# COMP 3311
# DATABASE MANAGEMENT SYSTEMS

## LECTURE 6 EXERCISES
## RELATIONAL ALGEBRA

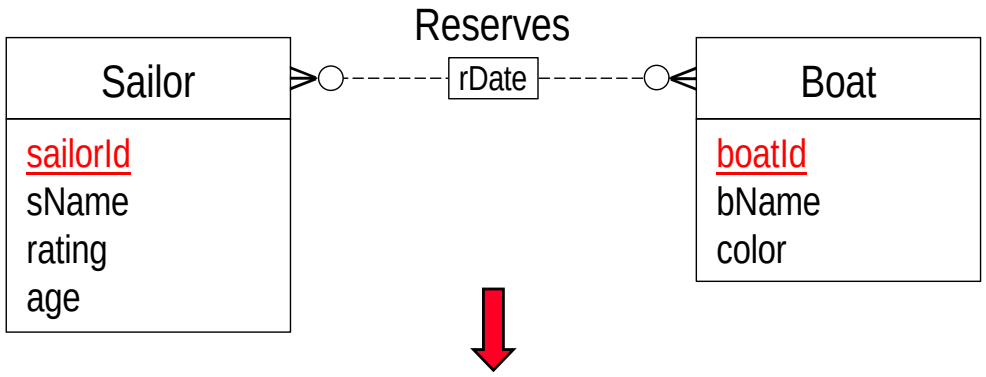
# EXAMPLE RELATIONAL SCHEMA

Sailor(sailorId, sName, rating, age)

Boat(boatId, bName, color)

Reserves(*sailorId, boatId*, rDate)

**What is the E-R schema for this relational schema?**




**What about this schema?**

Reserves(*sailorId, boatId*, rDate)

☞ **A sailor can reserve a given boat at most once!**

**What do we get if we reduce Reserves?**

☞ **rDate is not part of the key in the reduction!**

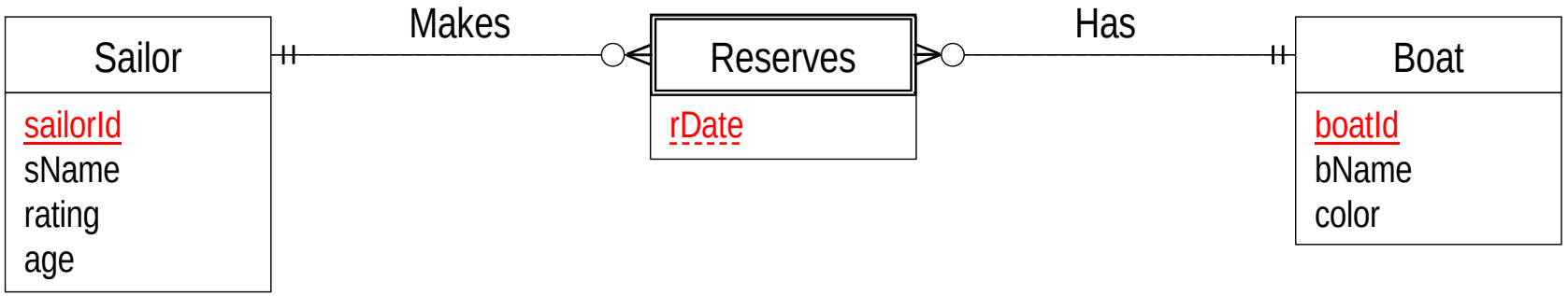
# EXAMPLE RELATIONAL SCHEMA

Sailor(sailorId, sName, rating, age)

Boat(boatId, bName, color)

Reserves(*sailorId*, *boatId*, rDate)

**What about this schema?**




**What kind of entity is Reserves?** ⇒ Weak entity.

**On which entity is Reserves dependent?** ⇒ Both Sailor and Boat!

**Is rDate a discriminator for Reserves?** ⇒ Yes

**What should be the cardinality constraints for Makes?** ⇒ 1:N

**What should be the participation constraints for Makes?** ⇒ Sailor - partial; Reserves - total

**What should be the cardinality constraints for Has?** ⇒ 1:N

**What should be the participation constraints for Has?** ⇒ Boat - partial; Reserves - total

# EXAMPLE RELATIONAL SCHEMA AND DATABASE

Sailor(sailorId, sName, rating, age)

Boat(boatId, bName, color)

Reserves(*sailorId*, *boatId*, rDate)

Attribute names in italics are foreign key attributes.

Sailor

| sailorId | sName | rating | age |
|---|---|---|---|
| 22 | Dustin | 7 | 45 |
| 29 | Brutus | 1 | 33 |
| 31 | Lubber | 8 | 55 |
| 32 | Andy | 8 | 25 |
| 58 | Rusty | 10 | 35 |
| 64 | Horatio | 7 | 35 |
| 71 | Zorba | 10 | 16 |
| 74 | Horatio | 9 | 35 |
| 85 | Art | 3 | 25 |
| 95 | Bob | 3 | 63 |
| 99 | Chris | 10 | 30 |

11 tuples

Reserves

| *sailorId* | *boatId* | rDate |
|---|---|---|
| 22 | 101 | 10/10/17 |
| 22 | 102 | 10/10/17 |
| 22 | 103 | 08/10/17 |
| 22 | 104 | 07/10/17 |
| 31 | 102 | 10/11/17 |
| 31 | 103 | 06/11/17 |
| 31 | 104 | 12/11/17 |
| 64 | 101 | 05/09/17 |
| 64 | 102 | 08/09/17 |
| 74 | 103 | 08/09/17 |
| 99 | 104 | 08/08/17 |

11 tuples

Boat

| boatId | bName | color |
|---|---|---|
| 101 | Interlake | blue |
| 102 | Interlake | red |
| 103 | Clipper | green |
| 104 | Marine | red |
| 105 | Serenity | Cyan |

5 tuples

# EXERCISE 1

**Find the ids of sailors who have reserved boat 103.**

☞ 22, 31, 74

## 1. Is this a solution?

$\sigma_{boatId=103}(\pi_{sailorId}Reserves)$ X

$\pi_{sailorId}Reserves$

| sailorId |
|---|
| 22 |
| 31 |
| 64 |
| 74 |

$\sigma_{boatId=103}$ ?

