	22	103	10/10/96
R →	31	101	11/12/96
R →	22	103	12/12/03
	58	105	8/21/05

Example: Find names of sailors with at most one reservation for boat #103

```
SELECT  S.sname
FROM  Sailors S
WHERE   EXISTS  UNIQUE (SELECT  R.bid
                        FROM  Reserves R
                        WHERE  R.bid=103 AND
                               S.sid=R.sid)
```

EXIST UNIQUE evaluates to true if the subquery returns a relation that contains no duplicated tuples (empty is a special case)

- Why do we have to replace * by *R.bid*?

Set-comparison Operators

- We’ve already seen IN, EXISTS and UNIQUE. We can also use NOT IN, NOT EXISTS and NOT UNIQUE.
- Also available: *op* ANY, *op* ALL
  - Where op is one of the arithmetic comparison operator $<, >, =, \le, \ge, \ne$
  - SOME is also available, but it is just a synonym for ANY.
- Example: Find sailors whose rating is greater than that of some sailor called Horatio:

```
SELECT  *
FROM  Sailors S
WHERE  S.rating > ANY  (SELECT  S2.rating
                        FROM  Sailors S2
                        WHERE S2.sname=‘Horatio’)
```

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

Example: Find sailors whose rating is better than every sailor called Horatio.

```
SELECT  *
FROM  Sailors S
WHERE  S.rating > ALL  (SELECT  S2.rating
                        FROM  Sailors S2
                        WHERE S2.sname=‘Horatio’)
```

Example: Find the sailors with the highest rating.

```
SELECT  *
FROM  Sailors S
WHERE  S.rating >= ALL  (SELECT  S2.rating
                         FROM  Sailors S2)
```

• Rewriting INTERSECT queries using IN

Example: Find sid's of sailors who've reserved both a red and a green boat:

```
SELECT  S.sid
FROM  Sailors S, Boats B, Reserves R
WHERE  S.sid=R.sid AND R.bid=B.bid AND B.color='red'
          AND S.sid IN  (SELECT  S2.sid
                         FROM  Sailors S2, Boats B2, Reserves R2
                         WHERE  S2.sid=R2.sid AND R2.bid=B2.bid
                                    AND  B2.color='green')
```

- Similarly, EXCEPT queries can be re-written using NOT IN.
- To find *names* (not *sid*'s) of Sailors who've reserved both red and green boats, just replace *S.sid* by *S.sname* in SELECT clause.

Division in SQL

Example: Find names of sailors who've reserved all boats.

```
SELECT  S.sname
FROM  Sailors S
WHERE  NOT EXISTS
          ((SELECT  B.bid
            FROM  Boats B)
           EXCEPT
           (SELECT  R.bid
            FROM  Reserves R
            WHERE  R.sid=S.sid))
```

All boats

All boats reserved by S

sailors				
	<u>sid</u>	sname	rating	age

Boats			
	<u>bid</u>	bname	color

Reserves			
	<u>sid</u>	<u>bid</u>	<u>day</u>

Note that this query is correlated – for each sailor S, we select it if there does not exist a boat that has not been reserves by him/her.

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

An Alternative way to write the previous query without using EXCEPT

```
SELECT  S.sname
FROM  Sailors S
WHERE  NOT EXISTS  (SELECT  B.bid
                    FROM  Boats B
                    WHERE  NOT EXISTS  (SELECT  R.bid
                                        FROM  Reserves R
                                        WHERE  R.bid=B.bid
                                              AND R.sid=S.sid))
```

Again, for each sailor we check that there is no boat that has not been reserved by him/her:

The 3rd level query returns empty set if B.bid is not reserved by S.sid

The 2nd level query returns empty set if no such B.bid exists

Aggregate Operators

- SQL allows the use of arithmetic expressions.
- SQL supports five aggregate operations, which can be applied on any column of a relation.

COUNT([DISTINCT] A)	The number of (unique) value in the A column.
SUM ([DISTINCT] A)	The sum of all (unique) values in the A column.
AVG ([DISTINCT A)	The average of all (unique) values in the A column.
MAX (A)	The maximum value in the A column.
MIN (A)	The minimum value in the A column.

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

Example: *Count the number of Sailor*

```
SELECT  COUNT (*)
FROM    Sailors S
```

Example: *Count the number of different sailor names*

```
SELECT  COUNT (DISTINCT S.name)
FROM    Sailors S
```

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

Example: Find the average age of all sailors

```
SELECT  AVG (S.age)
FROM    Sailors S
```

Example: Find the average age of sailors with rating of 10

```
SELECT  AVG (S.age)
FROM    Sailors S
WHERE   S.rating = 10
```

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

Example: Find the name and age of the oldest sailor

```
SELECT  S.sname, MAX (S.age)
FROM      Sailors S
```

✗

```
SELECT  S.sname, S.age
FROM  Sailors S
WHERE  S.age =
          (SELECT  MAX (S2.age)
           FROM  Sailors S2)
```

✓

```
SELECT  S.sname, S.age
FROM  Sailors S
WHERE  (SELECT  MAX (S2.age)
        FROM  Sailors S2)
        = S.age
```

Equivalent to the second query, and is allowed in the SQL/92 standard, but is not supported in some systems.

