



# Getting Your Ducks In A Row

## Understanding ordered data flows

Daniel Hutmacher

(he/him)

Principal Consultant

Structured Concepts



# Daniel Hutmacher



Principal consultant  
Structured Concepts

 @dhmacher

 strd.co

 sqlsunday.com

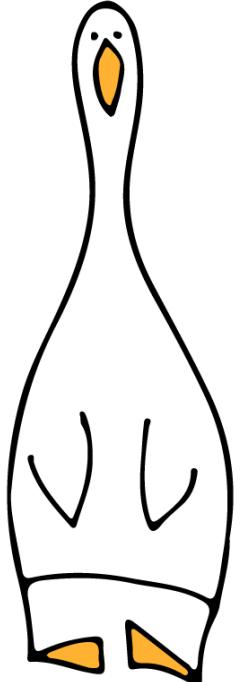
I'm a SQL Server consultant with over 20 years of experience.

Data Platform MVP, conference organizer, and blogger.

Big fan of travel, coffee, and dogs.

I live with my wonderful wife in Stockholm, Sweden.





# DISCLAIMER.

There will be simplifications.



# **HOW DATA IS STORED IN SQL SERVER.**

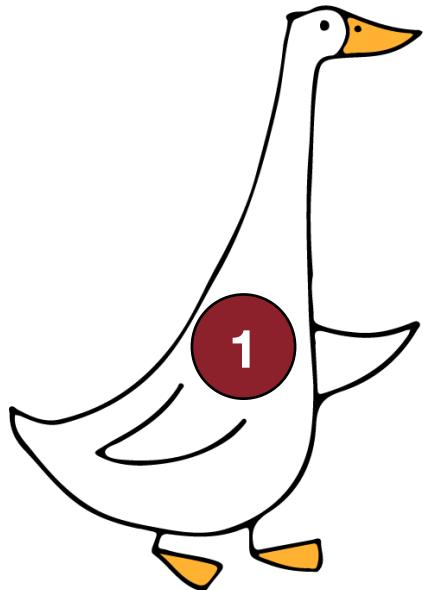


```
CREATE TABLE dbo.Ducks (
    ID          int NOT NULL,
    FirstName   varchar(100) NOT NULL,
    BirthDate   date NOT NULL,
    [Role]       varchar(100) NOT NULL
);

CREATE UNIQUE CLUSTERED INDEX PK_Ducks
    ON dbo.Ducks (ID);
```

```
CREATE TABLE dbo.Ducks (
    ID          int NOT NULL,
    FirstName   varchar(100) NOT NULL,
    BirthDate   date NOT NULL,
    [Role]      varchar(100) NOT NULL
);
```

```
CREATE UNIQUE CLUSTERED INDEX PK_Ducks
ON dbo.Ducks (ID);
```



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

**PAGE 1**



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

**2**

FirstName	BirthDate	Role
Donna	2018-11-14	Developer

**3**

FirstName	BirthDate	Role
Moby	2018-09-22	Accounting

**4**

FirstName	BirthDate	Role
Chuck	2018-08-14	QA

**5**

FirstName	BirthDate	Role
Arne	2019-07-04	Developer

A page can contain rows

**PAGE 1**



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

②

FirstName	BirthDate	Role
Donna	2018-11-14	Developer

③

FirstName	BirthDate	Role
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FirstName	BirthDate	Role
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⑤

FirstName	BirthDate	Role
Arne	2019-07-04	Developer

A page can contain rows  
and is about 8 kB.

**PAGE 1**



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

①

FirstName	BirthDate	Role
Donna	2018-11-14	Developer

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Moby	2018-09-22	Accounting

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FirstName	BirthDate	Role
Chuck	2018-08-14	QA

④

FirstName	BirthDate	Role
Arne	2019-07-04	Developer

⑤

**PAGE 2**

⑥

FirstName	BirthDate	Role
Plucky	2019-04-04	...

⑦

FirstName	BirthDate	Role
Scrooge	2016-01-14	...

⑧

FirstName	BirthDate	Role
Daisy	2018-09-12	...

⑨

FirstName	BirthDate	Role
Doofus	2017-07-14	...

⑩

FirstName	BirthDate	Role
Angus	2017-02-11	...

## PAGE 1



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

②

FirstName	BirthDate	Role
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FirstName	BirthDate	Role
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FirstName	BirthDate	Role
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FirstName	BirthDate	Role
Arne	2019-07-04	Developer

## PAGE 2

⑥

FirstName	BirthDate	Role
Plucky	2019-04-04	...

⑦

FirstName	BirthDate	Role
Scrooge	2016-01-14	...

⑧

FirstName	BirthDate	Role
Daisy	2018-09-12	...

⑨

FirstName	BirthDate	Role
Doofus	2017-07-14	...

⑩

FirstName	BirthDate	Role
Angus	2017-02-11	...

## PAGE 3

⑪

FirstName	BirthDate	Role
Bubba	2017-02-14	...

⑫

FirstName	BirthDate	Role
Phooey	2018-10-10	...

⑬

FirstName	BirthDate	Role
Huey	2017-12-31	...

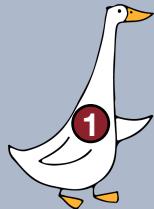
⑭

FirstName	BirthDate	Role
Dewey	2017-12-07	...

⑮

FirstName	BirthDate	Role
Louie	2019-01-02	...

**PAGE 1**



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

②

FirstName	BirthDate	Role
Donna	2018-11-14	Developer

③

FirstName	BirthDate	Role
Moby	2018-09-22	Accounting

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FirstName	BirthDate	Role
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FirstName	BirthDate	Role
Arne	2019-07-04	Developer

**PAGE 2**

⑥

FirstName	BirthDate	Role
Plucky	2019-04-04	...

⑦

FirstName	BirthDate	Role
Scrooge	2016-01-14	...

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FirstName	BirthDate	Role
Daisy	2018-09-12	...

⑨

FirstName	BirthDate	Role
Doofus	2017-07-14	...

⑩

FirstName	BirthDate	Role
Angus	2017-02-11	...

**PAGE 3**

⑪

FirstName	BirthDate	Role
Bubba	2017-02-14	...

⑫

FirstName	BirthDate	Role
Phooey	2018-10-10	...

⑬

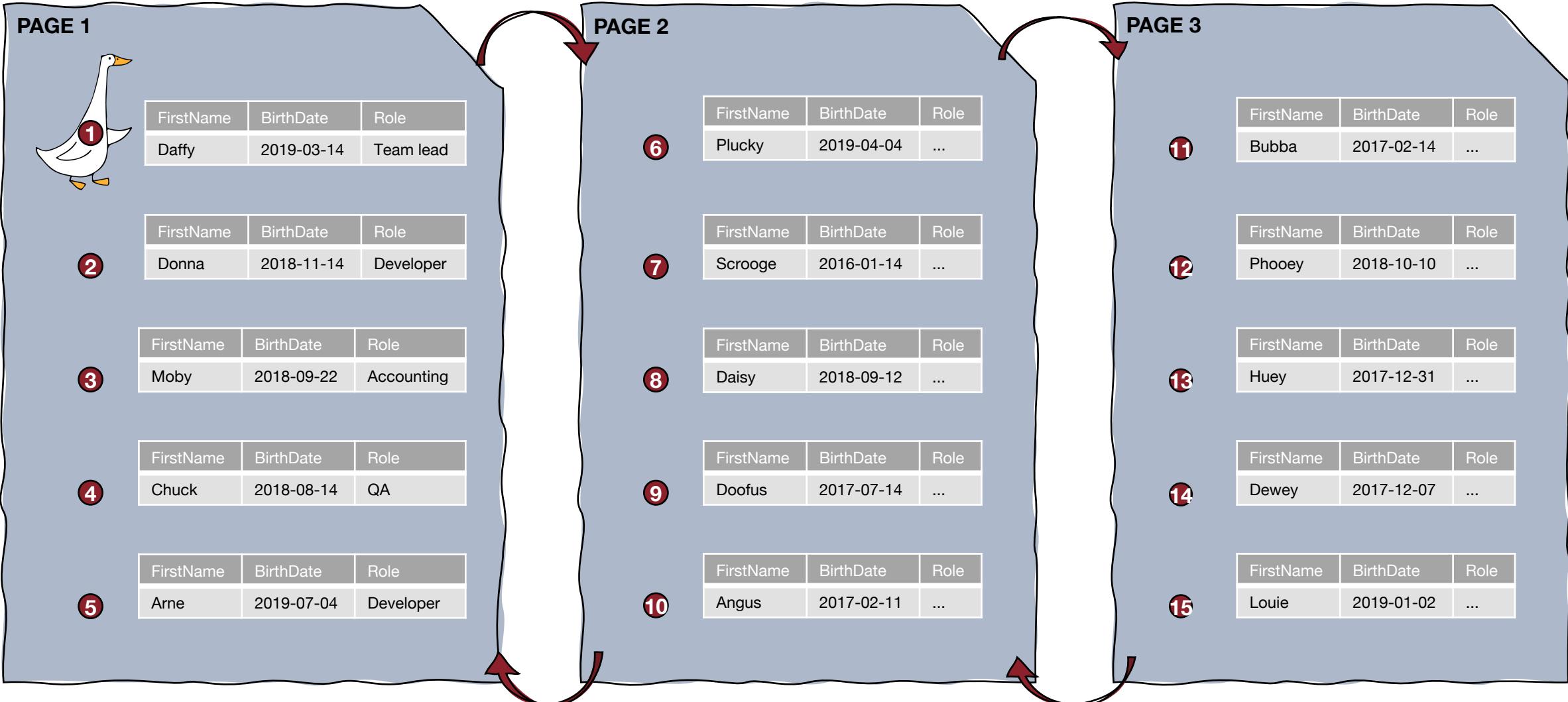
FirstName	BirthDate	Role
Huey	2017-12-31	...

⑭

FirstName	BirthDate	Role
Dewey	2017-12-07	...

⑮

FirstName	BirthDate	Role
Louie	2019-01-02	...



PAGE 1



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④

FirstName	BirthDate	Role
Chuck	2018-08-14	QA

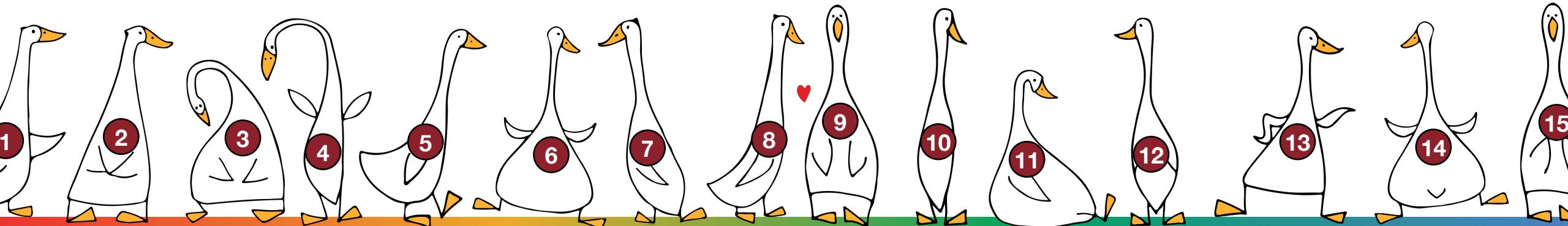
⑤

FirstName	BirthDate	Role
Arne	2019-07-04	Developer

A [rowstore] table can exist as a heap or as a clustered index.

# CLUSTERED INDEX.

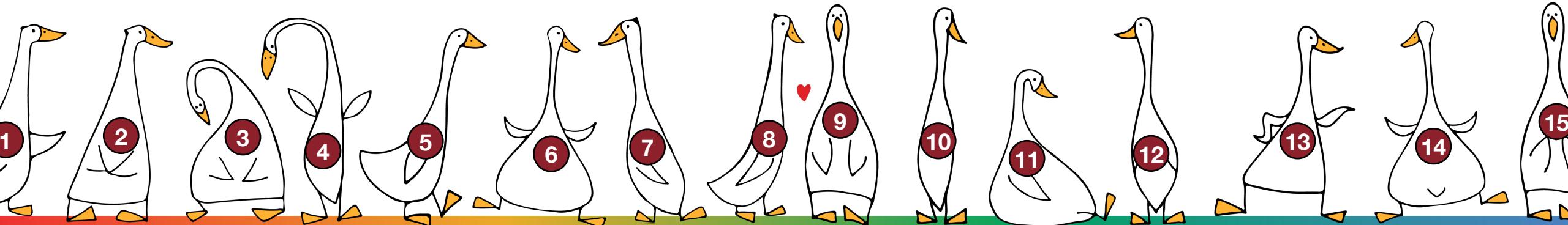
A clustered index is stored in sequential order, using its clustering key.

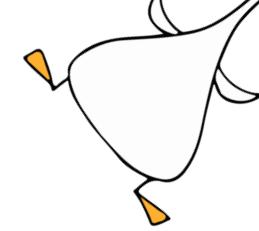


# CLUSTERED INDEX.

A clustered index is stored in sequential order, using its clustering key.

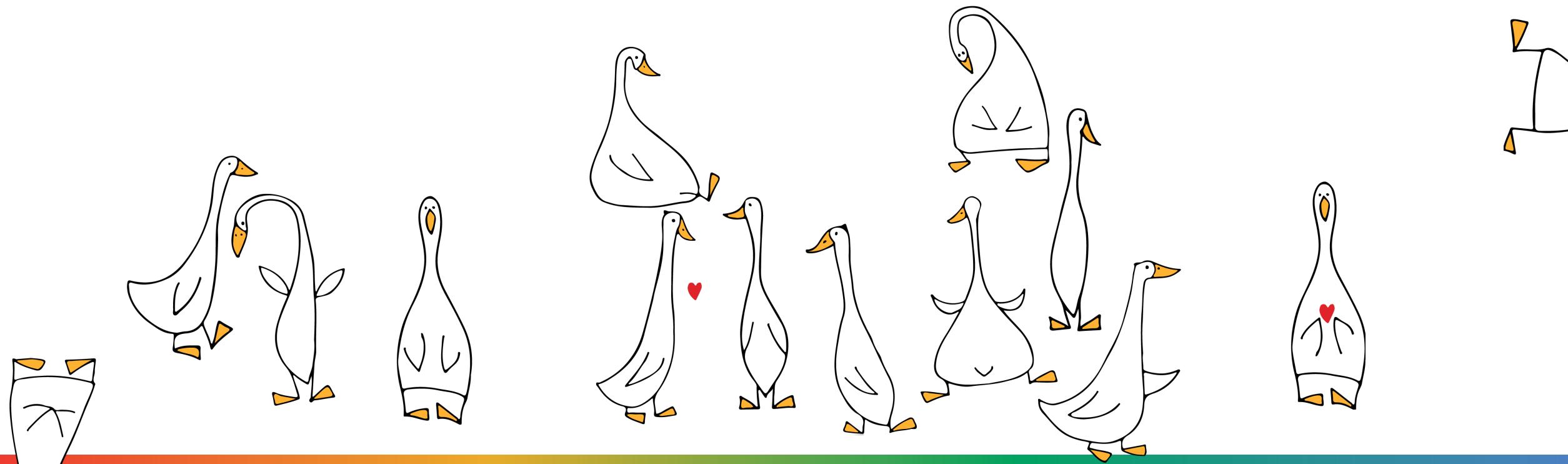
The clustered index *is* the table.

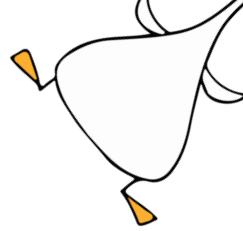




# HEAP.

A table when you don't have a clustered index.

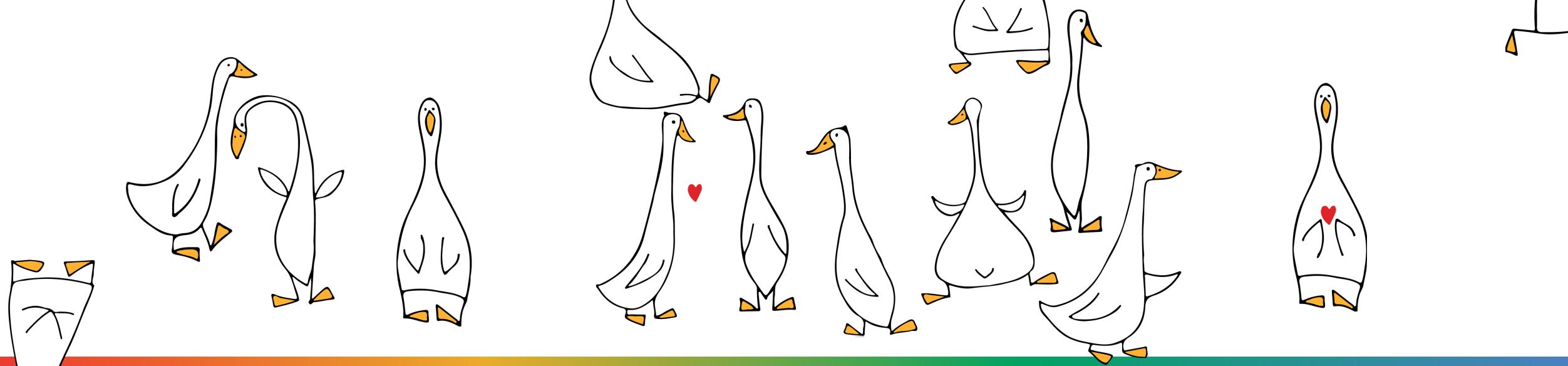




# HEAP.

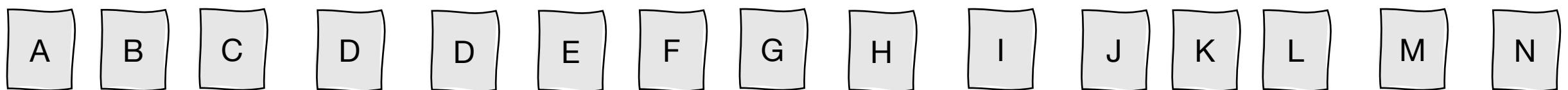
A table when you don't have a clustered index.

Also stored in pages, but *in no particular order*.



# NON-CLUSTERED INDEX.

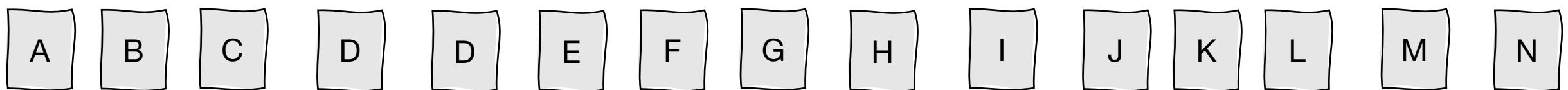
A subset of the clustered index.



# NON-CLUSTERED INDEX.

A subset of the clustered index.

Ordered by the *index key*, not the clustering key.

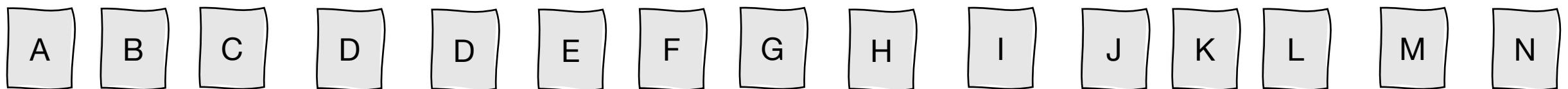


# NON-CLUSTERED INDEX.

A subset of the clustered index.

Ordered by the *index key*, not the clustering key.

Also stored in pages.



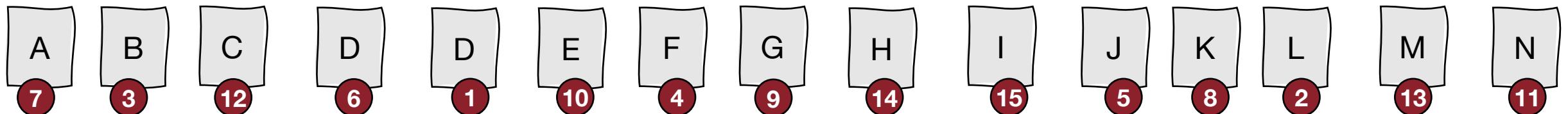
# NON-CLUSTERED INDEX.

A subset of the clustered index.

Ordered by the *index key*, not the clustering key.

Also stored in pages.

Also contains the clustering key.



## CLUSTERED INDEX (ID)

PAGE 1



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

②

FirstName	BirthDate	Role
Donna	2018-11-14	Developer

③

FirstName	BirthDate	Role
Moby	2018-09-22	Accounting

④

FirstName	BirthDate	Role
Chuck	2018-08-14	QA

⑤

FirstName	BirthDate	Role
Arne	2019-07-04	Developer

## NONCLUSTERED INDEX (FirstName)

PAGE 4

FirstName
Angus

⑩

FirstName
Arne

⑤

FirstName
Bubba

⑪

FirstName
Chuck

④

FirstName
Daffy

①

FirstName
Huey

⑬

FirstName
Daisy

⑧

FirstName
-----------

⑭

FirstName
-----------

②

FirstName
-----------

⑨

FirstName
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⑬

FirstName
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⑯

FirstName
-----------

③

FirstName
-----------

⑫

FirstName
-----------

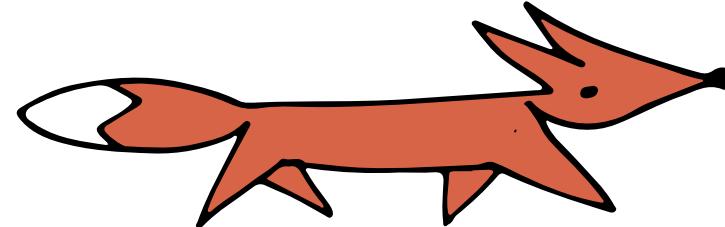
⑦

FirstName
-----------

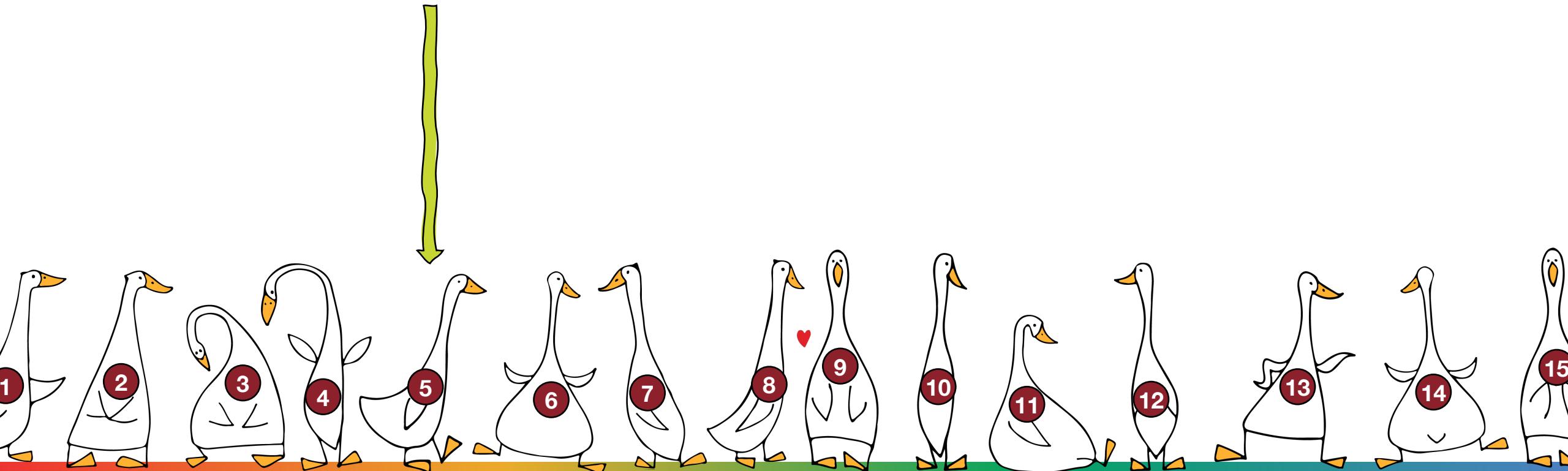
⑥



# SCANS AND SEEKS.



Index Seek



# Clustered index

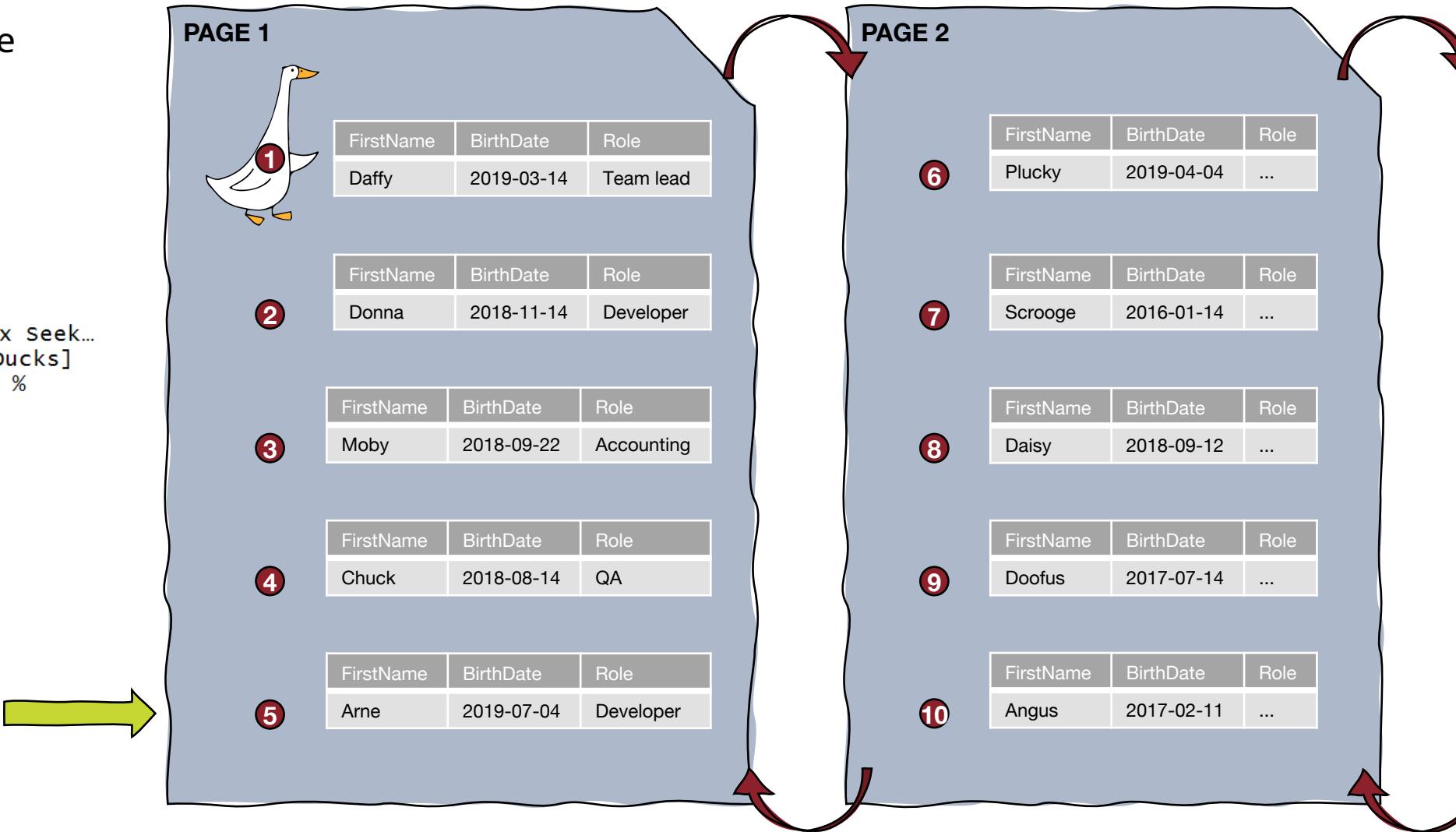
## CLUSTERED INDEX (ID)

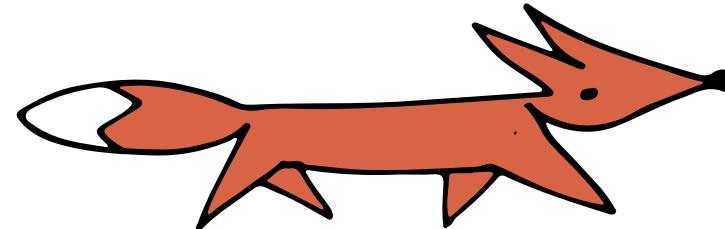
```
SELECT ID, FirstName
FROM dbo.Ducks
WHERE ID=5;
```

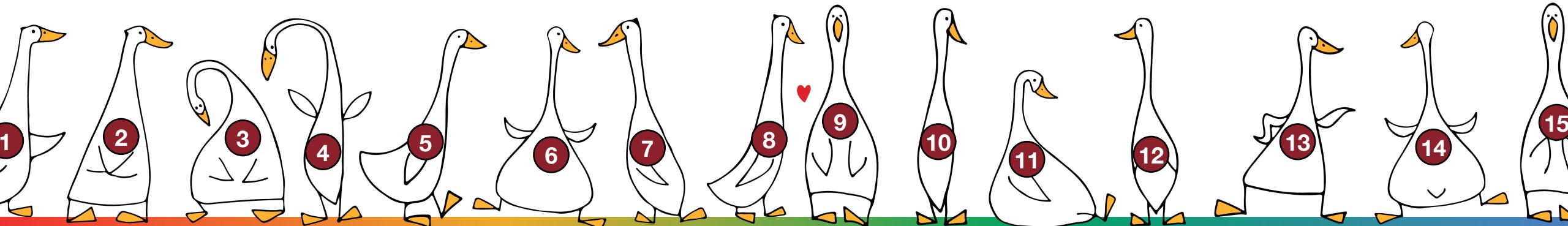
SELECT  
Cost: 0 %

Clustered Index Seek...  
[Ducks].[PK\_Ducks]  
Cost: 100 %





## Index Seek (Range Scan)



# Clustered index

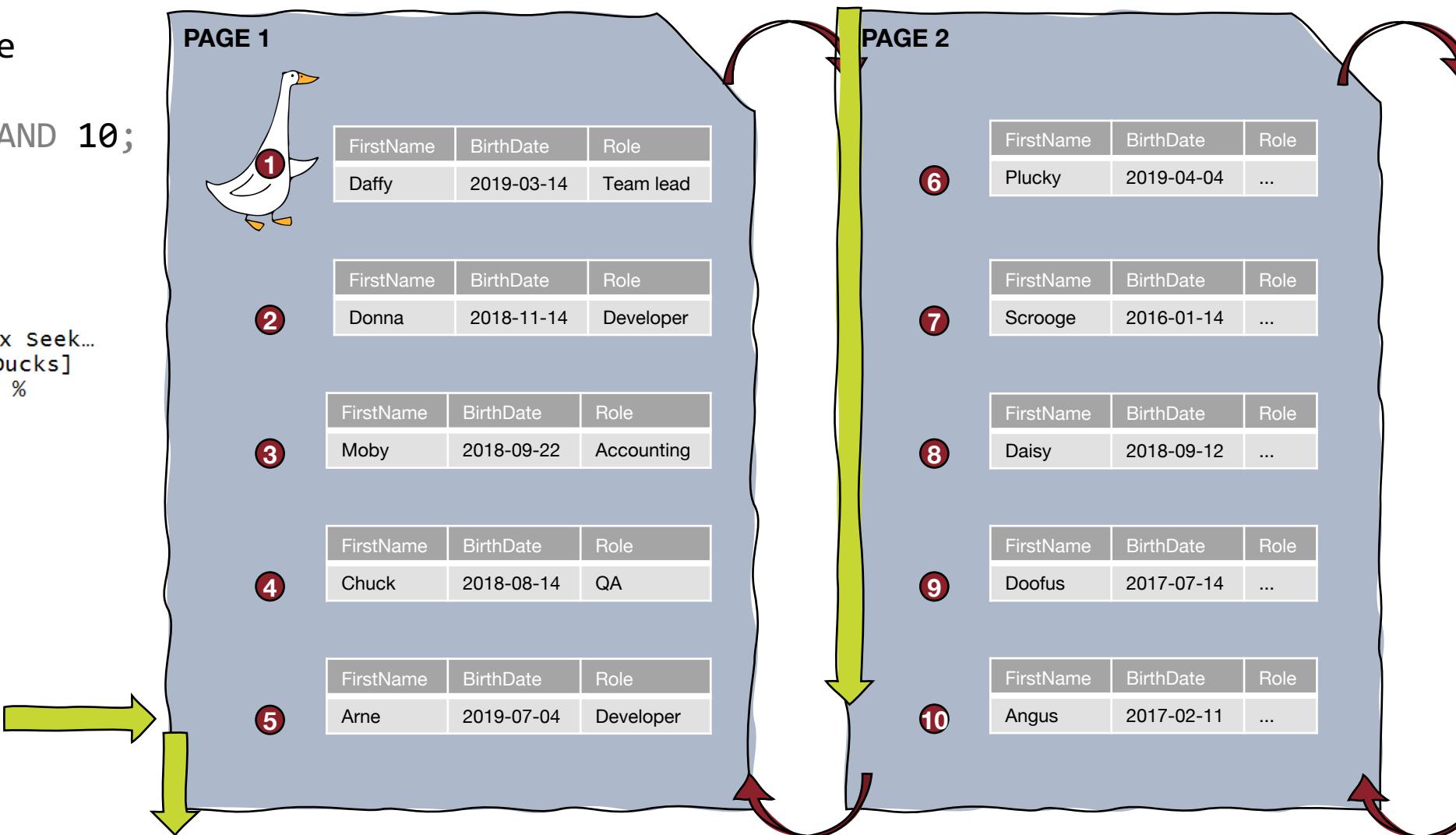
## CLUSTERED INDEX (ID)

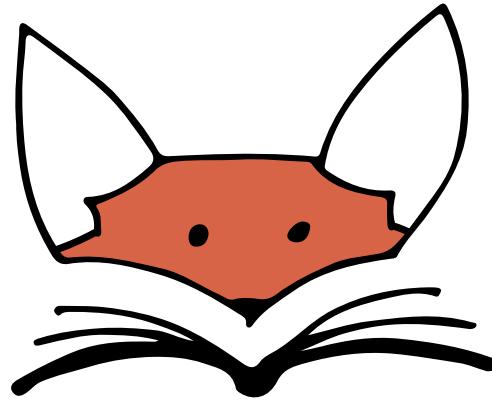
```
SELECT ID, FirstName
FROM dbo.Ducks
WHERE ID BETWEEN 5 AND 10;
```

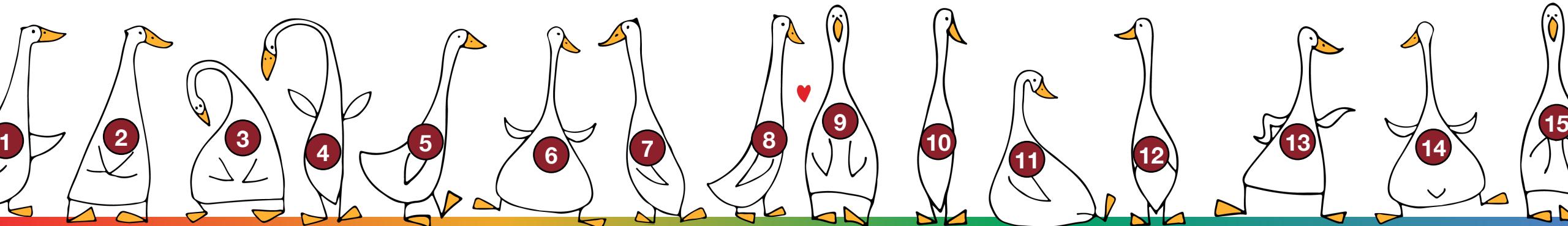
SELECT  
Cost: 0 %

clustered Index Seek...  
[Ducks].[PK\_Ducks]  
Cost: 100 %





## Index Scan



# Non-clustered index

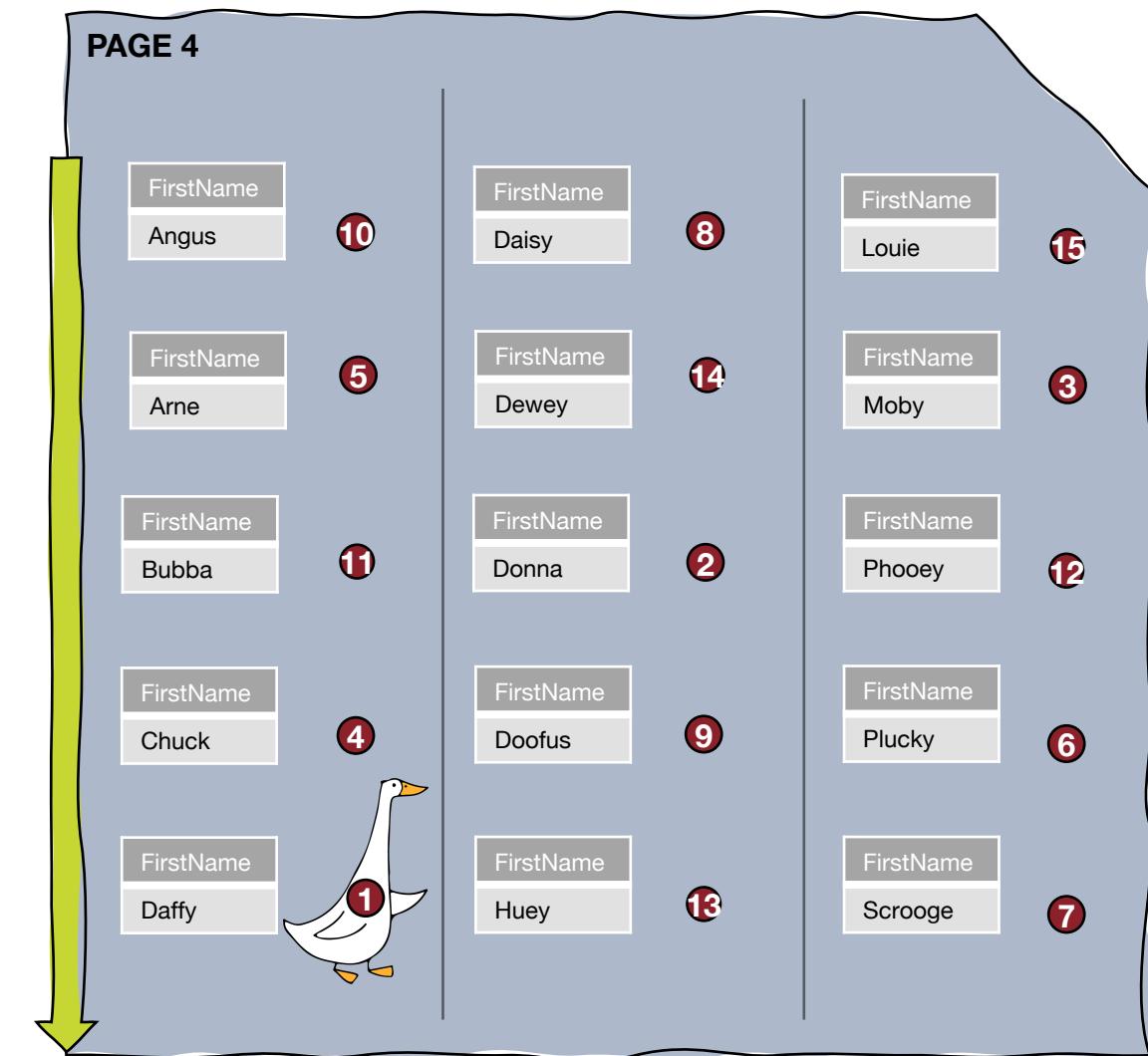
NONCLUSTERED INDEX (FirstName)

```
SELECT ID, FirstName
FROM dbo.Ducks;
```

```
 SELECT
Cost: 0 %
```

←  Index Scan (Nonclustered)
[ Ducks ]. [ Ducks\_FirstN... ]

```
Cost: 100 %
```

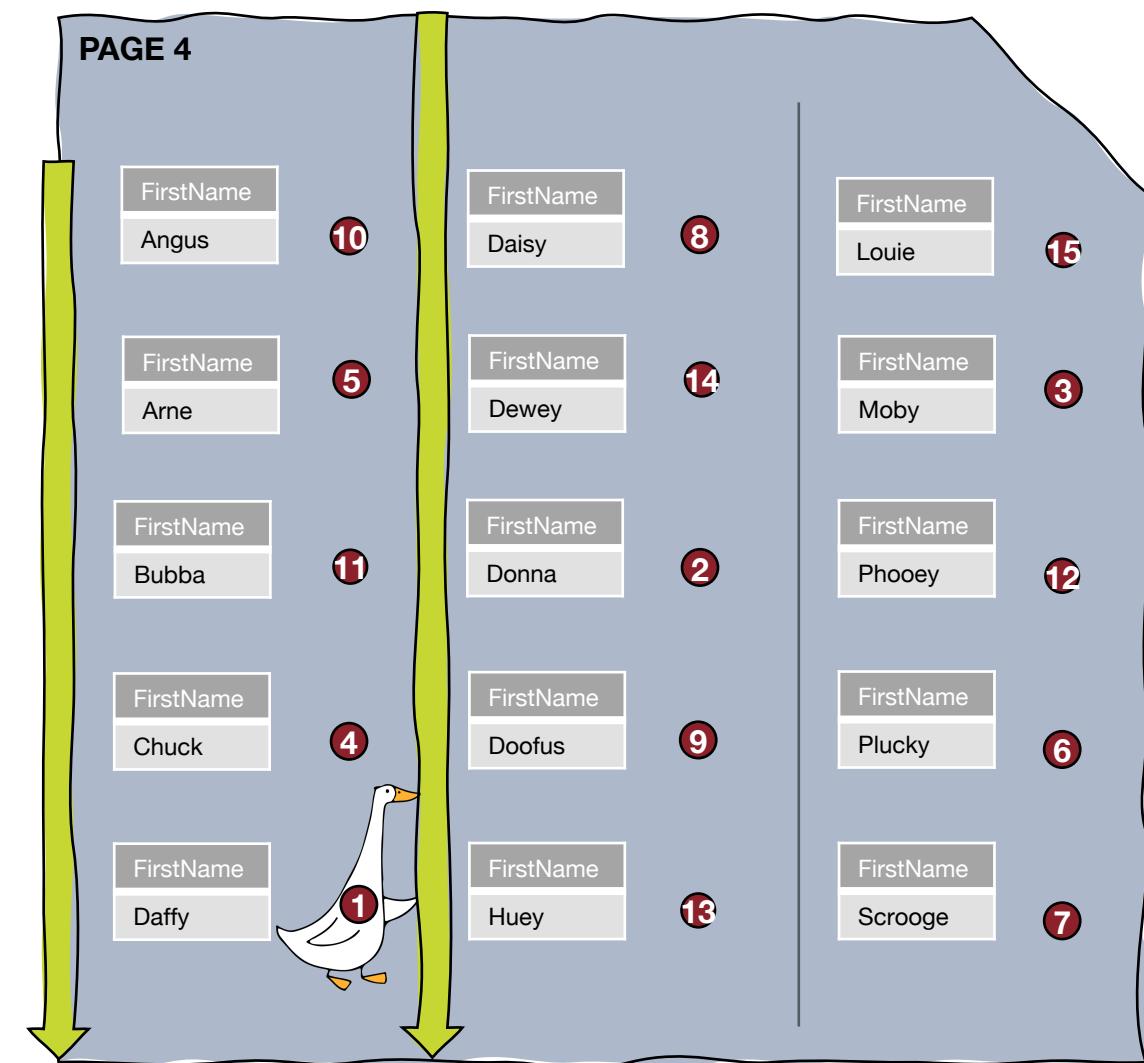


# Non-clustered index

NONCLUSTERED INDEX (FirstName)

```
SELECT ID, FirstName
FROM dbo.Ducks;
```

```
 SELECT
Cost: 0 %
 Index Scan (Nonclustered)
[ Ducks ]. [ Ducks_FirstN...
Cost: 100 %
```