## 2. Is this a solution?

$\pi_{sailorId}(\sigma_{boatId=103}Reserves)$ ✓

$\sigma_{boatId=103}Reserves$

| sailorId | boatId | rDate |
|---|---|---|
| 22 | 103 | 08/10/17 |
| 31 | 103 | 06/11/17 |
| 74 | 103 | 08/09/17 |

$\pi_{sailorId}$

| sailorId |
|---|
| 22 |
| 31 |
| 74 |

# EXERCISE 2

**Find the names of sailors who have reserved boat 103.**

☞ **Dustin, Lubber, Horatio**

1. **Is this a solution?**

$$\pi_{sName}(\sigma_{Reserves.sailorId=Sailor.sailorId \wedge boatId=103}(Reserves \times Sailor))$$

2. **Is this a solution?**

$$\pi_{sName}(\sigma_{Reserves.sailorId=Sailor.sailorId}((\sigma_{boatId=103}Reserves) \times Sailor))$$

Find the names of sailors who have reserved boat 103.

# EXERCISE 2: SOLUTION 1

$$\pi_{sName}(\sigma_{Reserves.sailorId=Sailor.sailorId \wedge boatId=103}(Reserves \times Sailor))$$

☞ **Dustin, Lubber, Horatio**

Reserves

| sailorId | boatId | rDate |
|---|---|---|
| 22 | 101 | 10/10/17 |
| 22 | 102 | 10/10/17 |
| 22 | 103 | 08/10/17 |
| 22 | 104 | 07/10/17 |
| 31 | 102 | 10/11/17 |
| 31 | 103 | 06/11/17 |
| 31 | 104 | 12/11/17 |
| 64 | 101 | 05/09/17 |
| 64 | 102 | 08/09/17 |
| 74 | 103 | 08/09/17 |
| 99 | 104 | 08/08/17 |

11 tuples

X

Sailor

| sailorId | sName | rating | age |
|---|---|---|---|
| 22 | Dustin | 7 | 45 |
| 29 | Brutus | 1 | 33 |
| 31 | Lubber | 8 | 55 |
| 32 | Andy | 8 | 25 |
| 58 | Rusty | 10 | 35 |
| 64 | Horatio | 7 | 35 |
| 71 | Zorba | 10 | 16 |
| 74 | Horatio | 9 | 35 |
| 85 | Art | 3 | 25 |
| 95 | Bob | 3 | 63 |
| 99 | Chris | 10 | 30 |

11 tuples

=

**How many tuples in the result? 11 x 11 = 121 tuples!**

Find the names of sailors who have reserved boat 103.

# EXERCISE 2: SOLUTION 1

$$\pi_{sName}(\sigma_{Reserves.sailorId=Sailor.sailorId \wedge boatId=103}(Reserves \times Sailor))$$

☞ **Dustin, Lubber, Horatio**

Reserves X Sailor

| Reserves.sailorId | boatId | rDate | Sailor.sailorId | sName | rating | age |
|---|---|---|---|---|---|---|
| 22 | 101 | 10/10/17 | 22 | Dustin | 7 | 45 |
| 22 | 101 | 10/10/17 | 29 | Brutus | 1 | 33 |
| 22 | 101 | 10/10/17 | 31 | Lubber | 8 | 55 |
| 22 | 101 | 10/10/17 | 32 | Andy | 8 | 25 |
| 22 | 101 | 10/10/17 | 58 | Rusty | 10 | 35 |
| 22 | 101 | 10/10/17 | 64 | Horatio | 7 | 35 |
| 22 | 101 | 10/10/17 | 71 | Zorba | 10 | 16 |
| 22 | 101 | 10/10/17 | 74 | Horatio | 9 | 35 |
| 22 | 101 | 10/10/17 | 85 | Art | 3 | 25 |
| 22 | 101 | 10/10/17 | 95 | Bob | 3 | 63 |
| 22 | 101 | 10/10/17 | 99 | Chris | 10 | 30 |
| 22 | 102 | 10/10/17 | 22 | Dustin | 7 | 45 |
| 22 | 102 | 10/10/17 | 29 | Brutus | 1 | 33 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

**Find the names of sailors who have reserved boat 103.**

# EXERCISE 2: SOLUTION 1

$$\pi_{sName}(\sigma_{Reserves.sailorId=Sailor.sailorId \wedge boatId=103}(Reserves \times Sailor))$$

☞ **Dustin, Lubber, Horatio**

$\sigma_{Reserves.sailorId=Sailor.sailorId \wedge boatId=103}(Reserves \times Sailor)$

| Reserves.sailorId | boatId | rDate | Sailor.sailorId | sName | rating | age |
|---|---|---|---|---|---|---|
| 22 | 103 | 08/10/17 | 22 | Dustin | 7 | 45 |
| 31 | 103 | 06/11/17 | 31 | Lubber | 8 | 55 |
| 74 | 103 | 08/09/17 | 74 | Horatio | 9 | 35 |

**Apply** $\pi_{sName}$ to above result:

| sName |
|---|
| Dustin |
| Lubber |
| Horatio |

✓

Find the names of sailors who have reserved boat 103.

