Image-Source

- Open Source analytics engine for large-scale data processing
- Provides interface to program entire clusters
- APIs in Scala, Java, Python and R + Interactive Spark-Shell in Scala

Apache Spark - Programming Model

RDDs

Resilient distributed dataset

- Immutable distributed collection of data
- Can be cached in memory across the cluster
- Manipulation through parallel functional operators
- Operators can be chained

Limitations:

Datamodel = opaque blobs
→ no optimizations possible

DataFrame API

Data is organized into named columns, like a table in a relational database

Benefits:

- Declarativity allows query plan optimization
- Strongly typed data model allows for optimized storage

Limitations:

- No custom lambdas possible, first have to be converted to RDDs
- Syntax checking is limited

Dataset API

Combination of RDD and DataFrames

Benefits:

- Object-oriented programming interface
- Optionally also weakly typed objects are allowed
- When only strong typed used - everything can be checked during compile time

DataFrame = Dataset [Row]

- Stack

Spark Core

Task distribution, scheduling, I/O functionalities

Spark SQL

Expressive queries using SQL

Spark Streaming

Streaming data analysis instead of only batch analysis

MLib

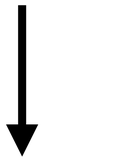
Provides machine learning algorithms

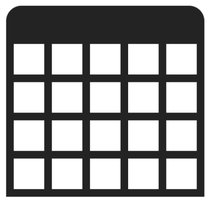
GraphX

An API tailored towards analyzing graphs and also implementing custom graph algorithms

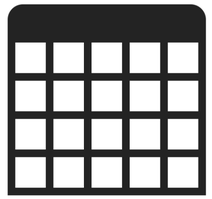
Apache Spark - DataFrame API

Initialization

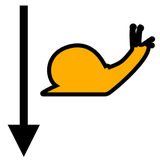




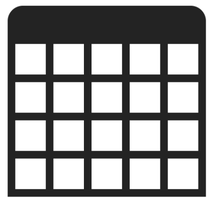
Transformations



- select()
- filter()

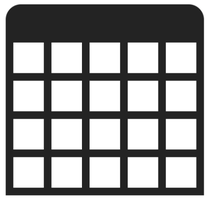


- join()
- union()

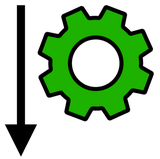


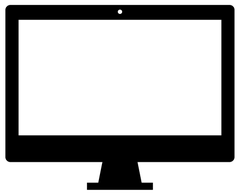
- sort()
- limit()

Actions



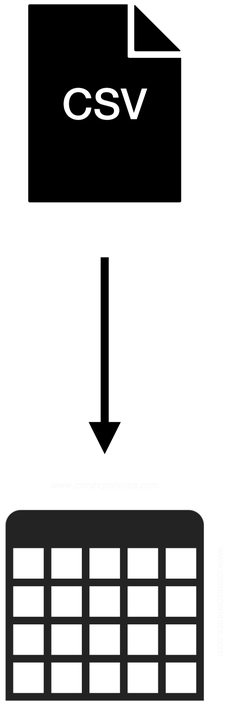
- show()
- count()