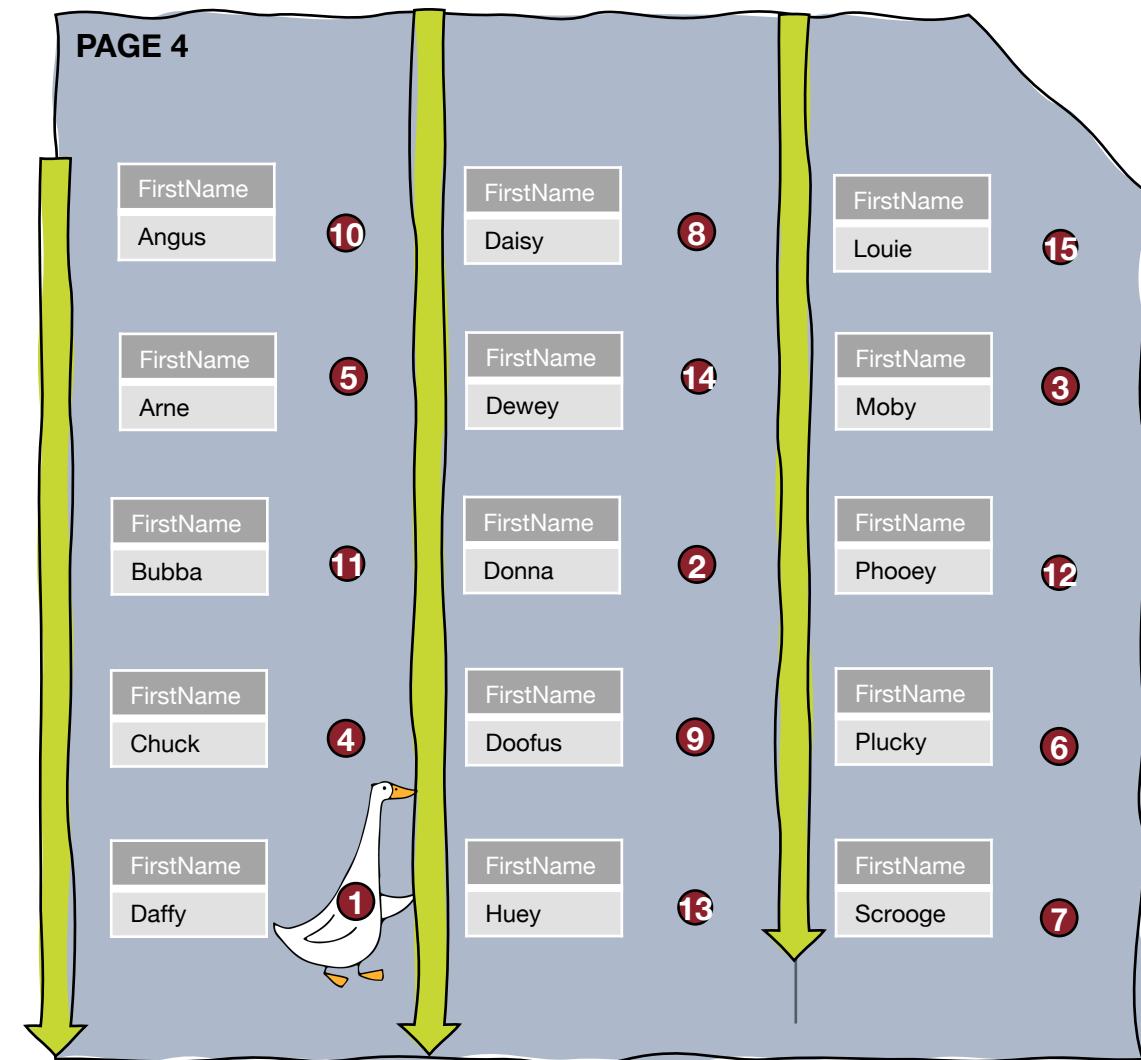


# Non-clustered index

## NONCLUSTERED INDEX (FirstName)

```
SELECT ID, FirstName
FROM dbo.Ducks;
```

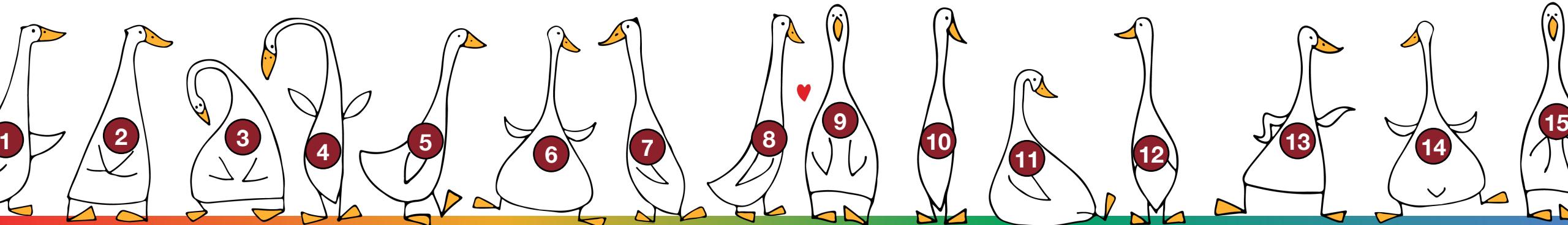
```
 SELECT Cost: 0 %
 Index Scan (Nonclustered)
[ Ducks ]. [ Ducks_FirstName ]
Cost: 100 %
```



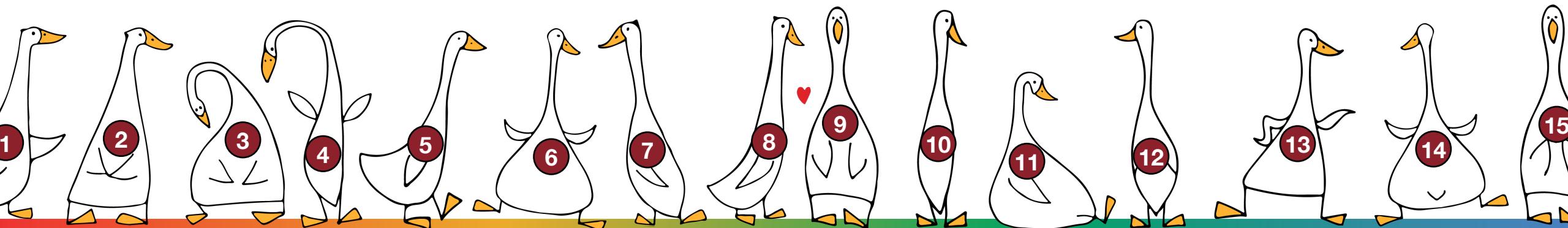


# SARGABILITY.

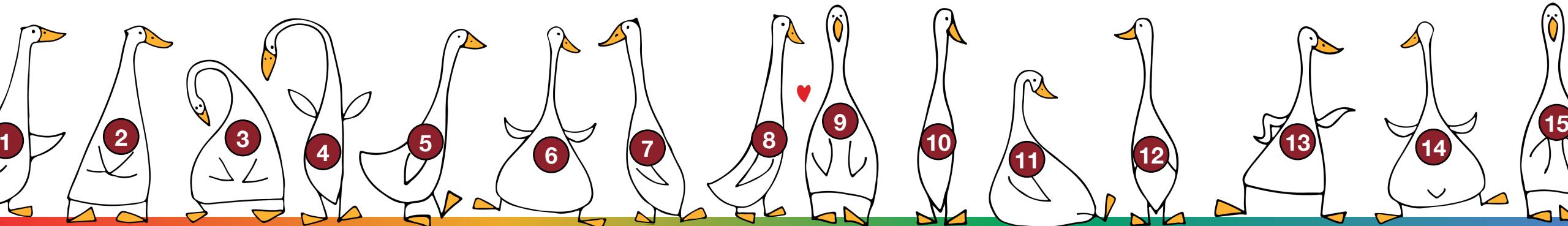
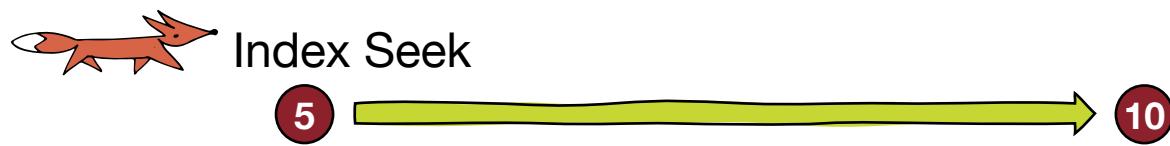
WHERE ID BETWEEN 5 AND 10



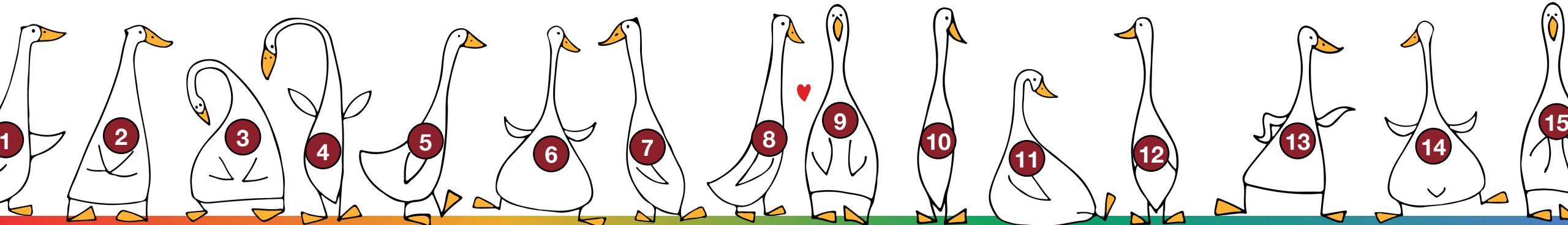
WHERE ID BETWEEN 5 AND 10



WHERE ID BETWEEN 5 AND 10



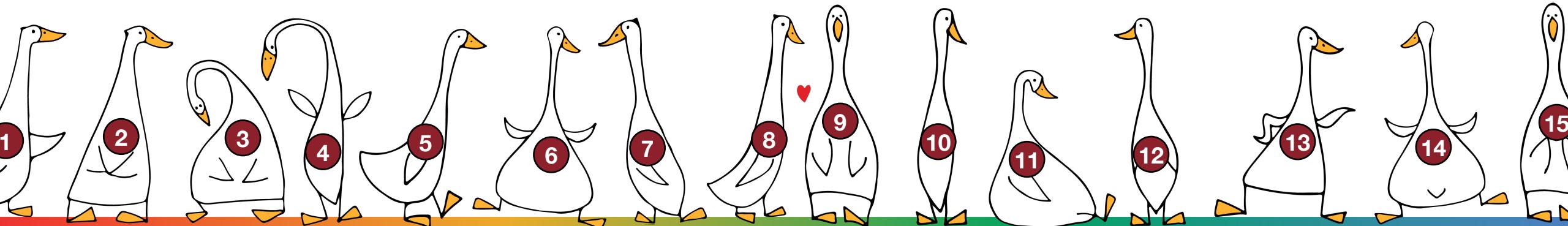
WHERE ID BETWEEN SQRT(25) AND SQRT(100)



WHERE ID BETWEEN SQRT(25) AND SQRT(100)

$$\sqrt{25} = 5$$

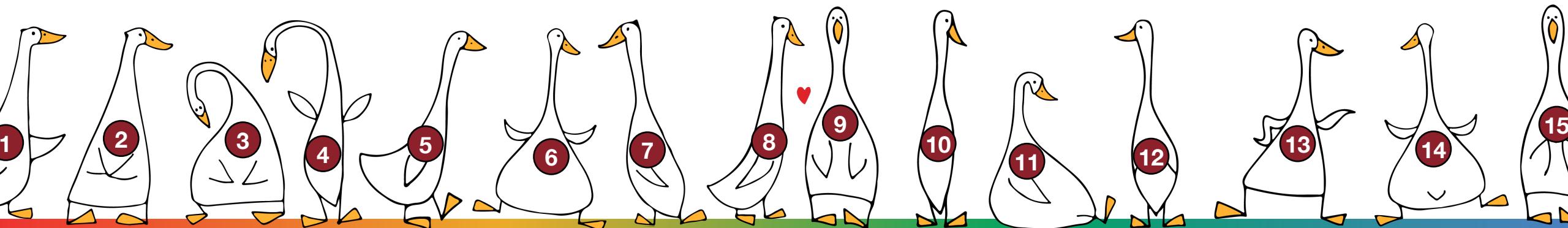
$$\sqrt{100} = 10$$



WHERE ID BETWEEN SQRT(25) AND SQRT(100)

$$\sqrt{25} = 5$$

$$\sqrt{100} = 10$$



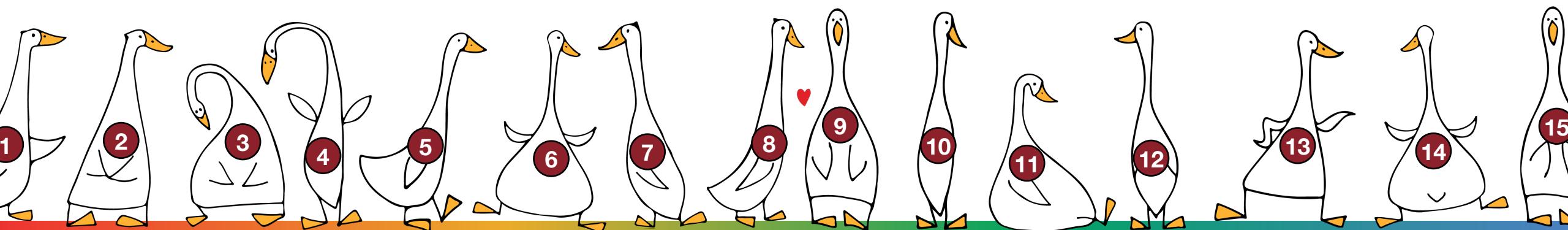
WHERE ID BETWEEN  $\text{SQRT}(25)$  AND  $\text{SQRT}(100)$

$$\sqrt{25} = 5$$

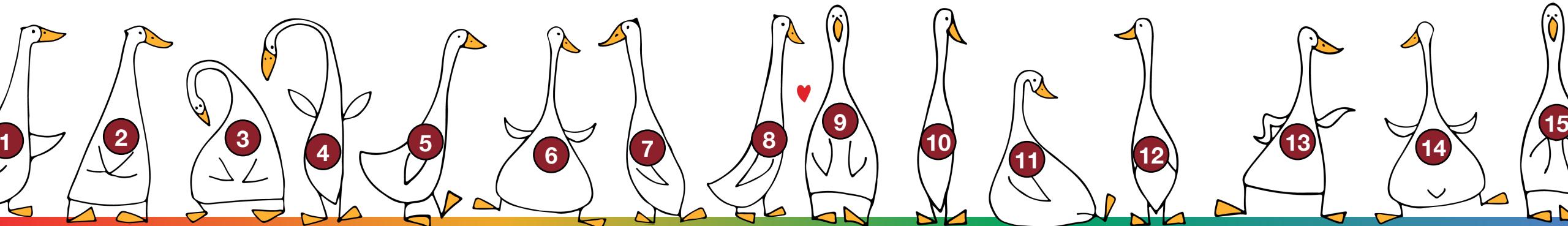
$$\sqrt{100} = 10$$



Index Seek



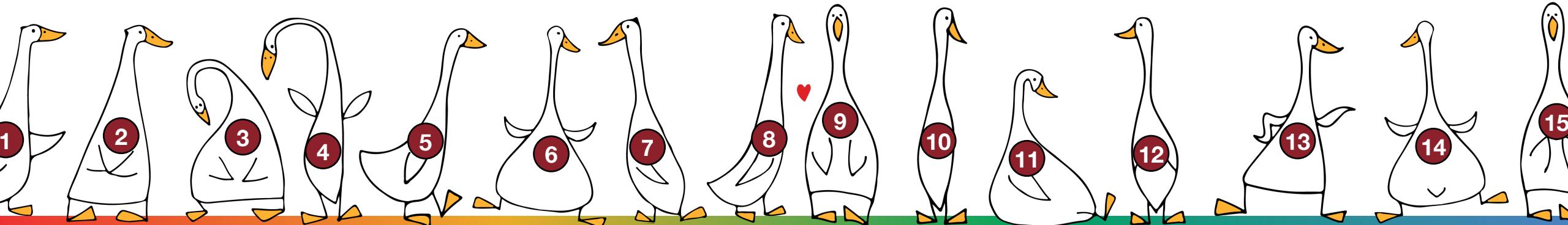
WHERE POWER(ID, 2) BETWEEN 25 AND 100



WHERE POWER(ID, 2) BETWEEN 25 AND 100

No, 1 is not between 25 and 100.

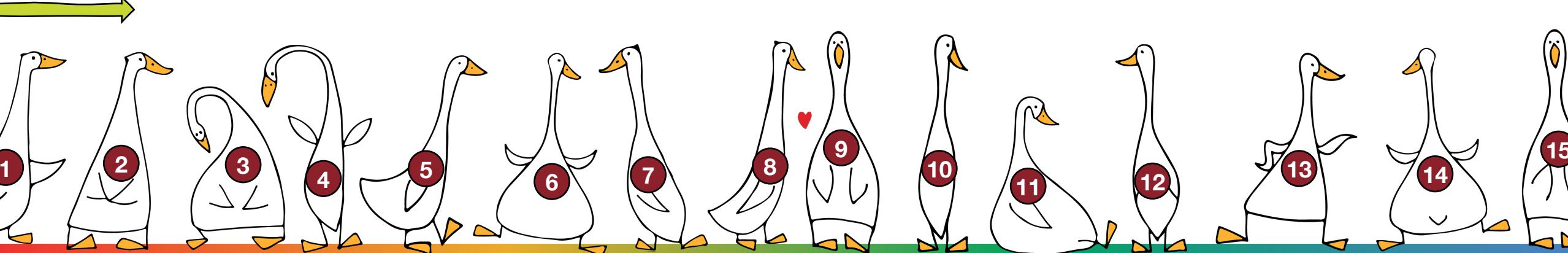
$$1^2=1$$



WHERE POWER(ID, 2) BETWEEN 25 AND 100

No

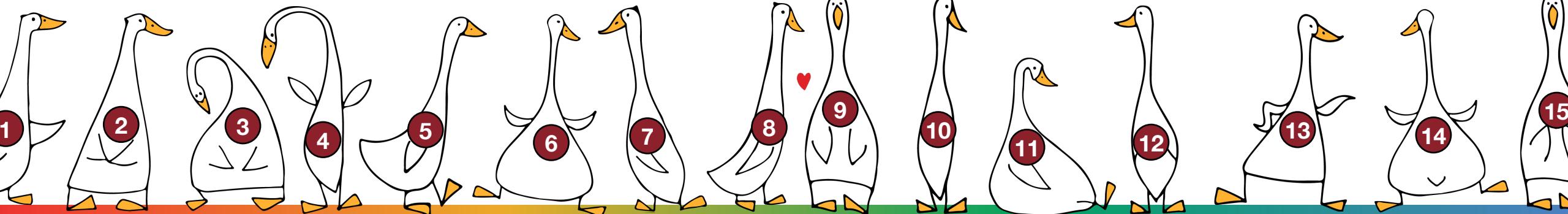
$$2^2=4$$



WHERE POWER(ID, 2) BETWEEN 25 AND 100

No

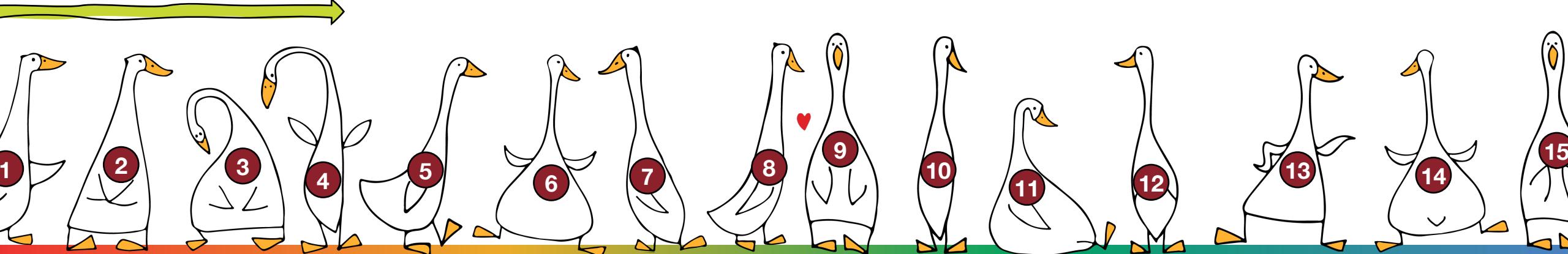
$$3^2=9$$



WHERE POWER(ID, 2) BETWEEN 25 AND 100

Still no

$$4^2=16$$

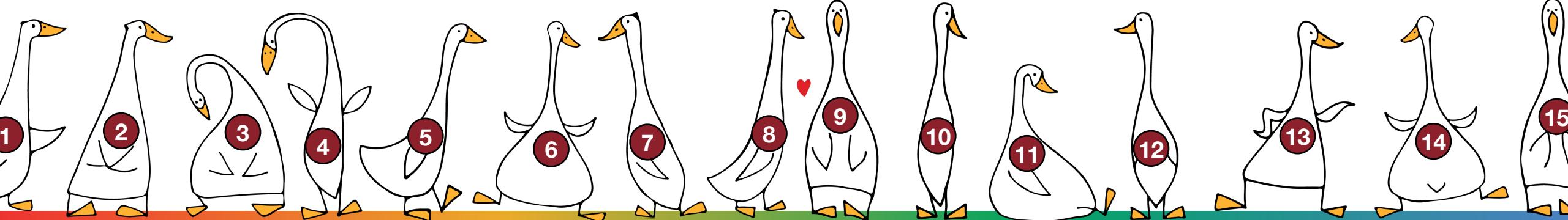


WHERE POWER(ID, 2) BETWEEN 25 AND 100

Yes

$$5^2=25$$

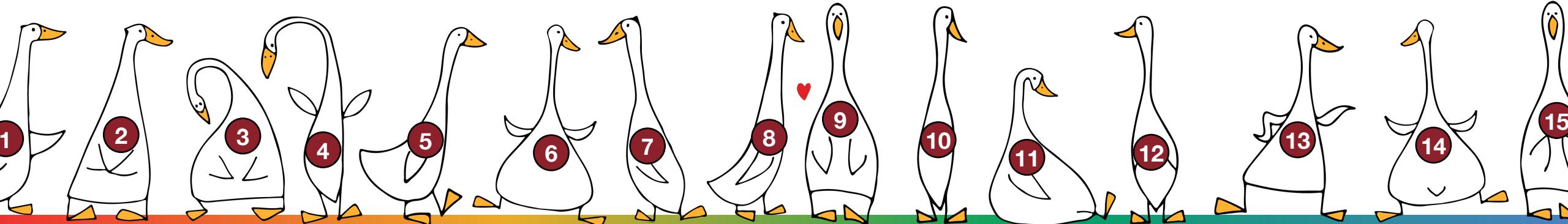
5



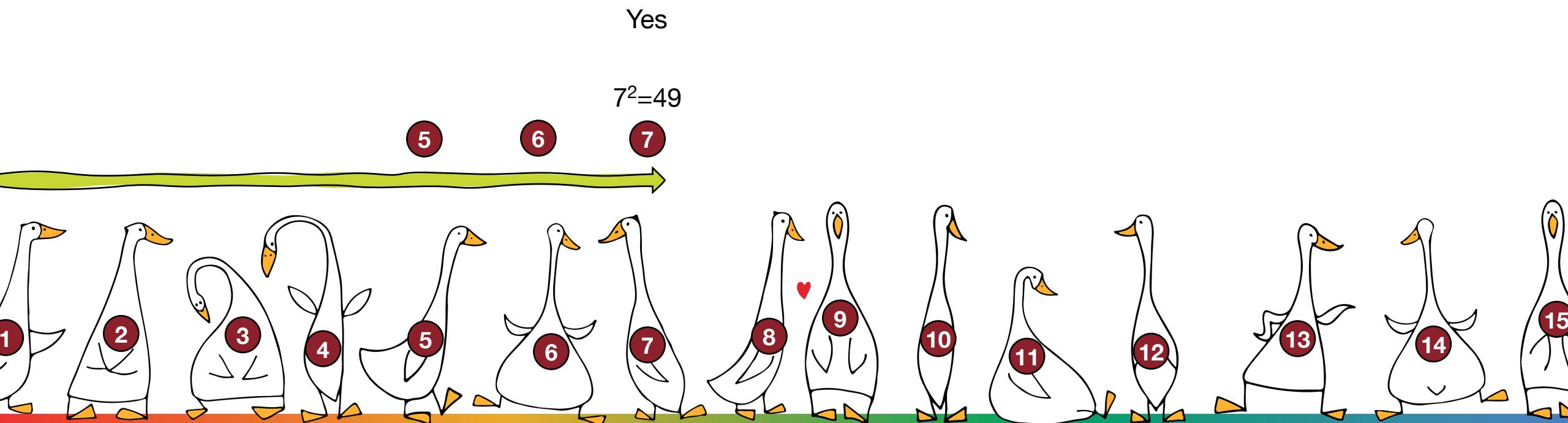
WHERE POWER(ID, 2) BETWEEN 25 AND 100

Yes

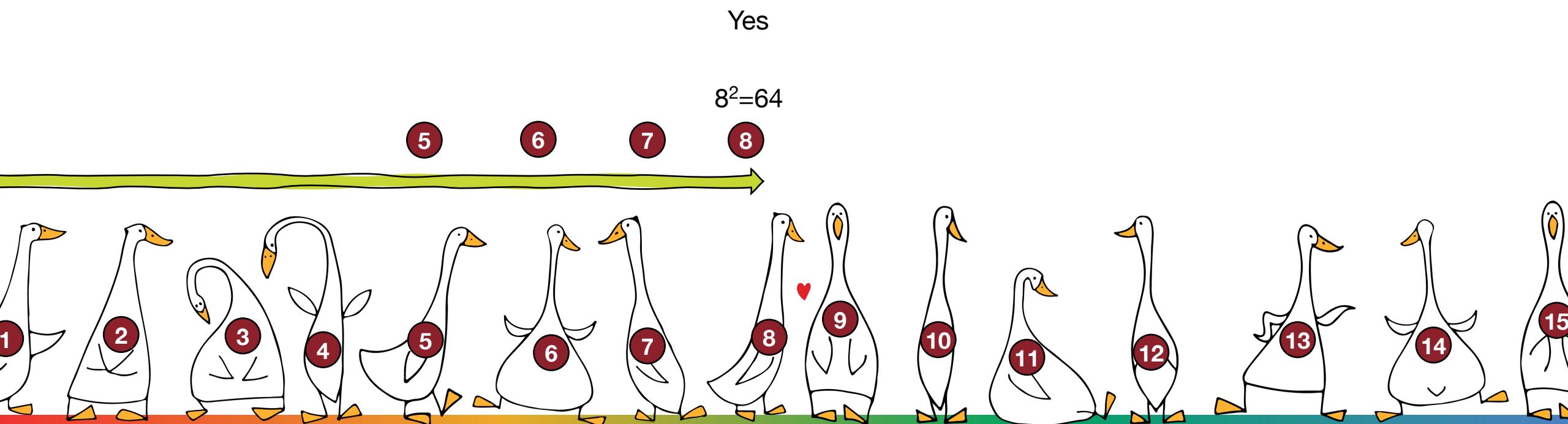
$$6^2=36$$



WHERE POWER(ID, 2) BETWEEN 25 AND 100



WHERE POWER(ID, 2) BETWEEN 25 AND 100



WHERE POWER(ID, 2) BETWEEN 25 AND 100



Index Scan

Yes

$$9^2=81$$

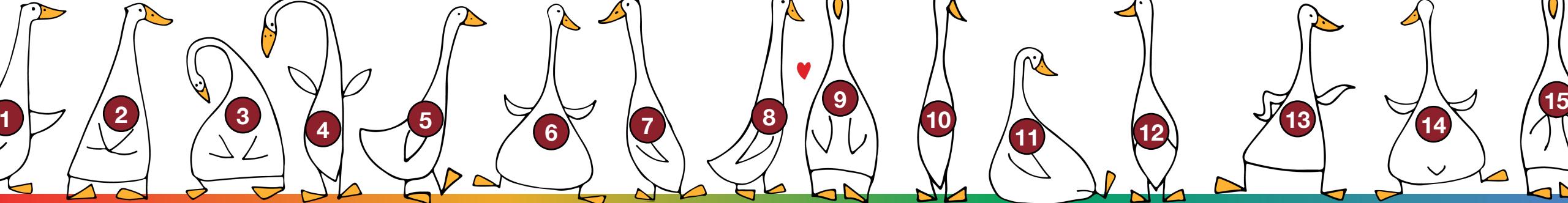
5

6

7

8

9



WHERE POWER(ID, 2) BETWEEN 25 AND 100



Index Scan

Yes

$$10^2=100$$

5

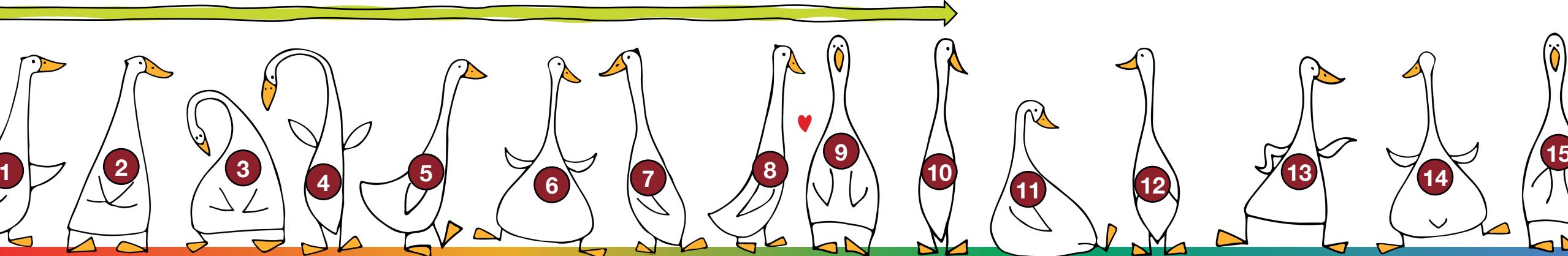
6

7

8

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10



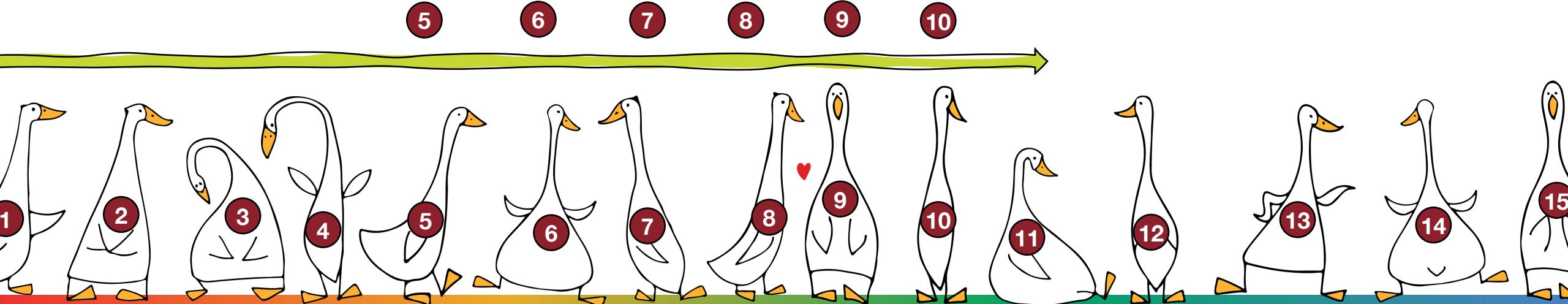
WHERE POWER(ID, 2) BETWEEN 25 AND 100



Index Scan

No

$$11^2=121$$



WHERE POWER(ID, 2) BETWEEN 25 AND 100



Index Scan

No

$$12^2=144$$

5

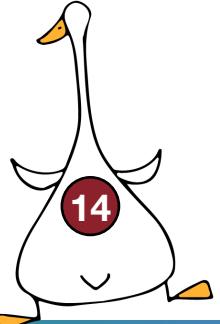
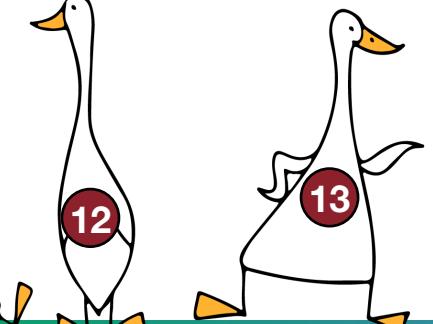
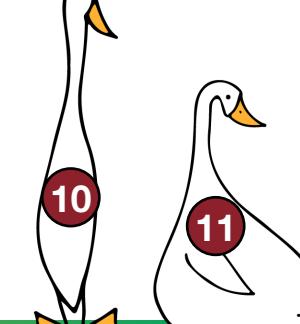
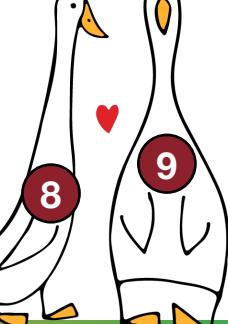
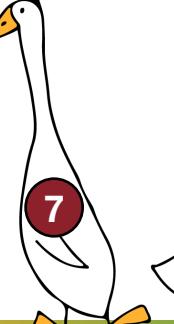
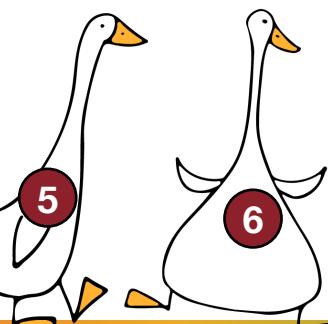
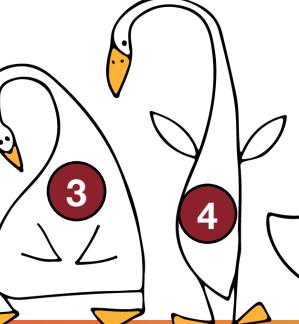
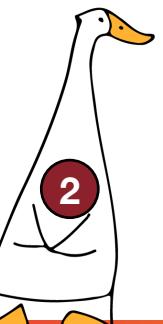
6

7

8

9

10



3

4

5

6

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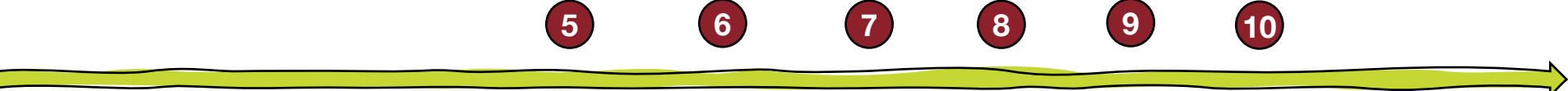
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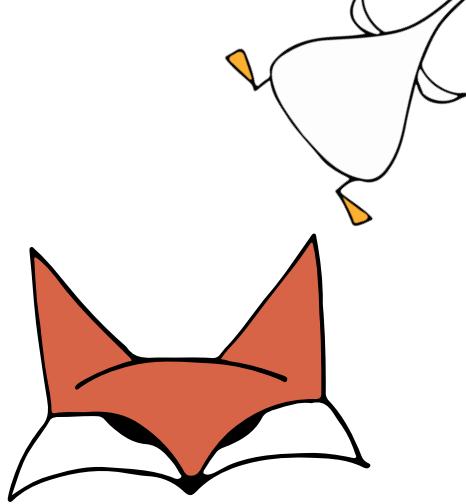
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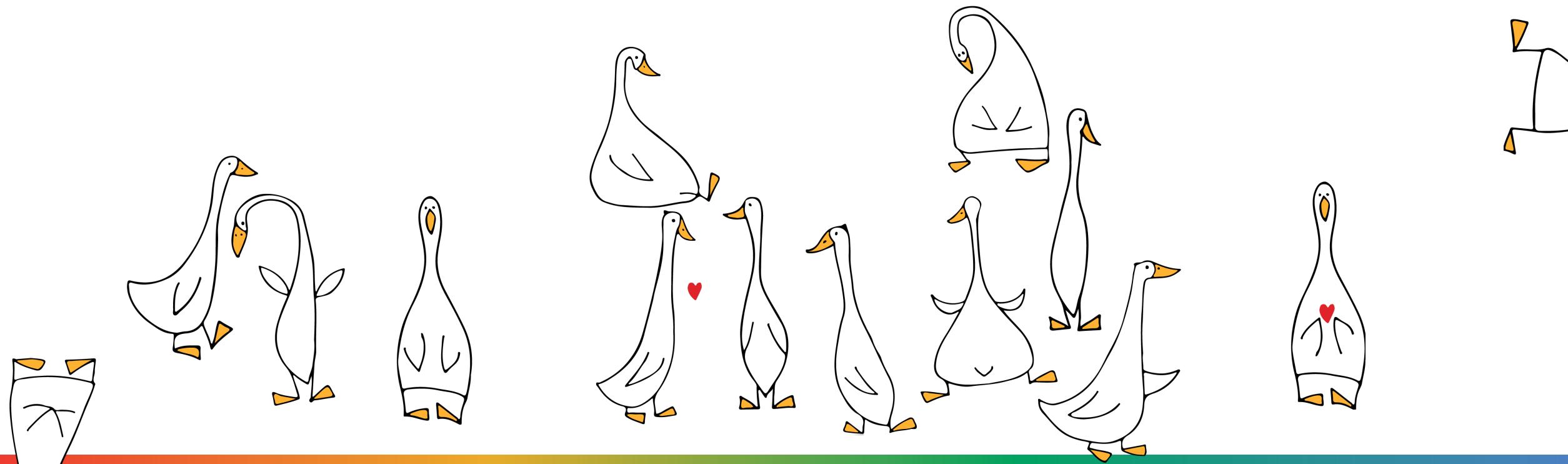
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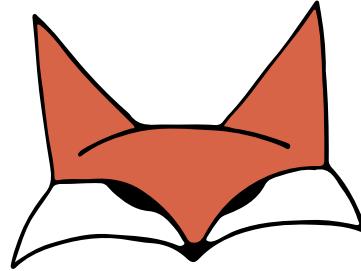
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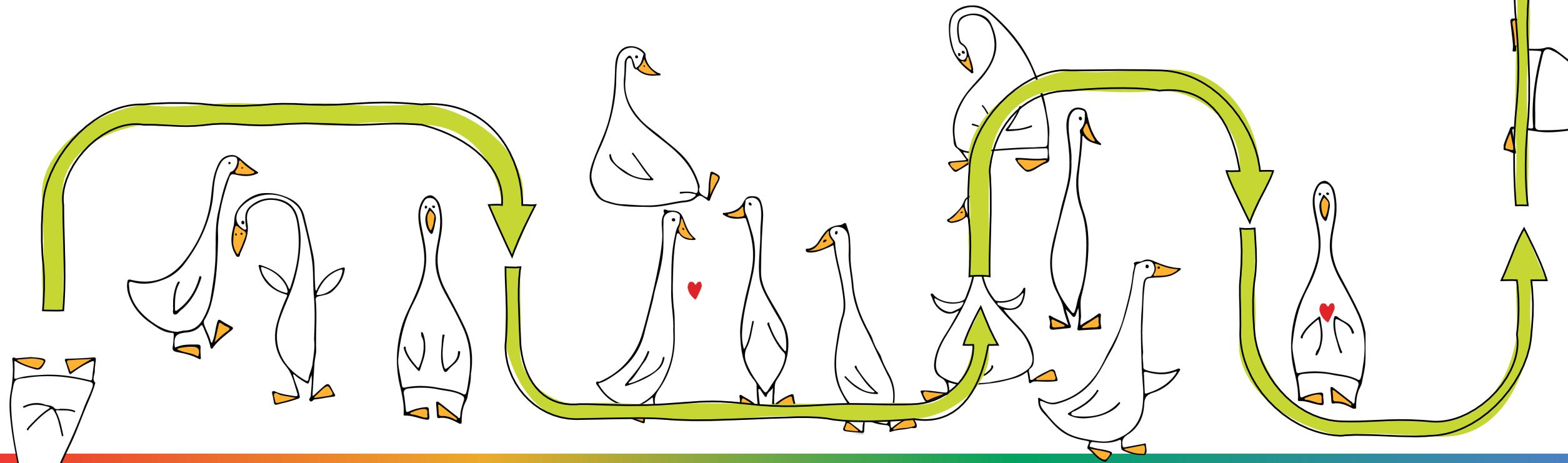