# EXERCISE 2: SOLUTION 2

$$\pi_{sName}(\sigma_{Reserves.sailorId=Sailor.sailorId}((\sigma_{boatId=103}Reserves) \times Sailor))$$

☞ **Dustin, Lubber, Horatio**

$\sigma_{boatId=103}$Reserves

| sailorId | boatId | rDate |
|---|---|---|
| 22 | 103 | 08/10/17 |
| 31 | 103 | 06/11/17 |
| 74 | 103 | 08/09/17 |

X

Sailor

| sailorId | name | rating | age |
|---|---|---|---|
| 22 | Dustin | 7 | 45 |
| 29 | Brutus | 1 | 33 |
| 31 | Lubber | 8 | 55 |
| 32 | Andy | 8 | 25 |
| 58 | Rusty | 10 | 35 |
| 64 | Horatio | 7 | 35 |
| 71 | Zorba | 10 | 16 |
| 74 | Horatio | 9 | 35 |
| 85 | Art | 3 | 25 |
| 95 | Bob | 3 | 63 |
| 99 | Chris | 10 | 30 |

11 tuples

=

**How many tuples in the result? 3 x 11 = 33 tuples!**

Find the names of sailors who have reserved boat 103.

# EXERCISE 2: SOLUTION 2

$$\pi_{sName}(\sigma_{Reserves.sailorId=Sailor.sailorId}((\sigma_{boatId=103}Reserves) \times Sailor))$$

☞ **Dustin, Lubber, Horatio**

$(\sigma_{boatId=103}Reserves) \times Sailor$

| Reserves.sailorId | boatId | rDate | Sailor.sailorId | sName | rating | age |
|---|---|---|---|---|---|---|
| 22 | 103 | 08/10/17 | 22 | Dustin | 7 | 45 |
| 22 | 103 | 08/10/17 | 29 | Brutus | 1 | 33 |
| 22 | 103 | 08/10/17 | 31 | Lubber | 8 | 55 |
| 22 | 103 | 08/10/17 | 32 | Andy | 8 | 25 |
| 22 | 103 | 08/10/17 | 58 | Rusty | 10 | 35 |
| 22 | 103 | 08/10/17 | 64 | Horatio | 7 | 35 |
| 22 | 103 | 08/10/17 | 71 | Zorba | 10 | 16 |
| 22 | 103 | 08/10/17 | 74 | Horatio | 9 | 35 |
| 22 | 103 | 08/10/17 | 85 | Art | 3 | 25 |
| 22 | 103 | 08/10/17 | 95 | Bob | 3 | 63 |
| 22 | 103 | 08/10/17 | 99 | Chris | 10 | 30 |
| 31 | 103 | 06/11/17 | 22 | Dustin | 7 | 45 |
| 31 | 103 | 06/11/17 | 29 | Brutus | 1 | 33 |
| 31 | 103 | 06/11/17 | 31 | Lubber | 8 | 55 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

Find the names of sailors who have reserved boat 103.

# EXERCISE 2: SOLUTION 2

$$\pi_{sName}(\sigma_{Reserves.sailorId=Sailor.sailorId}((\sigma_{boatId=103}Reserves) \times Sailor))$$

☞ **Dustin, Lubber, Horatio**

$\sigma_{Reserves.sailorId=Sailor.sailorId}((\sigma_{boatId=103}Reserves) \times Sailor)$

| Reserves.sailorId | boatId | rDate | Sailor.sailorId | sName | rating | age |
|---|---|---|---|---|---|---|
| 22 | 103 | 08/10/17 | 22 | Dustin | 7 | 45 |
| 31 | 103 | 06/11/17 | 31 | Lubber | 8 | 55 |
| 74 | 103 | 08/09/17 | 74 | Horatio | 9 | 35 |

**Apply** $\pi_{sName}$ to above result:

| sName |
|---|
| Dustin |
| Lubber |
| Horatio |

✓

Find the names of sailors who have reserved boat 103.

# EXERCISE 2: SOLUTION 3

$\pi_{sName}((\sigma_{boatId=103}Reserves)$ JOIN Sailor)

☞ **Dustin, Lubber, Horatio**

$\sigma_{boatId=103}Reserves$

| sailorId | boatId | rDate |
|---|---|---|
| 22 | 103 | 08/10/17 |
| 31 | 103 | 06/11/17 |
| 74 | 103 | 08/09/17 |

JOIN

Sailor

| sailorId | sName | rating | age |
|---|---|---|---|
| 22 | Dustin | 7 | 45 |
| 29 | Brutus | 1 | 33 |
| 31 | Lubber | 8 | 55 |
| 32 | Andy | 8 | 25 |
| 58 | Rusty | 10 | 35 |
| 64 | Horatio | 7 | 35 |
| 71 | Zorba | 10 | 16 |
| 74 | Horatio | 9 | 35 |
| 85 | Art | 3 | 25 |
| 95 | Bob | 3 | 63 |
| 99 | Chris | 10 | 30 |

11 tuples

=

**How many tuples in the result? 3 tuples!**

Find the names of sailors who have reserved boat 103.