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

Aggregate operations offer an alternative to the ANY and ALL constructs.

Example: *Find the names of sailors who are older than the oldest sailor with a rating of 10.*

```
SELECT   S.name
FROM     Sailors S
WHERE    S.age > ANY (SELET S2.age
                FROM Sailors S2
                WHERE S2.rating = 10)
```

Alternative

```
SELECT   S.name
FROM     Sailors S
WHERE    S.age > (   SELECT    MAX (S2.age)
         FROM        Sailors S2
         WHERE       S2.rating = 10)
```

Group by and Having

- So far, we've applied aggregate operators to all (qualifying) tuples. Sometimes, we want to apply them to each of several *groups* of tuples.
- Consider: *Find the age of the youngest sailor for each rating level*.
  - In general, we don't know how many rating levels exist, and what the rating values for these levels are!
  - Suppose we know that rating values go from 1 to 10; we can write 10 queries that look like this (!):

For *i* = 1, 2, ... , 10:

```
SELECT  MIN (S.age)
FROM  Sailors S
WHERE  S.rating = i
```

- To write such queries, we need a major extension to the basic SQL query form, namely the Group BY clause.
- The extension also includes an optional HAVING clause that can be used to specify qualifications over groups.

The query can be expressed as follows

```
SELECT       S.rating, MIN (S.age)
FROM         Sailors S
GROUP BY     S.rating
```

The general format of GROUP BY and Having

```
SELECT      [DISTINCT]  target-list
FROM        relation-list
WHERE       qualification
GROUP BY    grouping-list
HAVING      group-qualification
```

- The *target-list* contains (i) attribute list (ii) terms with aggregate operations (e.g., MIN (*S.age*)).
  - The attribute list (i) must be a subset of *grouping-list*. Intuitively, each answer tuple corresponds to a *group*, and these attributes must have a single value per group. (A *group* is a set of tuples that have the same value for all attributes in *grouping-list*.)

```
SELECT     [DISTINCT]  target-list
FROM       relation-list
WHERE      qualification
GROUP BY   grouping-list
HAVING     group-qualification
```

Conceptual Evaluation

- The cross-product of *relation-list* is computed, tuples that fail *qualification* are discarded, `*unnecessary*' fields are deleted, and the remaining tuples are partitioned into groups by the value of attributes in *grouping-list*.
- The *group-qualification* is then applied to eliminate some groups. Expressions in *group-qualification* must have a *single value per group*!
  - In effect, an attribute in *group-qualification* that is not an argument of an aggregate op also appears in *grouping-list*. (SQL does not exploit primary key semantics here!)
- One answer tuple is generated per qualifying group.

sailors	sid	sname	rating	age
Boats	bid	bname	color	
Reserves	sid	bid	day	

For each red boat, find its bid, and the number of reservations

```
SELECT  B.bid,  COUNT (*) AS reservationcount
FROM  Boats B, Reserves R
WHERE  R.bid=B.bid AND B.color='red'
GROUP BY  B.bid
```

- **Only B.bid is mentioned in the SELECT clause; other attributes are `*unnecessary*'.**
- **COUNT(*) is renamed**

alternative?

```
SELECT  B.bid,  COUNT (*) AS reservationcount
FROM  Boats B, Reserves R
WHERE  R.bid=B.bid
GROUP BY  B.bid
HAVING B.color = 'red'
```

Only columns that appear in the GROUP BY clause can appear in the HAVING clause, unless they appear as arguments to an aggregate operator in the HAVING clause.

Example: Find the average age of sailors for each rating level that has at least two sailors.

```
SELECT  S.rating, AVG(S.age)  AS avgage
FROM  Sailor S
GROUP BY S.rating
HAVING COUNT (S.sid) > 1
```

OR

```
SELECT  S.rating, AVG(S.age)  AS avgage
FROM  Sailor S
GROUP BY S.rating
HAVING 1 < (SELECT COUNT (S2.sid)
       FROM Sailors S2
       WHERE S.rating = S2.rating)
```

We can use S.rating inside the nested subquery in the HAVING because it has a single value for the current group of sailors