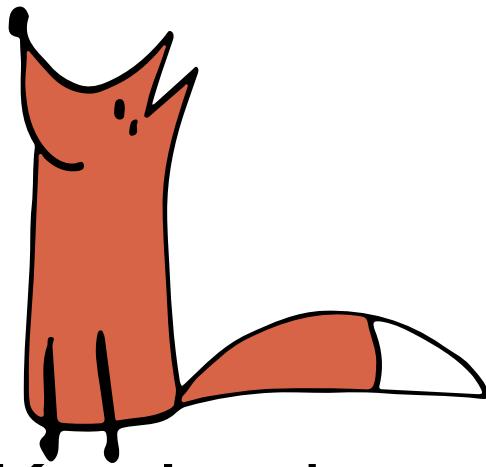
## Table Scan



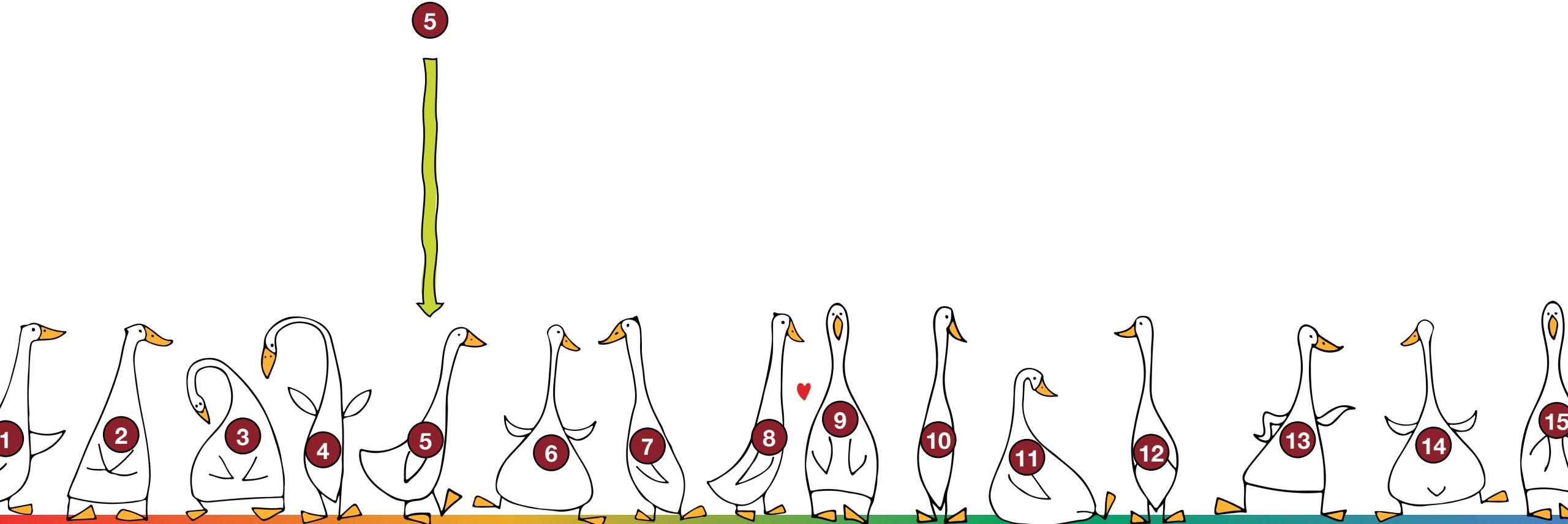


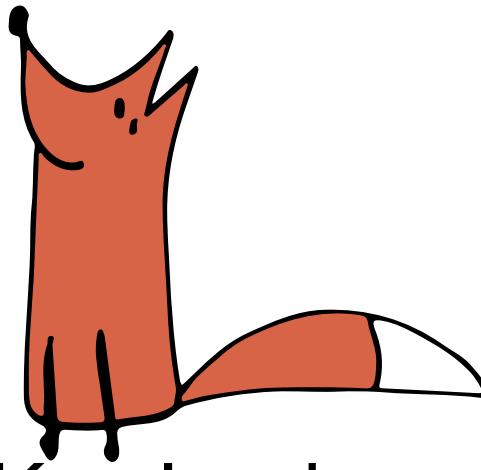
## Table Scan



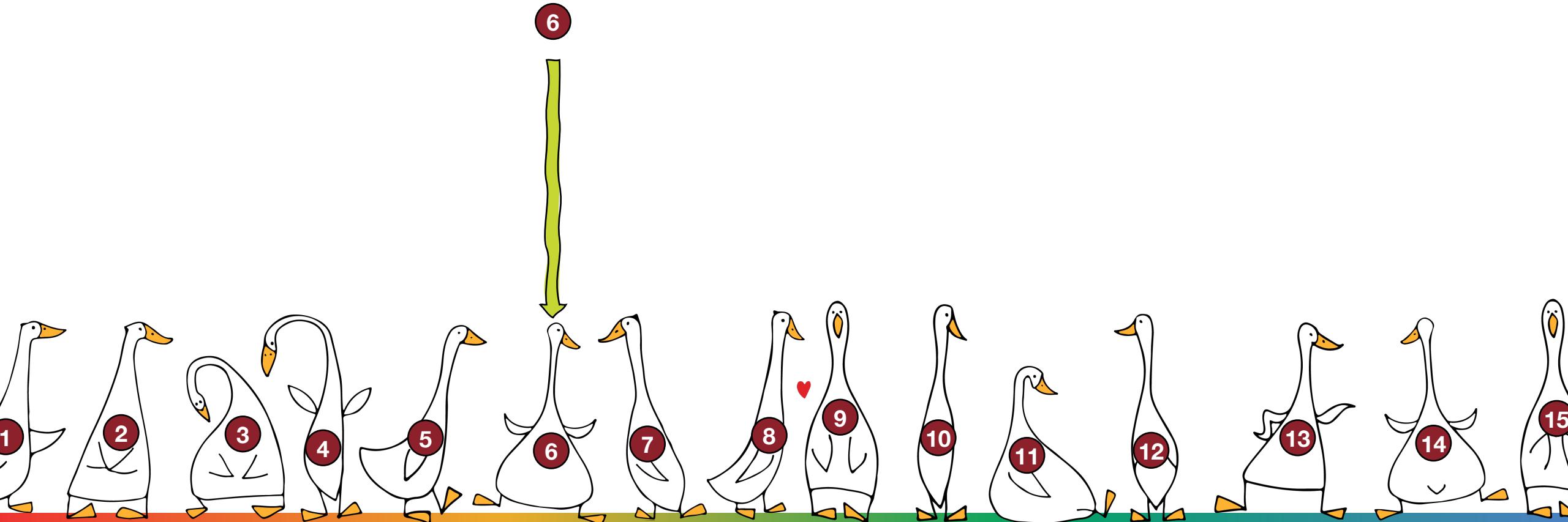


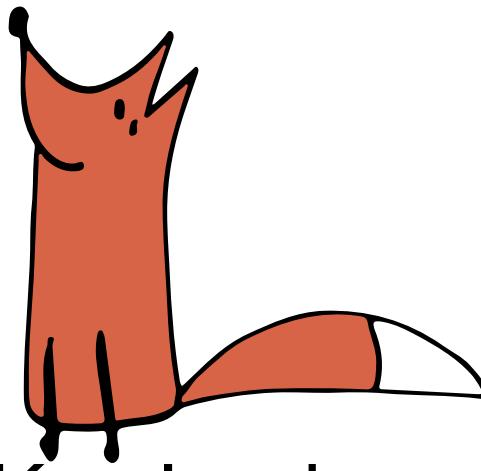
## Key Lookup



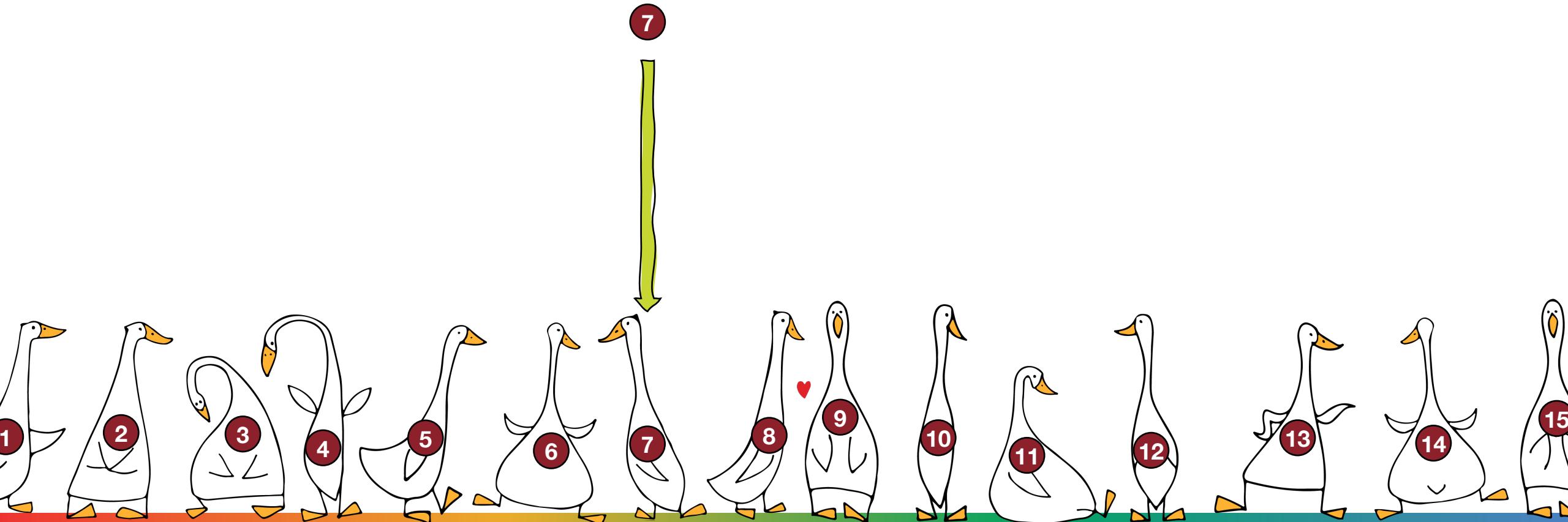


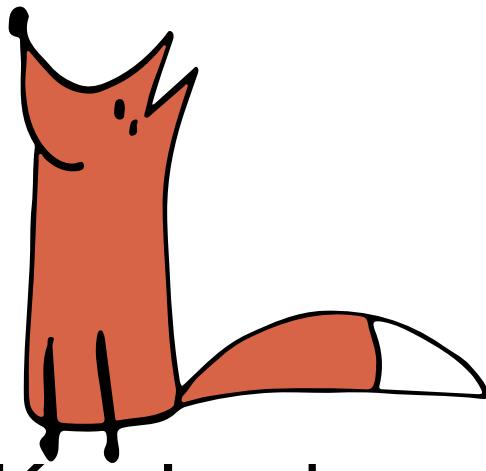
## Key Lookup



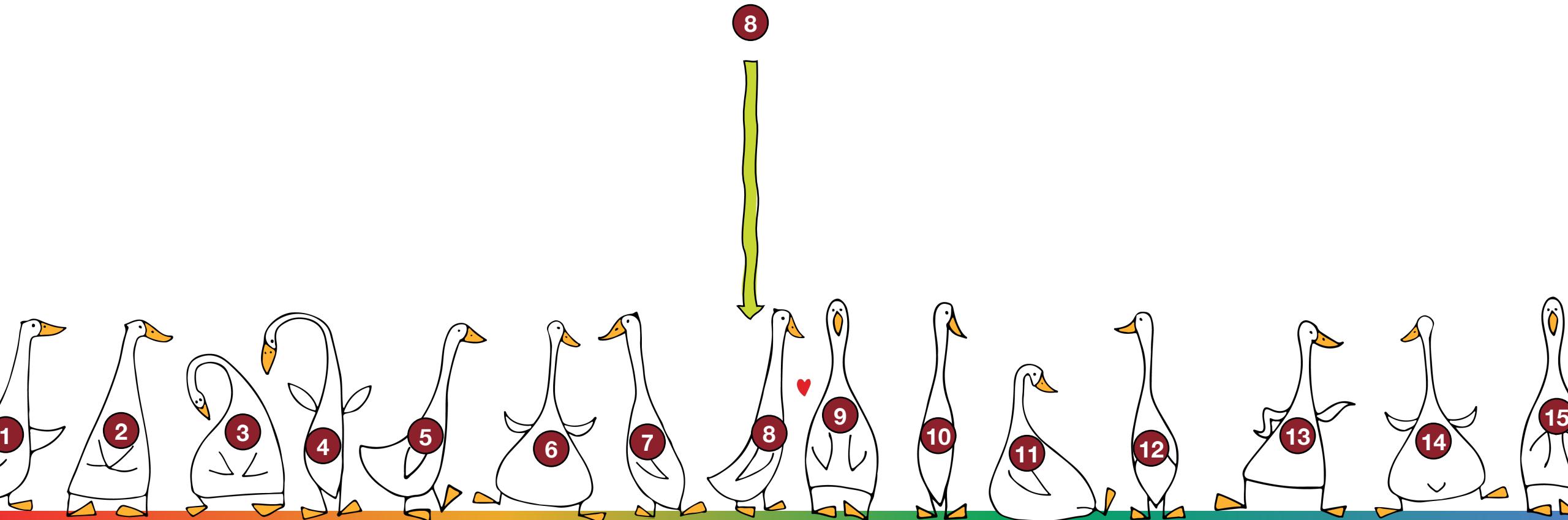


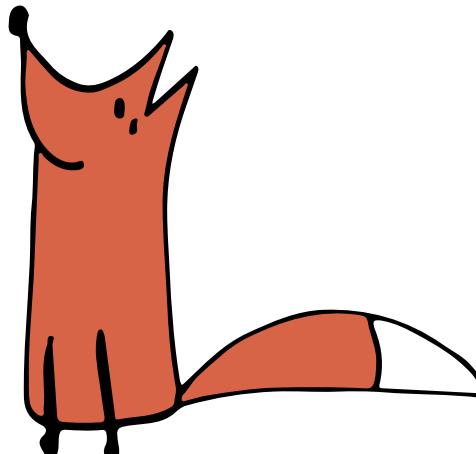
## Key Lookup





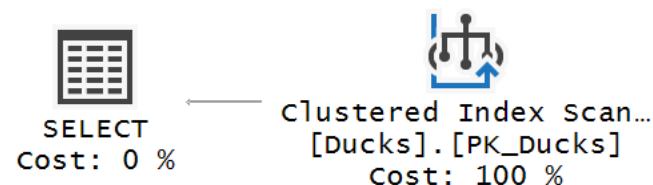
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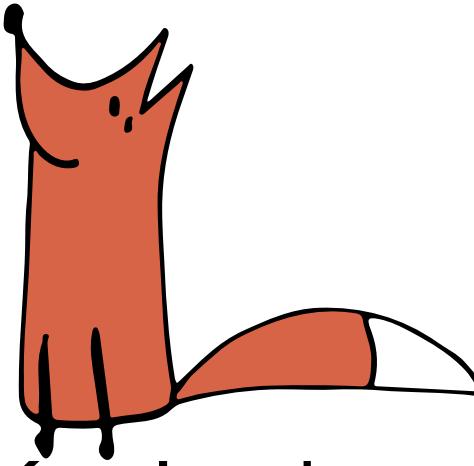




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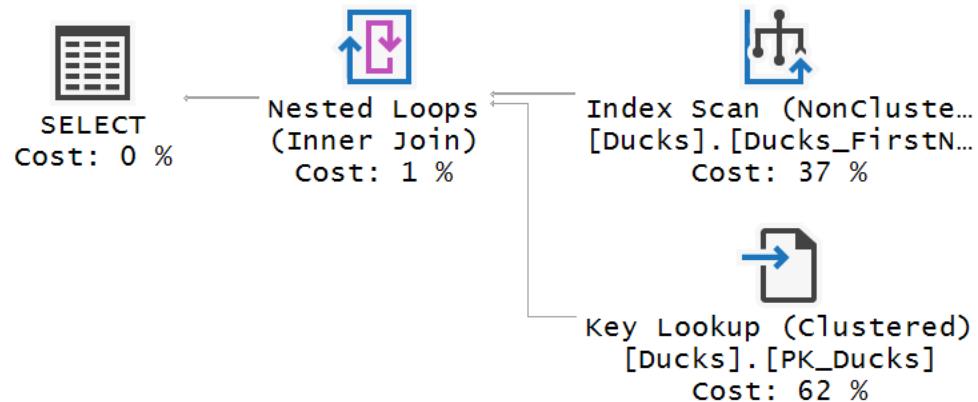
```
SELECT ID, FirstName, BirthDate  
FROM dbo.Ducks;
```





## Key Lookup

```
SELECT ID, FirstName, BirthDate  
FROM dbo.Ducks  
ORDER BY FirstName;
```



## CLUSTERED INDEX (ID)

PAGE 1



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

②

FirstName	BirthDate	Role
Donna	2018-11-14	Developer

③

FirstName	BirthDate	Role
Moby	2018-09-22	Accounting

④

FirstName	BirthDate	Role
Chuck	2018-08-14	QA

⑤

FirstName	BirthDate	Role
Arne	2019-07-04	Developer

## NONCLUSTERED INDEX (FirstName)

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FirstName
Angus

⑩

FirstName
Arne

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FirstName
Bubba

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FirstName
Chuck

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FirstName
Daffy

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Huey

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FirstName

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## CLUSTERED INDEX (ID)

PAGE 1



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

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FirstName	BirthDate	Role
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⑤

FirstName	BirthDate	Role
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Angus

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Arne

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Bubba

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FirstName
Chuck

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Daffy

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## CLUSTERED INDEX (ID)

PAGE 1



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

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FirstName	BirthDate	Role
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⑤

FirstName	BirthDate	Role
Arne	2019-07-04	Developer

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FirstName

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FirstName

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Daffy

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Daisy

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Doofus

FirstName

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Huey

FirstName

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Bubba

FirstName

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Plucky

FirstName

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Scrooge

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Louie

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Moby

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Phooey

FirstName

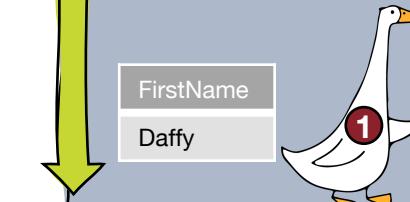
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Plucky

FirstName

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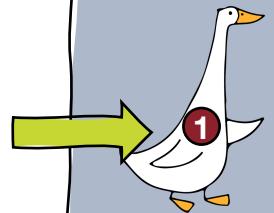
Scrooge



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PAGE 1



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

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FirstName	BirthDate	Role
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FirstName	BirthDate	Role
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⑤

FirstName	BirthDate	Role
Arne	2019-07-04	Developer

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⑤

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Arne	2019-07-04	Developer

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④

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Chuck	2018-08-14	QA

⑤

FirstName	BirthDate	Role
Arne	2019-07-04	Developer

## NONCLUSTERED INDEX (FirstName)

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Angus

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Daisy

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Bubba

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Plucky

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Scrooge

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Scrooge

## CLUSTERED INDEX (ID)

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Daffy	2019-03-14	Team lead

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③

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Moby	2018-09-22	Accounting

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FirstName	BirthDate	Role
Chuck	2018-08-14	QA

⑤

FirstName	BirthDate	Role
Arne	2019-07-04	Developer

## NONCLUSTERED INDEX (FirstName)

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Chuck

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Huey

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FirstName

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## CLUSTERED INDEX (ID)

PAGE 1



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

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FirstName	BirthDate	Role
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FirstName	BirthDate	Role
Chuck	2018-08-14	QA

⑤

FirstName	BirthDate	Role
Arne	2019-07-04	Developer

## NONCLUSTERED INDEX (FirstName)

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FirstName
Angus

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FirstName
Arne

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Chuck

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## CLUSTERED INDEX (ID)

PAGE 1



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Daffy	2019-03-14	Team lead

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FirstName	BirthDate	Role
Donna	2018-11-14	Developer

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FirstName	BirthDate	Role
Moby	2018-09-22	Accounting

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FirstName	BirthDate	Role
Chuck	2018-08-14	QA

⑤

FirstName	BirthDate	Role
Arne	2019-07-04	Developer

## NONCLUSTERED INDEX (FirstName)

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FirstName

Angus

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FirstName

Arne

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FirstName

Bubba

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FirstName

Chuck

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FirstName

Daffy

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FirstName

Daisy

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FirstName

Dewey

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FirstName

Doofus

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Huey

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FirstName

Louie

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Moby

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FirstName

Phooey

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FirstName

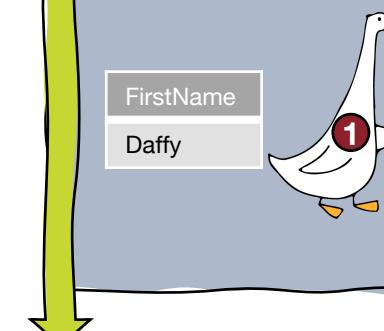
Plucky

⑥

FirstName

Scrooge

⑦



## CLUSTERED INDEX (ID)

PAGE 1



FirstName	BirthDate	Role
Daffy	2019-03-14	Team lead

FirstName	BirthDate	Role
Donna	2018-11-14	Developer

FirstName	BirthDate	Role
Moby	2018-09-22	Accounting

FirstName	BirthDate	Role
Chuck	2018-08-14	QA

FirstName	BirthDate	Role
Arne	2019-07-04	Developer



## NONCLUSTERED INDEX (FirstName)

PAGE 4

FirstName  
Angus

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FirstName  
Arne

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Chuck

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Moby

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Phooey

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Plucky

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FirstName  
Scrooge

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# **INCLUDED COLUMNS.**

How to fix key lookups.

# Non-clustered index

## NONCLUSTERED INDEX (FirstName)

PAGE 4

FirstName
Angus

10

FirstName
Arne

5

FirstName
Bubba

11

FirstName
Chuck

4

FirstName
Daffy

1



FirstName
Daisy

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Dewey

14

FirstName
Donna

2

FirstName
Doofus

9

FirstName
Huey

13

FirstName
Louie

15

FirstName
Moby

3

FirstName
Phooey

12

FirstName
Plucky

6

FirstName
Scrooge

7

# Non-clustered index

NONCLUSTERED INDEX (FirstName)  
INCLUDE (BirthDate)

PAGE 4

FirstName	BirthDate
Angus	2017-12-11

FirstName	BirthDate
Daisy	2018-09-12

FirstName	BirthDate
Louie	2019-01-02

FirstName	BirthDate
Arne	2019-07-04

FirstName	BirthDate
Dewey	2017-12-07

FirstName	BirthDate
Moby	2018-09-22

FirstName	BirthDate
Bubba	2019-03-14

FirstName	BirthDate
Donna	2018-11-14

FirstName	BirthDate
Phooey	2018-10-10

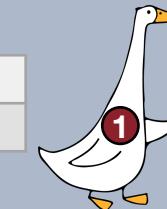
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Chuck	2018-08-14

FirstName	BirthDate
Doofus	2017-02-14

FirstName	BirthDate
Plucky	2019-04-04

FirstName	BirthDate
Daffy	2019-03-14

FirstName	BirthDate
Huey	2017-12-31



10

8

15

5

14

3

11

2

12

4

9

6

13

7

```
SELECT ID, FirstName, BirthDate
FROM dbo.Ducks
ORDER BY FirstName;
```

 SELECT Cost: 0 %       Index Scan (Nonclustered) [Ducks].[Ducks\_FirstName] Cost: 100 %

# Non-clustered index

NONCLUSTERED INDEX (FirstName)  
INCLUDE (BirthDate)

PAGE 4

FirstName	BirthDate
Angus	2017-12-11

10

FirstName	BirthDate
Arne	2019-07-04

5

FirstName	BirthDate
Bubba	2019-03-14

11

FirstName	BirthDate
Chuck	2018-08-14

4

FirstName	BirthDate
Daffy	2019-03-14

1



FirstName	BirthDate
Daisy	2018-09-12

8

FirstName	BirthDate
Dewey	2017-12-07

14

FirstName	BirthDate
Donna	2018-11-14

2

FirstName	BirthDate
Doofus	2017-02-14

9

FirstName	BirthDate
Huey	2017-12-31

13

FirstName	BirthDate
Louie	2019-01-02

15

FirstName	BirthDate
Moby	2018-09-22

3

FirstName	BirthDate
Phooey	2018-10-10

12

FirstName	BirthDate
Plucky	2019-04-04

6

FirstName	BirthDate
Scrooge	2016-01-14

7



# SORTING.



```
SELECT ID, FirstName, [Role]  
FROM dbo.Ducks  
ORDER BY ID;
```

 SELECT  
Cost: 0 %

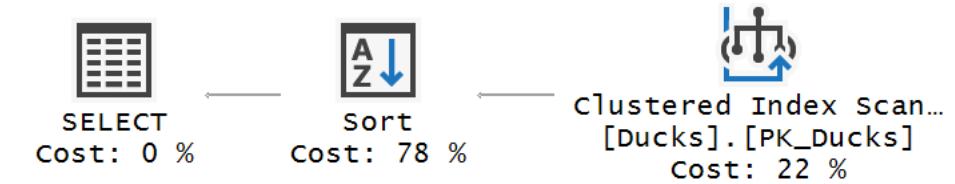
 Clustered Index Scan...  
[Ducks].[PK\_Ducks]  
Cost: 100 %

A diagram illustrating a database query execution plan. On the left, a table icon is connected by a line to a clustered index scan icon. Below the table icon is the text "SELECT Cost: 0 %". Below the clustered index scan icon is the text "Clustered Index Scan... [Ducks].[PK\_Ducks] Cost: 100 %".

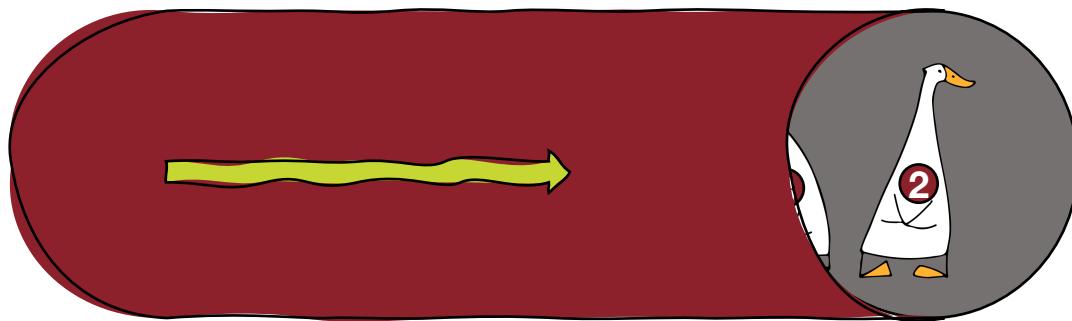
```
SELECT ID, FirstName, [Role]  
FROM dbo.Ducks  
ORDER BY ID;
```



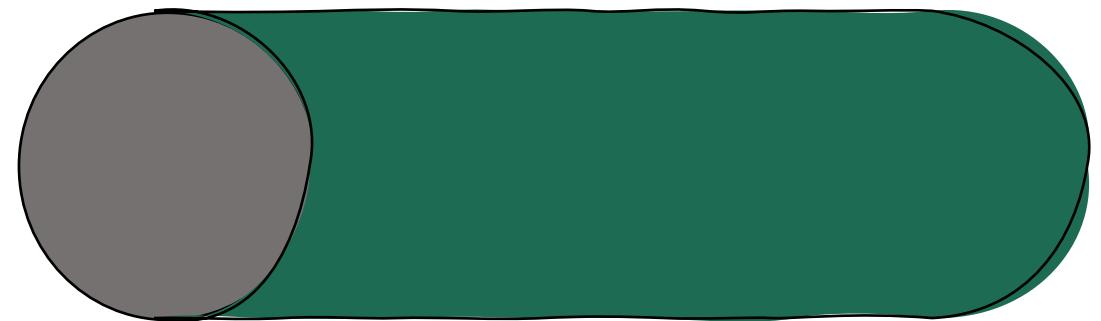
```
SELECT ID, FirstName, [Role]  
FROM dbo.Ducks  
ORDER BY FirstName;
```



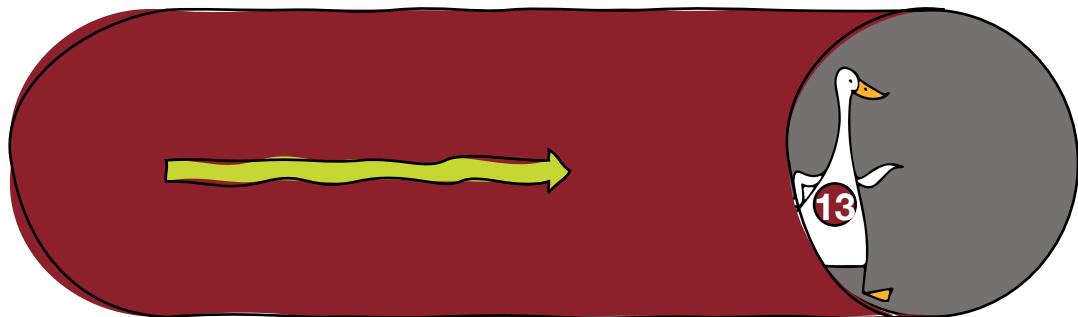
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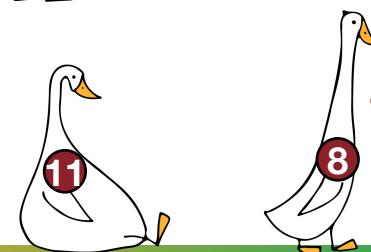
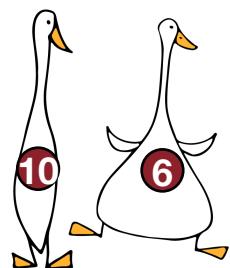
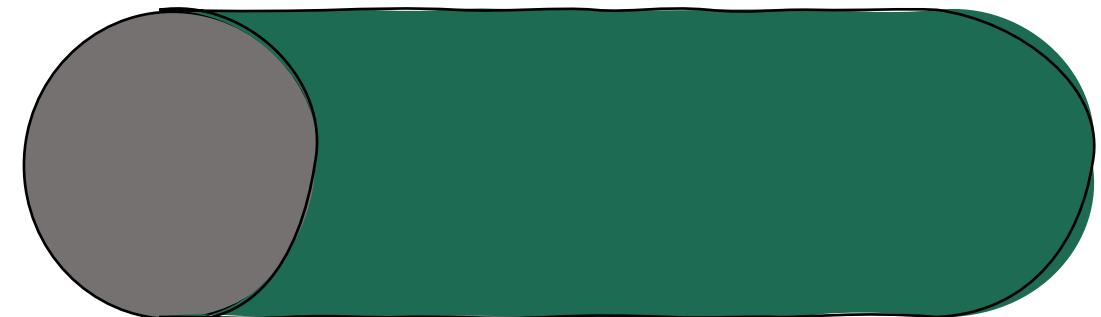
Sorted output



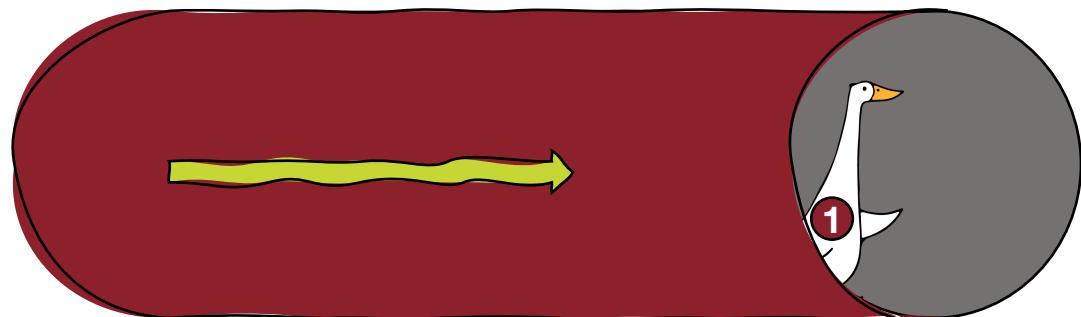
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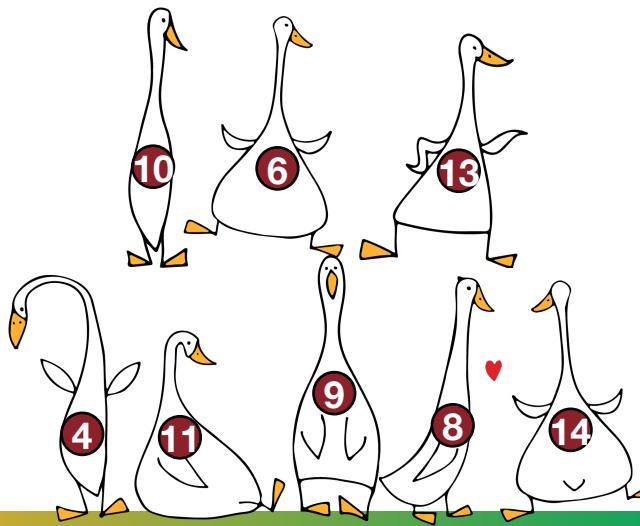
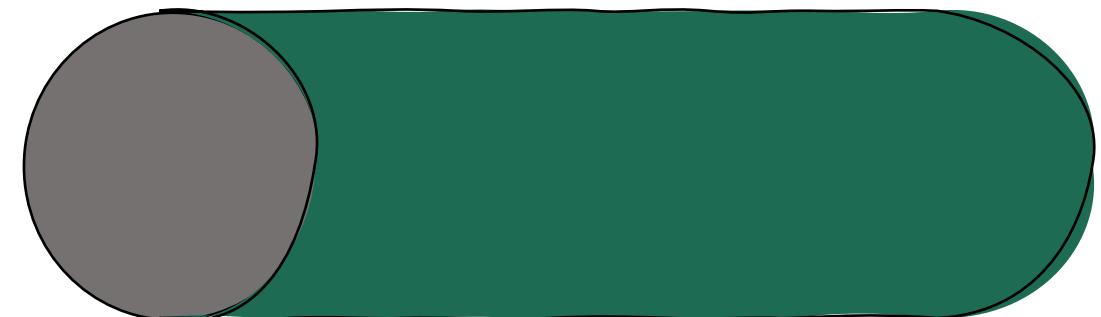
Sorted output



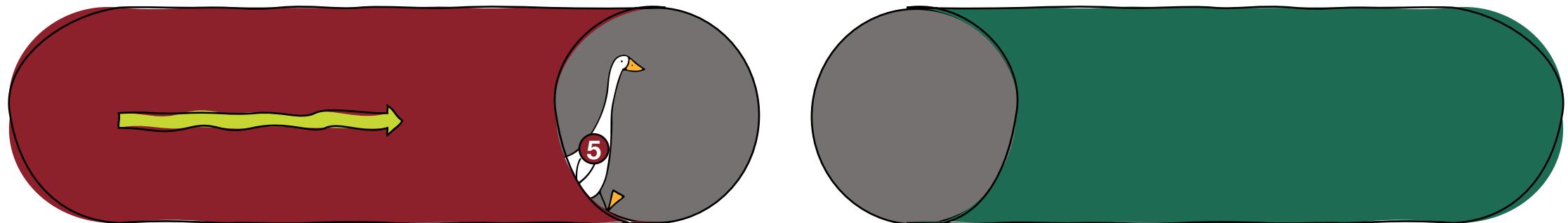
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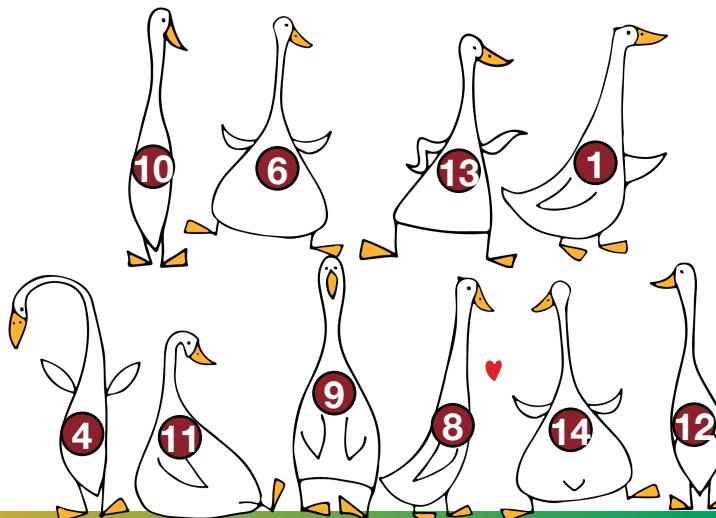
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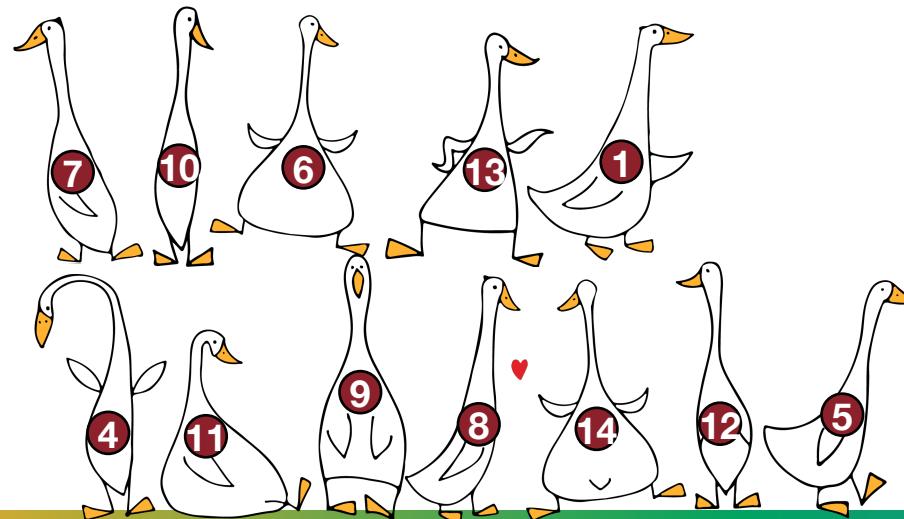
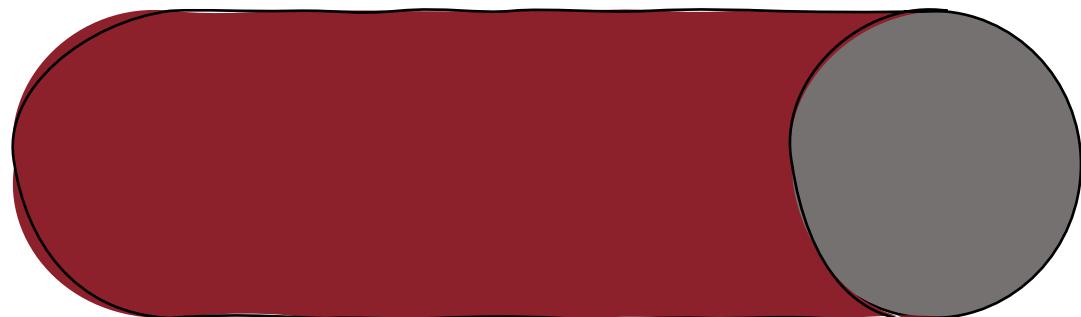
Unsorted input



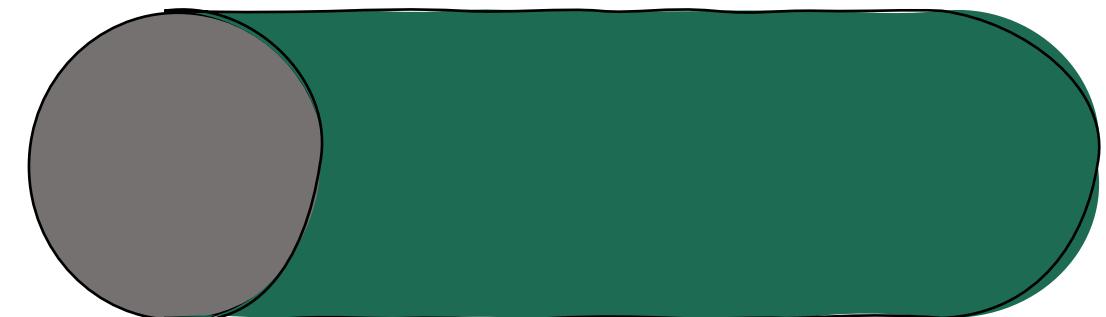
Sorted output



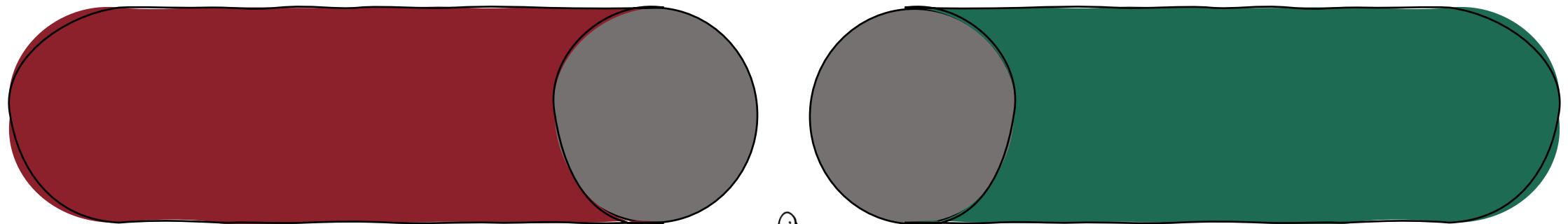
Unsorted input



Sorted output



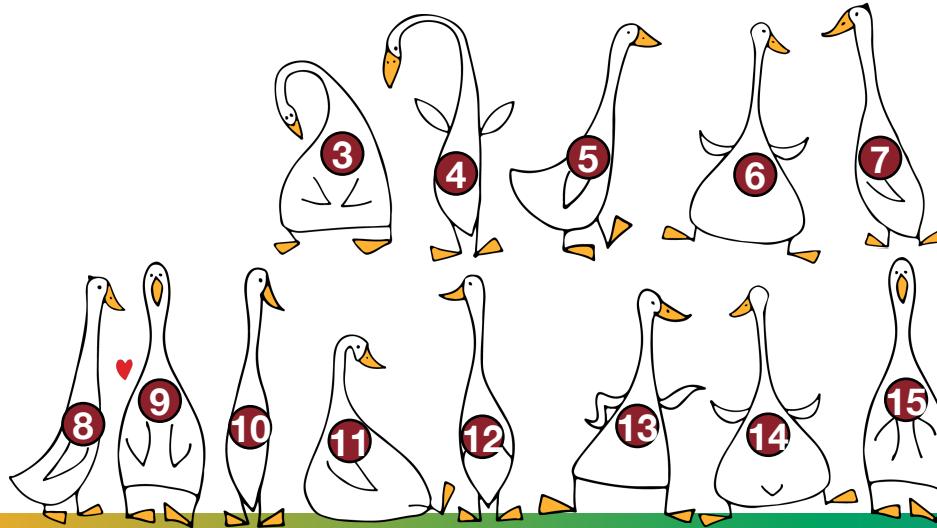
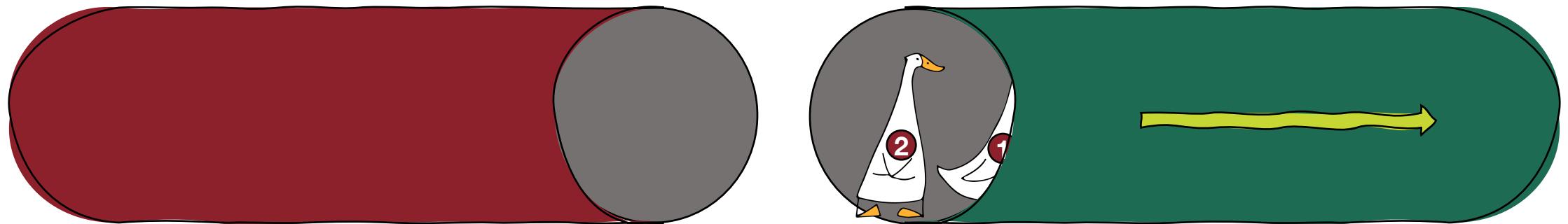
Unsorted input