# EXERCISE 2: SOLUTION 3

$\pi_{sName}((\sigma_{boatId=103}Reserves)$ JOIN Sailor)

☞ **Dustin, Lubber, Horatio**

$(\sigma_{boatId=103}Reserves)$ JOIN Sailor

| Reserves.sailorId | boatId | rDate | Sailor.sailorId | sName | rating | age |
|---|---|---|---|---|---|---|
| 22 | 103 | 08/10/17 | 22 | Dustin | 7 | 45 |
| 31 | 103 | 06/11/17 | 31 | Lubber | 8 | 55 |
| 74 | 103 | 08/09/17 | 74 | Horatio | 9 | 35 |

**Apply** $\pi_{sName}$ to above result:

| sName |
|---|
| Dustin |
| Lubber |
| Horatio |

✓

# EXERCISE 2: SUMMARY

**Find the names of sailors who have reserved boat 103.**

☞ **All three queries get the correct answer, BUT ...**

1. **Is this a solution?** ✓

$$\pi_{sName}(\sigma_{Reserves.sailorId=Sailor.sailorId \wedge boatId=103}(Reserves \times Sailor))$$

**Initial result: 121 tuples**

2. **Is this a solution?** ✓

$$\pi_{sName}(\sigma_{Reserves.sailorId=Sailor.sailorId}((\sigma_{boatId=103}Reserves) \times Sailor))$$

**Initial result: 33 tuples**

3. **Is this a solution?** ✓

$$\pi_{sName}((\sigma_{boatId=103}Reserves) \text{ JOIN } Sailor)$$

**Initial result: 3 tuples**

## Query Optimization

Relational DBMSs do such optimizations based on relational algebra.

# EXERCISE 3: SOLUTION 1

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

☞ **Dustin, Lubber, Horatio, Chris**

**Is this a solution?**

$\pi_{sName}((\sigma_{color='red'}Boat)$ JOIN Reserves JOIN Sailor)

$\sigma_{color='red'}$Boat

| boatId | bName | color |
|---|---|---|
| 102 | Interlake | red |
| 104 | Marine | red |

JOIN

Reserves

| sailorId | boatId | rDate |
|---|---|---|
| 22 | 101 | 10/10/17 |
| 22 | 102 | 10/10/17 |
| 22 | 103 | 08/10/17 |
| 22 | 104 | 07/10/17 |
| 31 | 102 | 10/11/17 |
| 31 | 103 | 06/11/17 |
| 31 | 104 | 12/11/17 |
| 64 | 101 | 05/09/17 |
| 64 | 102 | 08/09/17 |
| 74 | 103 | 08/09/17 |
| 99 | 104 | 08/08/17 |

=

**How many tuples in the result?**

**6 tuples!**

**How many columns in the result?**

**5 columns!**

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

# EXERCISE 3: SOLUTION 1

$\pi_{sName}((\sigma_{color='red'}Boat)$ JOIN Reserves JOIN Sailor)

☞ **Dustin, Lubber, Horatio, Chris**

$(\sigma_{color='red'}Boat)$ JOIN Reserves

| bName | color | sailorId | boatId | rDate |
|---|---|---|---|---|
| Interlake | red | 22 | 102 | 10/10/17 |
| Marine | red | 22 | 104 | 07/10/17 |
| Interlake | red | 31 | 102 | 10/11/17 |
| Marine | red | 31 | 104 | 12/11/17 |
| Interlake | red | 64 | 102 | 08/09/17 |
| Marine | red | 99 | 104 | 08/08/17 |

JOIN

Sailor

| sailorId | sName | rating | age |
|---|---|---|---|
| 22 | Dustin | 7 | 45 |
| 29 | Brutus | 1 | 33 |
| 31 | Lubber | 8 | 55 |
| 32 | Andy | 8 | 25 |
| 58 | Rusty | 10 | 35 |
| 64 | Horatio | 7 | 35 |
| 71 | Zorba | 10 | 16 |
| 74 | Horatio | 9 | 35 |
| 85 | Art | 3 | 25 |
| 95 | Bob | 3 | 63 |
| 99 | Chris | 10 | 30 |

=

**How many tuples in the result?**
**6 tuples!**

**How many columns in the result?**
**8 columns!**

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

# EXERCISE 3: SOLUTION 1

$\pi_{sName}((\sigma_{color='red'}Boat)$ JOIN Reserves JOIN Sailor)

☞ **Dustin, Lubber, Horatio, Chris**

$(\sigma_{color='red'}Boat)$ JOIN Reserves JOIN Sailor

| bName | color | sailorId | boatId | rDate | sName | rating | age |
|---|---|---|---|---|---|---|---|
| Interlake | red | 22 | 102 | 10/10/17 | Dustin | 7 | 45 |
| Marine | red | 22 | 104 | 07/10/17 | Dustin | 7 | 45 |
| Interlake | red | 31 | 102 | 10/11/17 | Lubber | 8 | 55 |
| Marine | red | 31 | 104 | 12/11/17 | Lubber | 8 | 55 |
| Interlake | red | 64 | 102 | 08/09/17 | Horatio | 7 | 35 |
| Marine | red | 99 | 104 | 08/08/17 | Chris | 10 | 30 |

**Apply** $\pi_{sName}$ to above result:

| sName |
|---|
| Dustin |
| Lubber |
| Horatio |
| Chris |

✓

# EXERCISE 3: SOLUTION 2

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

☞ **Dustin, Lubber, Horatio, Chris**

$\pi_{sName}((\sigma_{color='red'}Boat)$ JOIN Reserves JOIN Sailor)

**Can you give a more efficient solution in terms of result size?**

$\pi_{sName}((\pi_{boatId}(\sigma_{color='red'}Boat))$ JOIN Reserves JOIN Sailor)

$\sigma_{color='red'}Boat$

| boatId | bName | color |
|---|---|---|
| 102 | Interlake | red |
| 104 | Marine | red |

After selecting red boats, first project onto boatId before doing the join since the name and color of the boat is not needed for the query. Thus, only the boatId is "carried" when evaluating the rest of the query.