Apache Spark - DataFrame API

Initialization



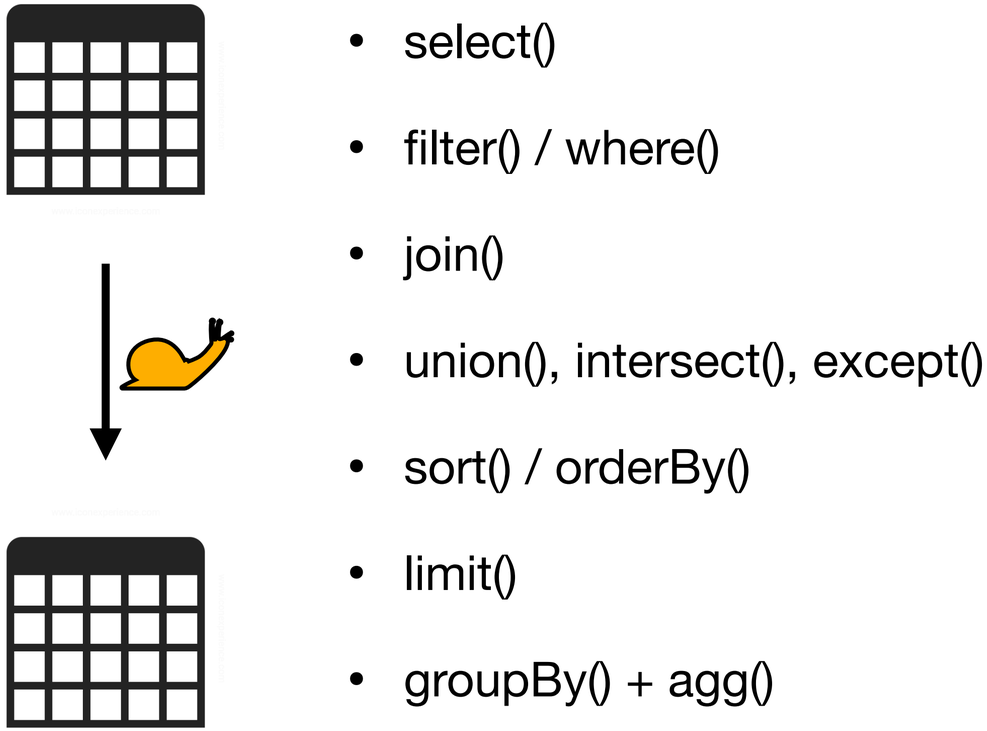
studenten.csv

```
24002|Xenokrates|18
25403|Jonas|12
26120|Fichte|10
26830|Aristoxenos|8
27550|Schopenhauer|6
28106|Carnap|3
29120|Theophrastos|2
29555|Feuerbach|2
```

```
val studenten = spark.read.format("csv").schema(StructType(
    List(
      StructField("matrnr", IntegerType, false),
      StructField("name", StringType, false),
      StructField("semester", IntegerType, false)
    )
  )).option("delimiter", "|").load("studenten.csv")
```

Spark - DataFrame API

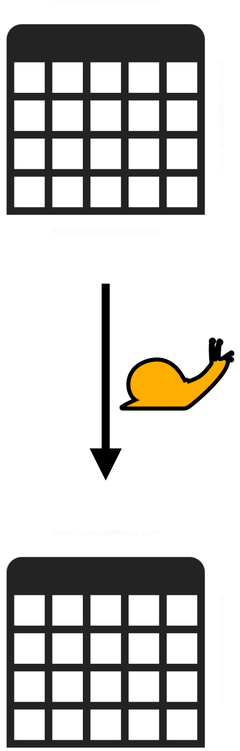
Transformation



- select()
- filter() / where()
- join()
- union(), intersect(), except()
- sort() / orderBy()
- limit()
- groupBy() + agg()

Spark - DataFrame API - Column

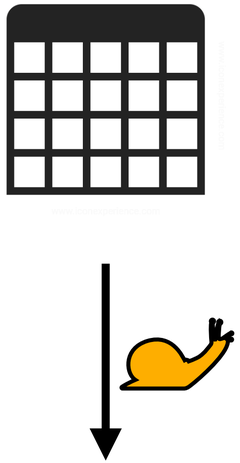
Transformation

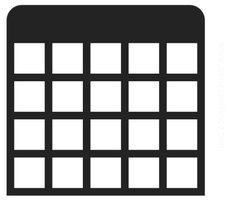


- Represents a column in a Dataset that holds a Catalyst Expression that produces a value per row.
- How to generate Column references:
  - With a $-prefixed string: `$"matrnr"`
  - With the `"col"` or `"column"` functions: `col("matrnr")`
  - From a dataset: `studenten("matrnr")`
- With column references as base types, more complex expression trees can be build:
  - `when($"semester" <= 3, "Grundstudium").otherwise("Hauptstudium")`
  - `$"semester" === 18 && $"name".startsWith("X")`