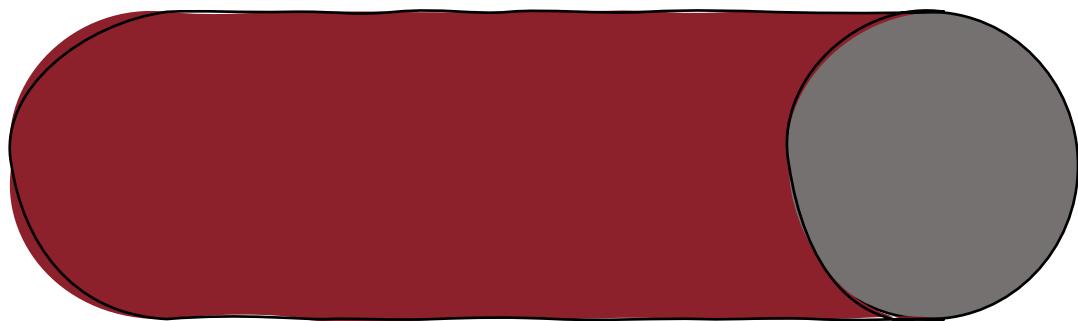
Sort operation



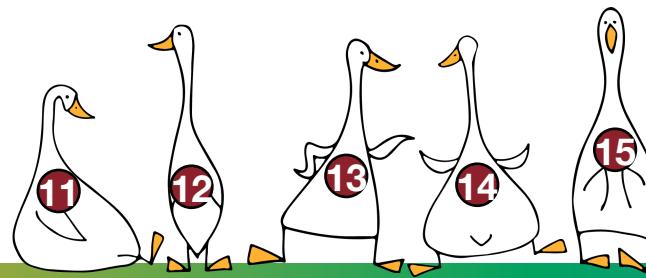
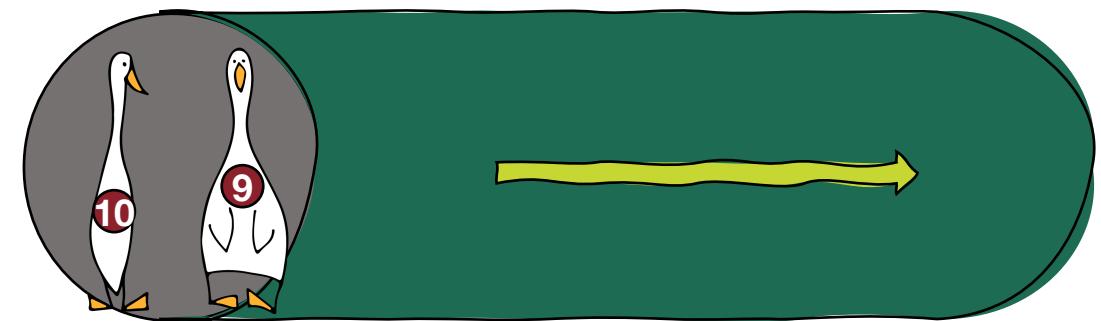
Unsorted input



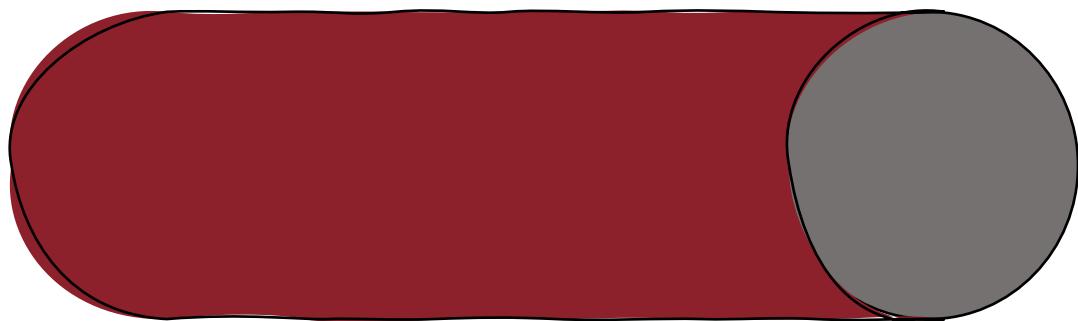
Unsorted input



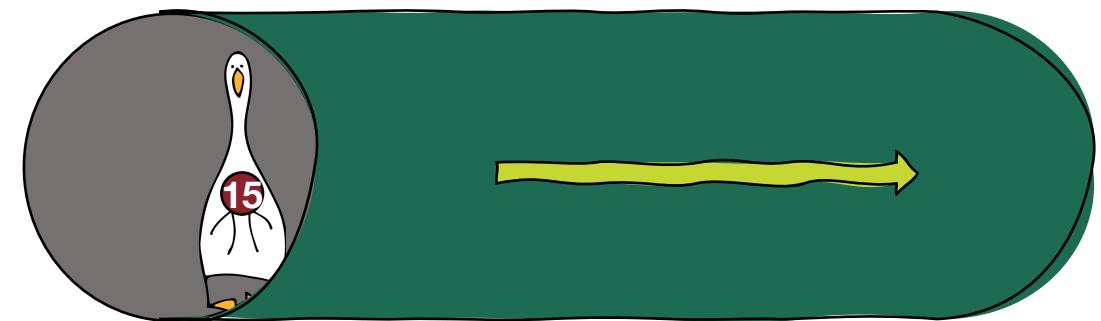
Sorted output



Unsorted input



Sorted output





# WINDOW FUNCTIONS.

```
SELECT ID, FirstName,  
       ROW_NUMBER() OVER (ORDER BY FirstName, ID)  
FROM dbo.Ducks;
```

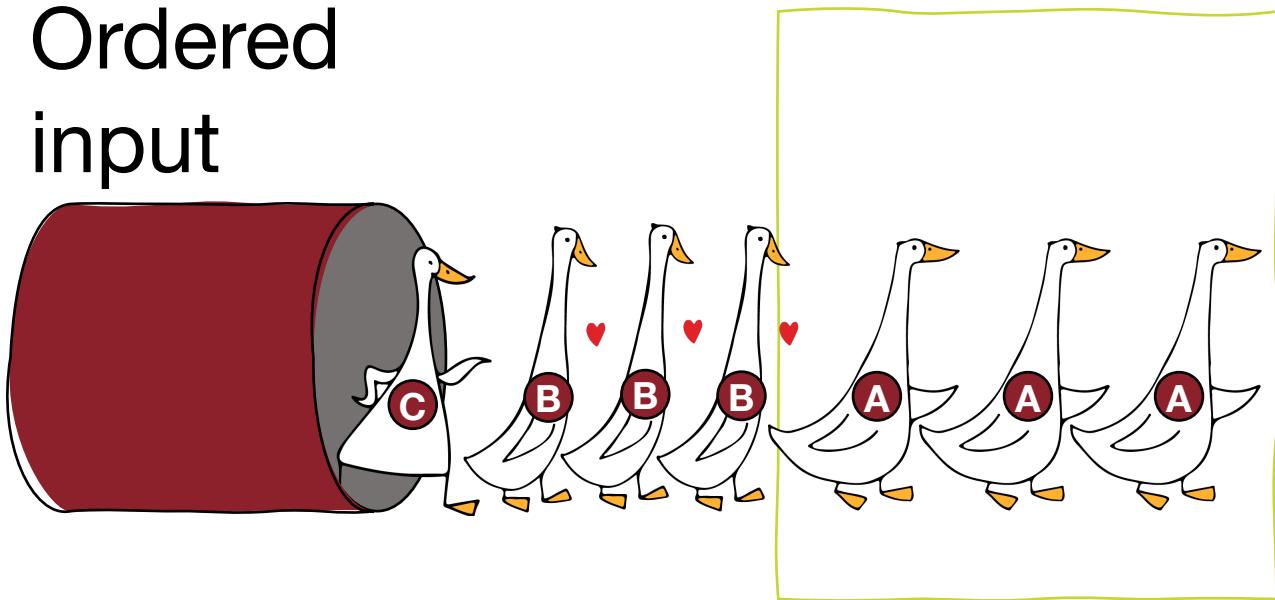
ID	FirstName	ROW_NUMBER()
4	Angus	1
6	Angus	2
12	Angus	3
1	Bubba	4
2	Bubba	5
7	Bubba	6
5	Chuck	7

```
SELECT ID, FirstName,  
       ROW_NUMBER() OVER (PARTITION BY FirstName ORDER BY ID)  
FROM dbo.Ducks;
```

ID	FirstName	ROW_NUMBER()
4	Angus	1
6	Angus	2
12	Angus	3
1	Bubba	1
2	Bubba	2
7	Bubba	3
5	Chuck	1

# Segment and Sequence Project

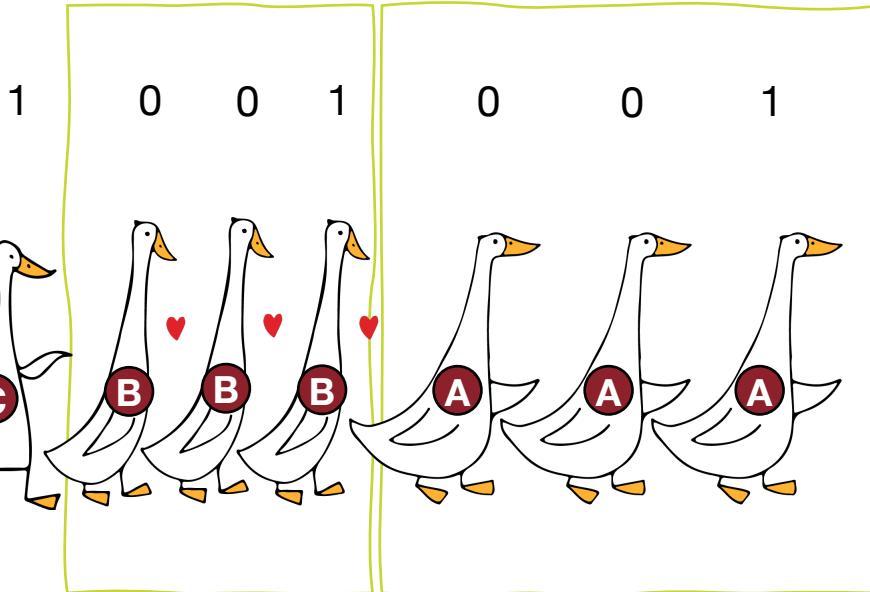
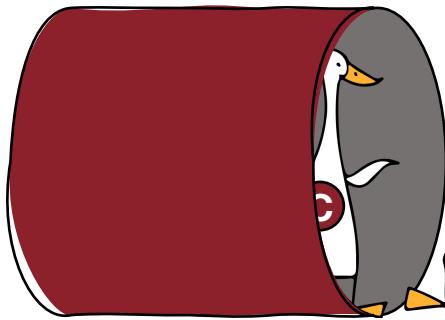
Ordered  
input



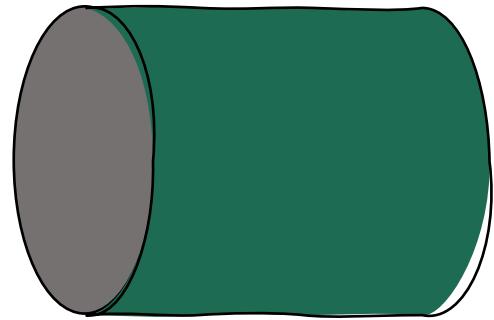
Output

# Segment and Sequence Project

Ordered  
input

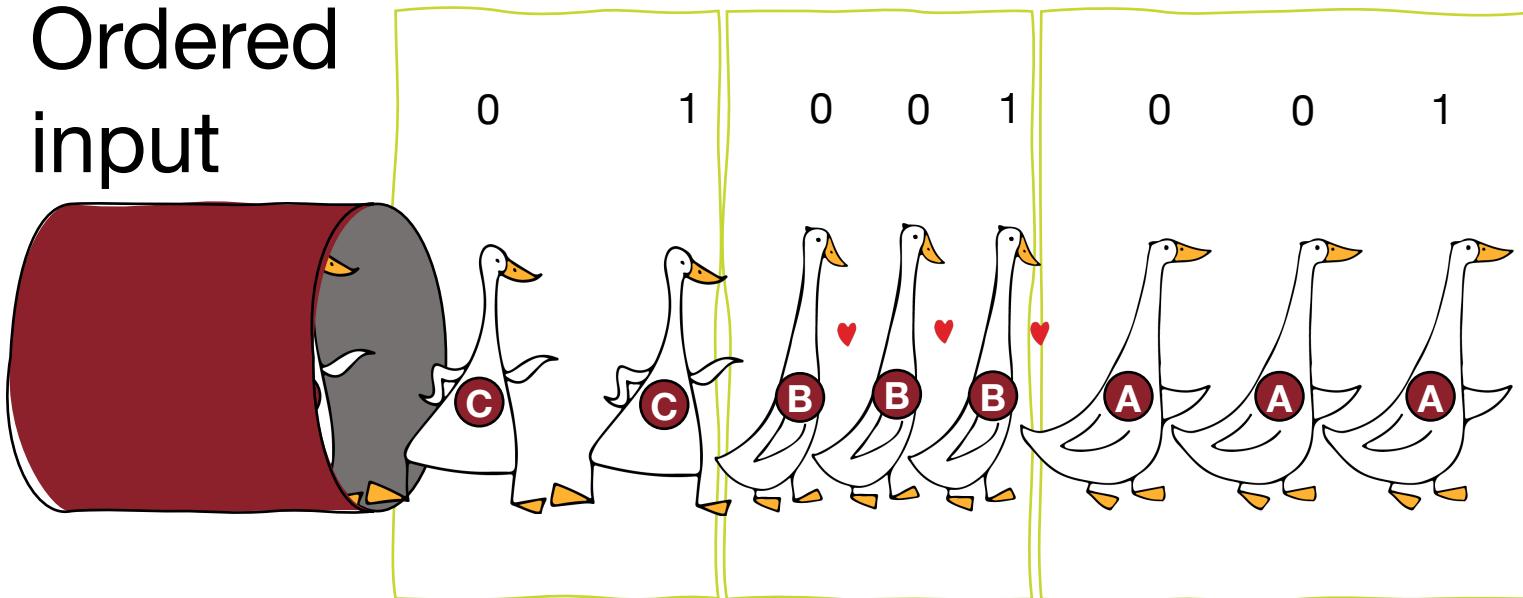


Output

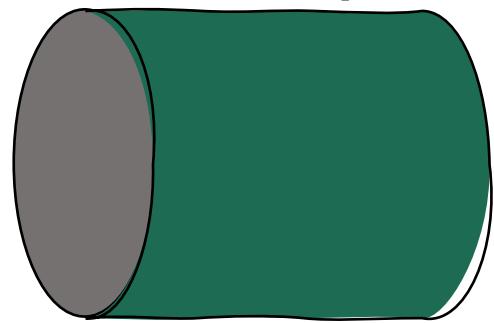


# Segment and Sequence Project

Ordered  
input

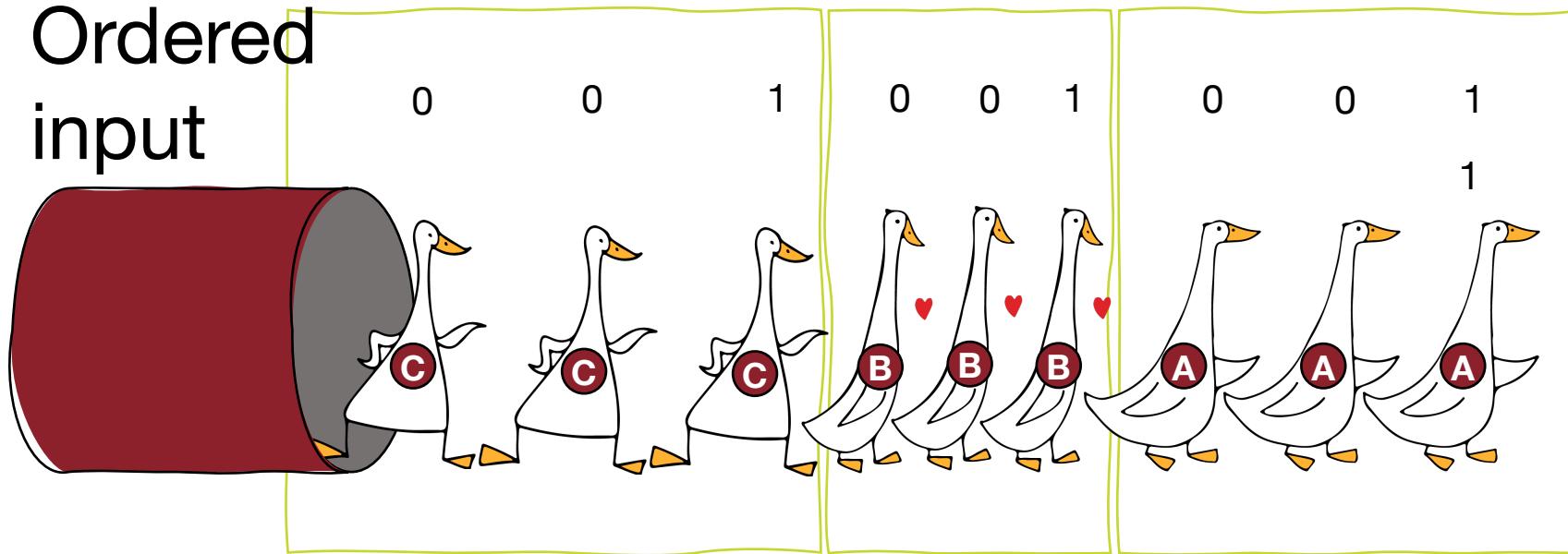


Output

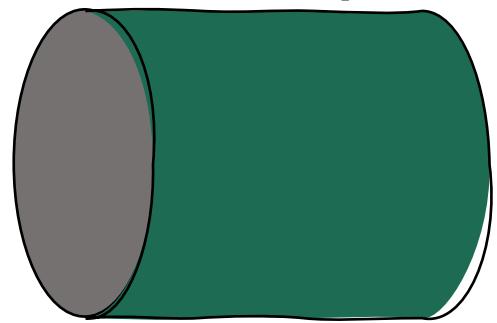


# Segment and Sequence Project

Ordered  
input

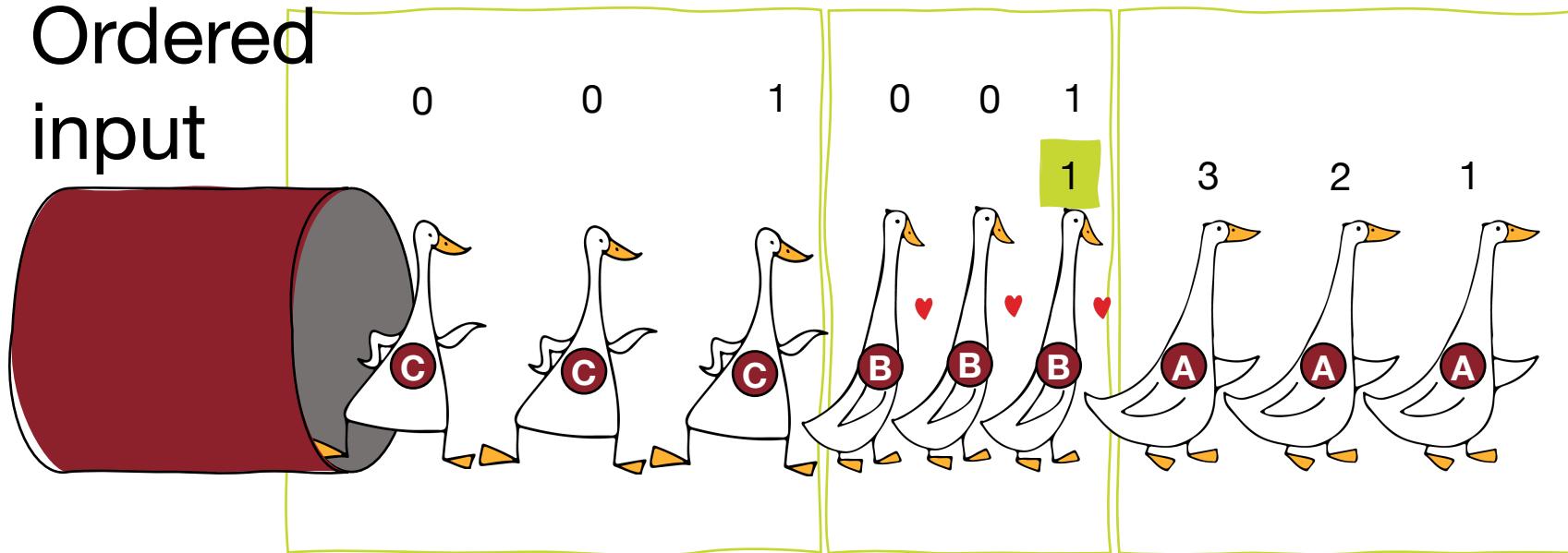


Output



# Segment and Sequence Project

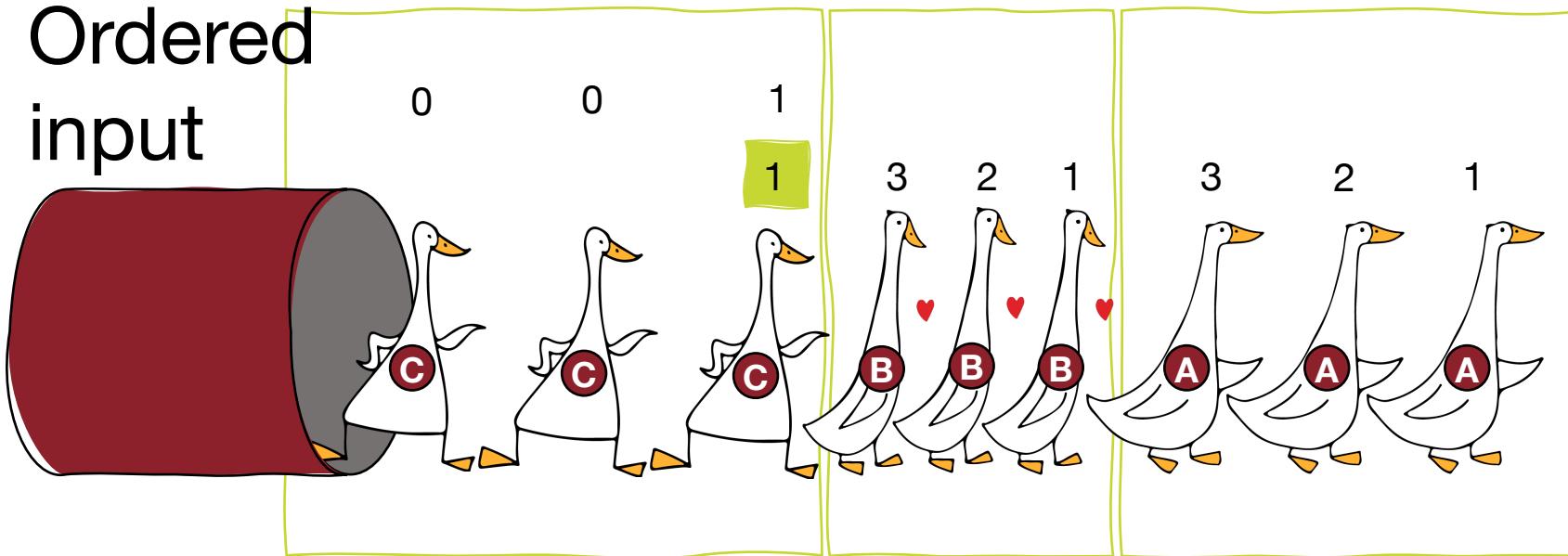
Ordered  
input



Output

# Segment and Sequence Project

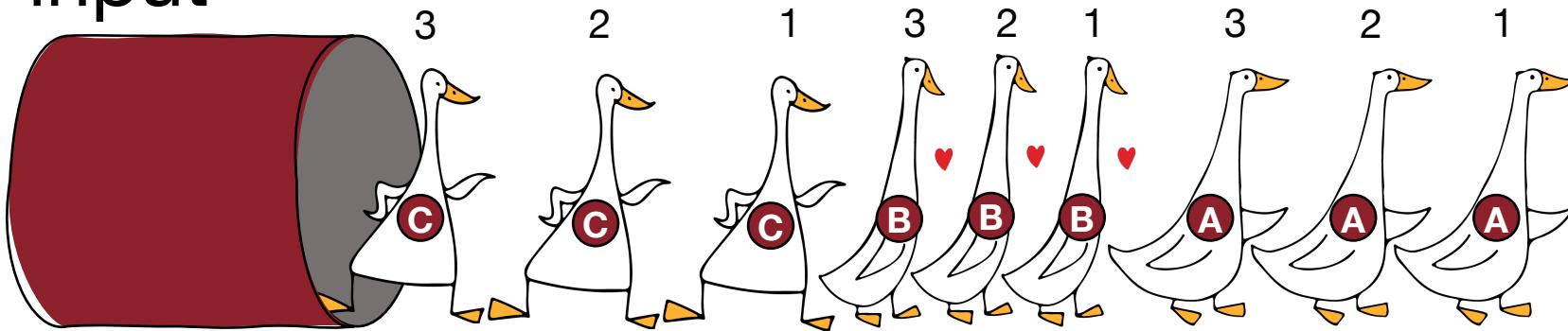
Ordered  
input



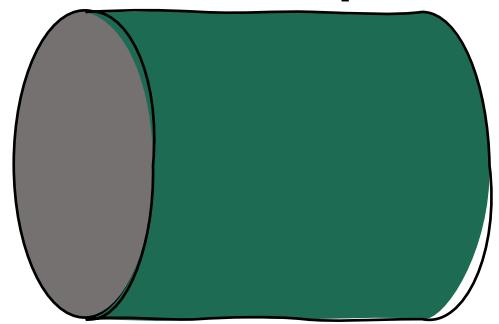
Output

# Segment and Sequence Project

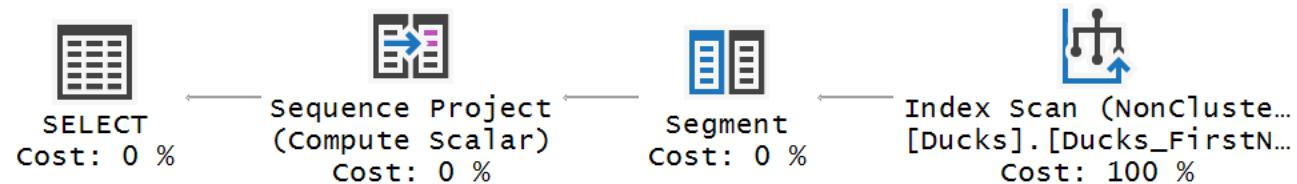
Ordered  
input



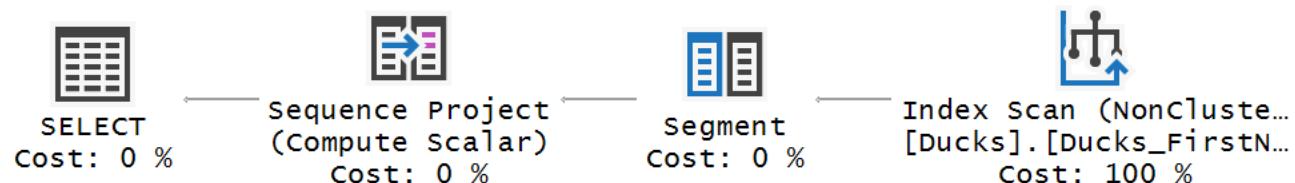
Output



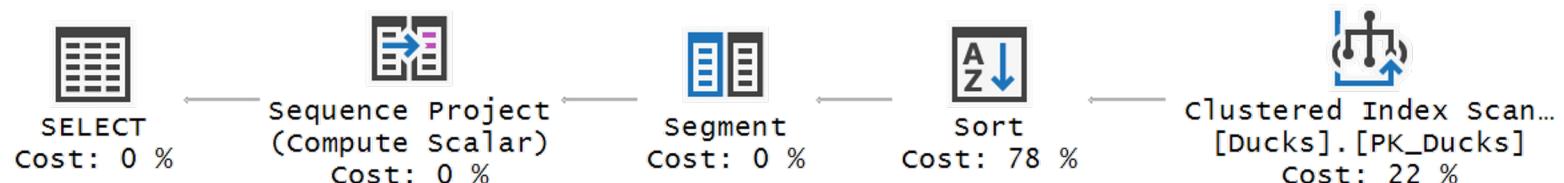
```
SELECT ID, FirstName,  
       ROW_NUMBER() OVER (PARTITION BY FirstName ORDER BY ID)  
FROM dbo.Ducks;
```



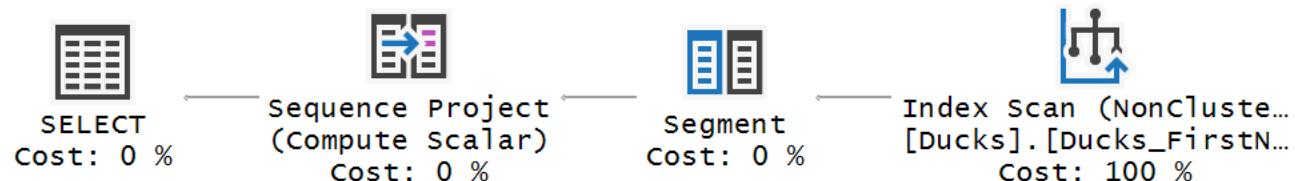
```
SELECT ID, FirstName,  
       ROW_NUMBER() OVER (PARTITION BY FirstName ORDER BY ID)  
FROM dbo.Ducks;
```



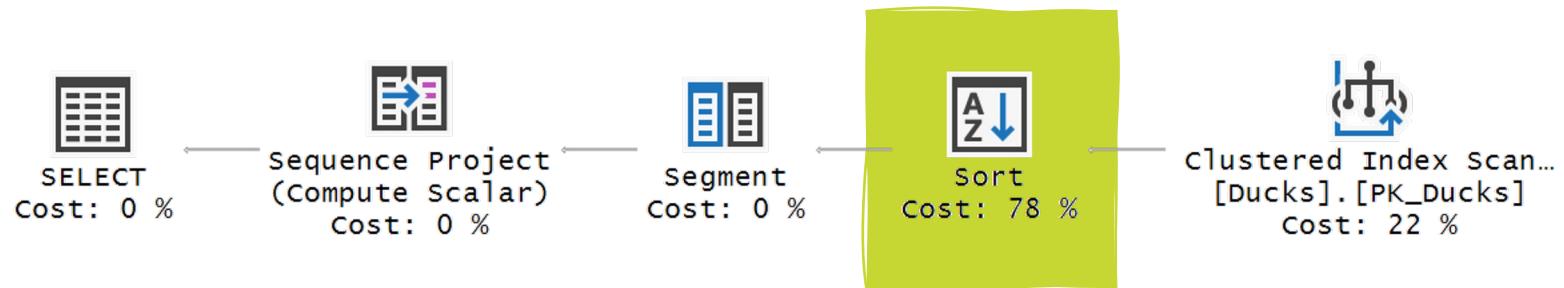
```
SELECT ID, BirthDate,  
       ROW_NUMBER() OVER (PARTITION BY BirthDate ORDER BY ID)  
FROM dbo.Ducks;
```



```
SELECT ID, FirstName,
       ROW_NUMBER() OVER (PARTITION BY FirstName ORDER BY ID)
FROM dbo.Ducks;
```



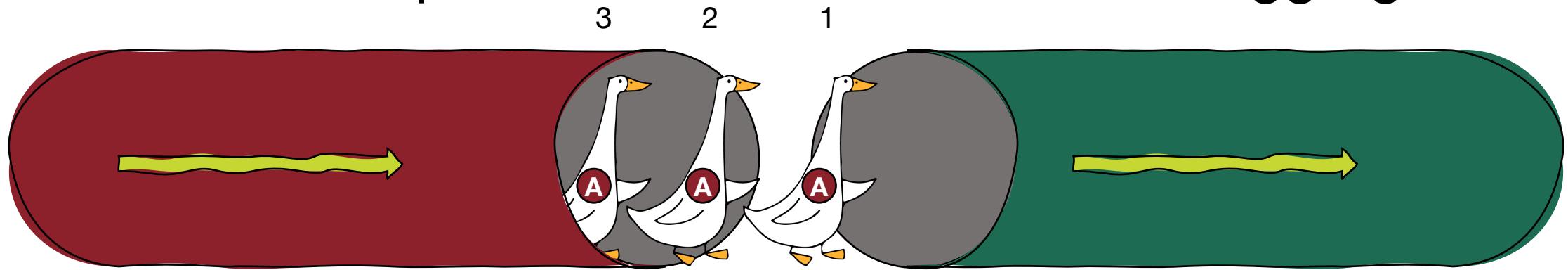
```
SELECT ID, BirthDate,
       ROW_NUMBER() OVER (PARTITION BY BirthDate ORDER BY ID)
FROM dbo.Ducks;
```





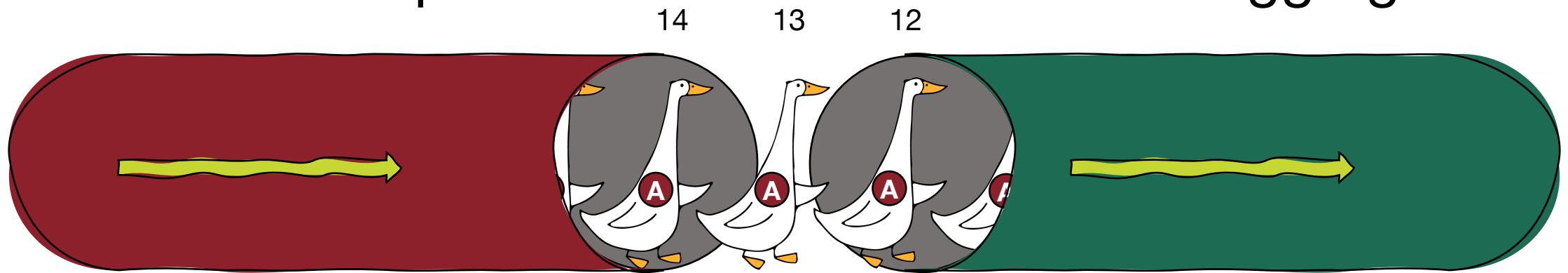
# STREAM AGGREGATE.

Sorted input



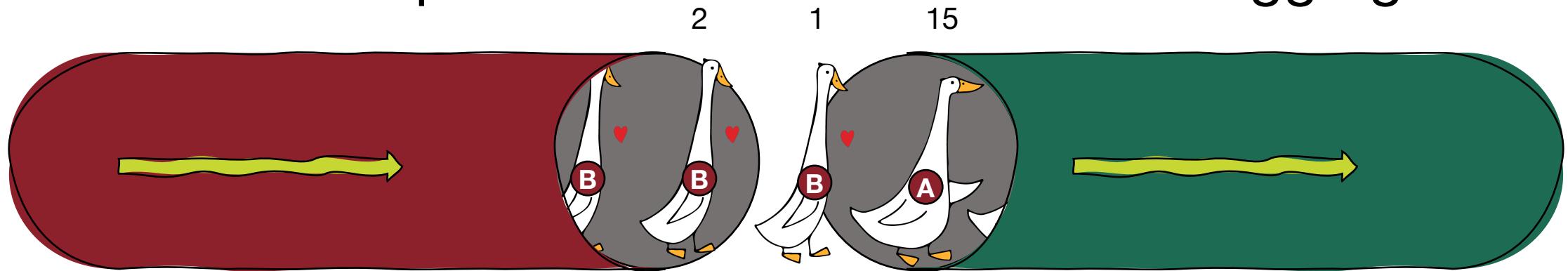
Stream Aggregate

Sorted input



Stream Aggregate

Sorted input

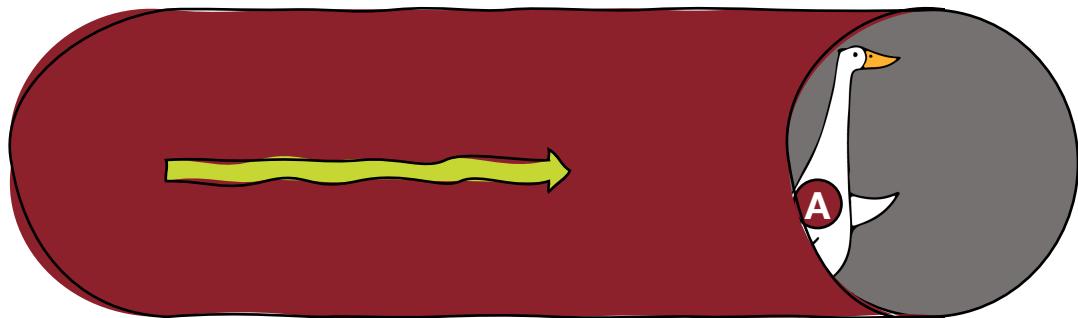


Stream Aggregate

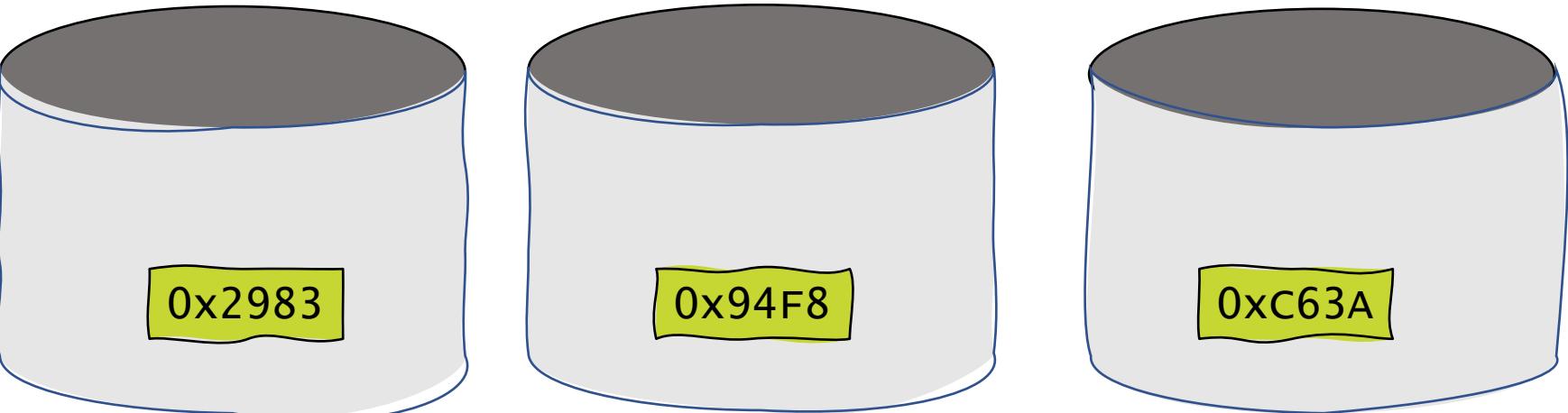
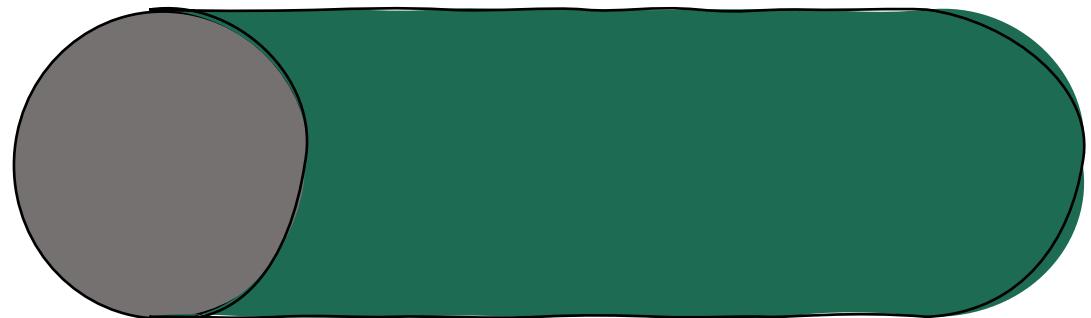