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

# EXERCISE 3: SOLUTION 2

$\pi_{sName}((\pi_{boatId}(\sigma_{color='red'}Boat))$ JOIN Reserves JOIN Sailor)

☞ **Dustin, Lubber, Horatio, Chris**

$\pi_{boatId}(\sigma_{color='red'}Boat)$

| boatId |
|---|
| 102 |
| 104 |

JOIN

Reserves

| sailorId | boatId | rDate |
|---|---|---|
| 22 | 101 | 10/10/17 |
| 22 | 102 | 10/10/17 |
| 22 | 103 | 08/10/17 |
| 22 | 104 | 07/10/17 |
| 31 | 102 | 10/11/17 |
| 31 | 103 | 06/11/17 |
| 31 | 104 | 12/11/17 |
| 64 | 101 | 05/09/17 |
| 64 | 102 | 08/09/17 |
| 74 | 103 | 08/09/17 |
| 99 | 104 | 08/08/17 |

=

**How many tuples in the result? 6 tuples!**

**How many columns in the result? 3 columns!**

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

# EXERCISE 3: SOLUTION 2

$\pi_{sName}((\pi_{boatId}(\sigma_{color='red'}Boat))$ JOIN Reserves JOIN Sailor)

☞ **Dustin, Lubber, Horatio, Chris**

$(\pi_{boatId}(\sigma_{color='red'}Boat))$ JOIN Reserves

| sailorId | boatId | rDate |
|---|---|---|
| 22 | 102 | 10/10/17 |
| 22 | 104 | 07/10/17 |
| 31 | 102 | 10/11/17 |
| 31 | 104 | 12/11/17 |
| 64 | 102 | 08/09/17 |
| 99 | 104 | 08/08/17 |

JOIN

Sailor

| sailorId | sName | rating | age |
|---|---|---|---|
| 22 | Dustin | 7 | 45 |
| 29 | Brutus | 1 | 33 |
| 31 | Lubber | 8 | 55 |
| 32 | Andy | 8 | 25 |
| 58 | Rusty | 10 | 35 |
| 64 | Horatio | 7 | 35 |
| 71 | Zorba | 10 | 16 |
| 74 | Horatio | 9 | 35 |
| 85 | Art | 3 | 25 |
| 95 | Bob | 3 | 63 |
| 99 | Chris | 10 | 30 |

=

**How many tuples in the result? 6 tuples!**

**How many columns in the result? 6 columns!**

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

# EXERCISE 3: SOLUTION 2

$\pi_{sName}((\pi_{boatId}(\sigma_{color='red'}Boat))$ JOIN Reserves JOIN Sailor)

☞ **Dustin, Lubber, Horatio, Chris**

$(\sigma_{color='red'}Boat)$ JOIN Reserves JOIN Sailor

| sailorId | boatId | rDate | sName | rating | age |
|---|---|---|---|---|---|
| 22 | 102 | 10/10/17 | Dustin | 7 | 45 |
| 22 | 104 | 07/10/17 | Dustin | 7 | 45 |
| 31 | 102 | 10/11/17 | Lubber | 8 | 55 |
| 31 | 104 | 12/11/17 | Lubber | 8 | 55 |
| 64 | 102 | 08/09/17 | Horatio | 7 | 35 |
| 99 | 104 | 08/08/17 | Chris | 10 | 30 |

**Apply** $\pi_{sName}$ to above result:

| sName |
|---|
| Dustin |
| Lubber |
| Horatio |
| Chris |

✓

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

# EXERCISE 3: SUMMARY

## Solution 1

$\pi_{sName}((\sigma_{color='red'}Boat)$ JOIN Reserves JOIN Sailor)

(6 tuples, 5 columns) + (6 tuples, 8 columns)

## Solution 2

$\pi_{sName}((\pi_{boatId}(\sigma_{color='red'}Boat))$ JOIN Reserves JOIN Sailor)

(6 tuples, 3 columns) + (6 tuples, 6 columns)

☞ **Solution 2 is more efficient in terms of tuple size.**

## Query Optimization

Relational DBMSs do such optimizations based on relational algebra.

# EXERCISE 4

**Find the names of sailors who have reserved either a red or a green boat.**

☞ **Dustin (22), Lubber (31), Horatio (64), Horatio (74), Chris (99)**

$\pi_{sName}(\pi_{boatId}(\sigma_{color='red' \vee color='green'} Boat))$ JOIN Reserves JOIN Sailor)

Identify all red or green boats ($\sigma_{color='red' \vee color='green'} Boat$), then find sailors who have reserved one of these boats (... JOIN Reserves JOIN Sailor).

$\pi_{boatId}$ is a nice optimization but is not strictly needed to answer the query.

# EXERCISE 5: SOLUTION 1

**Is this a solution?**

**Find the names of sailors who have reserved both a red and a green boat.**

☞ **Dustin (22), Lubber (31)**

$\pi_{sName}((\sigma_{color='red' \wedge color='green'}Boat)$ JOIN Reserves JOIN Sailor)

Boat

| boatId | bName | color |
|---|---|---|
| 101 | Interlake | blue |
| 102 | Interlake | red |
| 103 | Clipper | green |
| 104 | Marine | red |
| 105 | Serenity | cyan |

**No! Why?**

☞ **Nothing is selected! Why?**

The condition color='red' $\wedge$ color='green' can *never* be satisfied!