Spark - DataFrame API

Transformation





- select()
- filter() / where()
- join()
- union(), intersect(), except()
- sort() / orderBy()
- limit()
- groupBy() + agg()

```
studenten.select($"matrnr", $"name")
```

```
studenten.filter($"name" === "Fichte")
```

```
studenten.join(hoeren, hoeren("matrnr") === studenten("matrnr"))
```

```
val studierende = studenten.union(studentinnen)
```

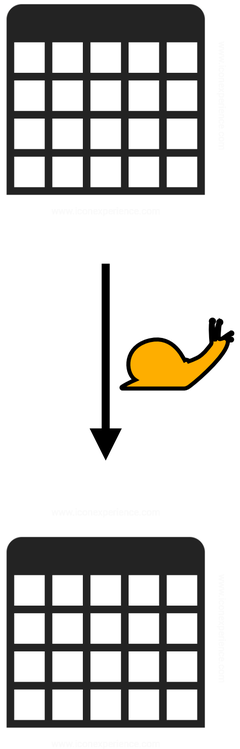
```
studenten.sort($"matrnr".desc)
```

```
studenten.limit(3)
```

```
vorlesungen
   .groupBy("gelesenvon")
   .agg(count("*").as("#vorlesungen"),
        sum("sws").as("gesamtstunden"))
```

Apache Spark - DataFrame API - join

Transformation



- Inner join

```
studenten.join(hoeren, hoeren("matrnr") === studenten("matrnr"))
```

- Specify join type as third argument

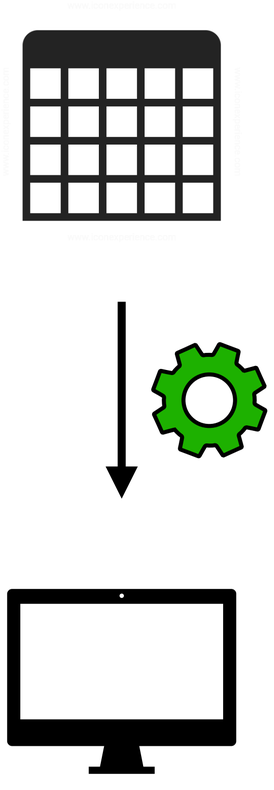
```
studenten.join(hoeren, hoeren("matrnr") === studenten("matrnr"), "leftsemi")
```

  - Supported types: '*inner*', '*fullouter*', '*leftouter*', '*rightouter*', '*leftsemi*', '*leftanti*', '*cross*'

- Self-Join

```
studenten.as("a").join(studenten.as("b"), $"a.matrnr" === $"b.matrnr")
```

Spark Actions - DataFrame API



- show()

```
studenten.show(8)
```

  - shows top 20 rows when no parameter is passed

```
+------+-----------+--------+
|matrnr|       name|semester|
+------+-----------+--------+
| 24002|  Xenokrates|      18|
| 25403|      Jonas|      12|
| 26120|     Fichte|      10|
| 26830| Aristoxenos|       8|
| 27550|Schopenhauer|       6|
| 28106|     Carnap|       3|
| 29120|Theophrastos|       2|
| 29555|   Feuerbach|       2|
+------+-----------+--------+
```

- count()

```
val anzahlStudenten = studenten.count()
```

References

- Foundations in Data Engineering (Lecture 4): Distributed Processing
- https://spark.apache.org/
- https://databricks.com/de/blog/2016/07/14/a-tale-of-three-apache-spark-apis-rdds-dataframes-and-datasets.html
- http://www.tpc.org/tpch/
- https://www.exasol.com/de/ressource/10-fragen-zum-tpc-h-benchmark/