# HASH MATCH AGGREGATE.

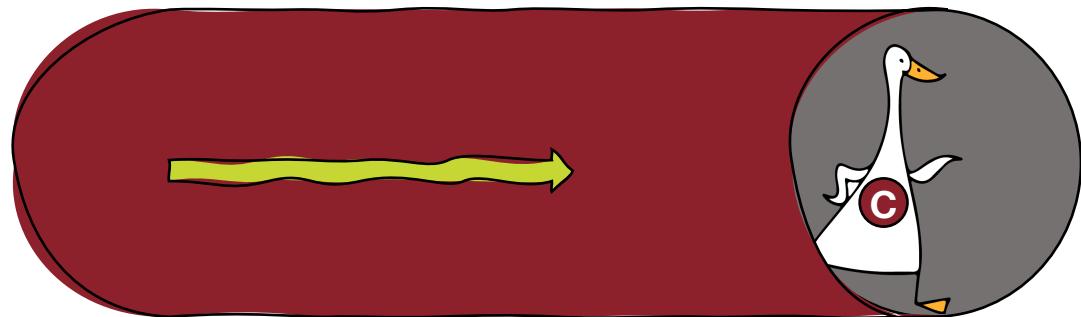
## Unsorted input



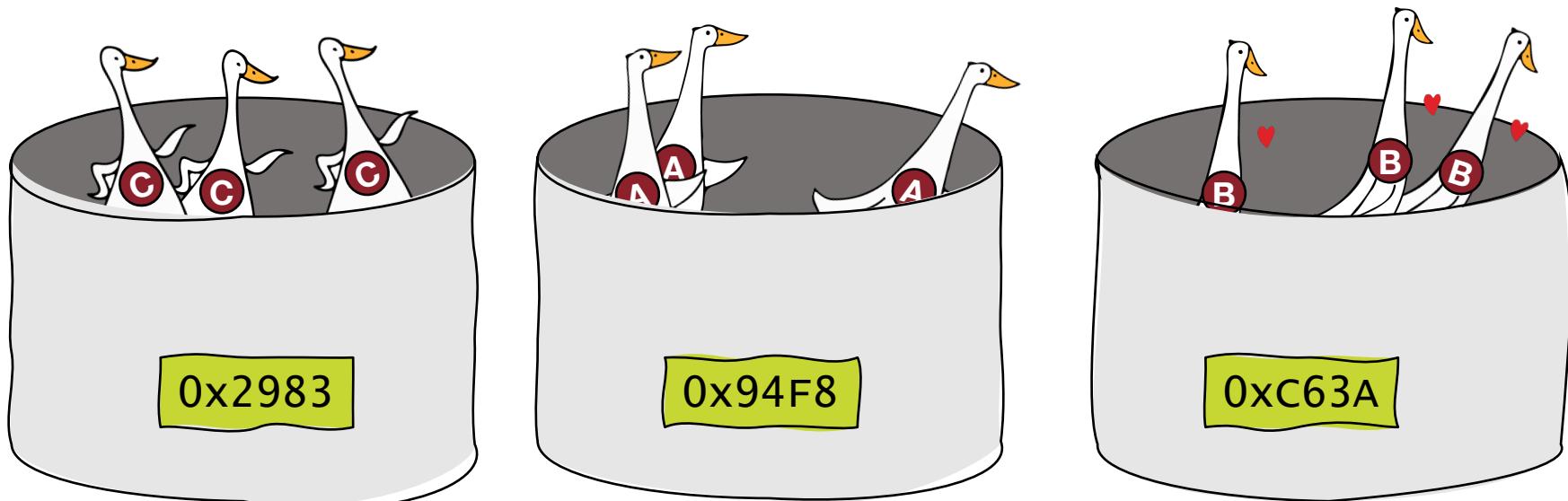
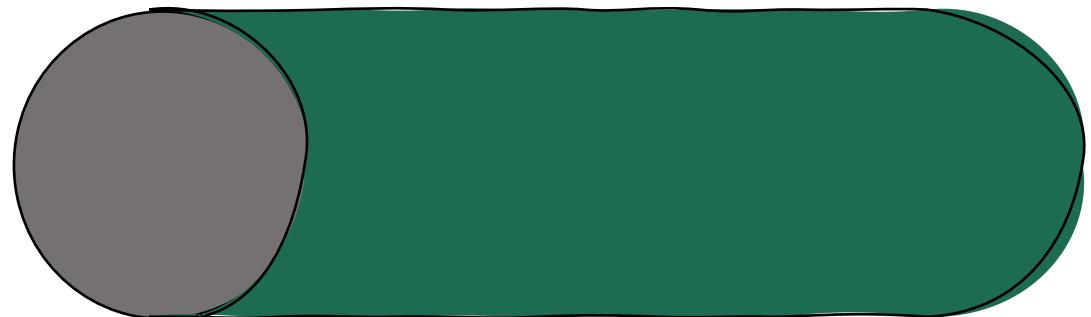
## Mash Match



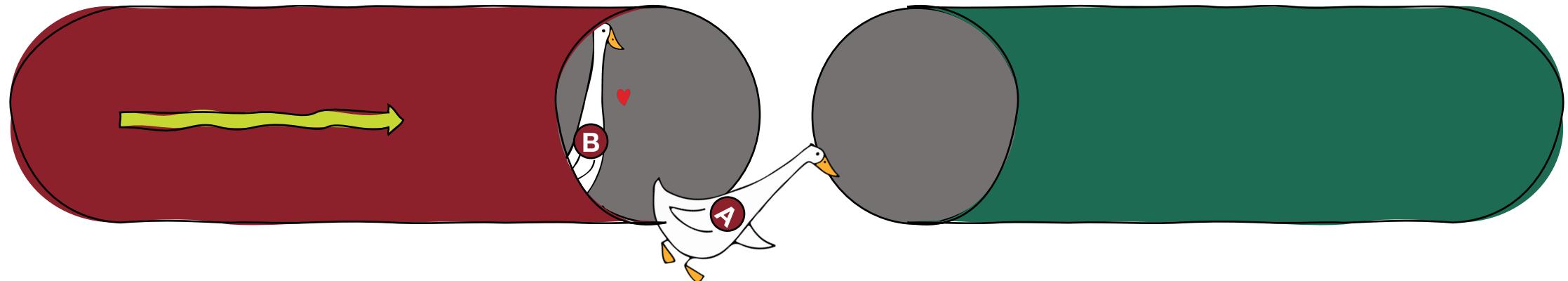
## Unsorted input



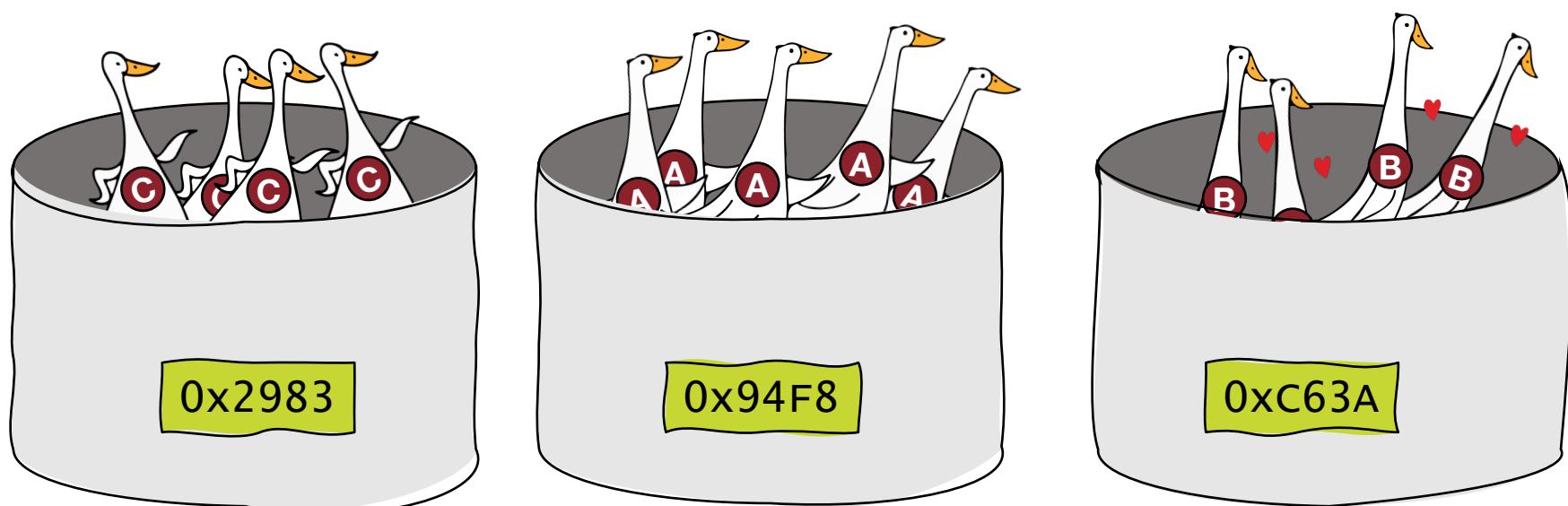
## Mash Match



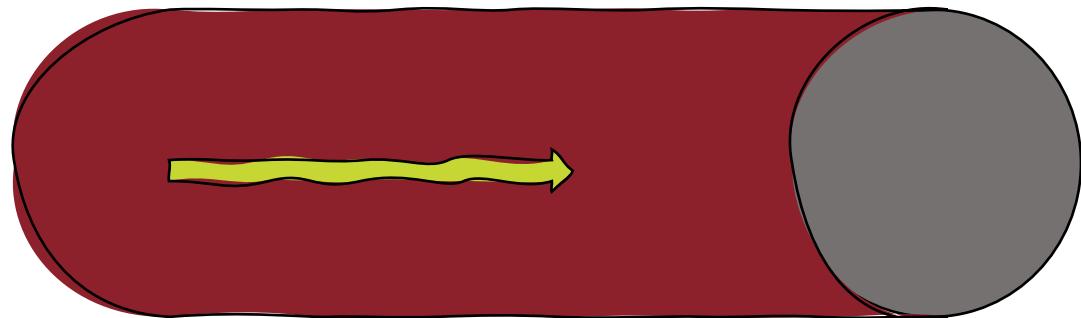
## Unsorted input



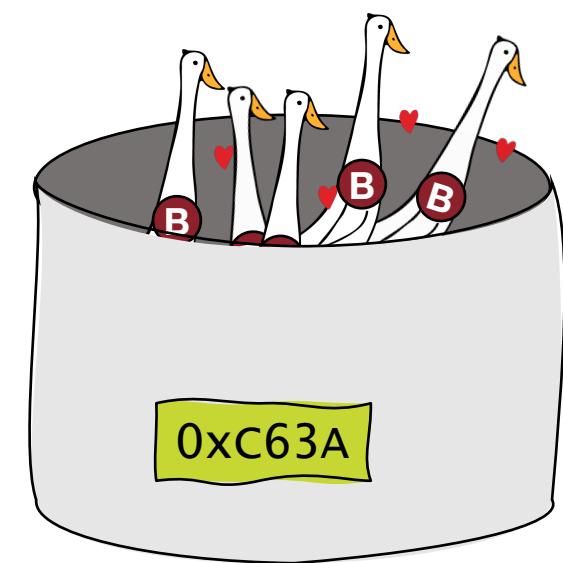
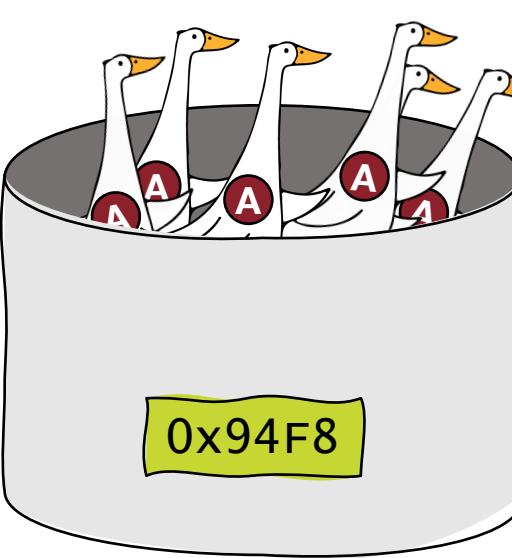
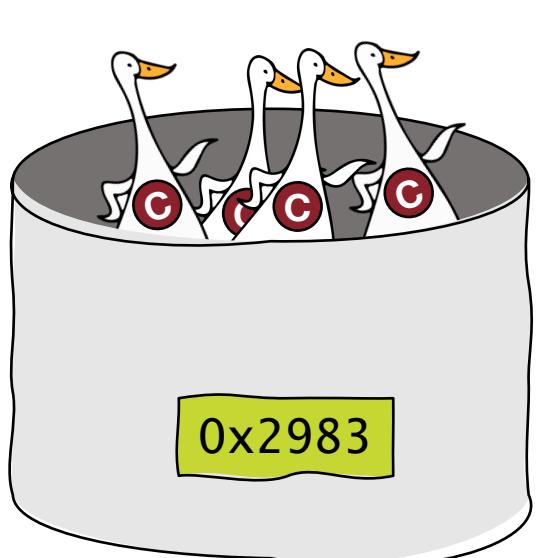
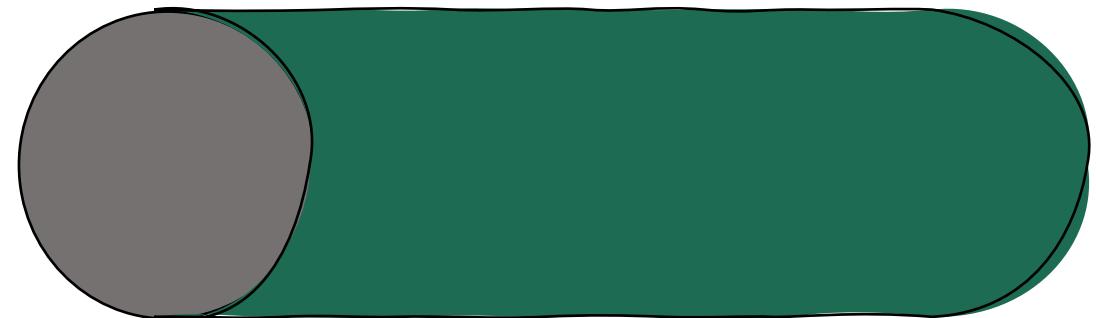
## Mash Match



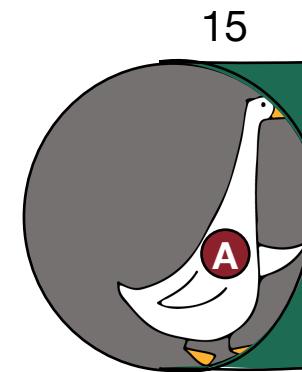
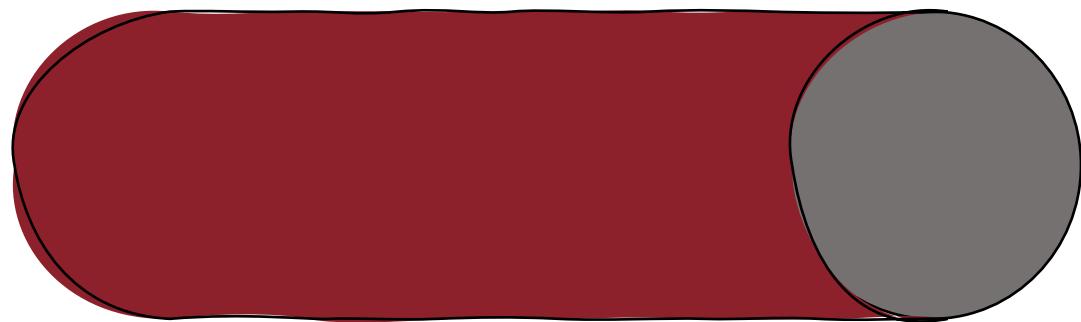
## Unsorted input



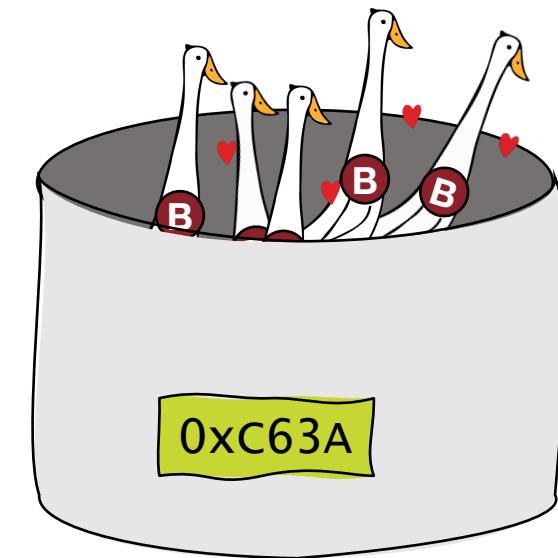
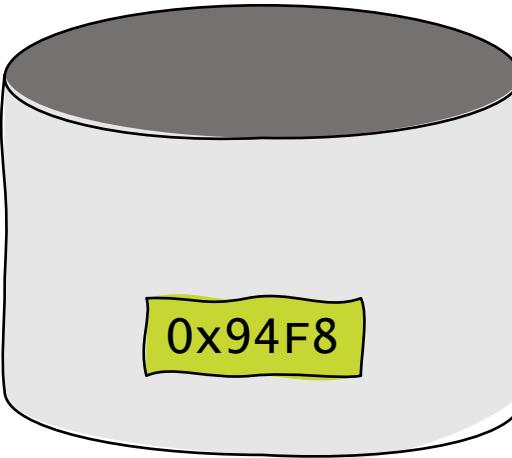
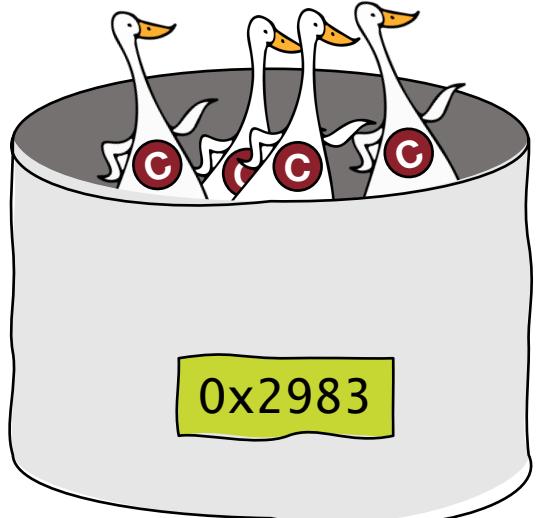
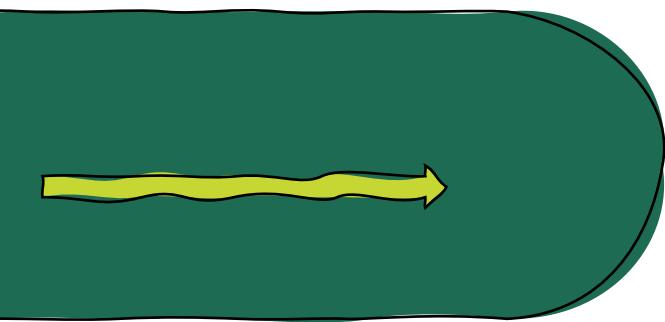
## Mash Match



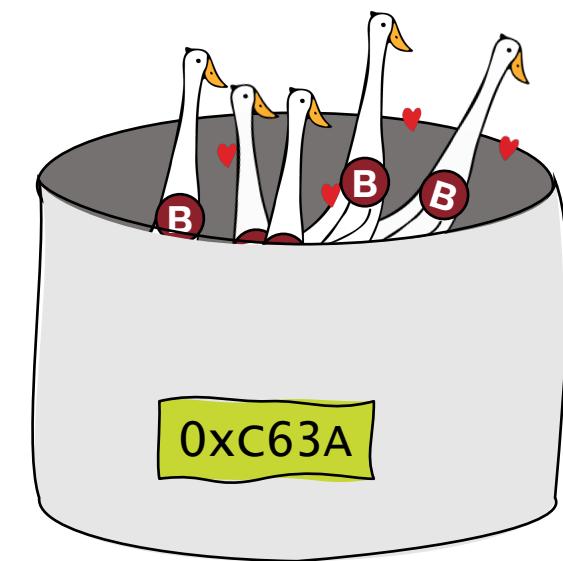
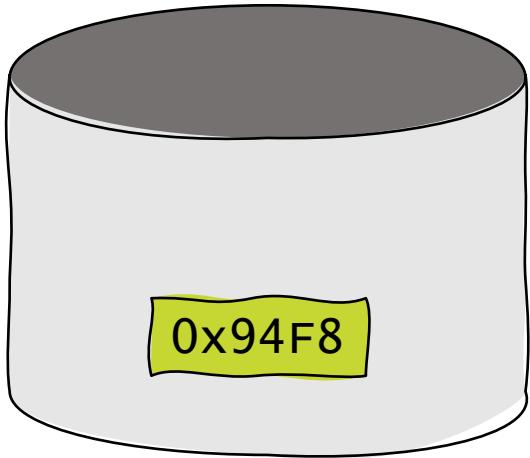
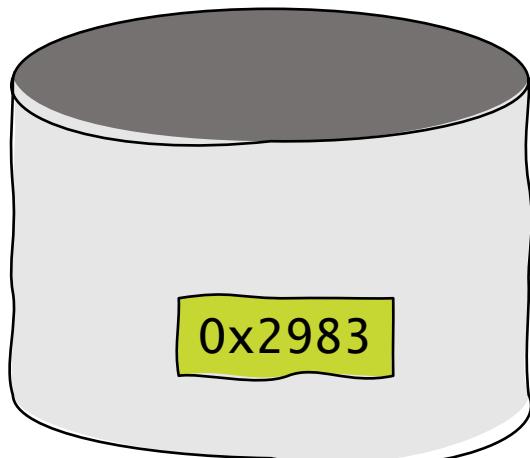
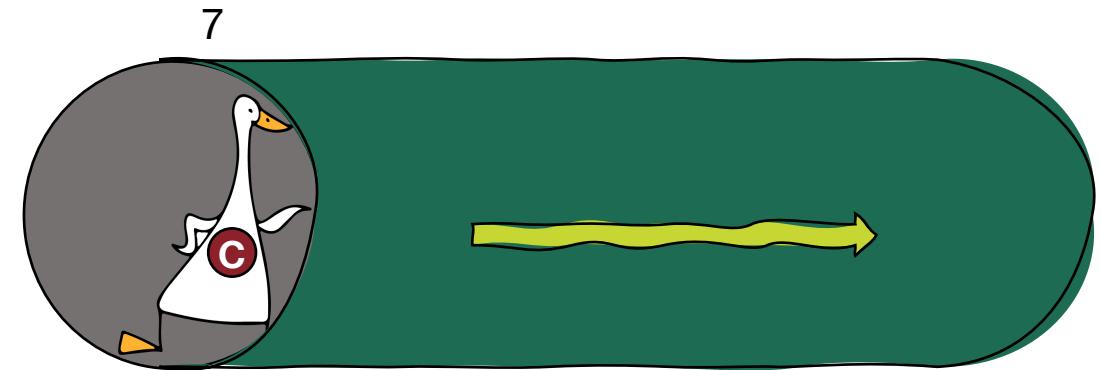
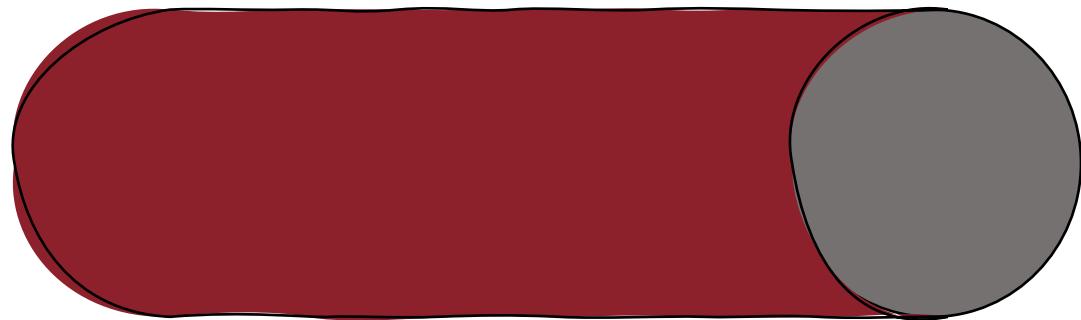
## Unsorted input



## Mash Match

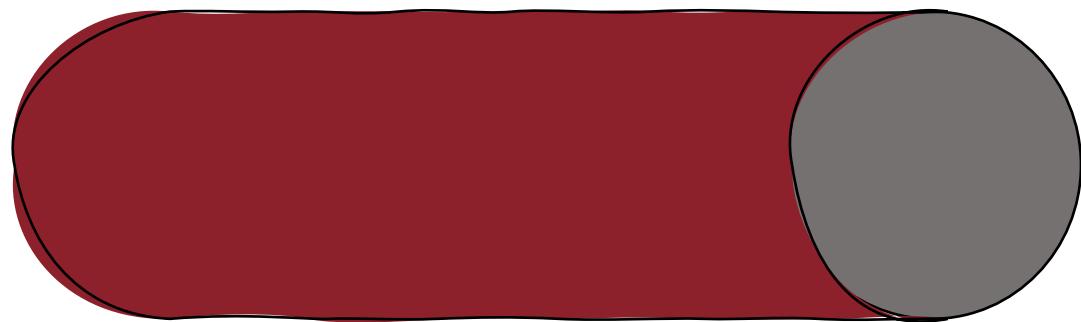


## Unsorted input

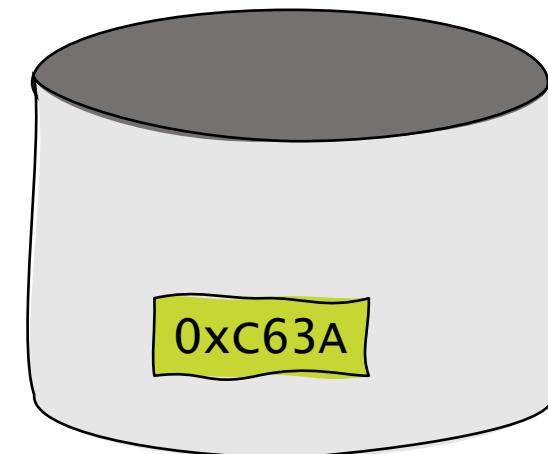
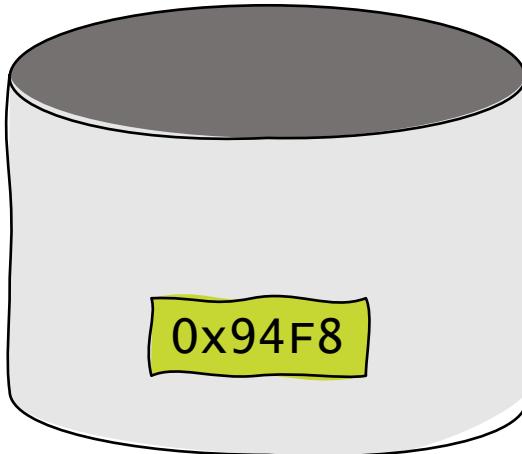
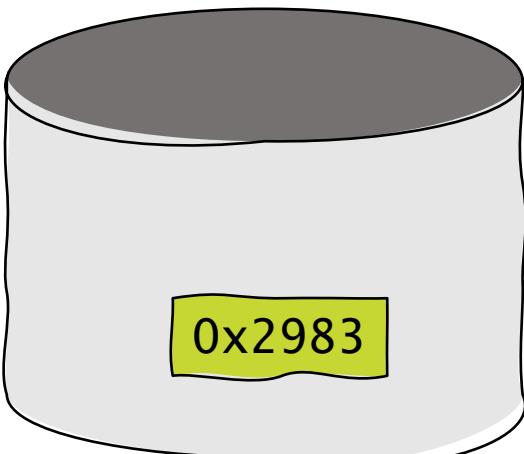
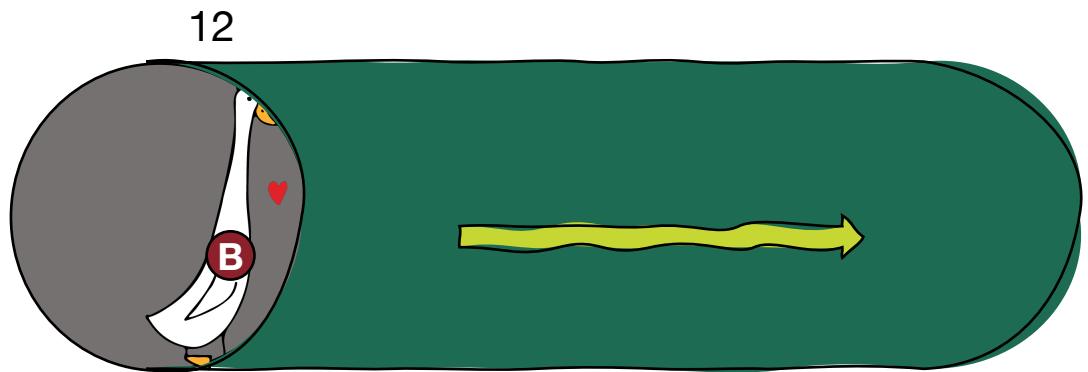


## Mash Match

## Unsorted input

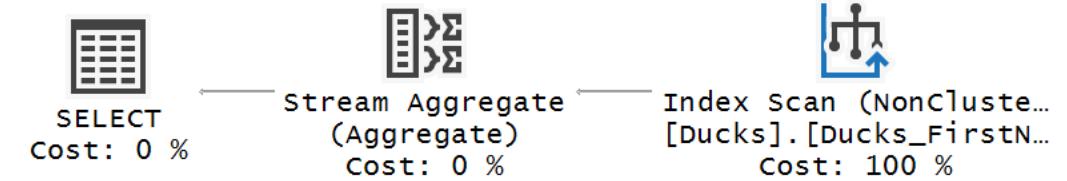


## Mash Match





```
SELECT FirstName, COUNT_BIG(*)  
FROM dbo.Ducks  
GROUP BY FirstName;
```

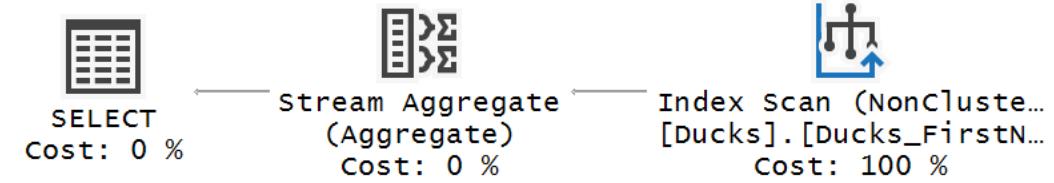




```
SELECT FirstName, COUNT_BIG(*)  
FROM dbo.Ducks  
GROUP BY FirstName;
```

```
SELECT DISTINCT FirstName  
FROM dbo.Ducks;
```

{}

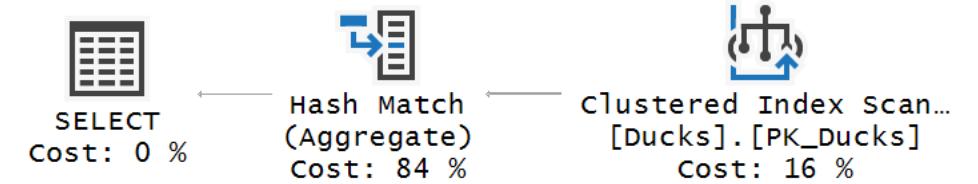
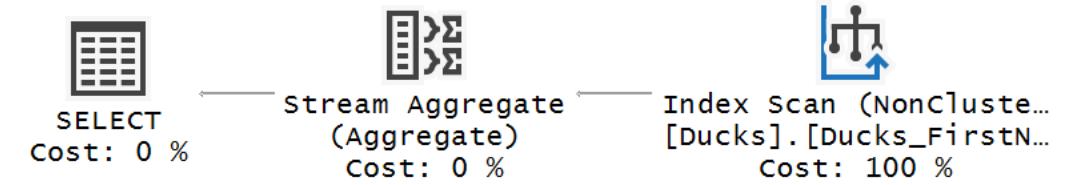




```
SELECT FirstName, COUNT_BIG(*)  
FROM dbo.Ducks  
GROUP BY FirstName;
```

```
SELECT DISTINCT FirstName  
FROM dbo.Ducks;
```

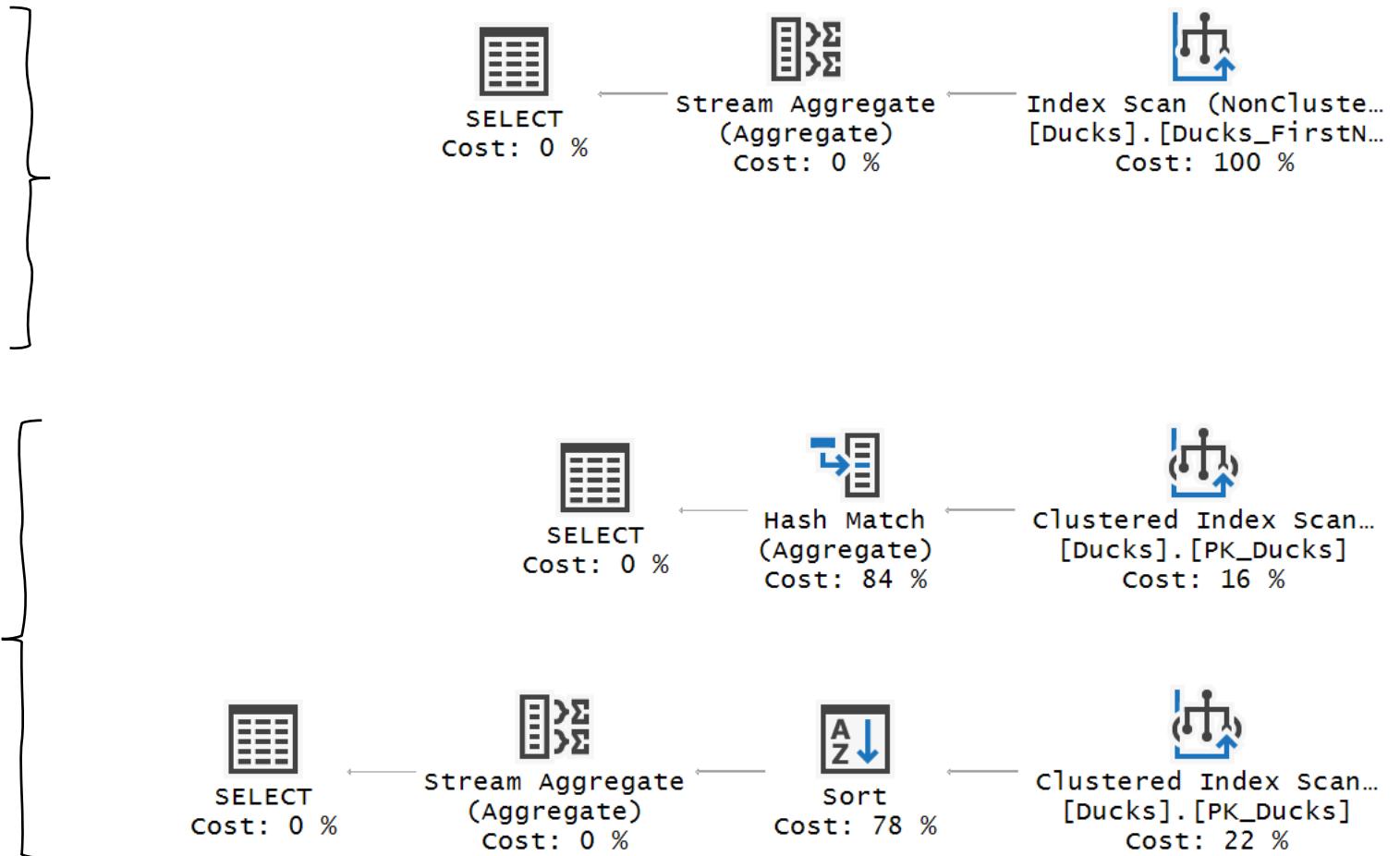
```
SELECT BirthDate, COUNT_BIG(*)  
FROM dbo.Ducks  
GROUP BY BirthDate;
```



```
SELECT FirstName, COUNT_BIG(*)
FROM dbo.Ducks
GROUP BY FirstName;
```

```
SELECT DISTINCT FirstName
FROM dbo.Ducks;
```

```
SELECT BirthDate, COUNT_BIG(*)
FROM dbo.Ducks
GROUP BY BirthDate;
```

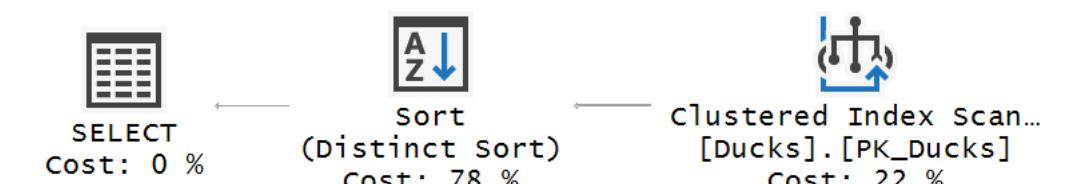
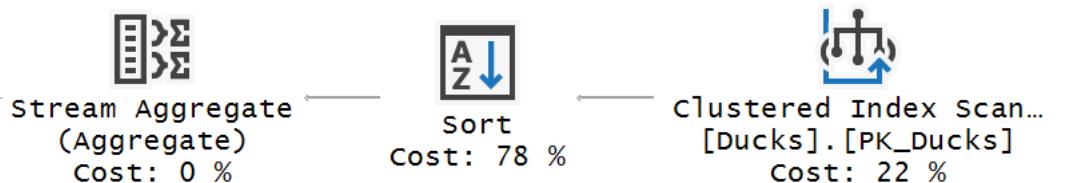
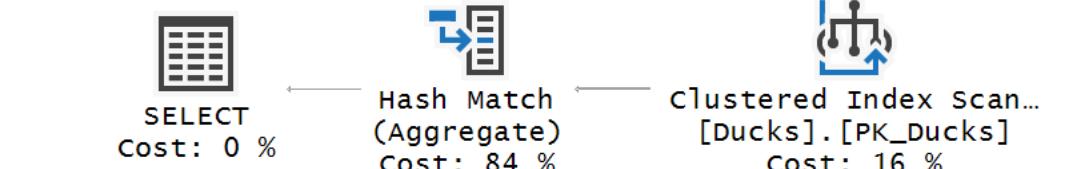
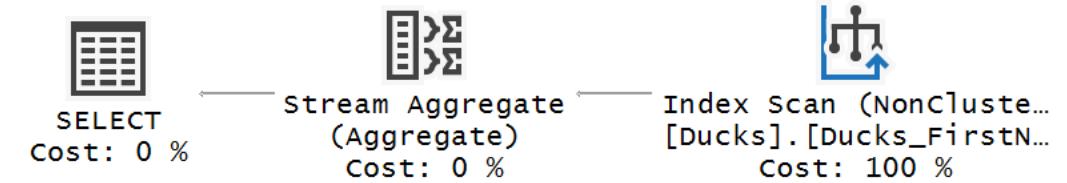


```
SELECT FirstName, COUNT_BIG(*)
FROM dbo.Ducks
GROUP BY FirstName;
```

```
SELECT DISTINCT FirstName
FROM dbo.Ducks;
```

```
SELECT BirthDate, COUNT_BIG(*)
FROM dbo.Ducks
GROUP BY BirthDate;
```

```
SELECT DISTINCT BirthDate
FROM dbo.Ducks;
```

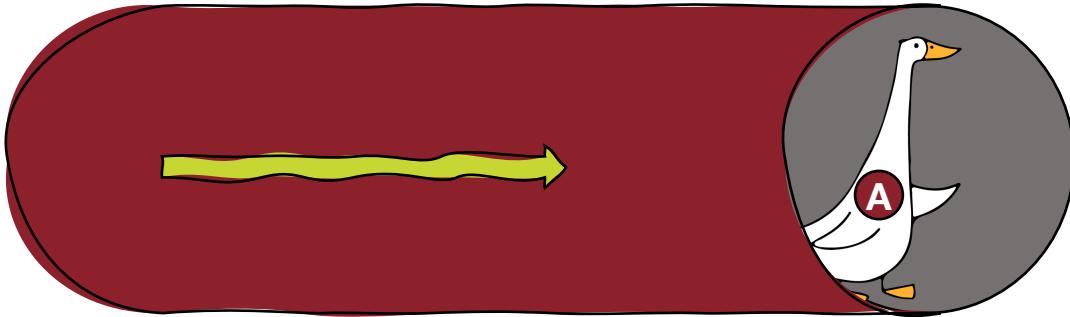




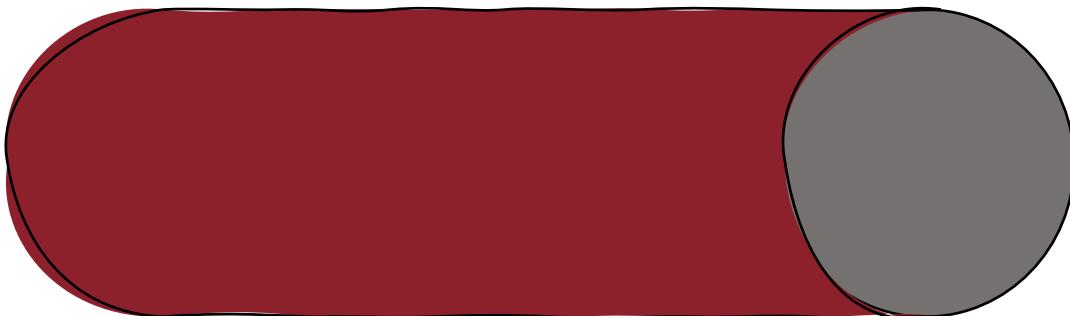
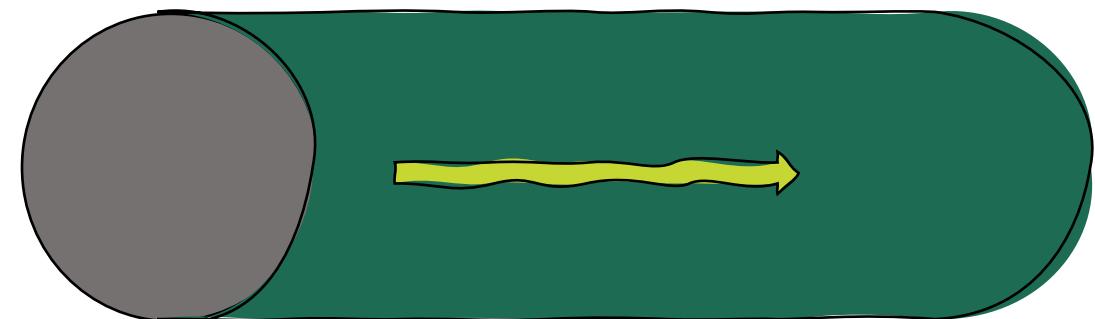
# NESTED LOOP JOIN.