**Find the names of sailors who have reserved both a red and a green boat.**

# EXERCISE 5: SOLUTION 2

**Is this a solution?**

$\pi_{sName}((\sigma_{color='red' \vee color='green'}Boat)$ JOIN Reserves JOIN Sailor)

☞ **Dustin (22), Lubber (31)**

$(\sigma_{color='red' \vee color='green'}Boat)$ JOIN Reserves JOIN Sailor

| bName | color | sailorId | boatId | rDate | sName | rating | age |
|---|---|---|---|---|---|---|---|
| Interlake | red | 22 | 102 | 10/10/17 | Dustin | 7 | 45 |
| Marine | red | 22 | 104 | 07/10/17 | Dustin | 7 | 45 |
| Interlake | red | 31 | 102 | 10/11/17 | Lubber | 8 | 55 |
| Marine | red | 31 | 104 | 12/11/17 | Lubber | 8 | 55 |
| Interlake | red | 64 | 102 | 08/09/17 | Horatio | 7 | 35 |
| Marine | red | 99 | 104 | 08/08/17 | Chris | 10 | 30 |
| Clipper | green | 22 | 103 | 08/10/17 | Dustin | 7 | 45 |
| Clipper | green | 31 | 103 | 06/11/17 | Lubber | 8 | 55 |
| Clipper | green | 74 | 103 | 08/09/17 | Horatio | 7 | 35 |

**What's the problem?**

$\pi_{sName}$ ➡

| sName |
|---|
| Dustin |
| Lubber |
| Horatio |
| Chris |

X

The condition color='red' ∨ color='green' includes sailors who have reserved only a red or only a green boat, as well as both a red and a green boat!

Must identify sailors who have reserved red boats, sailors who have reserved green boats, then find the intersection.

**Find the names of sailors who have reserved both a red and a green boat.**

# EXERCISE 5: SOLUTION 3

**Is this a solution?**
(intersect join result)

$$\pi_{sName}((\sigma_{color='red'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor) \cap (\sigma_{color='green'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor)$$

☞ **Dustin (22), Lubber (31)**

$(\sigma_{color='red'}Boat)$ JOIN Reserves JOIN Sailor

| bName | color | sailorId | boatId | rDate | sName | rating | age |
|---|---|---|---|---|---|---|---|
| Interlake | red | 22 | 102 | 10/10/17 | Dustin | 7 | 45 |
| Marine | red | 22 | 104 | 07/10/17 | Dustin | 7 | 45 |
| Interlake | red | 31 | 102 | 10/11/17 | Lubber | 8 | 55 |
| Marine | red | 31 | 104 | 12/11/17 | Lubber | 8 | 55 |
| Interlake | red | 64 | 102 | 08/09/17 | Horatio | 7 | 35 |
| Marine | red | 99 | 104 | 08/08/17 | Chris | 10 | 30 |

∩

$(\sigma_{color='green'}Boat)$ JOIN Reserves JOIN Sailor

| bName | color | sailorId | boatId | rDate | sName | rating | age |
|---|---|---|---|---|---|---|---|
| Clipper | green | 22 | 103 | 08/10/17 | Dustin | 7 | 45 |
| Clipper | green | 31 | 103 | 06/11/17 | Lubber | 8 | 55 |
| Clipper | green | 74 | 103 | 08/09/17 | Horatio | 7 | 35 |

→ **The result is empty!**

Find the names of sailors who have reserved both a red and a green boat.

# EXERCISE 5: SOLUTION 4

**Is this a solution?**
(intersect on sName)

$$\pi_{sName}((\sigma_{color='red'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor) \cap \pi_{sName}((\sigma_{color='green'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor)$$

☞ **Dustin (22), Lubber (31)**

**Since sName is not unique, there may be incorrect tuples in the intersection (i.e., Horatio is not unique).**

$(\sigma_{color='red'}Boat)$ JOIN Reserves JOIN Sailor

| bName | color | sailorId | boatId | rDate | sName | rating | age |
|---|---|---|---|---|---|---|---|
| Interlake | red | 22 | 102 | 10/10/17 | Dustin | 7 | 45 |
| Marine | red | 22 | 104 | 07/10/17 | Dustin | 7 | 45 |
| Interlake | red | 31 | 102 | 10/11/17 | Lubber | 8 | 55 |
| Marine | red | 31 | 104 | 12/11/17 | Lubber | 8 | 55 |
| Interlake | red | 64 | 102 | 08/09/17 | Horatio | 7 | 35 |
| Marine | red | 99 | 104 | 08/08/17 | Chris | 10 | 30 |

$\pi_{sName}$ →

| sName |
|---|
| Dustin |
| Lubber |
| Horatio |
| ~~Chris~~ |

$(\sigma_{color='green'}Boat)$ JOIN Reserves JOIN Sailor

| bName | color | sailorId | boatId | rDate | sName | rating | age |
|---|---|---|---|---|---|---|---|
| Clipper | green | 22 | 103 | 08/10/17 | Dustin | 7 | 45 |
| Clipper | green | 31 | 103 | 06/11/17 | Lubber | 8 | 55 |
| Clipper | green | 74 | 103 | 08/09/17 | Horatio | 7 | 35 |

$\pi_{sName}$ →

| sName |
|---|
| Dustin |
| Lubber |
| Horatio |

$\cap$ $\pi_{sName}$ →

| sName |
|---|
| Dustin |
| Lubber |
| Horatio |

X

**Find the names of sailors who have reserved both a red and a green boat.**

# EXERCISE 5: SOLUTION 5

**Is this a solution?**
(intersect on sailorId, sName)

$$\pi_{sName}(\pi_{sailorId,\ sName}((\sigma_{color='red'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor) \cap \pi_{sailorId,\ sName}((\sigma_{color='green'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor))$$

☞ **Dustin (22), Lubber (31)**

$(\sigma_{color='red'}Boat)$ JOIN Reserves JOIN Sailor

| bName | color | sailorId | boatId | rDate | sName | rating | age |
|---|---|---|---|---|---|---|---|
| Interlake | red | 22 | 102 | 10/10/17 | Dustin | 7 | 45 |
| Marine | red | 22 | 104 | 07/10/17 | Dustin | 7 | 45 |
| Interlake | red | 31 | 102 | 10/11/17 | Lubber | 8 | 55 |
| Marine | red | 31 | 104 | 12/11/17 | Lubber | 8 | 55 |
| Interlake | red | 64 | 102 | 08/09/17 | Horatio | 7 | 35 |
| Marine | red | 99 | 104 | 08/08/17 | Chris | 10 | 30 |