Hands-on session

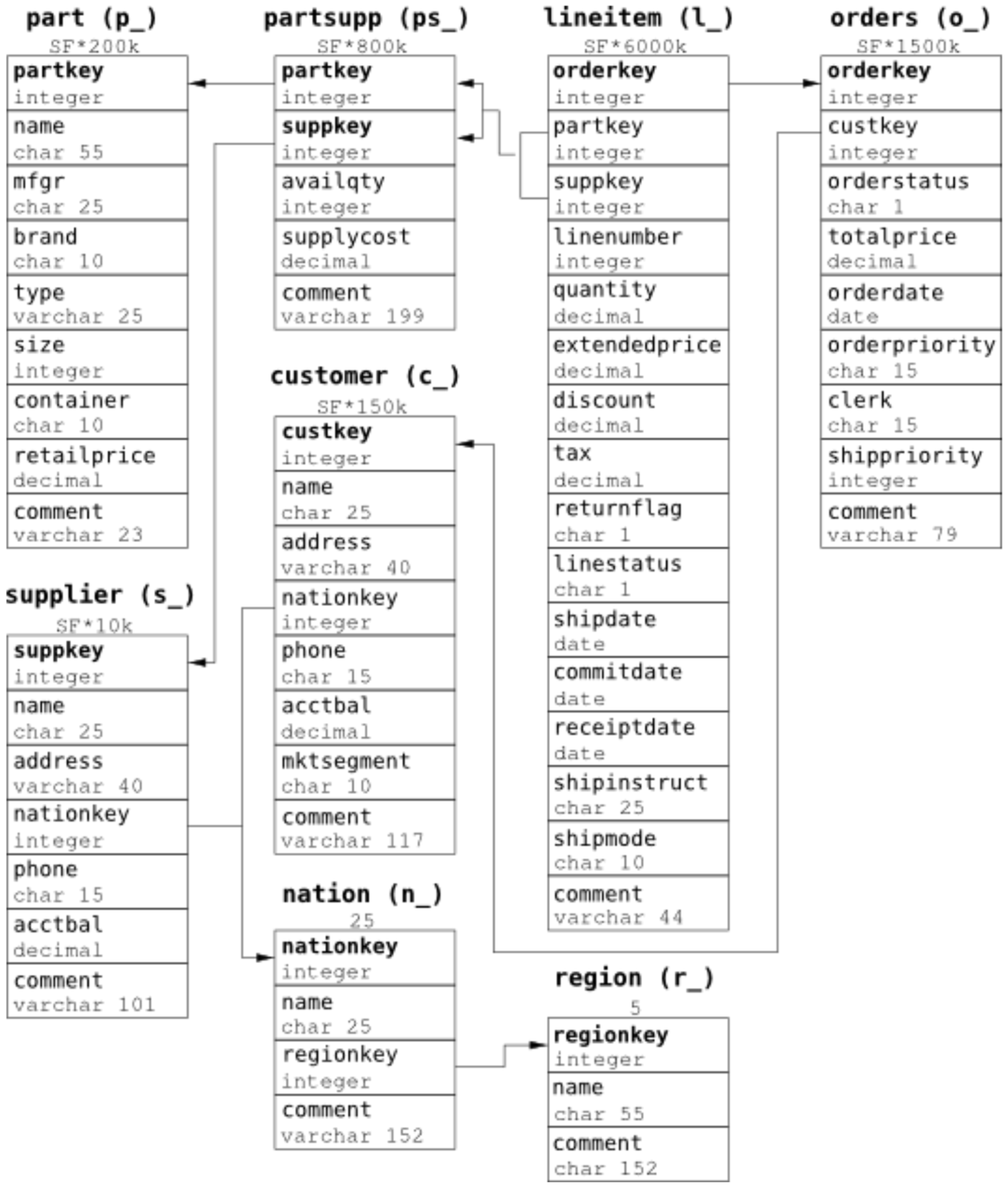
Image-Source

TPC-H Benchmark

- **Transaction Processing Performance Council (TPC)**
  - Big influence on the industry standard benchmarks
  - Companies use TPC-Benchmarks to demonstrate their competitiveness
  - The TPC committee belongs to large database vendors like IBM, Microsoft, Oracle and HP