# Nested Loop Join

Top input

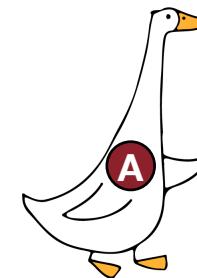
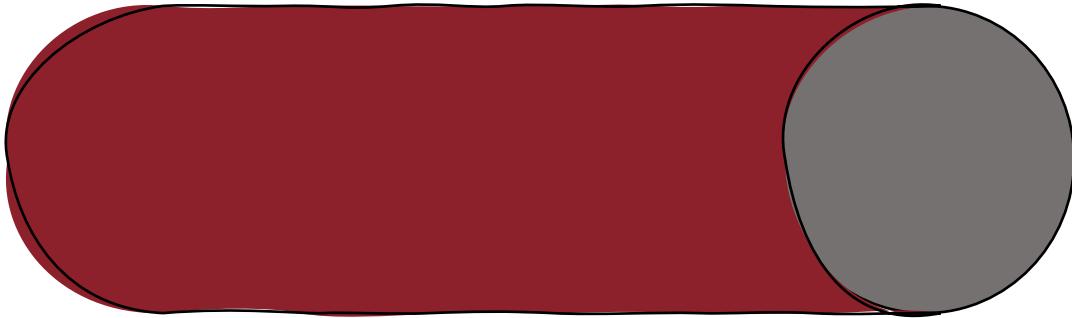


Output

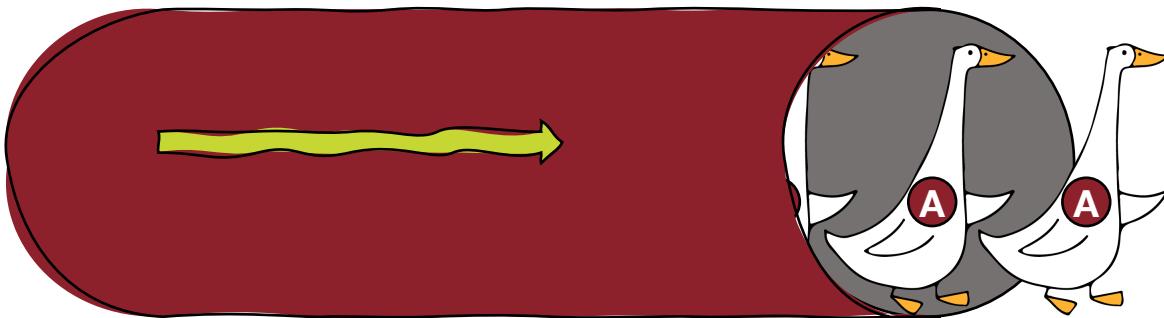
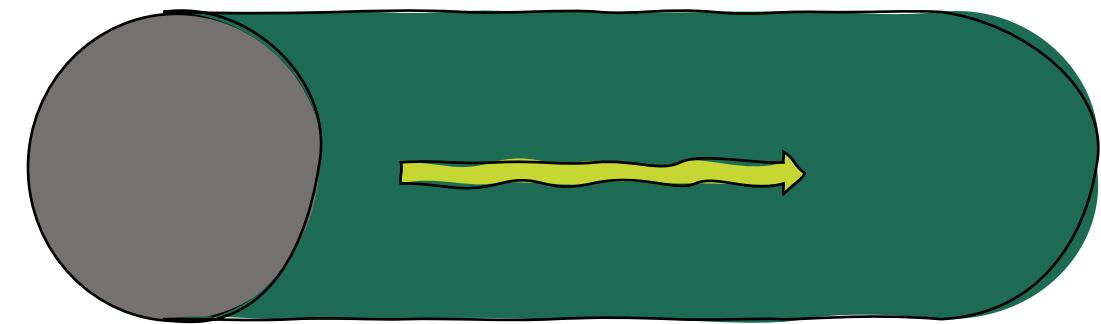


# Nested Loop Join

Top input

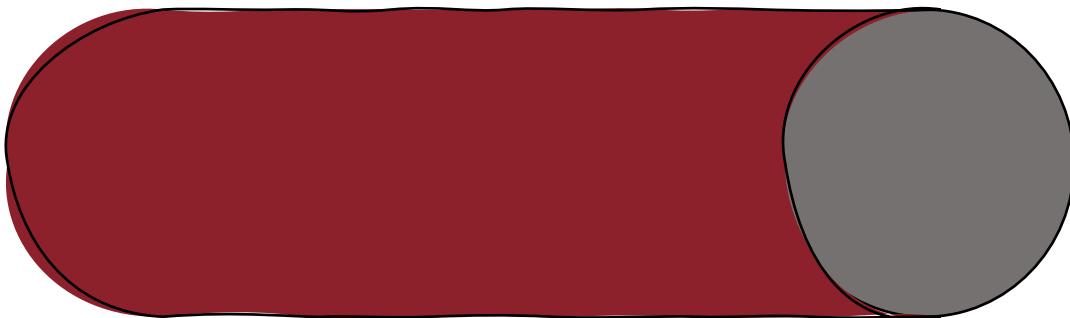
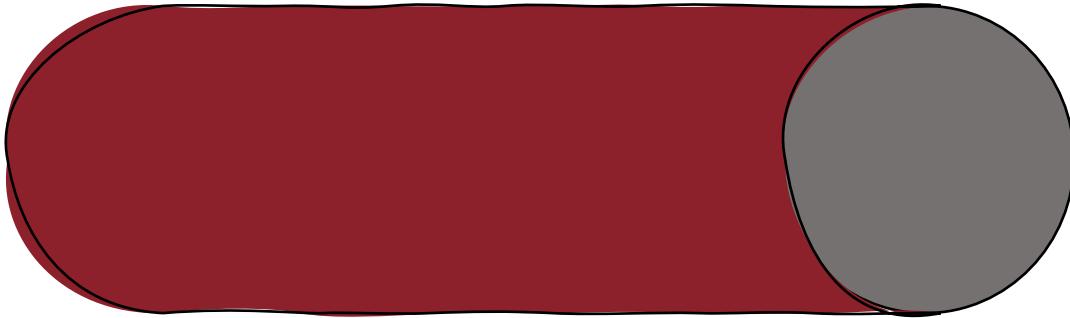


Output

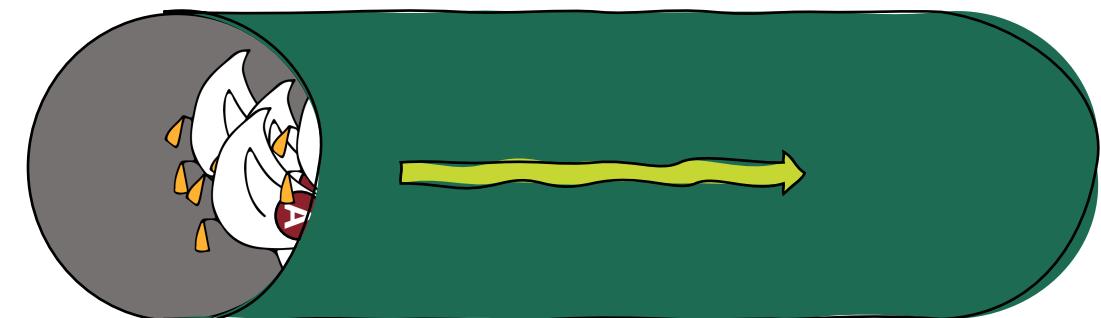


# Nested Loop Join

Top input

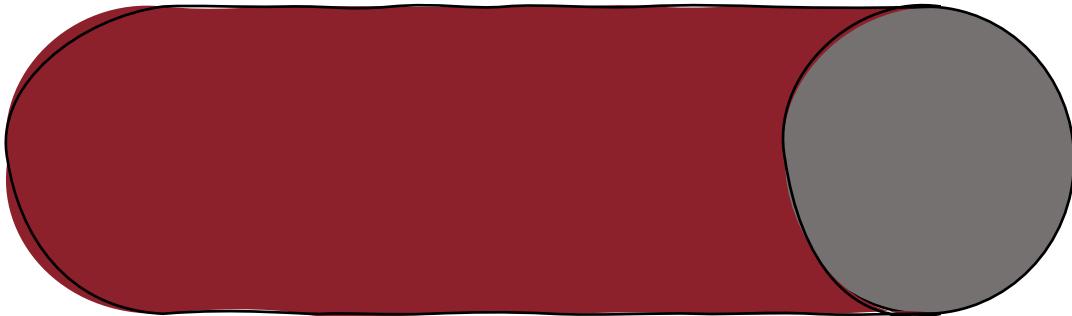
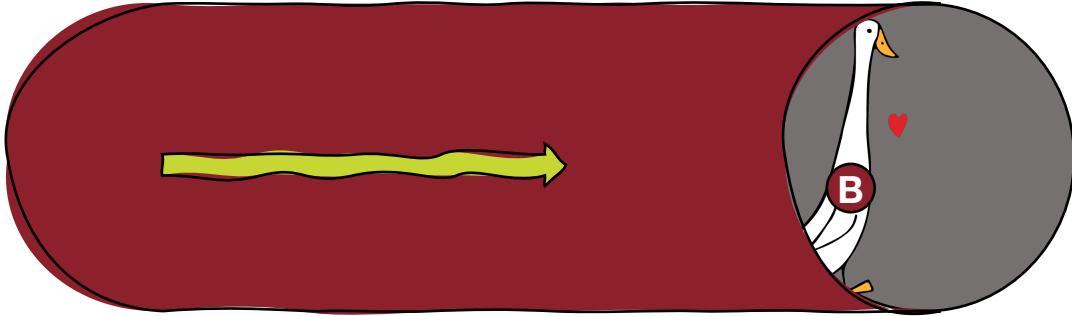


Output

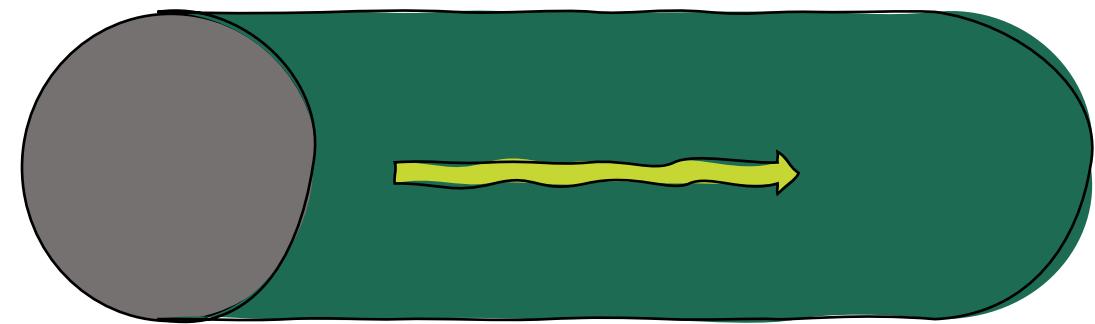


# Nested Loop Join

Top input

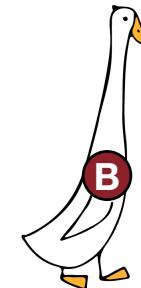
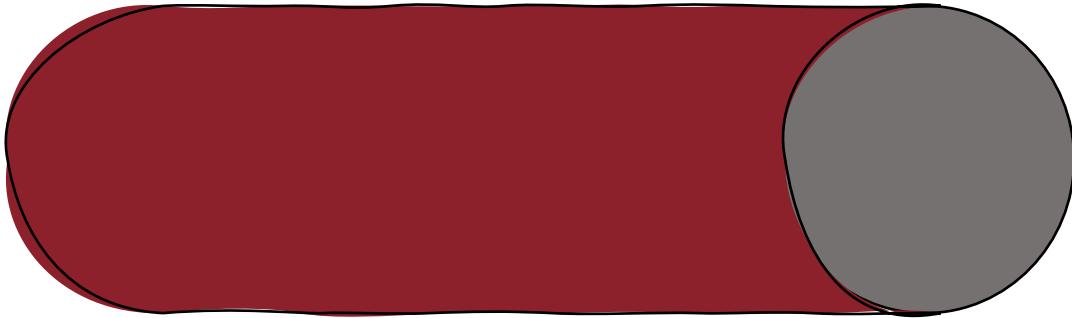


Output

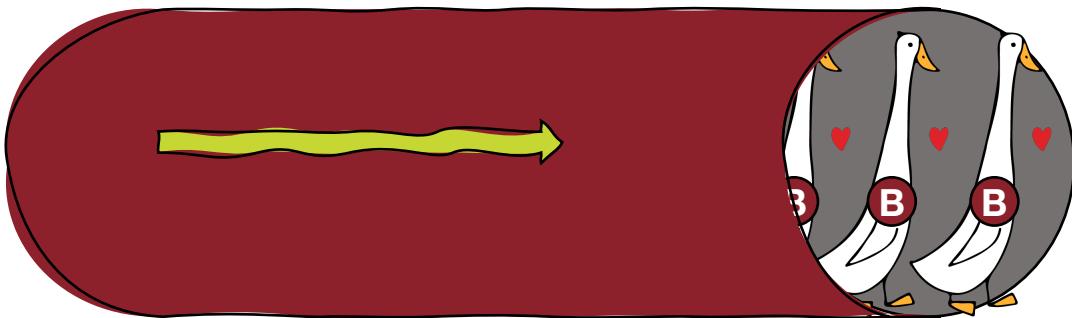
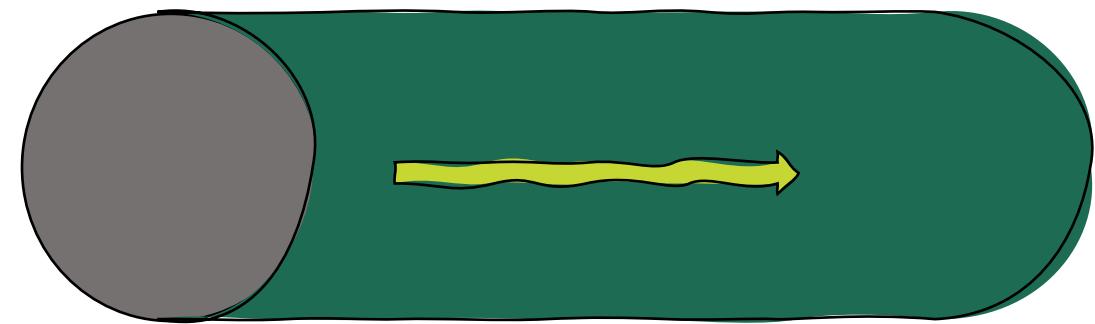


# Nested Loop Join

Top input

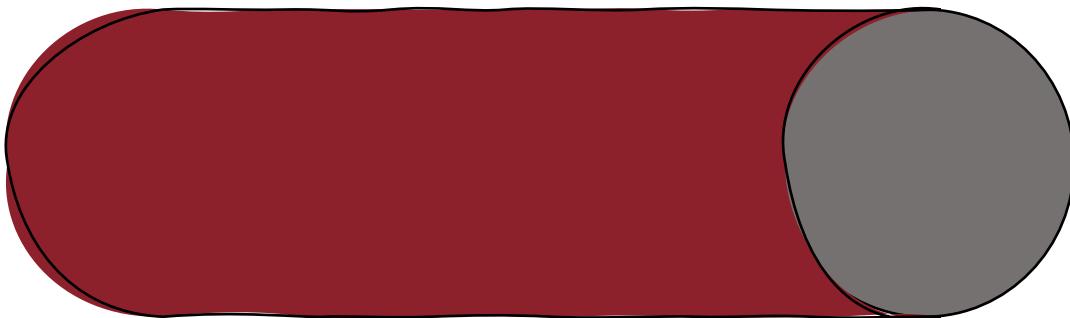
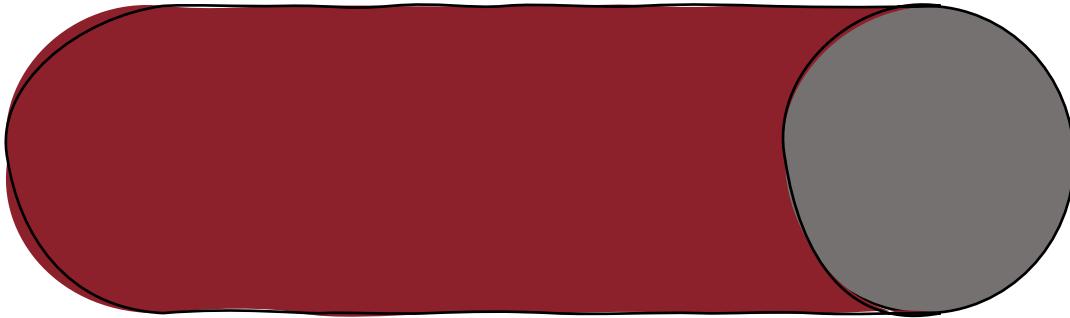


Output

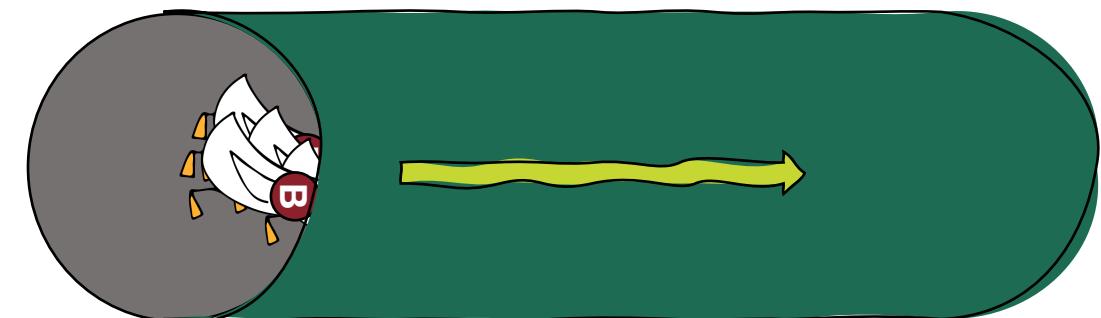


# Nested Loop Join

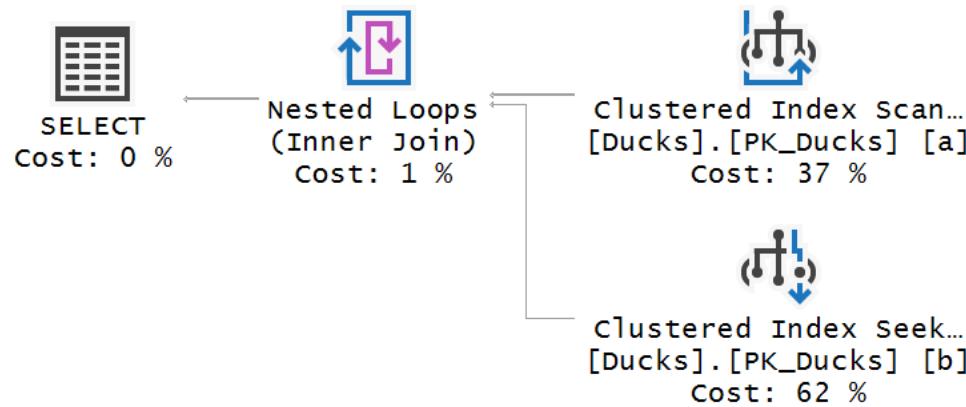
Top input



Output



```
SELECT *
FROM dbo.Ducks AS a
INNER JOIN dbo.Ducks AS b ON a.ID=b.ID;
```

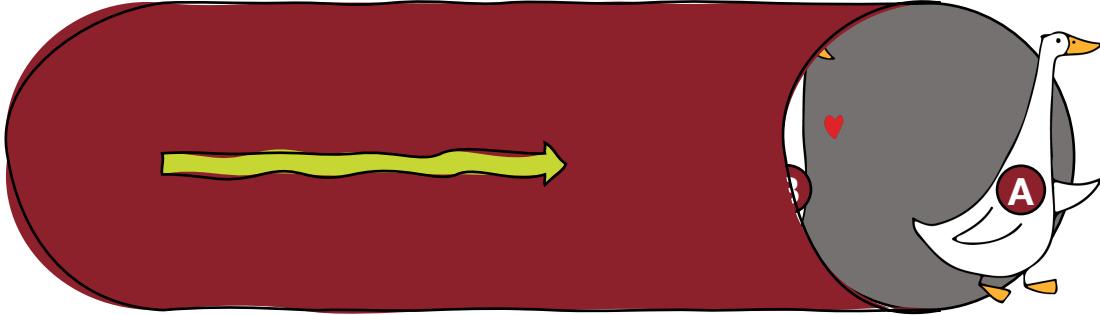




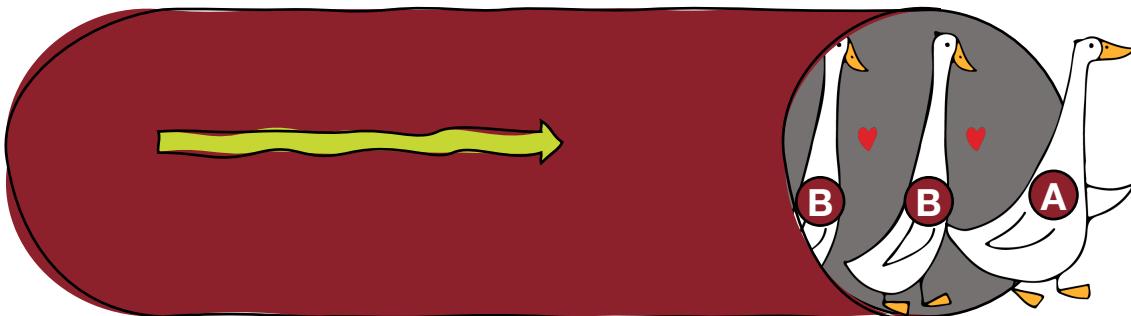
# MERGE JOIN.

# Merge Join

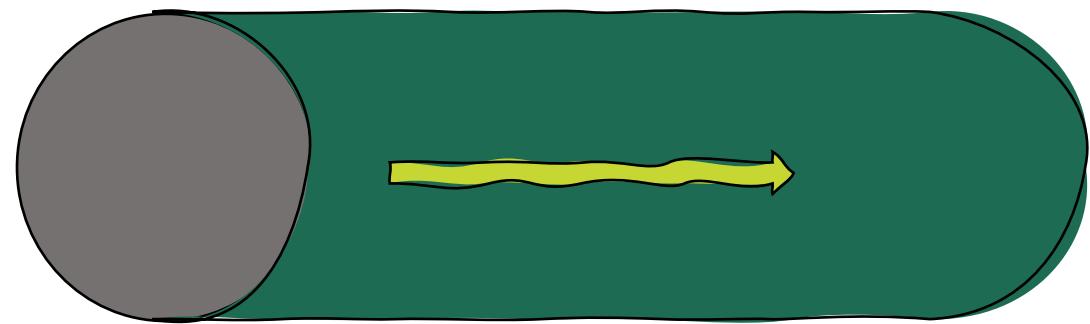
Sorted top input



Sorted bottom input

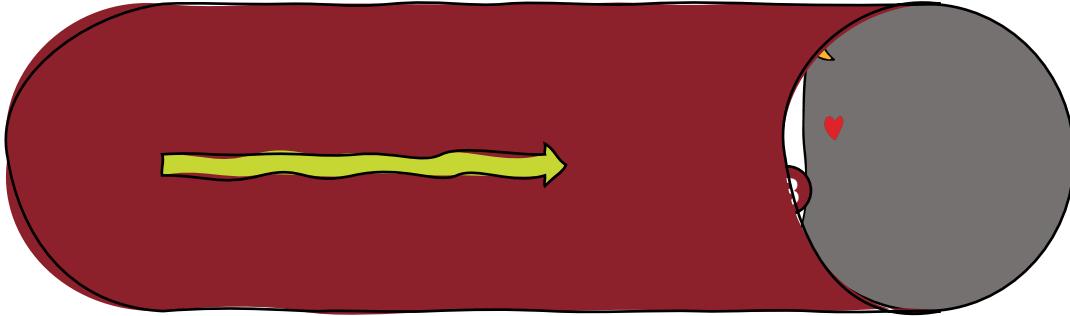


Output

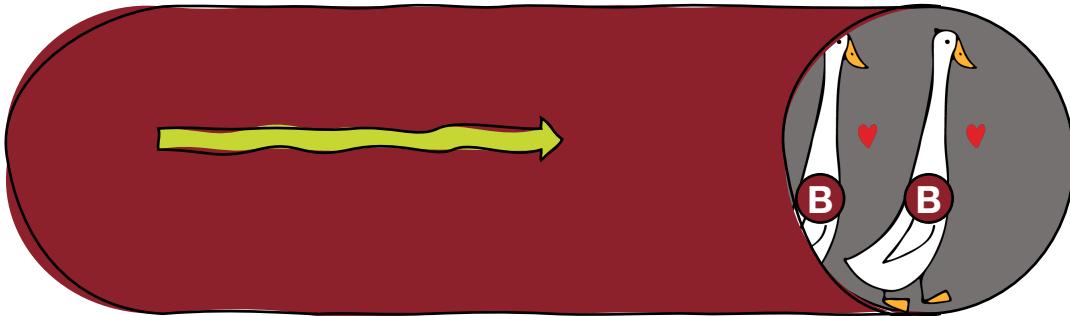


# Merge Join

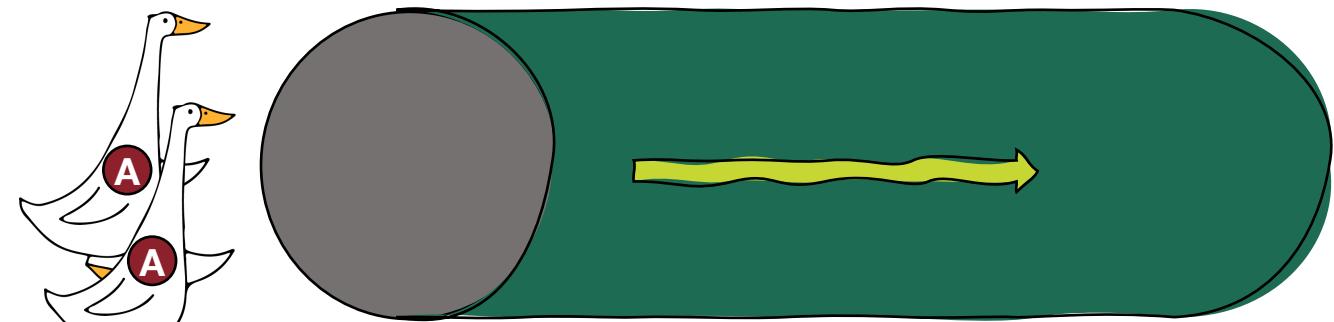
Sorted top input



Sorted bottom input

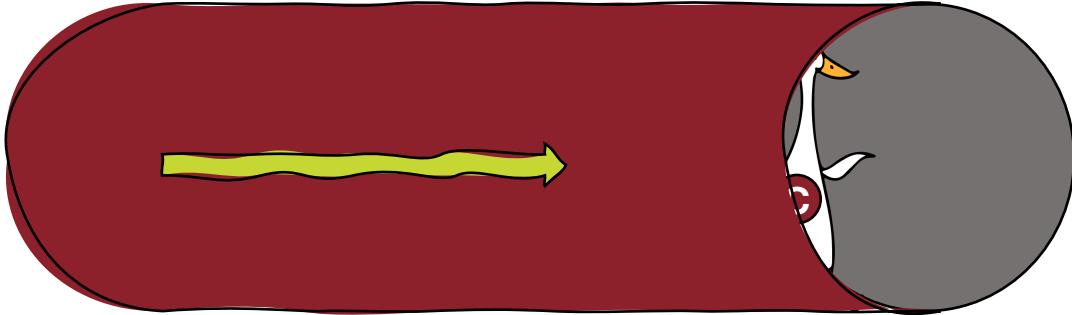


Output

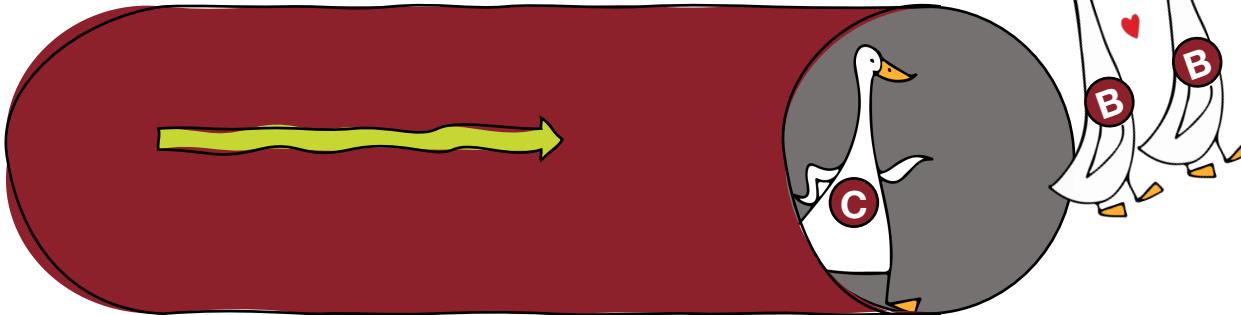


# Merge Join

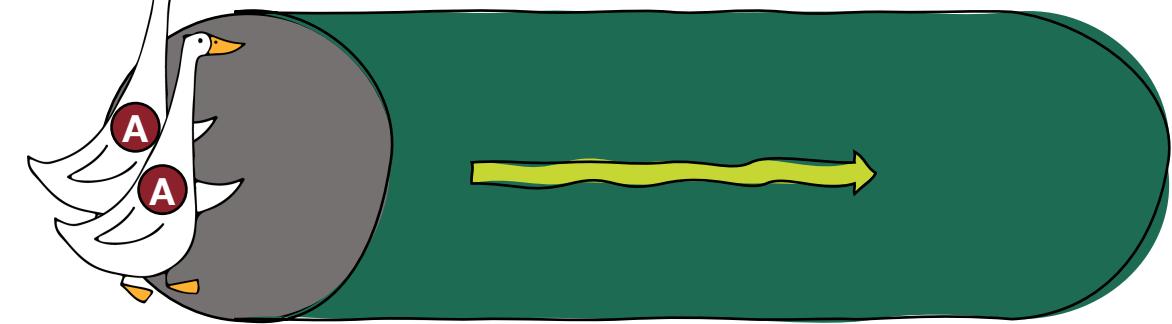
Sorted top input



Sorted bottom input

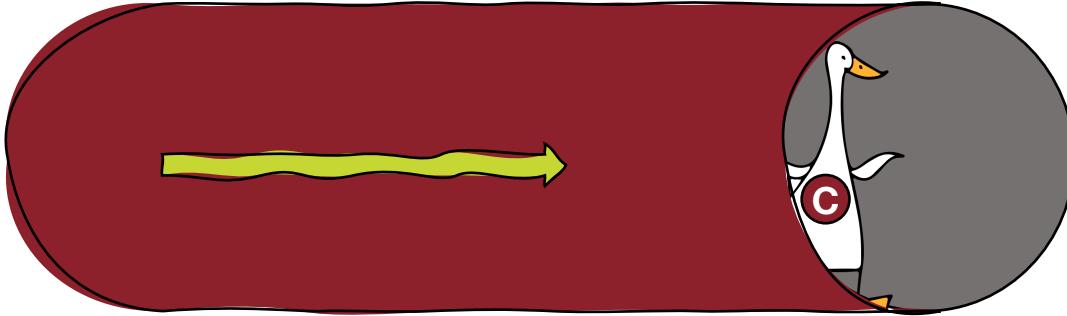


Output

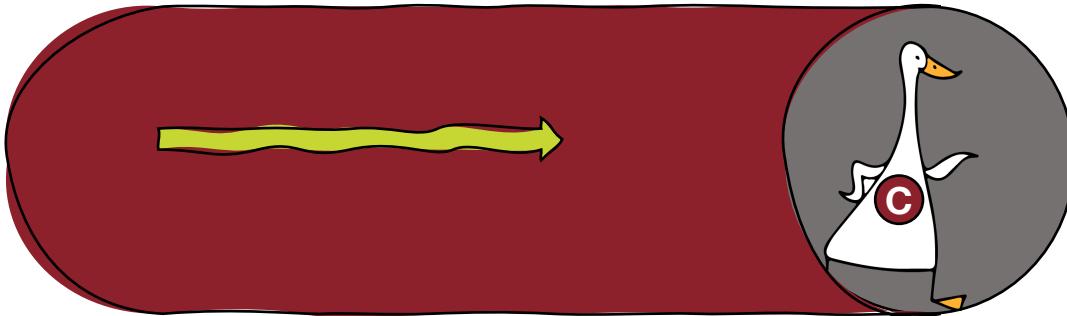


# Merge Join

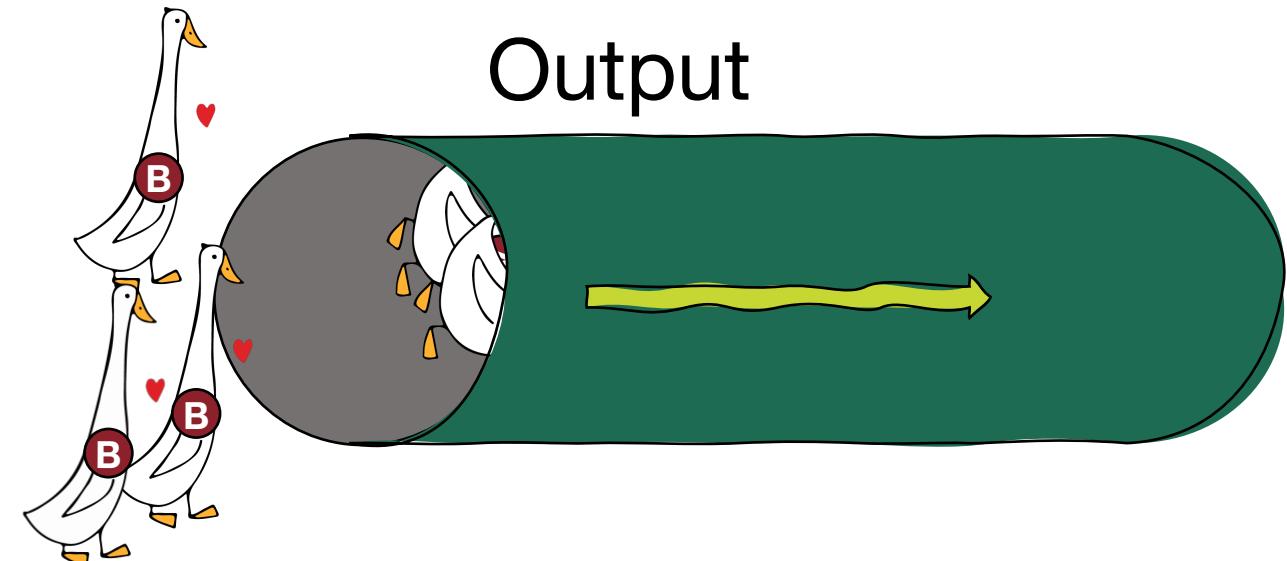
Sorted top input



Sorted bottom input

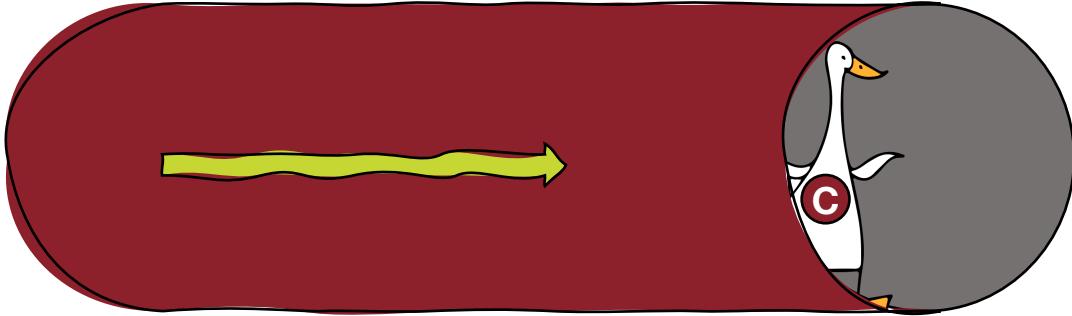


Output

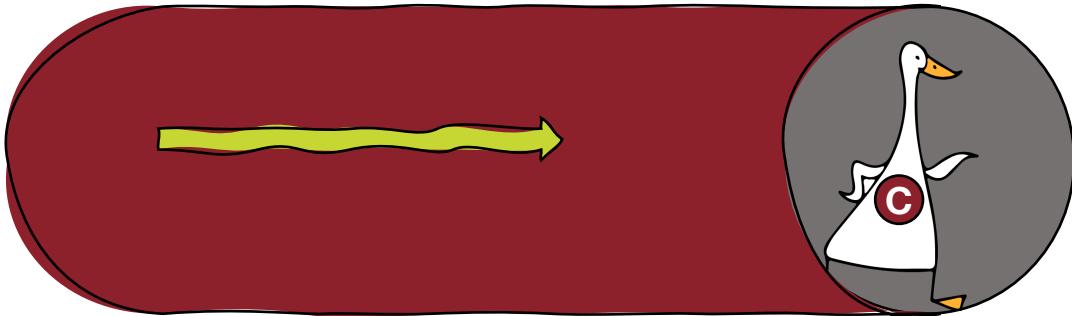


# Merge Join

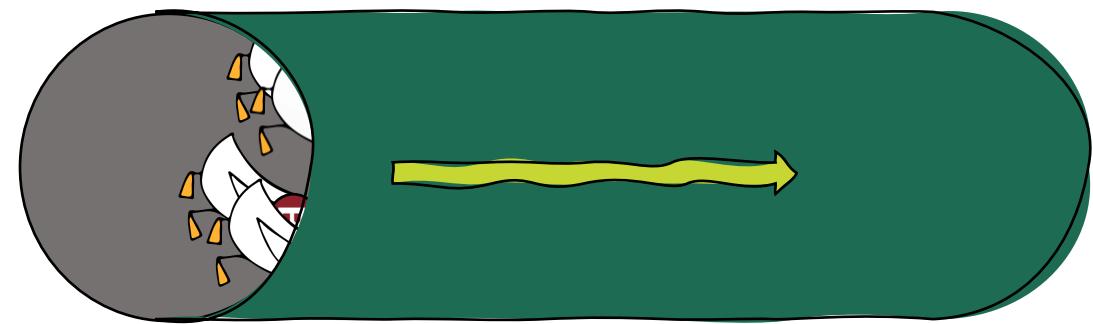
Sorted top input



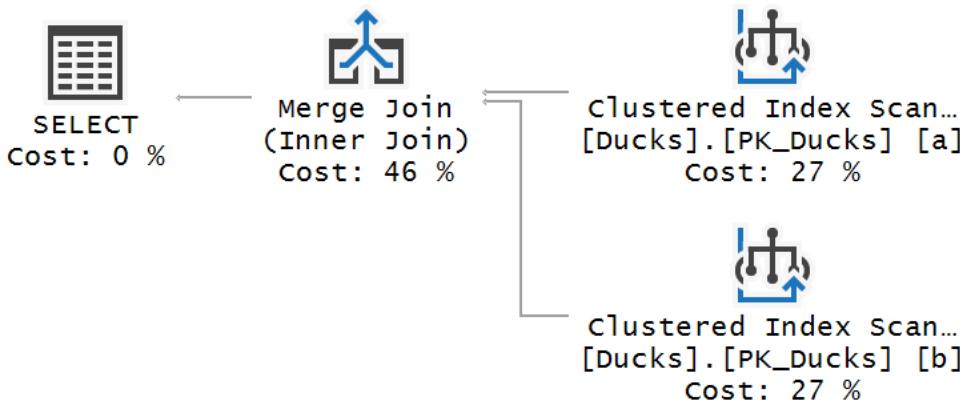
Sorted bottom input



Output

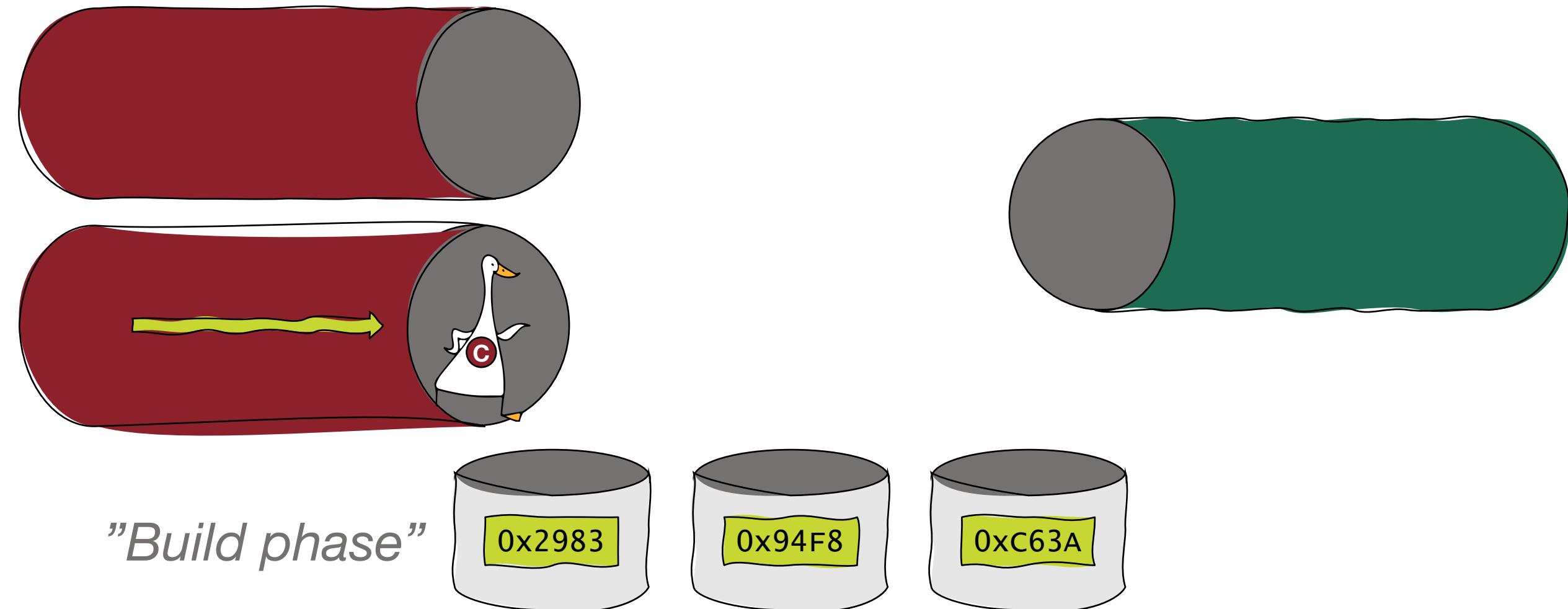


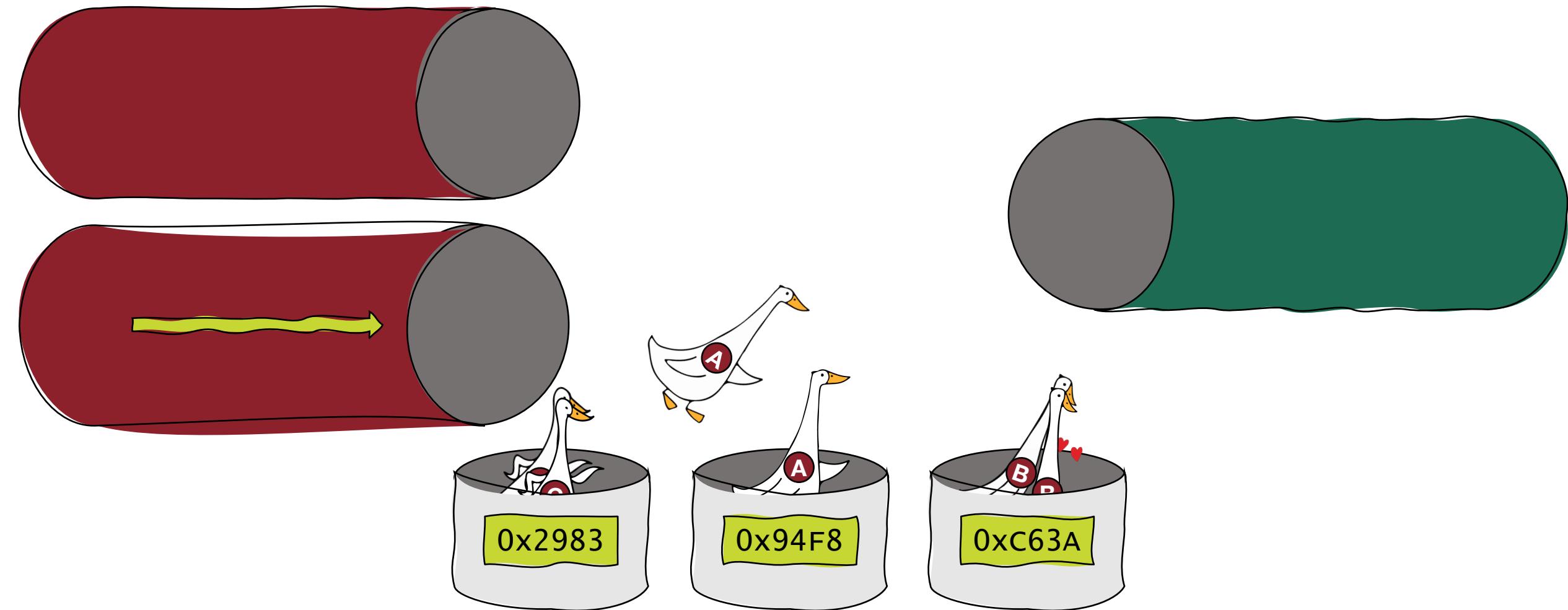
```
SELECT *
FROM dbo.Ducks AS a
INNER JOIN dbo.Ducks AS b ON a.ID=b.ID;
```