$\pi_{sailorId,\ sName}$ →

| sailorId | sName |
|---|---|
| 22 | Dustin |
| 31 | Lubber |
| ~~64~~ | ~~Horatio~~ |
| ~~99~~ | ~~Chris~~ |

$(\sigma_{color='green'}Boat)$ JOIN Reserves JOIN Sailor

| bName | color | sailorId | boatId | rDate | sName | rating | age |
|---|---|---|---|---|---|---|---|
| Clipper | green | 22 | 103 | 08/10/17 | Dustin | 7 | 45 |
| Clipper | green | 31 | 103 | 06/11/17 | Lubber | 8 | 55 |
| Clipper | green | 74 | 103 | 08/09/17 | Horatio | 7 | 35 |

$\pi_{sailorId,\ sName}$ →

| sailorId | sName |
|---|---|
| 22 | Dustin |
| 31 | Lubber |
| ~~74~~ | ~~Horatio~~ |

$\cap$ $\pi_{sName}$ →

| sName |
|---|
| Dustin |
| Lubber |

✓

**Find the names of sailors who have reserved both a red and a green boat.**

# EXERCISE 5: SOLUTION 6

**Is this a solution?**
(join on sName)

$$\pi_{sName}(\pi_{sailorId,\ sName}((\sigma_{color='red'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor)\ JOIN_{sName}\ \pi_{sailorId,\ sName}((\sigma_{color='green'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor))$$

☞ **Dustin (22), Lubber (31)**

$\pi_{sailorId,\ sName}((\sigma_{color='red'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor)$

| sailorId | sName |
|---|---|
| 22 | Dustin |
| 31 | Lubber |
| 64 | Horatio |
| 99 | Chris |

$JOIN_{sName}$

$\pi_{sailorId,\ sName}((\sigma_{color='green'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor)$

| sailorId | sName |
|---|---|
| 22 | Dustin |
| 31 | Lubber |
| 74 | Horatio |

**Since sName is not unique, there may be incorrect tuples in the join (i.e., there are two *different* sailors with the same name, Horatio).**

=

| R1.sailorId | sName | R2.sailorId |
|---|---|---|
| 22 | Dustin | 22 |
| 31 | Lubber | 31 |
| 64 | Horatio | 74 |

$\pi_{sName}$

| sName |
|---|
| Dustin |
| Lubber |
| Horatio |

X

Find the names of sailors who have reserved both a red and a green boat.

# EXERCISE 5: SOLUTION 7

**Is this a solution?**
(join on sailorId)

$$\pi_{sName}(\pi_{sailorId,\ sName}((\sigma_{color='red'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor)\ JOIN_{sailorId}\ \pi_{sailorId,\ sName}((\sigma_{color='green'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor))$$

☞ **Dustin (22), Lubber (31)**

$\pi_{sailorId,\ sName}((\sigma_{color='red'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor)$

| sailorId | sName |
|---|---|
| 22 | Dustin |
| 31 | Lubber |
| 64 | Horatio |
| 99 | Chris |

$JOIN_{sailorId}$

$\pi_{sailorId,\ sName}((\sigma_{color='green'}Boat)\ JOIN\ Reserves\ JOIN\ Sailor)$

| sailorId | sName |
|---|---|
| 22 | Dustin |
| 31 | Lubber |
| 74 | Horatio |

=

| sailorId | R1.sName | R2.sName |
|---|---|---|
| 22 | Dustin | Dustin |
| 31 | Lubber | Lubber |

$\pi_{sName}$

| sName |
|---|
| Dustin |
| Lubber |

✓

# EXERCISE 6: SOLUTION 1

**Find the ids of sailors who have made at least two reservations on the same date.**

☞ 22

We need to use rename: $\rho_{R1}$(Reserves), $\rho_{R2}$(Reserves)

$$\pi_{R1.sailorId}(\sigma_{R1.sailorId=R2.sailorId \wedge R1.rDate=R2.rDate \wedge R1.boatId<>R2.boatId}(\rho_{R1}(Reserves) \times \rho_{R2}(Reserves)))$$

Or equivalently:

$$\pi_{R1.sailorId}(\rho_{R1}(Reserves) \text{ JOIN}_{R1.sailorId=R2.sailorId \wedge R1.rDate=R2.rDate \wedge R1.boatId<>R2.boatId} \rho_{R2}(Reserves))$$

**Find the ids of sailors who have made at least two reservations on the same date.**

# EXERCISE 6: SOLUTION 1 (CONT'D)

$$\pi_{R1.sailorId}(\sigma_{R1.sailorId=R2.sailorId \wedge R1.rDate=R2.rDate \wedge R1.boatId<>R2.boatId}(R1 \times R2))$$

R1

| sailorId | boatId | rDate |
|---|---|---|
| 22 | 101 | 10/10/17 |
| 22 | 102 | 10/10/17 |
| 22 | 103 | 08/10/17 |
| 22 | 104 | 07/10/17 |
| 31 | 102 | 10/11/17 |
| 31 | 103 | 06/11/17 |
| 31 | 104 | 12/11/17 |
| 64 | 101 | 05/09/17 |
| 64 | 102 | 08/09/17 |
| 74 | 103 | 08/09/17 |
| 99 | 104 | 08/08/17 |

X

R2

| sailorId | boatId | rDate |
|---|---|---|
| 22 | 101 | 10/10/17 |
| 22 | 102 | 10/10/17 |
| 22 | 103 | 08/10/17 |
| 22 | 104 | 07/10/17 |
| 31 | 102 | 10/11/17 |
| 31 | 103 | 06/11/17 |
| 31 | 104 | 12/11/17 |
| 64 | 101 | 05/09/17 |
| 64 | 102 | 08/09/17 |
| 74 | 103 | 08/09/17 |
| 99 | 104 | 08/08/17 |