- **TPC-H** is a decision-support benchmark. It consists of ad-hoc queries and concurrent data modifications
  - The Database schema is in third normal form and contains **8 tables**
  - The Benchmark can be executed on different sizes of data. This can be configured with the scale factor. **Scale factor 1 corresponds to 1 GB of data**
    - 6 of the 8 tables grow linearly with the scale factor
  - There exist **22 complex queries** as well as two INSERT and UPDATE processes which are executed in parallel to test concurrency
  - The official specification how to execute the TPC-H benchmark is 137 pages long
  - On the website new results are published and the official specification can be downloaded: tpc.org

TPC-H Schema


part (p_)
SF*200k
partkey integer
name char 55
mfgr char 25
brand char 10
type varchar 25
size integer
container char 10
retailprice decimal
comment varchar 23
partsupp (ps_)
SF*800k
partkey integer
suppkey integer
availqty integer
supplycost decimal
comment varchar 199
lineitem (l_)
SF*6000k
orderkey integer
partkey integer
suppkey integer
linenumber integer
quantity decimal
extendedprice decimal
discount decimal
tax decimal
returnflag char 1
linestatus char 1
shipdate date
commitdate date
receiptdate date
shipinstruct char 25
shipmode char 10
comment varchar 44
orders (o_)
SF*1500k
orderkey integer
custkey integer
orderstatus char 1
totalprice decimal
orderdate date
orderpriority char 15
clerk char 15
shippriority integer
comment varchar 79
customer (c_)
SF*150k
custkey integer
name char 25
address varchar 40
nationkey integer
phone char 15
acctbal decimal
mktsegment char 10
comment varchar 117
supplier (s_)
SF*10k
suppkey integer
name char 25
address varchar 40
nationkey integer
phone char 15
acctbal decimal
comment varchar 101
nation (n_)
25
nationkey integer
name char 25
regionkey integer
comment varchar 152
region (r_)
5
regionkey integer
name char 55
comment char 152

Preparations

- Start Spark in Scala Shell:
  - Navigate to your spark directory
  - Start `./bin/spark-shell`
- Add necessary imports:
  - `import org.apache.spark.sql.types._`
  - `import org.apache.spark.sql._`

Exercise 1

- Load the region.tbl data into a data frame

Load all tables

- Load the tpch.scala file into your Spark Shell:
  - **Download tpch.scala**: https://tinyurl.com/3383aa4n

    ```
    wget https://tinyurl.com/3383aa4n/download/tpch.scala
    ```
  - **Update DATA_PATH variable** in **tpch.scala**:

    ```
    val DATA_PATH = /the/path/to/your/tpc-h/data
    ```
  - **Load the script into your shell**:
    - Option 1: Load the script into running Spark Shell:

      ```
      :load /path/to/tpch.scala
      ```
    - Option 2: Restart Spark:

      ```
      ./bin/spark-shell -I /path/to/tpch.scala
      ```

Exercise 2

- Show only the name of the regions

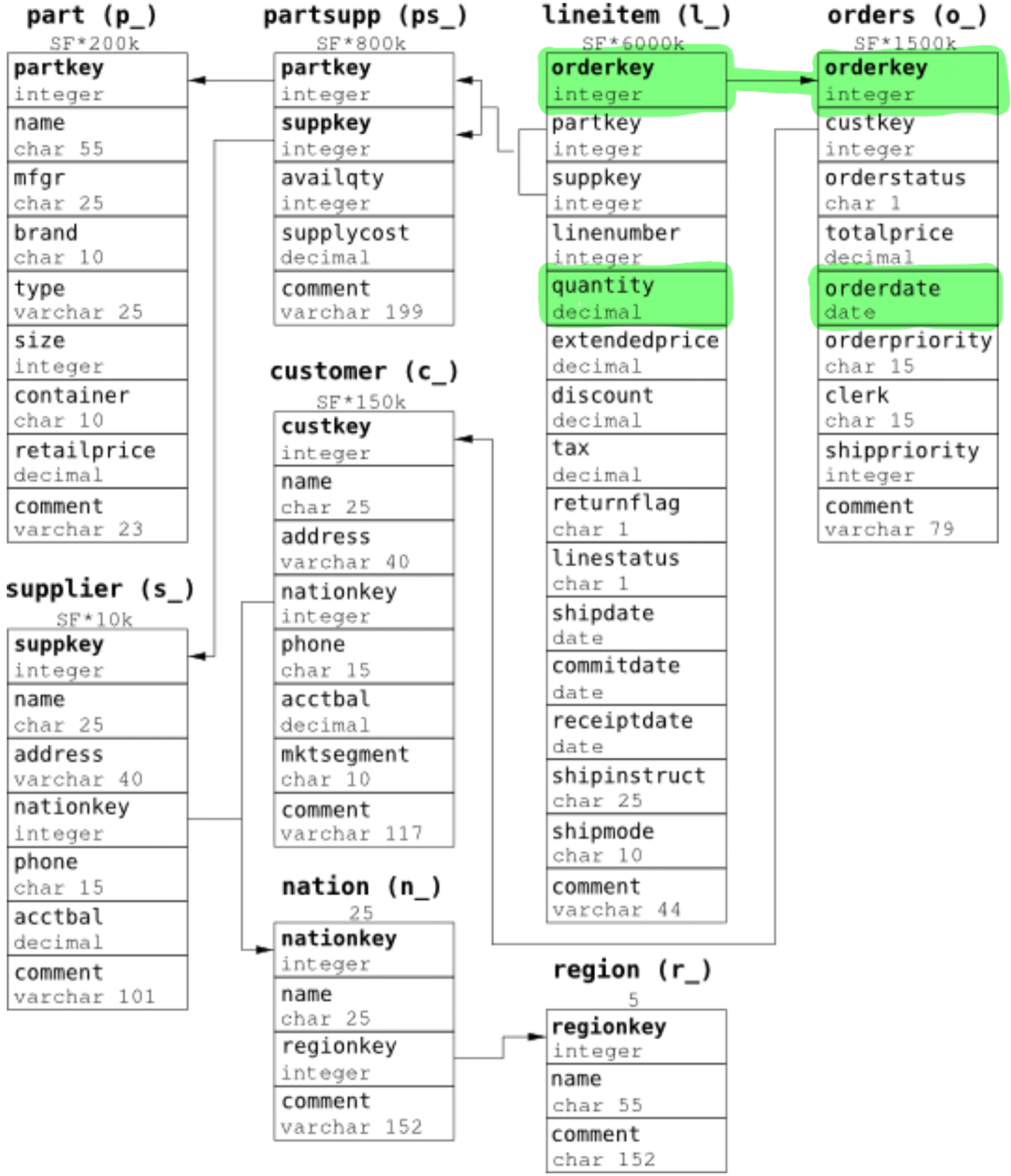
Exercise 3

- Count the nations that are not located in

  Europe

Exercise 4

- Which was the biggest order in 1996?