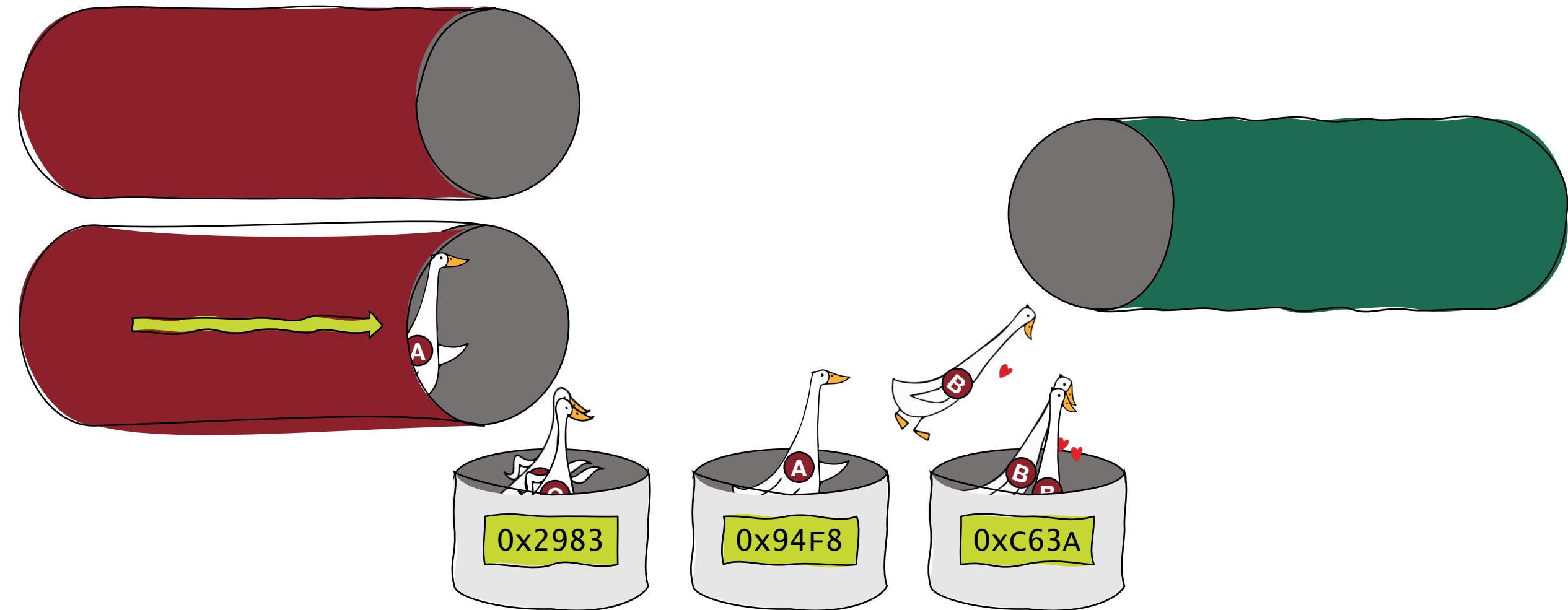


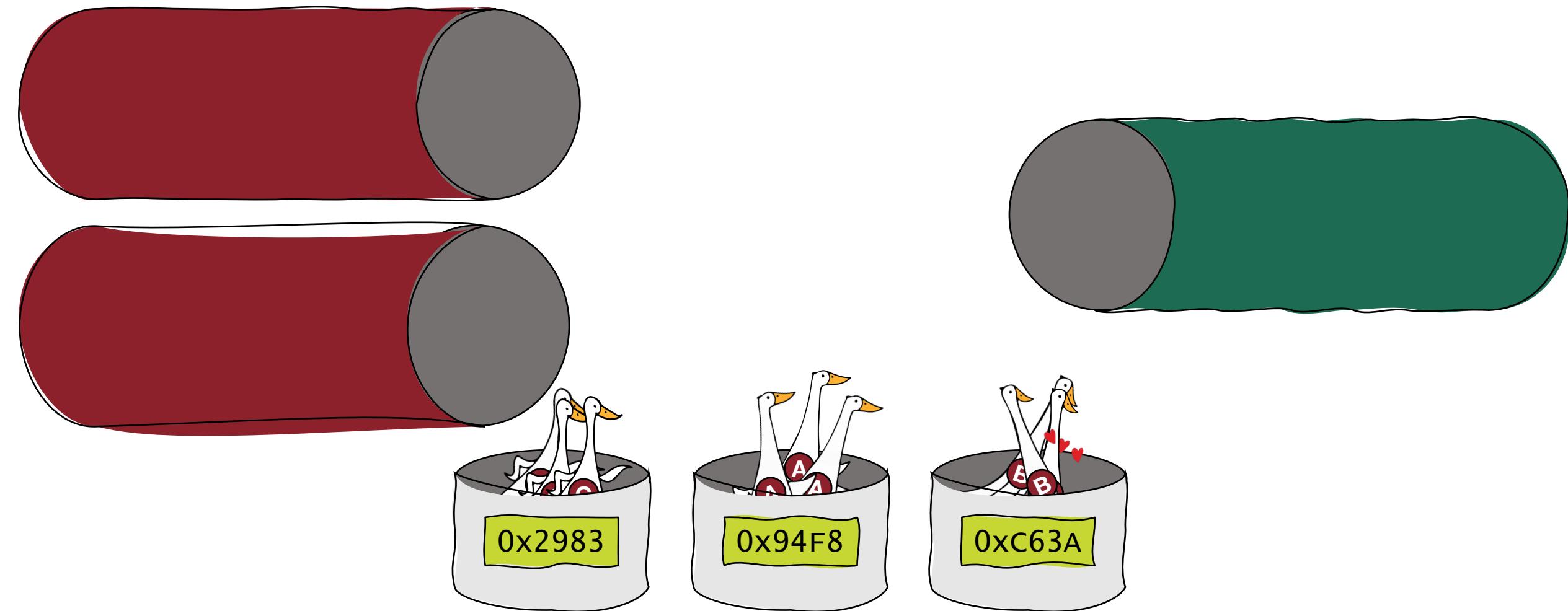


# HASH JOIN.

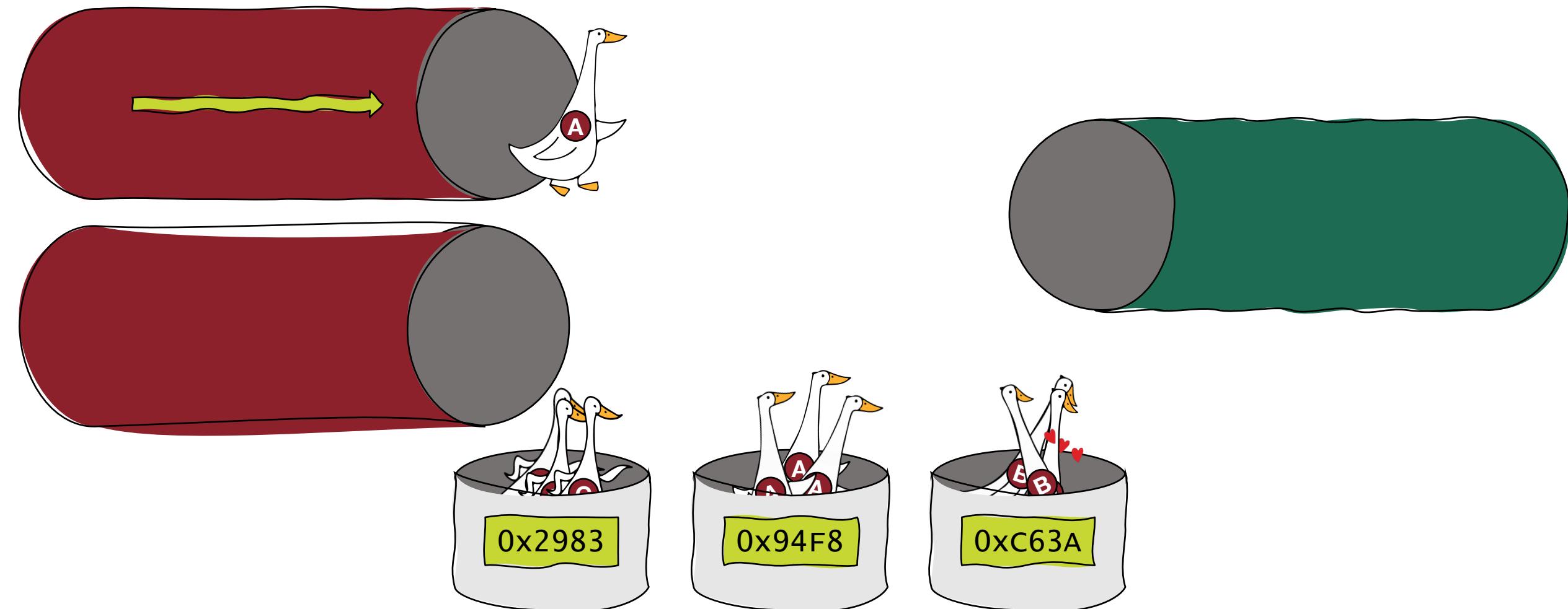


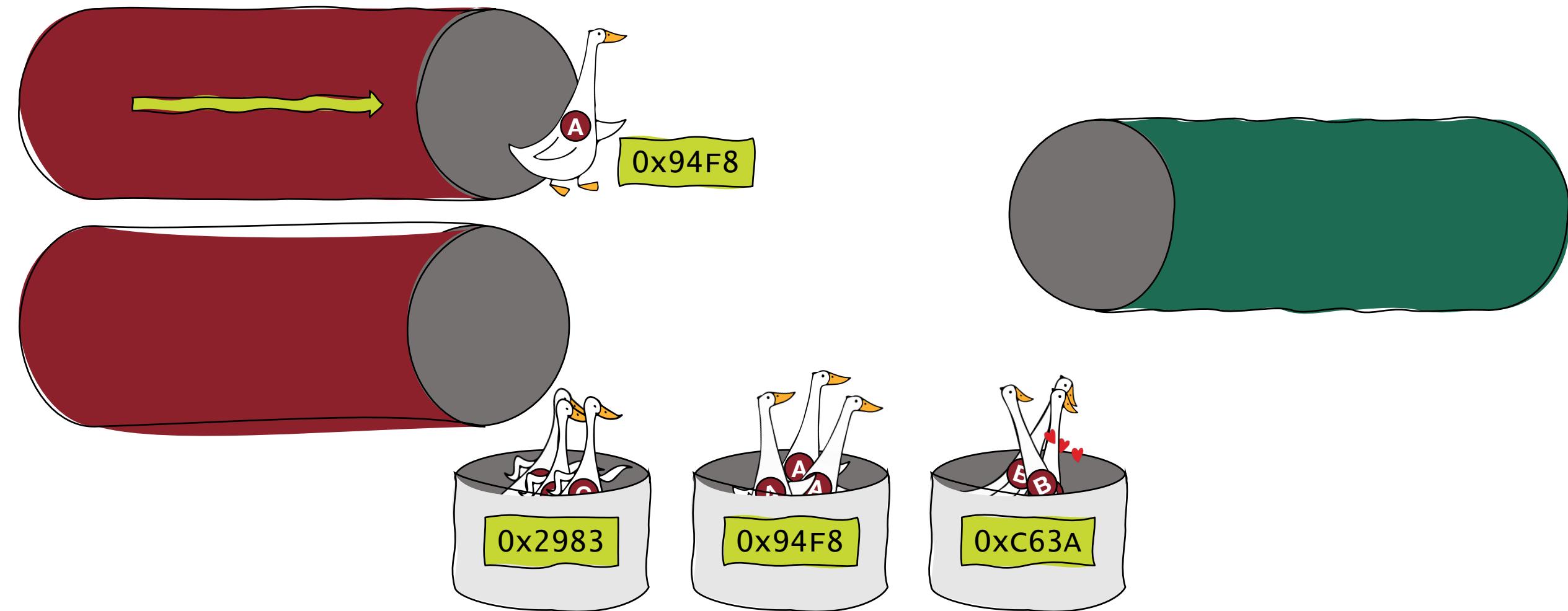


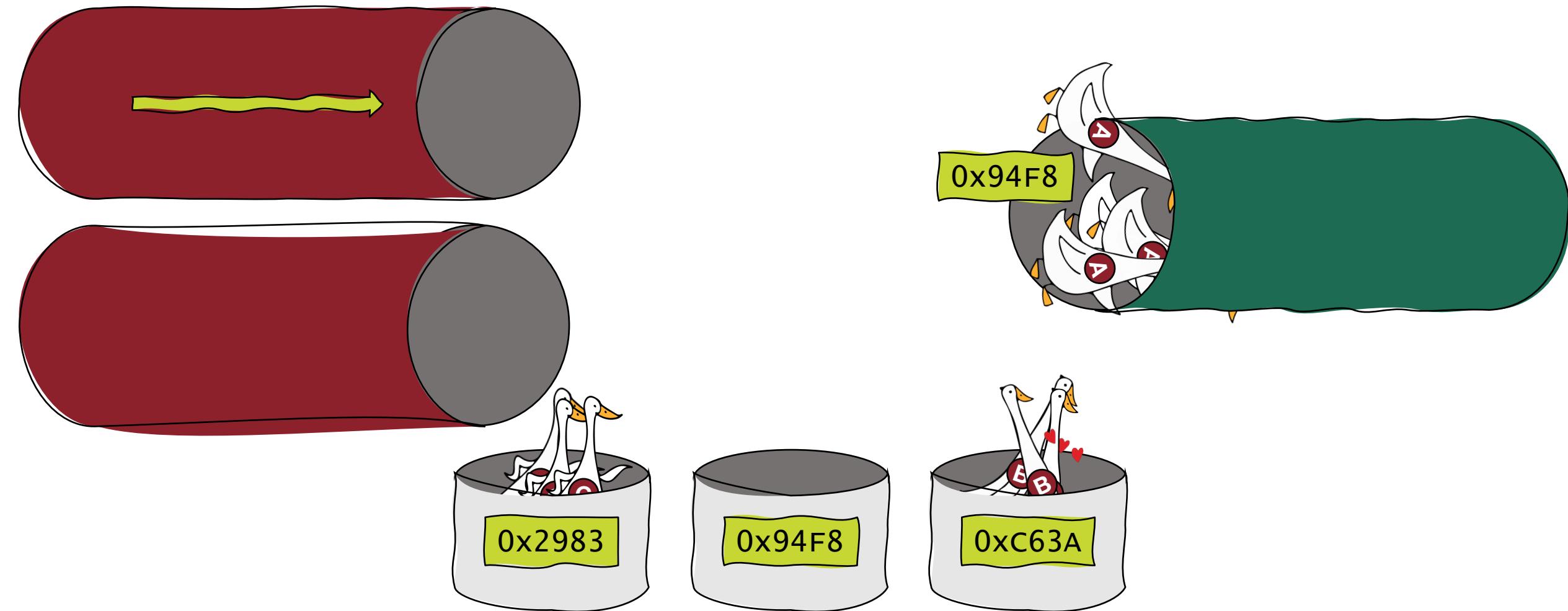


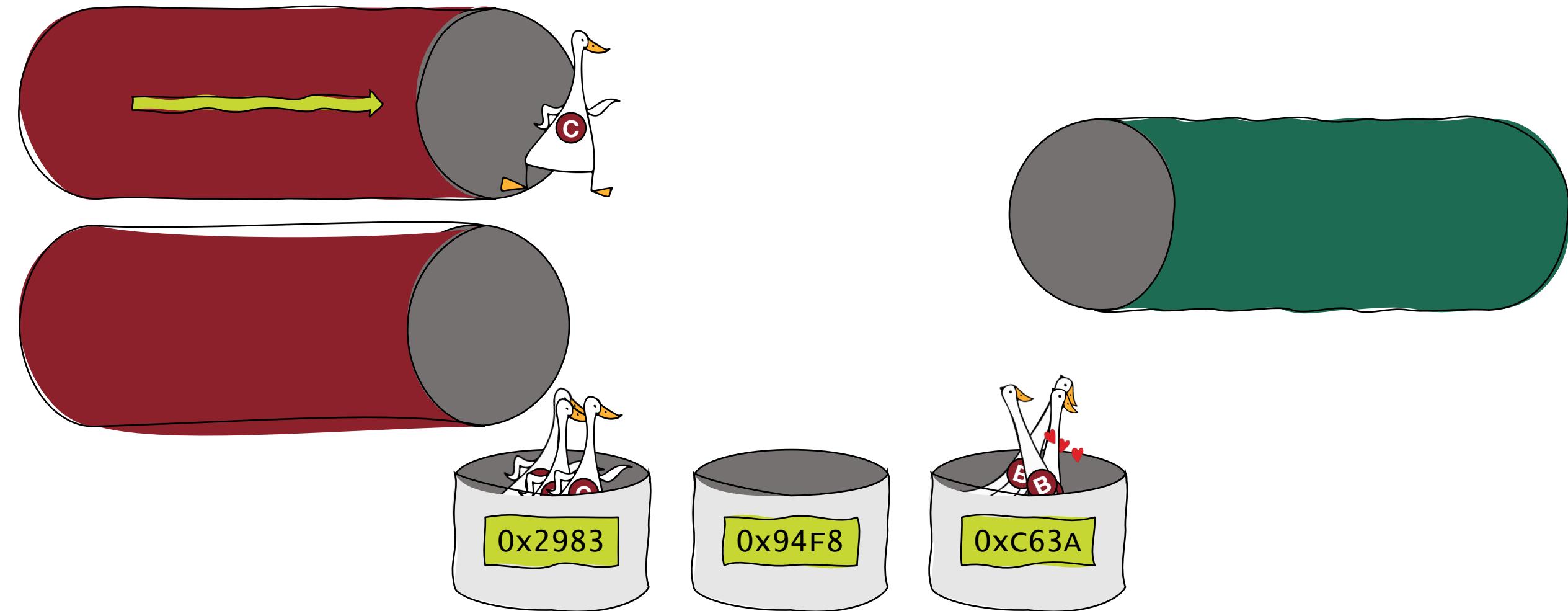


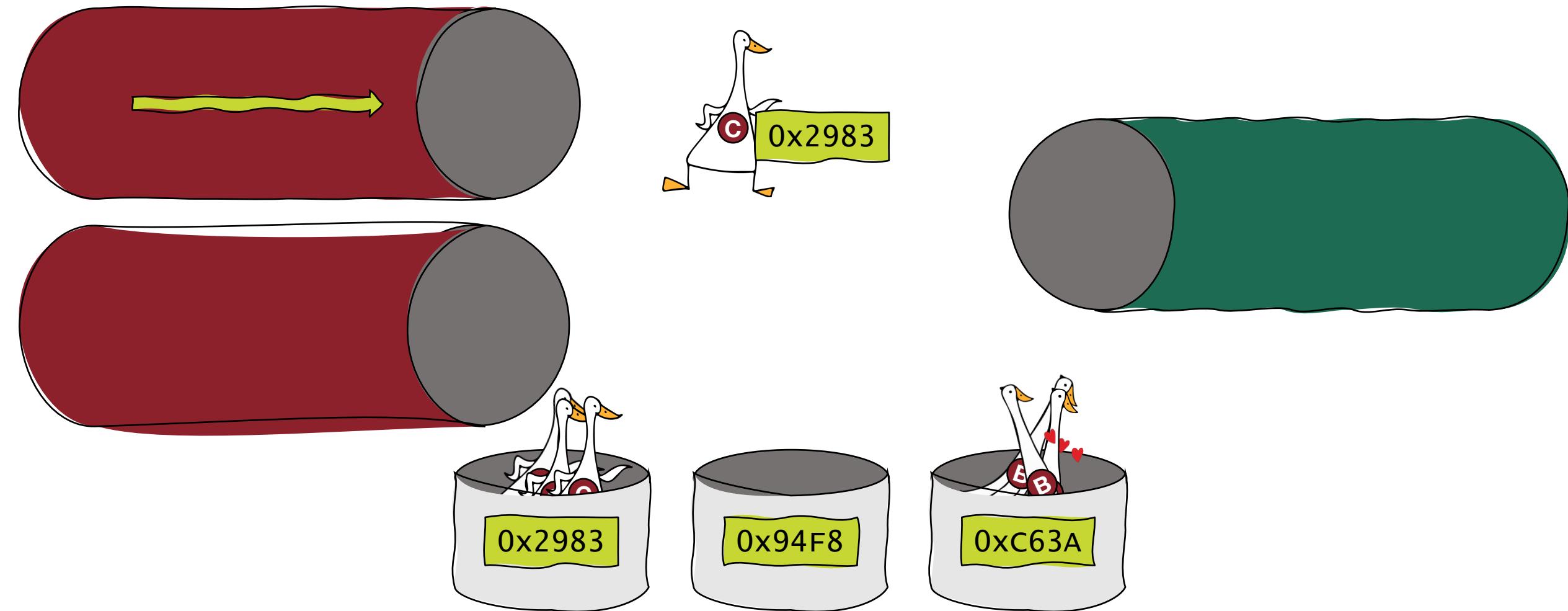
## "Probe phase"

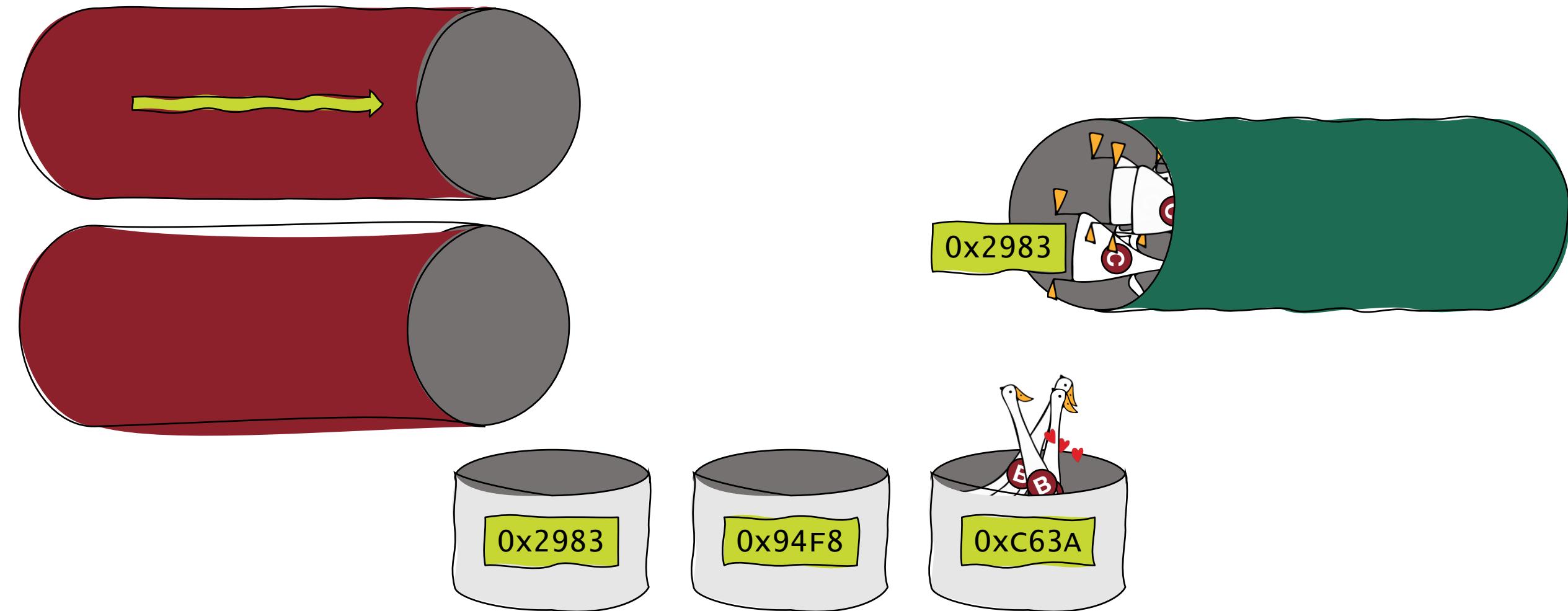




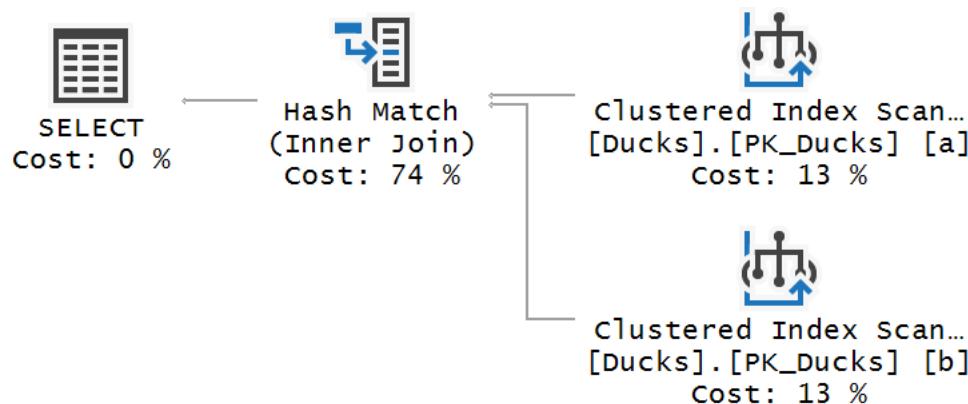








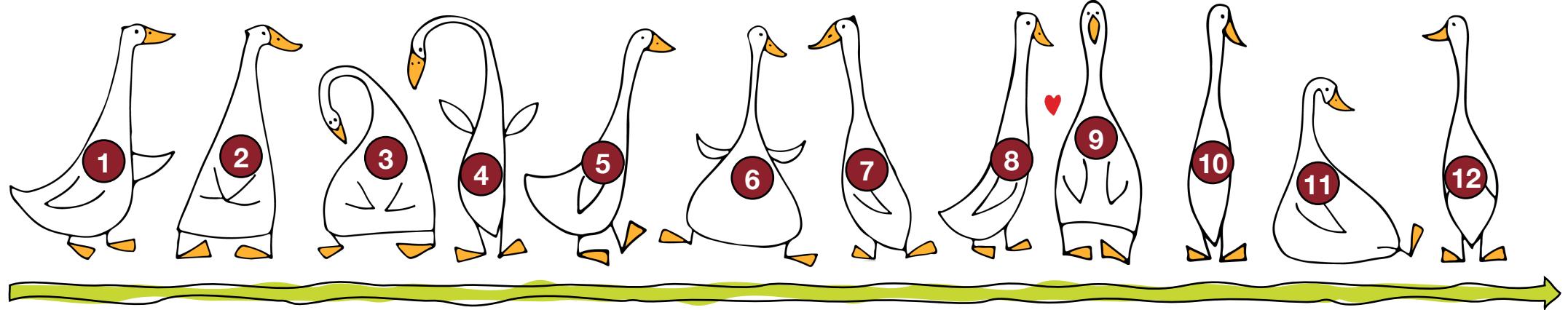
```
SELECT *
FROM dbo.Ducks AS a
INNER JOIN dbo.Ducks AS b ON a.ID=b.ID;
```





# PARALLELISM.

# Single-threaded flow:

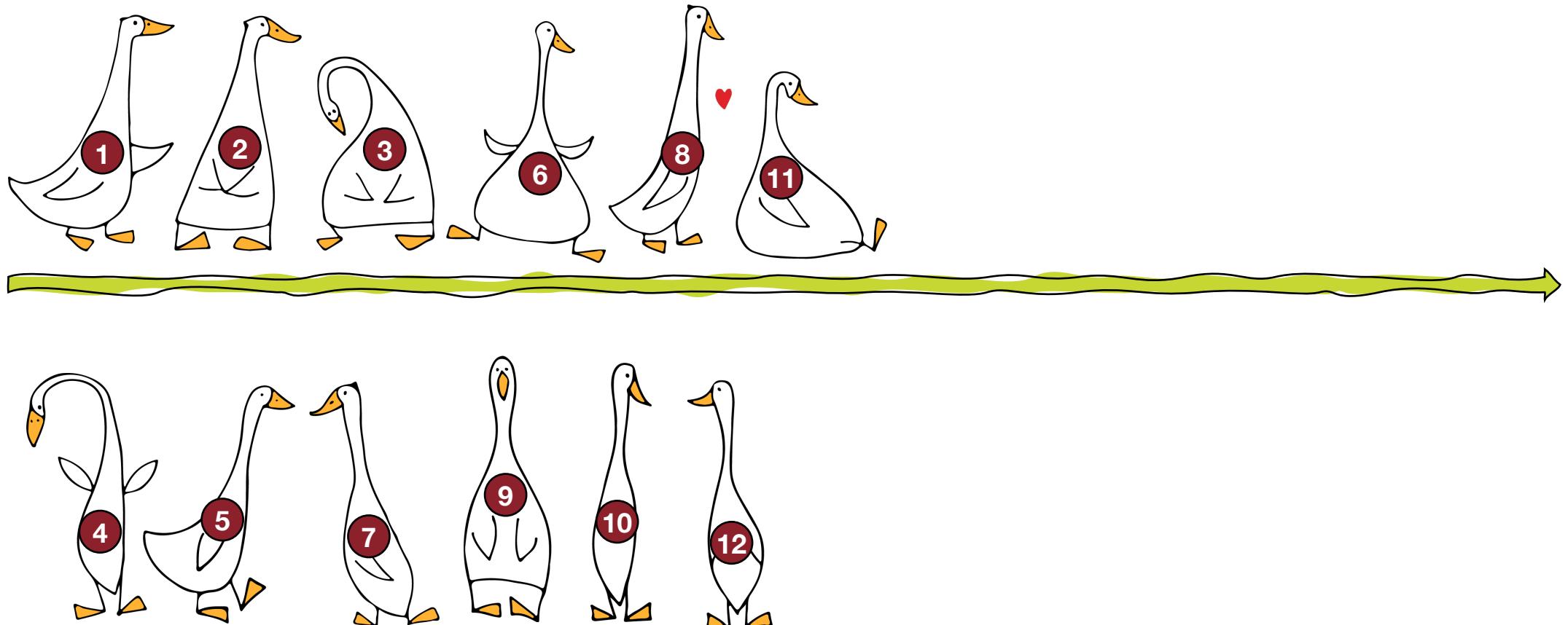


# Single-threaded flow:

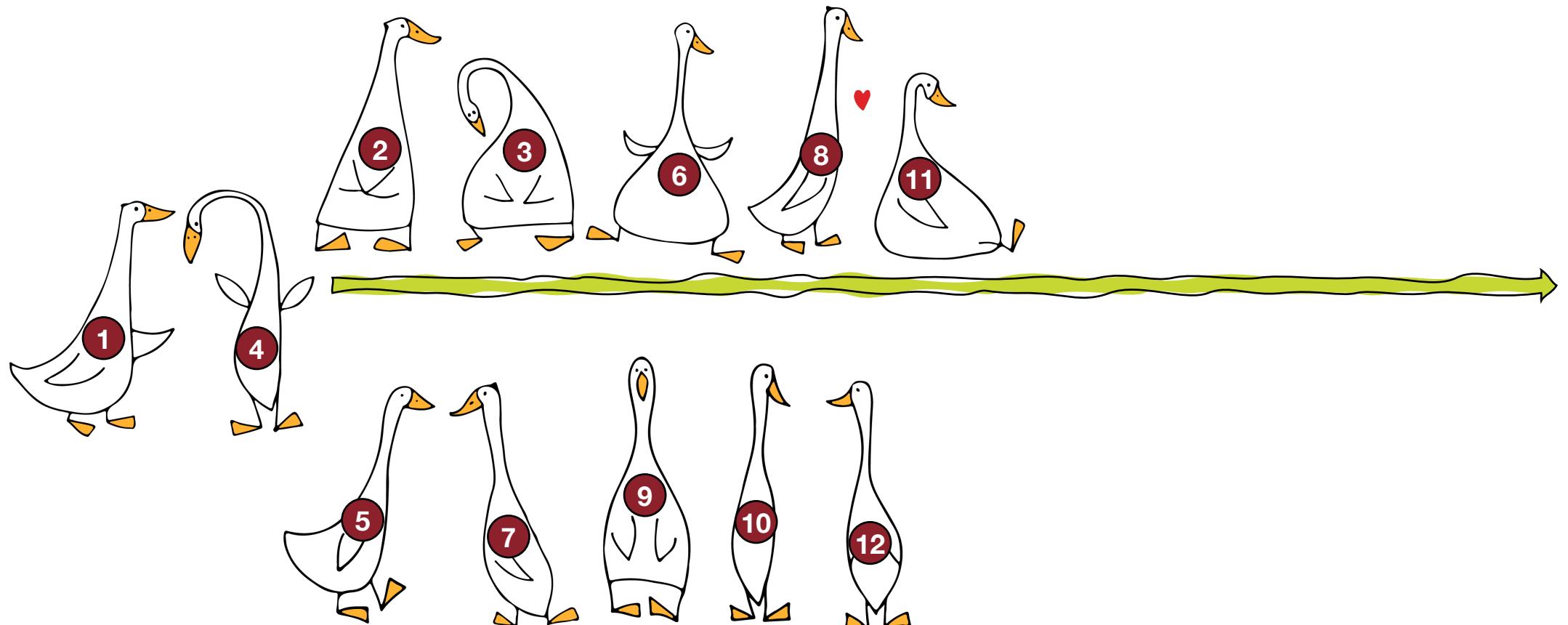
```
SELECT *
FROM dbo.Ducks;
```



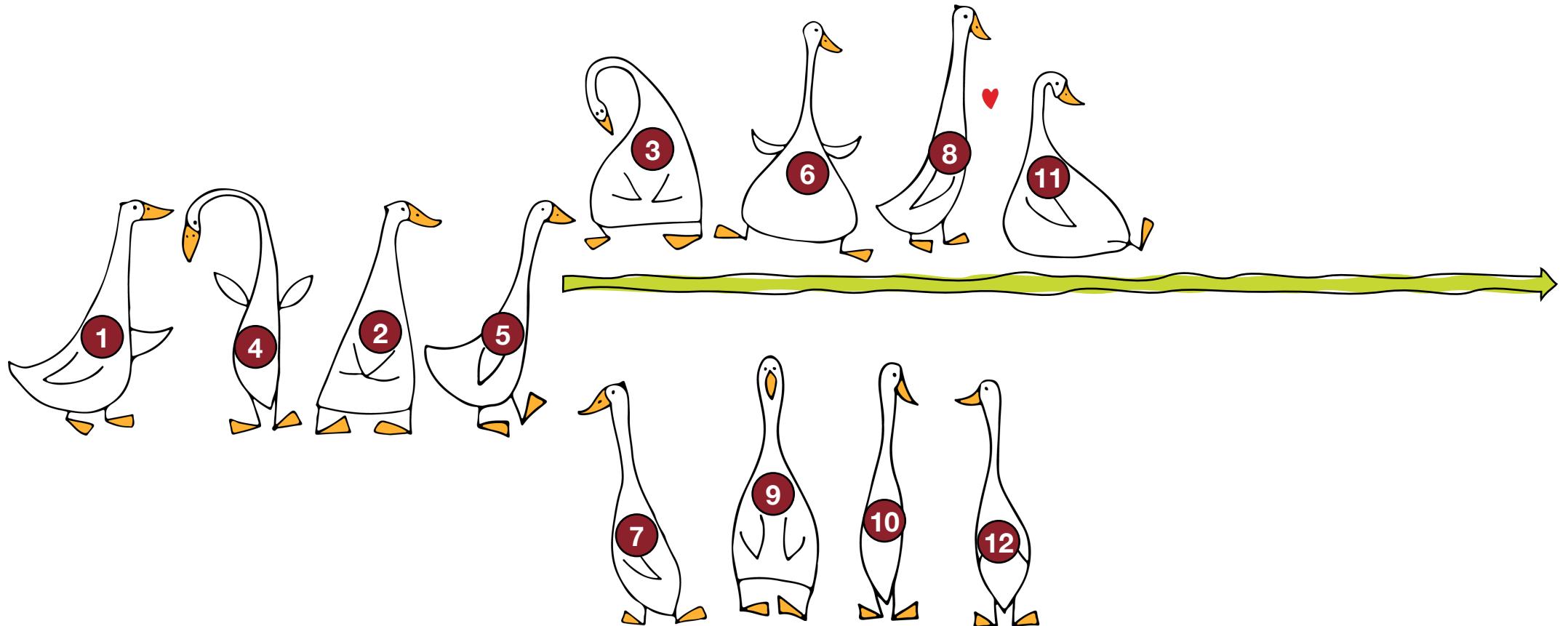
# Multi-threaded flow:



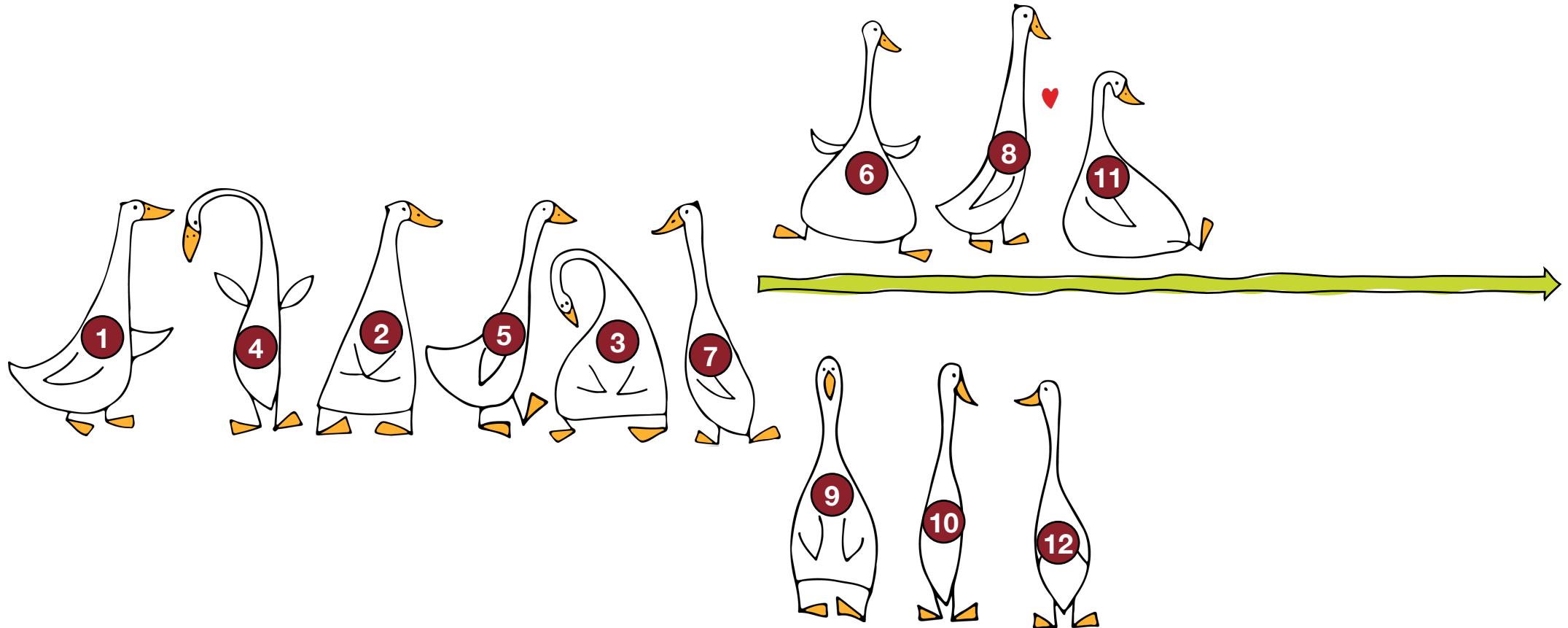
# Multi-threaded flow:



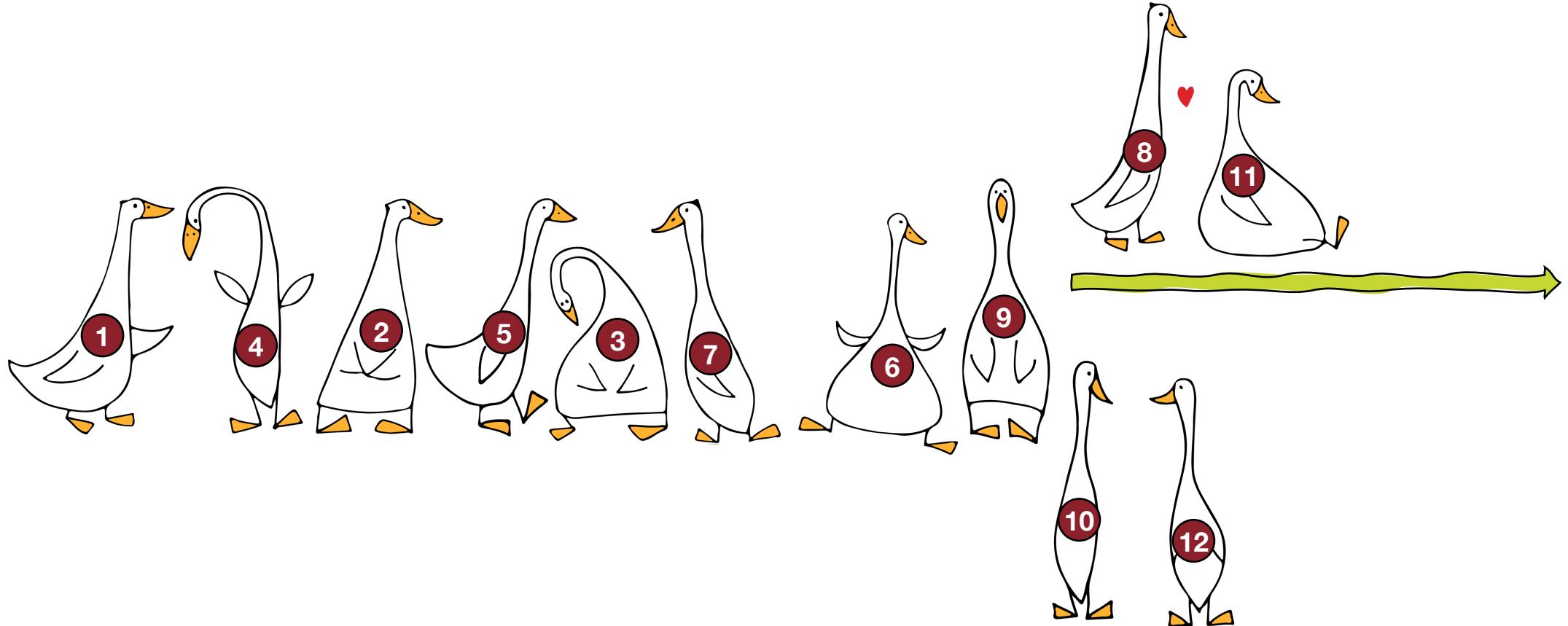
# Multi-threaded flow:



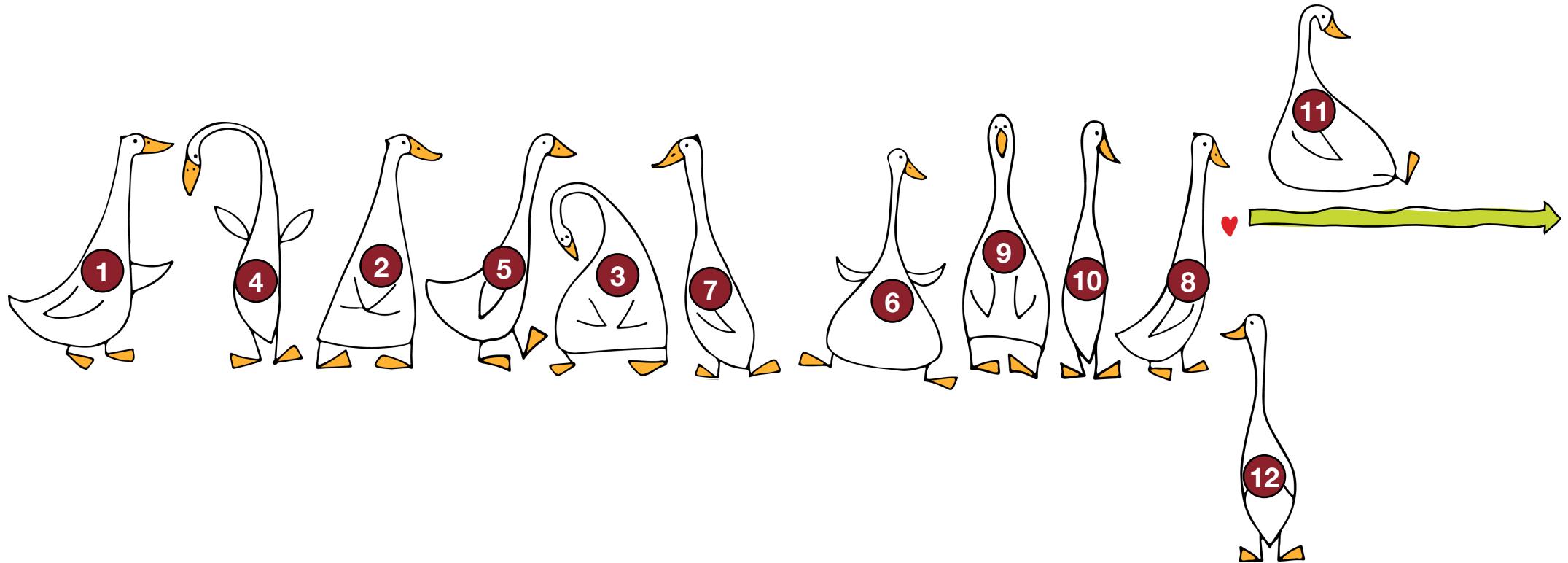
# Multi-threaded flow:



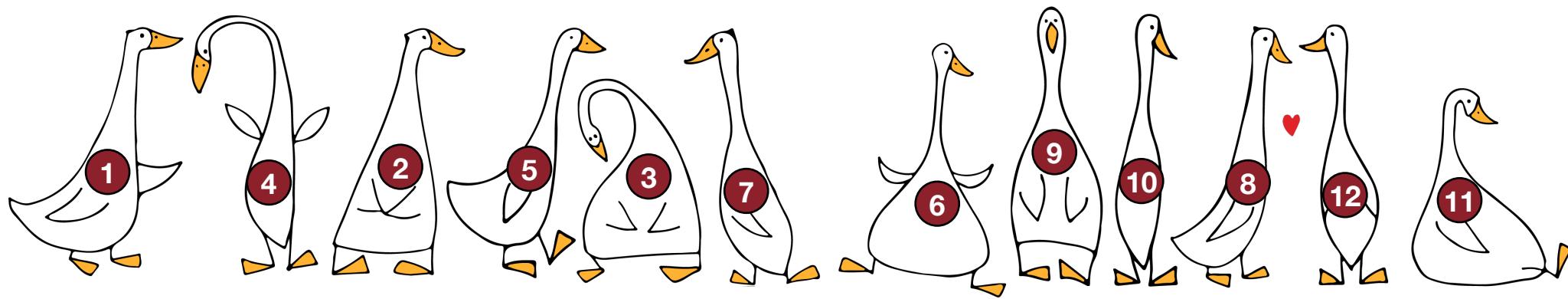
# Multi-threaded flow:



# Multi-threaded flow:



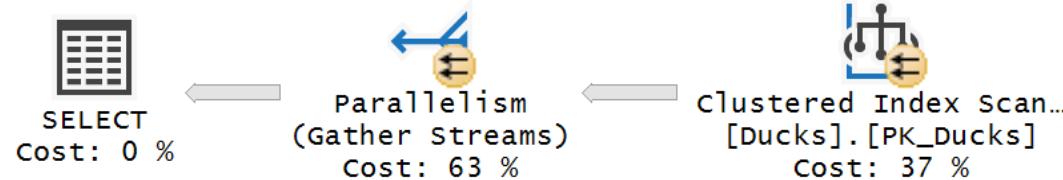
# Multi-threaded flow:



# Multi-threaded flow:

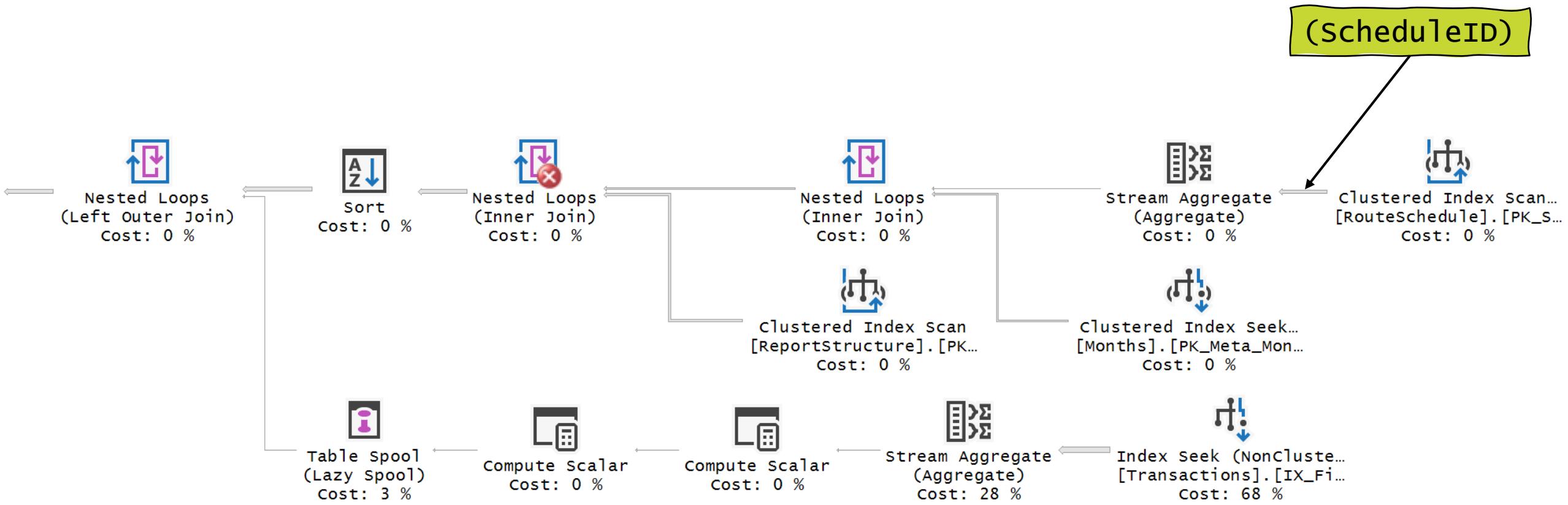
```
SELECT *
```

```
FROM dbo.Ducks;
```

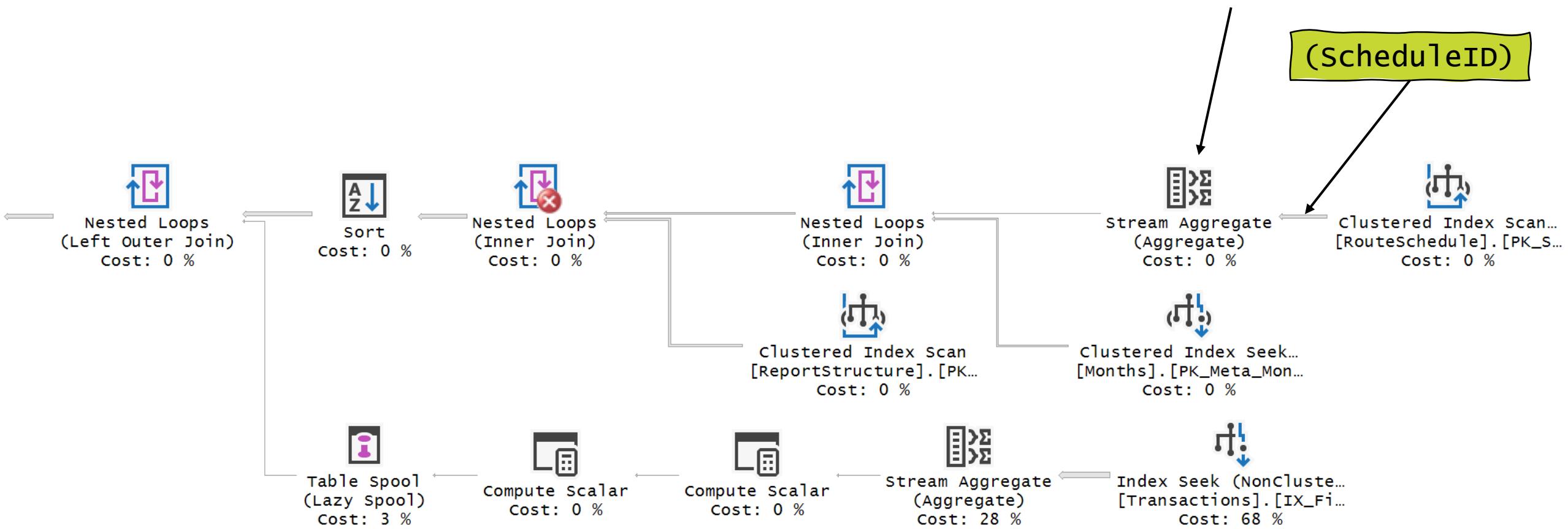


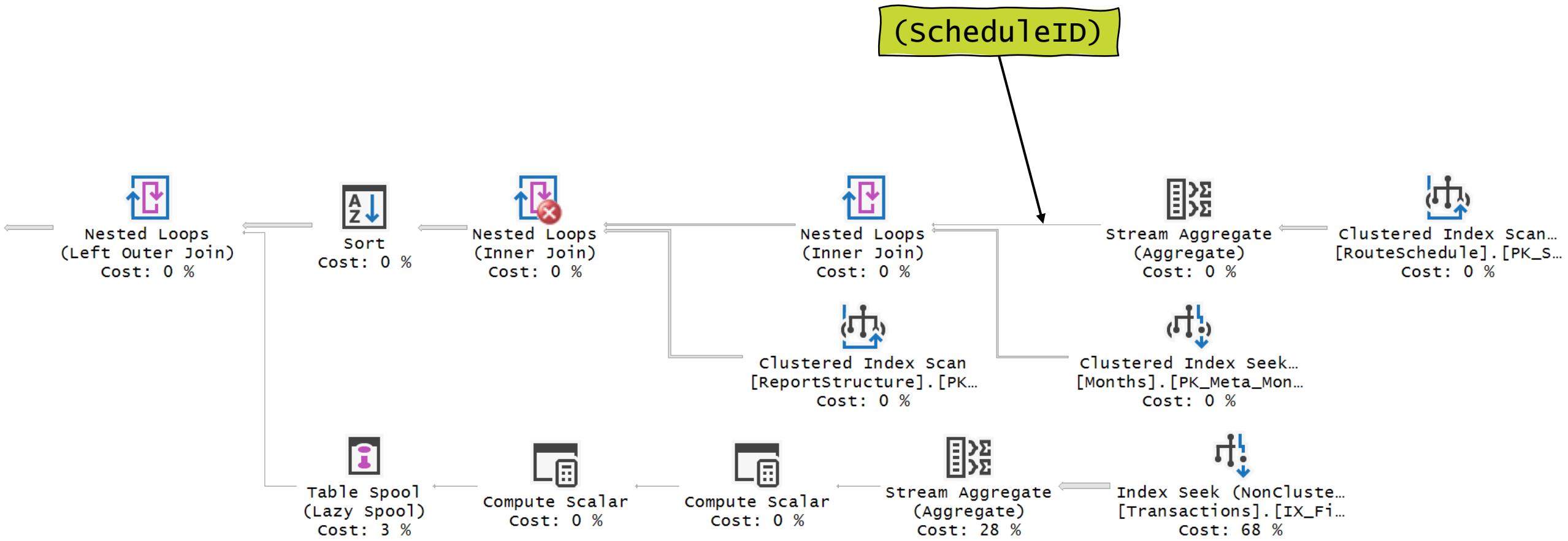


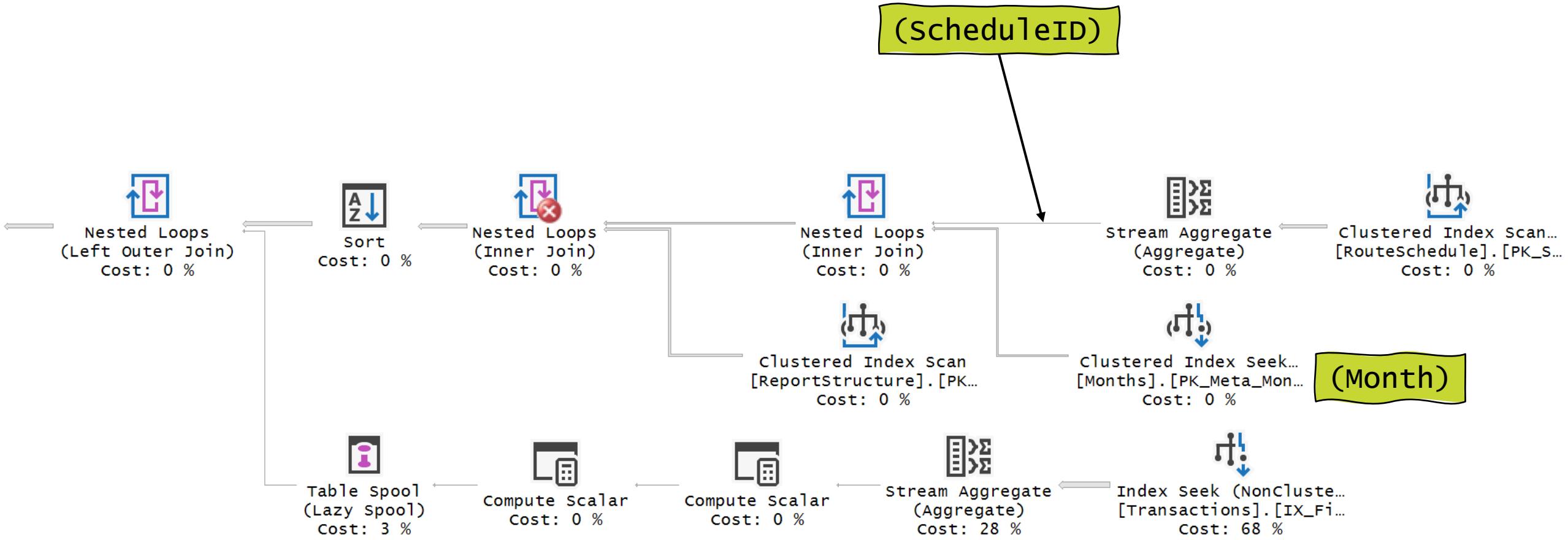
**WHY ALL OF THIS  
IS IMPORTANT.**

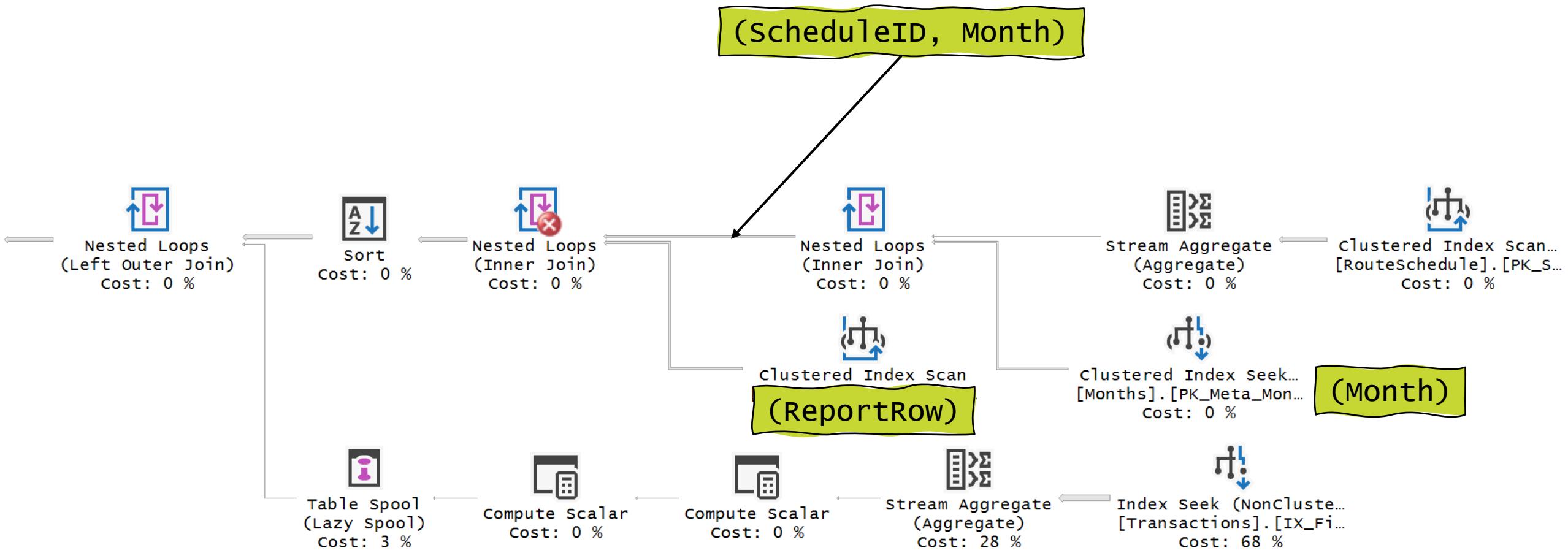


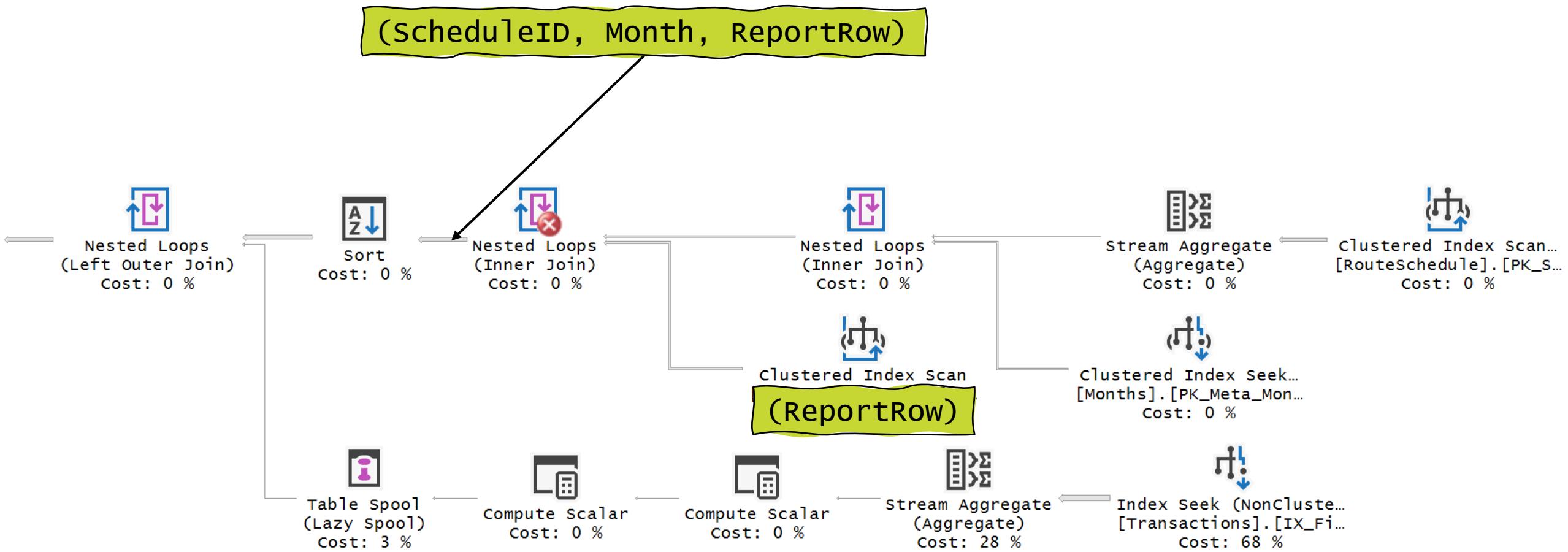
GROUP BY ScheduleID

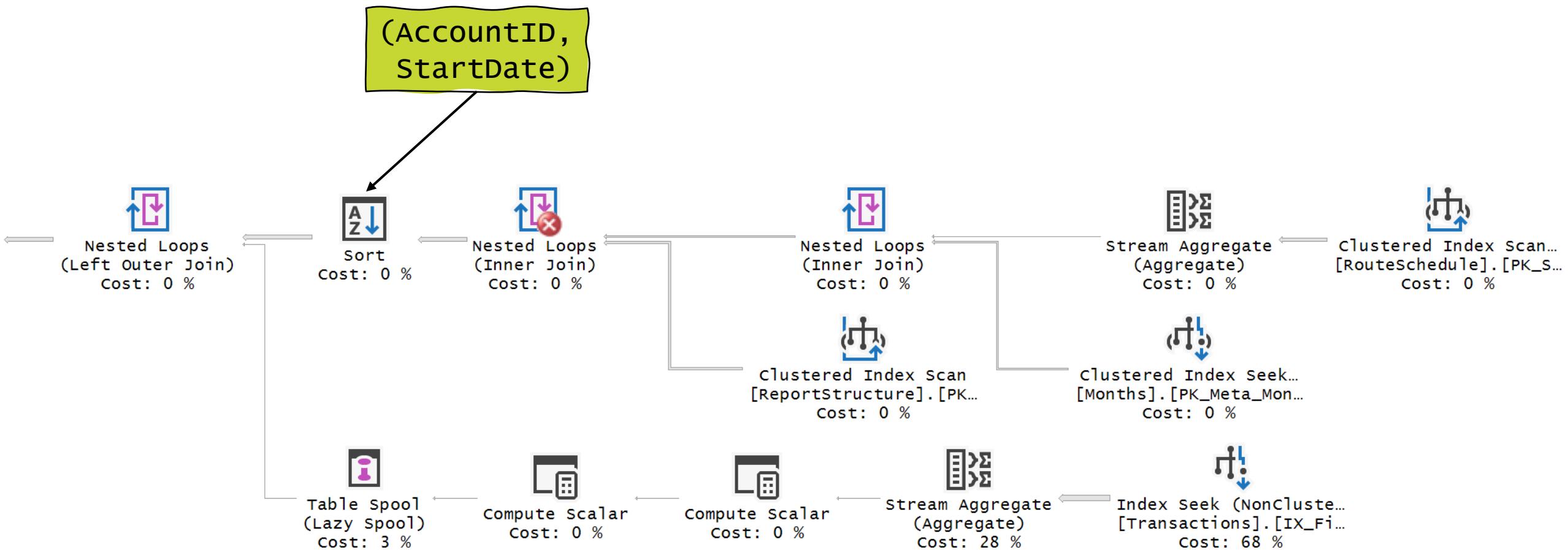


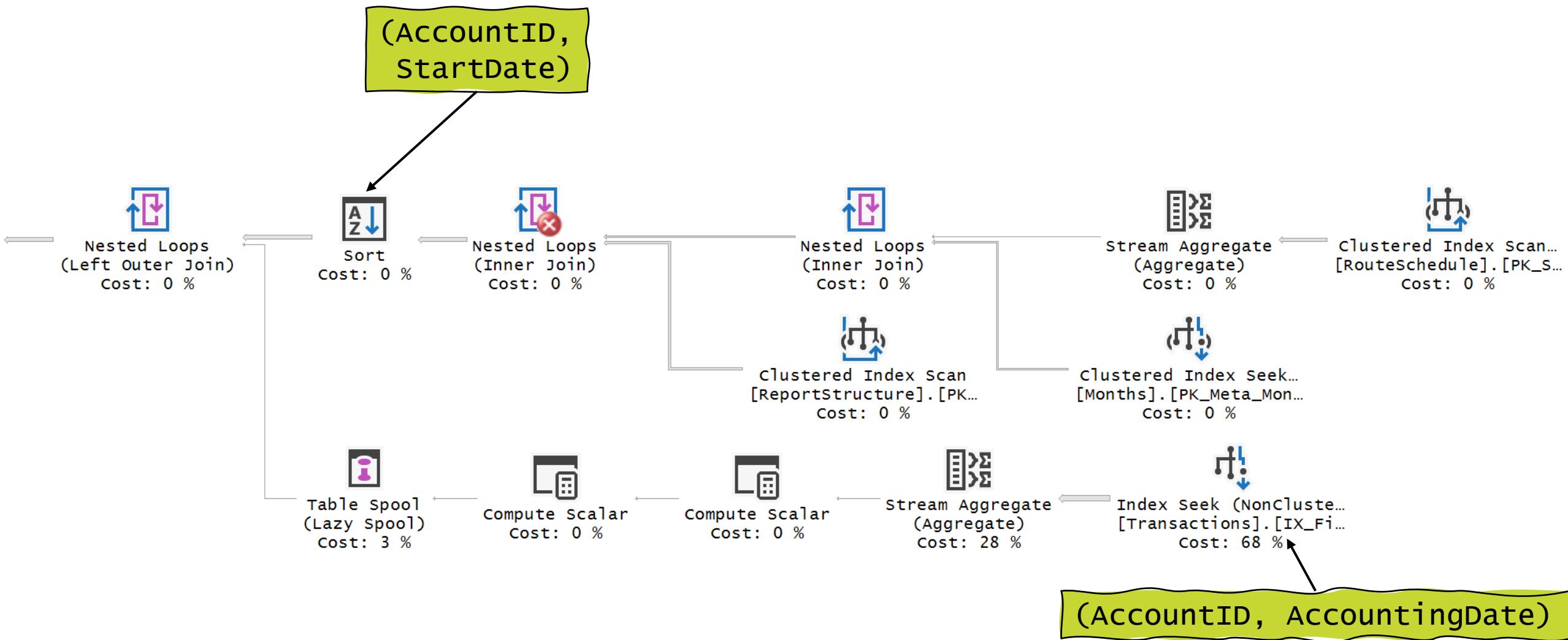


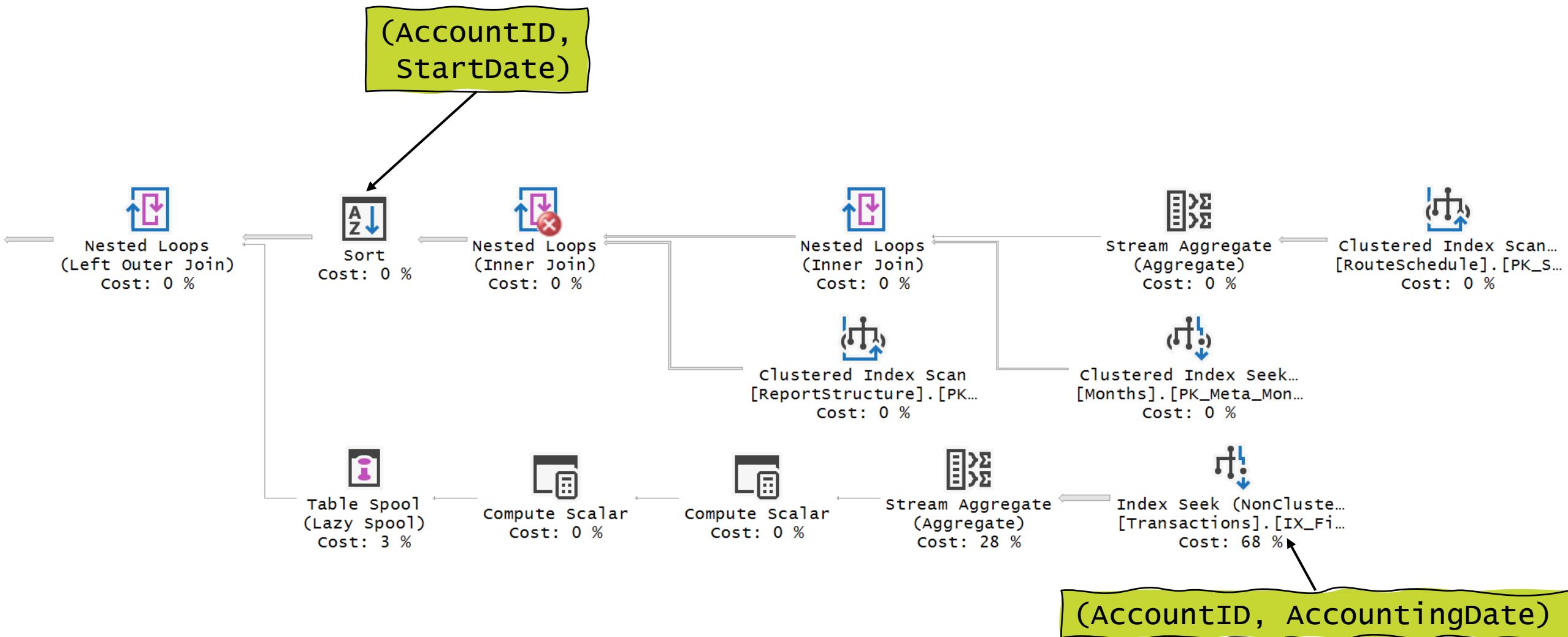




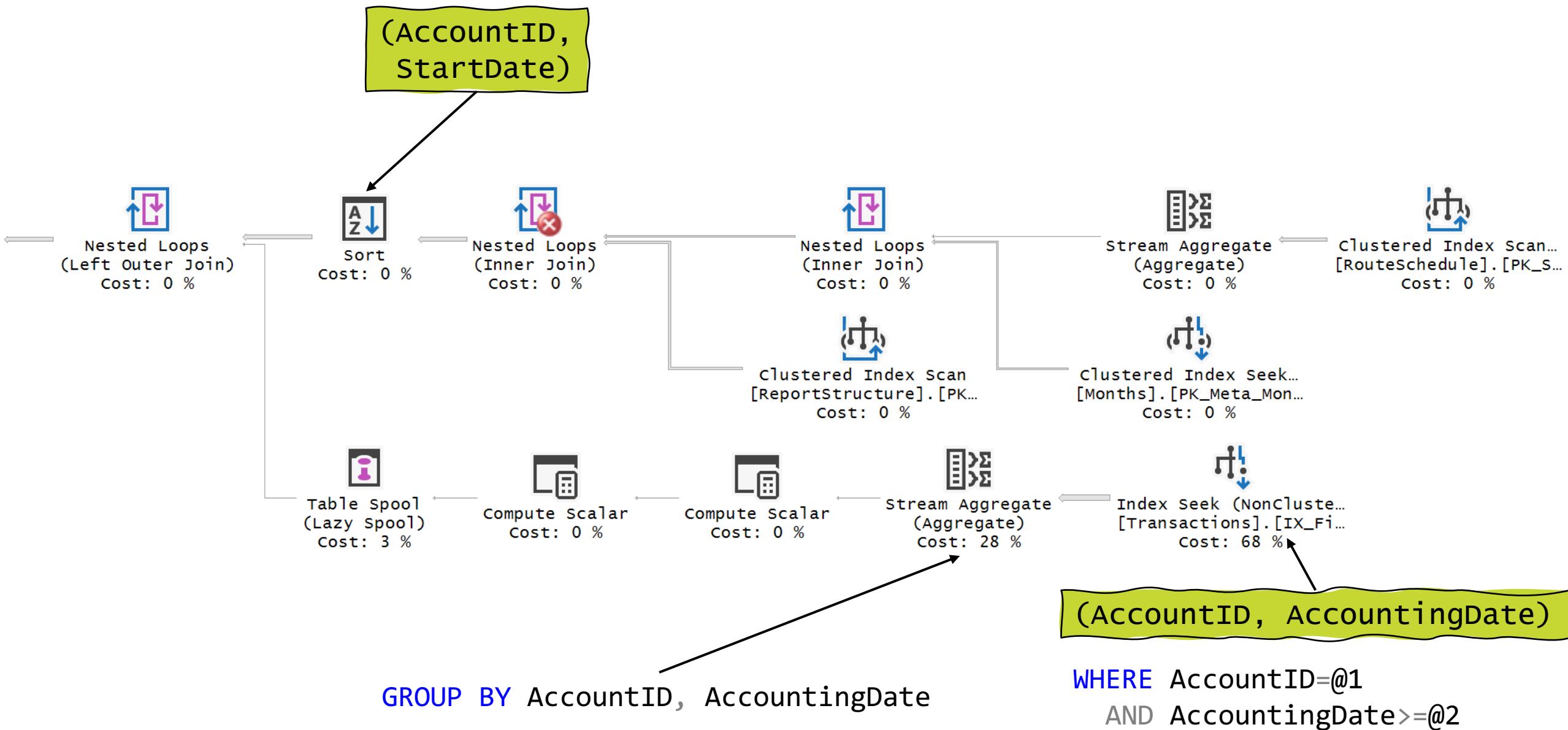


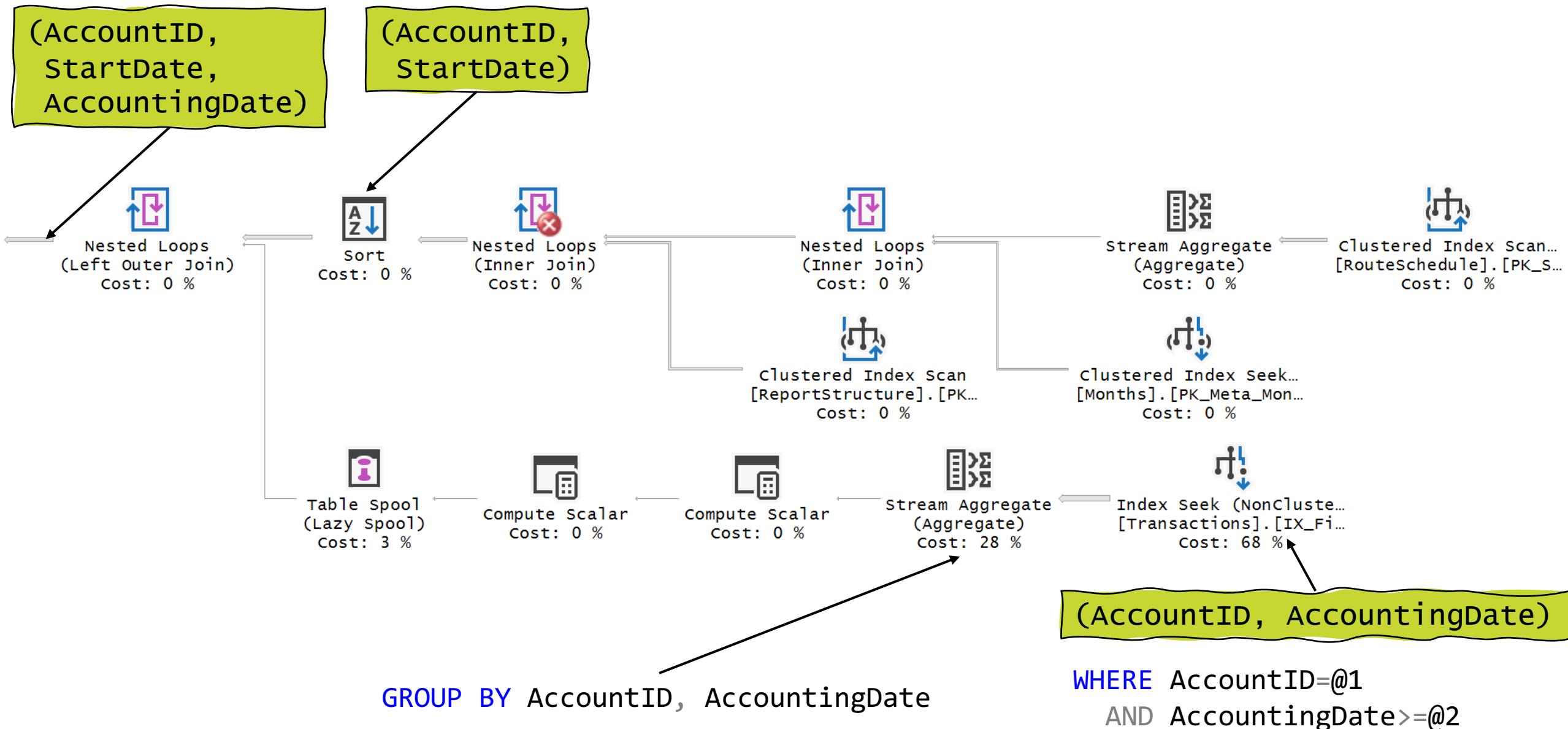






WHERE AccountID=@1  
AND AccountingDate>=@2



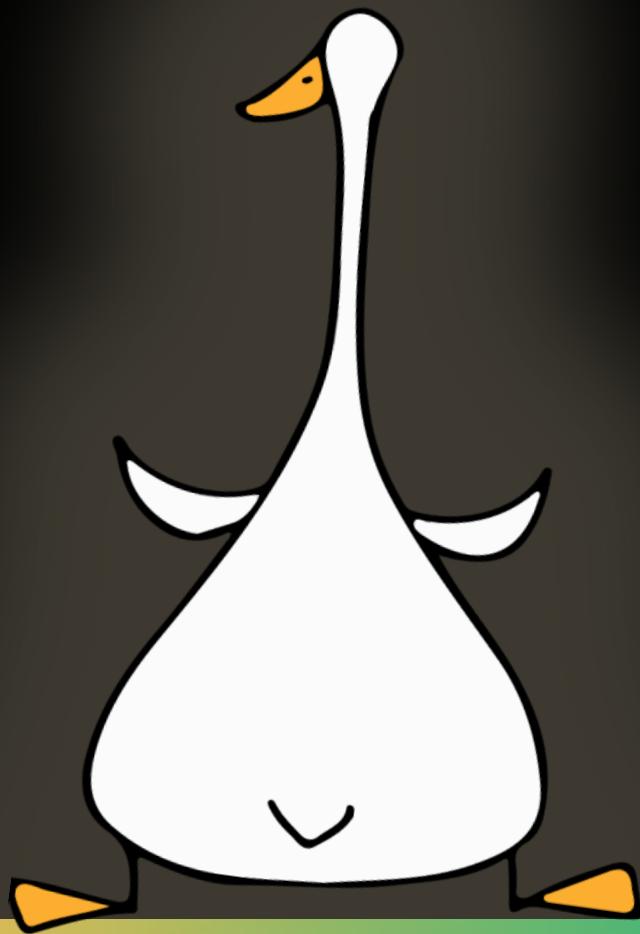


# Thank you

 @dhmacher

 strd.co

 sqlsunday.com



# Session evaluation

Your feedback is important to us



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