=

**Find the ids of sailors who have made at least two reservations on the same date.**

# EXERCISE 6: SOLUTION 1 (CONT'D)

$$\pi_{R1.sailorId}(\sigma_{R1.sailorId=R2.sailorId \wedge R1.rDate=R2.rDate \wedge R1.boatId<>R2.boatId}(R1 \times R2))$$

$\sigma_{R1.sailorId=R2.sailorId \wedge R1.rDate=R2.rDate \wedge R1.boatId<>R2.boatId}$

| R1.sailorId | R1.boatId | R1.rDate | R2.sailorId | R2.boatId | R2.rDate |
|---|---|---|---|---|---|
| 22 | 101 | 10/10/17 | 22 | 101 | 10/10/17 |
| 22 | 101 | 10/10/17 | 22 | 102 | 10/10/17 |
| 22 | 101 | 10/10/17 | 22 | 103 | 08/10/17 |
| 22 | 101 | 10/10/17 | 22 | 104 | 07/10/17 |
| 22 | 101 | 10/10/17 | 31 | 102 | 10/11/17 |
| 22 | 101 | 10/10/17 | 31 | 103 | 06/11/17 |
| 22 | 101 | 10/10/17 | 31 | 104 | 12/11/17 |
| 22 | 101 | 10/10/17 | 64 | 101 | 05/09/17 |
| 22 | 101 | 10/10/17 | 64 | 102 | 08/09/17 |
| 22 | 101 | 10/10/17 | 74 | 103 | 08/09/17 |
| 22 | 101 | 10/10/17 | 99 | 104 | 08/08/17 |
| 22 | 102 | 10/10/17 | 22 | 101 | 10/10/17 |
| 22 | 102 | 10/10/17 | 22 | 102 | 10/10/17 |
| 22 | 102 | 10/10/17 | 22 | 103 | 08/10/17 |
| 22 | 102 | 10/10/17 | 22 | 104 | 07/10/17 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

$\pi_{R1.sailorId}$ =

| sailorId |
|---|
| 22 |

# EXERCISE 6: SOLUTION 1 (CONT'D)

**What do we get if we omit R1.rDate=R2.rDate?**

$\sigma_{R1.sailorId=R2.sailorId \wedge R1.boatId<>R2.boatId}$

| R1.sailorId | R1.boatId | R1.rDate | R2.sailorId | R2.boatId | R2.rDate |
|---|---|---|---|---|---|
| 22 | 101 | 10/10/17 | 22 | 102 | 10/10/17 |
| 22 | 101 | 10/10/17 | 22 | 103 | 08/10/17 |
| 22 | 101 | 10/10/17 | 22 | 104 | 07/10/17 |
| 22 | 102 | 10/10/17 | 22 | 101 | 10/10/17 |
| 22 | 102 | 10/10/17 | 22 | 103 | 08/10/17 |
| 22 | 102 | 10/10/17 | 22 | 104 | 07/10/17 |
| 22 | 103 | 08/10/17 | 22 | 101 | 10/10/17 |
| 22 | 103 | 08/10/17 | 22 | 102 | 10/10/17 |
| 22 | 103 | 08/10/17 | 22 | 104 | 07/10/17 |
| 22 | 104 | 07/10/17 | 22 | 101 | 10/10/17 |
| 22 | 104 | 07/10/17 | 22 | 102 | 10/10/17 |
| 22 | 104 | 07/10/17 | 22 | 103 | 08/10/17 |
| 31 | 102 | 10/11/17 | 31 | 103 | 06/11/17 |
| 31 | 102 | 10/11/17 | 31 | 104 | 12/11/17 |
| 31 | 103 | 06/11/17 | 31 | 102 | 10/11/17 |
| 31 | 103 | 06/11/17 | 31 | 104 | 12/11/17 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

Sailors who have made more than one reservation.

$\pi_{R1.sailorId}$ =

| sailorId |
|---|
| 22 |
| 31 |
| 64 |

# EXERCISE 6: SOLUTION 1 (CONT'D)

**What do we get if we omit R1.boatId<>R2.boatId?**

$\sigma_{R1.sailorId=R2.sailorId \wedge R1.rDate=R2.rDate}$

| R1.sailorId | R1.boatId | R1.rDate | R2.sailorId | R2.boatId | R2.rDate |
|---|---|---|---|---|---|
| 22 | 101 | 10/10/17 | 22 | 101 | 10/10/17 |
| 22 | 101 | 10/10/17 | 22 | 102 | 10/10/17 |
| 22 | 102 | 10/10/17 | 22 | 101 | 10/10/17 |
| 22 | 102 | 10/10/17 | 22 | 102 | 10/10/17 |
| 22 | 103 | 08/10/17 | 22 | 103 | 08/10/17 |
| 22 | 104 | 07/10/17 | 22 | 104 | 07/10/17 |
| 31 | 102 | 10/11/17 | 31 | 102 | 10/11/17 |
| 31 | 103 | 06/11/17 | 31 | 103 | 06/11/17 |
| 31 | 104 | 12/11/17 | 31 | 104 | 12/11/17 |
| 64 | 101 | 05/09/17 | 64 | 101 | 05/09/17 |
| 64 | 102 | 08/09/17 | 64 | 102 | 08/09/17 |
| 74 | 103 | 08/09/17 | 74 | 103 | 08/09/17 |
| 99 | 104 | 08/08/17 | 99 | 104 | 08/08/17 |

Sailors who have made at least one reservation.

$\pi_{R1.sailorId}$ =

| sailorId |
|---|
| 22 |
| 31 |
| 64 |
| 74 |
| 99 |