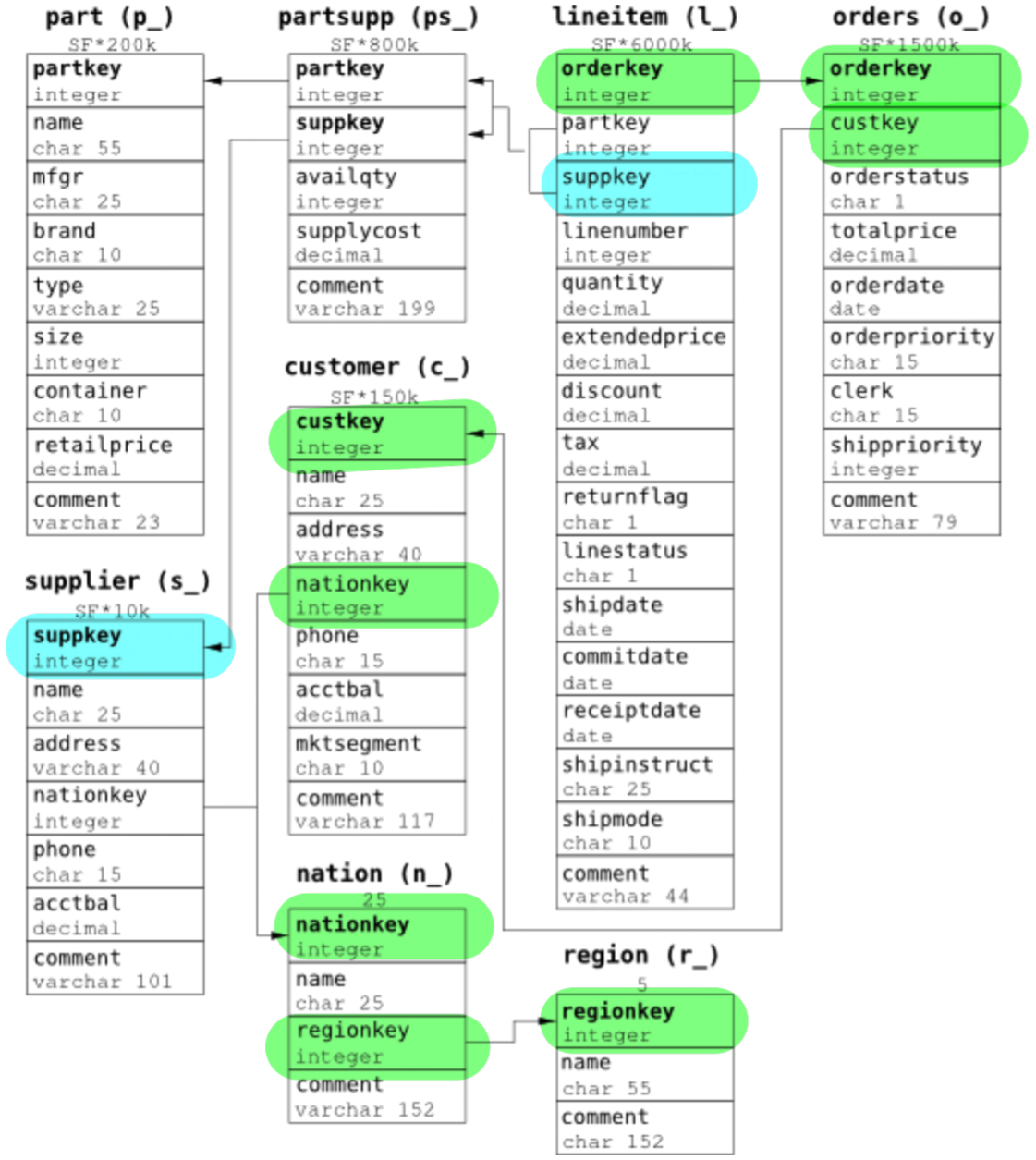


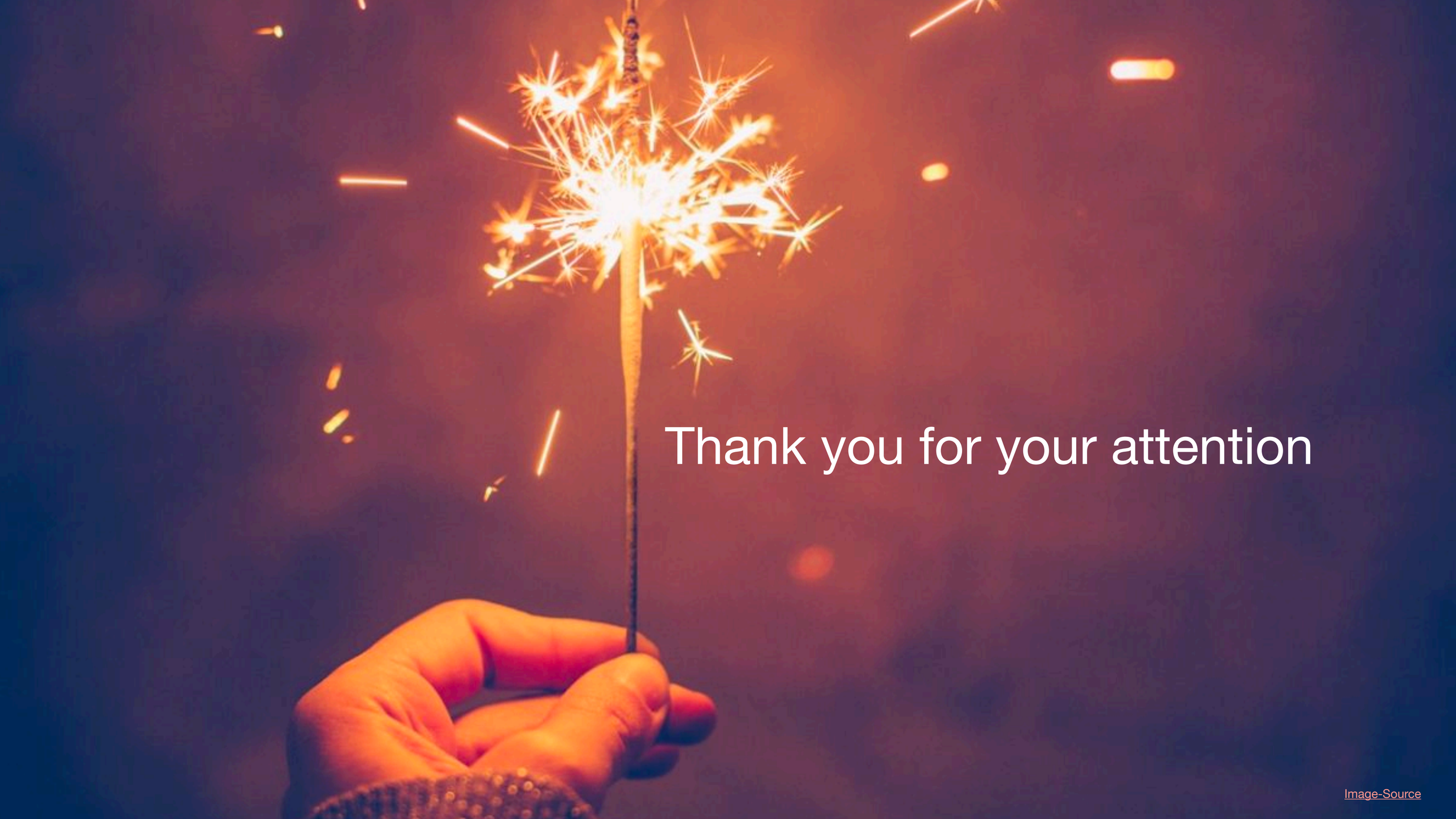
Exercise 5

- Which customer in Europe spent the most money in 1996?

Exercise 6

- Which suppliers have no customers in Europe?





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