Rating	avgage
3	44.5
7	40.0
8	40.5
10	25.5

Answer

sid	sname	rating	age
22	Dustin	7	45.0
29	Brutus	1	33.0
31	Lubber	8	55.5
32	Andy	8	25.5
58	Rusty	10	35.0
64	Horatio	7	35.0
71	Zorba	10	16.0
74	Horatio	9	35.0
85	Art	3	25.5
95	Bob	3	63.5

Instance of Sailor

Example: Find the average age of sailors who are at least 18 years old for each rating level that has at least two sailors.

```
SELECT  S.rating, AVG(S.age) AS avgage
FROM  Sailor S
WHERE S.age >=18
GROUP BY S.rating
HAVING 1 < (SELECT COUNT (*)
        FROM Sailors S2
        WHERE S.rating = S2.rating)
```

sid	sname	rating	age
22	Dustin	7	45.0
29	Brutus	1	33.0
31	Lubber	8	55.5
32	Andy	8	25.5
58	Rusty	10	35.0
64	Horatio	7	35.0
71	Zorba	10	16.0
74	Horatio	9	35.0
85	Art	3	25.5
95	Bo0b	3	63.5
96	Frodo	3	25.5

Instance S3 of Sailor

Note that the answer is very similar to the previous one, with the only difference being that for the group 10, we now ignore the sailor with age 16 while computing the average.

Rating	avgage
3	44.5
7	40.0
8	40.5
10	35.5

Answer

Example: Find the average age of sailors who are at least 18 years old for each rating level that has at least two *such* sailors.

```
SELECT  S.rating, AVG(S.age)  AS avgage
FROM  Sailor S
WHERE S.age >=18
GROUP BY S.rating
HAVING COUNT(S.sid) > 1
```

sid	sname	rating	age
22	Dustin	7	45.0
29	Brutus	1	33.0
31	Lubber	8	55.5
32	Andy	8	25.5
58	Rusty	10	35.0
64	Horatio	7	35.0
71	Zorba	10	16.0
74	Horatio	9	35.0
85	Art	3	25.5
95	Bo0b	3	63.5
96	Frodo	3	25.5

Instance S3 of Sailor

Rating	avgage
3	44.5
7	40.0
8	40.5

Answer

It differs from the answer of the previous question in that there is no tuple for rating 10, since there is only one tuple with rating and age >= 18.

Example: Find the age of the youngest sailor with age >18, for each rating with at least 2 <u>such</u> sailors

```
SELECT  S.rating,  MIN (S.age)
FROM  Sailors S
WHERE  S.age >= 18
GROUP BY  S.rating
HAVING  COUNT (*) > 1
```

<u>sid</u>	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
71	zorba	10	16.0
64	horatio	7	35.0
29	brutus	1	33.0
58	rusty	10	35.0

rating	age
1	33.0
7	45.0
7	35.0
8	55.5
10	35.0

rating	
7	35.0

Answer relation

Some other ways to write: Find the average age of the sailors with age >= 18, for each rating with at least 2 such sailors

```
SELECT  S.rating, AVG(S.age) AS avgage
FROM  Sailor S
WHERE S.age >=18
GROUP BY S.rating
HAVING  1 < (SELECT COUNT (*)
             FROM Sailor S1
             WHERE S1.age >= 18 AND S1.rating = S.rating)
```

alternative

```
SELECT Temp.rating, Temp.avgage
FROM   (SELECT  S.rating, AVG(S.age) AS avgage,
                COUNT (*) As ratingcount
         FROM  Sailor S
         WHERE S.age >=18
          GROUP BY S.rating) AS Temp
WHERE Temp.ratingcount > 1
```

The nested subquery returns the average age of the sailors with age >= 18 and a count of such sailors for each rating level

sailors	<u>sid</u>	sname	rating	age
Boats	<u>bid</u>	bname	color	
Reserves	<u>sid</u>	<u>bid</u>	<u>day</u>	

Find those ratings for which the average age is the minimum over all ratings

```
SELECT  S.rating
FROM  Sailors S
WHERE  S.age =  (SELECT  MIN (AVG (S2.age))
                 FROM Sailors S2
                        GROUP BY S2.rating)
```

Aggregate operations cannot be nested!
This query will not work even if the expression MIN(AVG(S2.age)), which is illegal, is allowed. In the nested query, Sailors is partitioned into groups by rating, and the average age is computed for each rating value. For each group, applying MIN to this average age value for the group will return the same value.

Correct solution:

```
SELECT  Temp.rating, Temp.avgage
FROM  (SELECT  S.rating, AVG (S.age) AS avgage
       FROM  Sailors S
       GROUP BY  S.rating) AS Temp
WHERE  Temp.avgage = (SELECT  MIN (Temp.avgage)
                      FROM  Temp)
```

1st subquery returns a table contains the average age for each rating value

2nd subquery returns a table contains the rating(s) for which this average age is the minimum.