TÉCNICO LISBOA

Data Analysis and Integration

Introduction to data warehousing

Steelwheels Database

A customer order

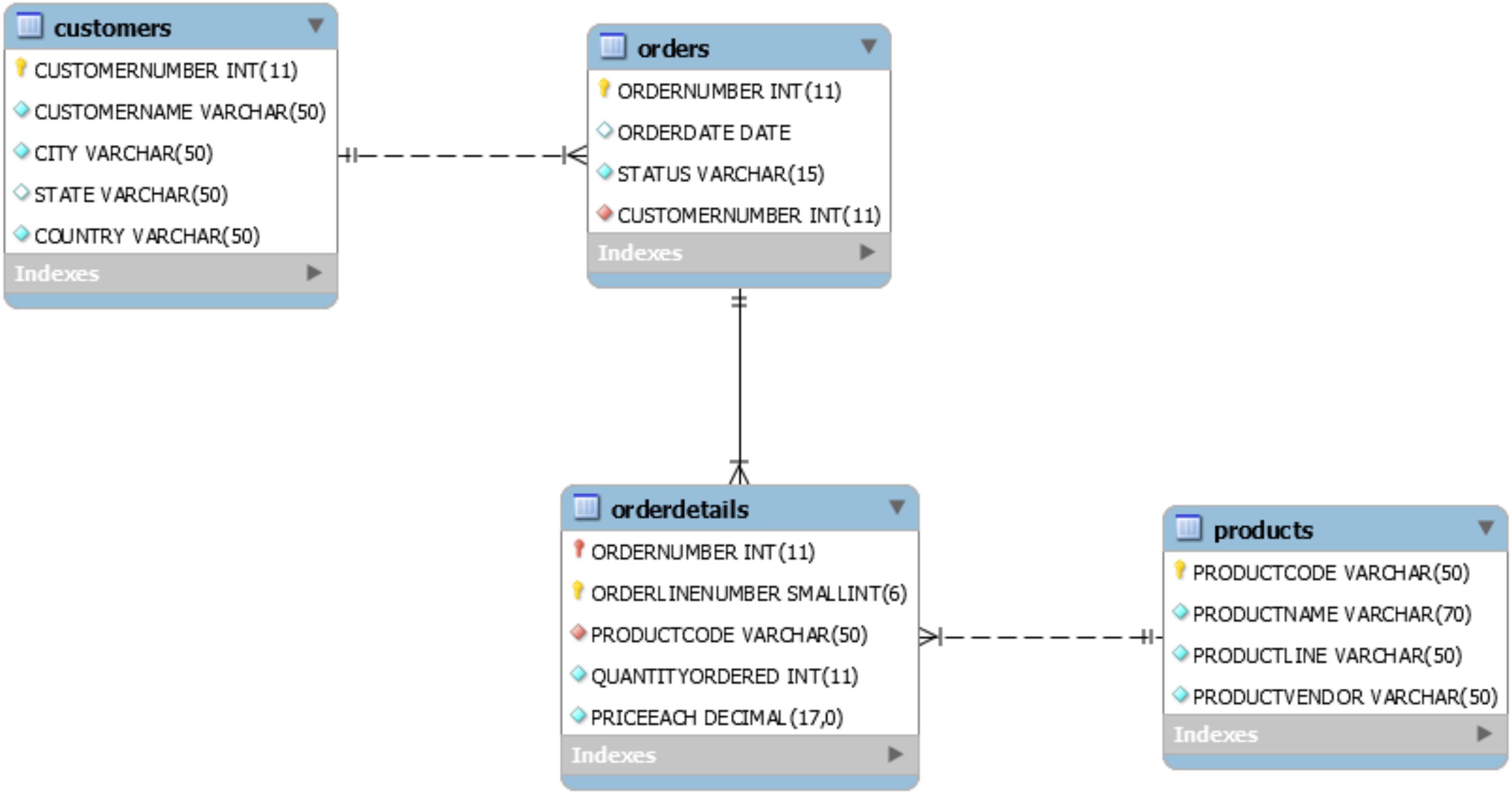
Order number: 10100
Order date: 2003-01-06

Customer:
Toys of Finland, Co.
Keskuskatu 45
Helsinki, Finland

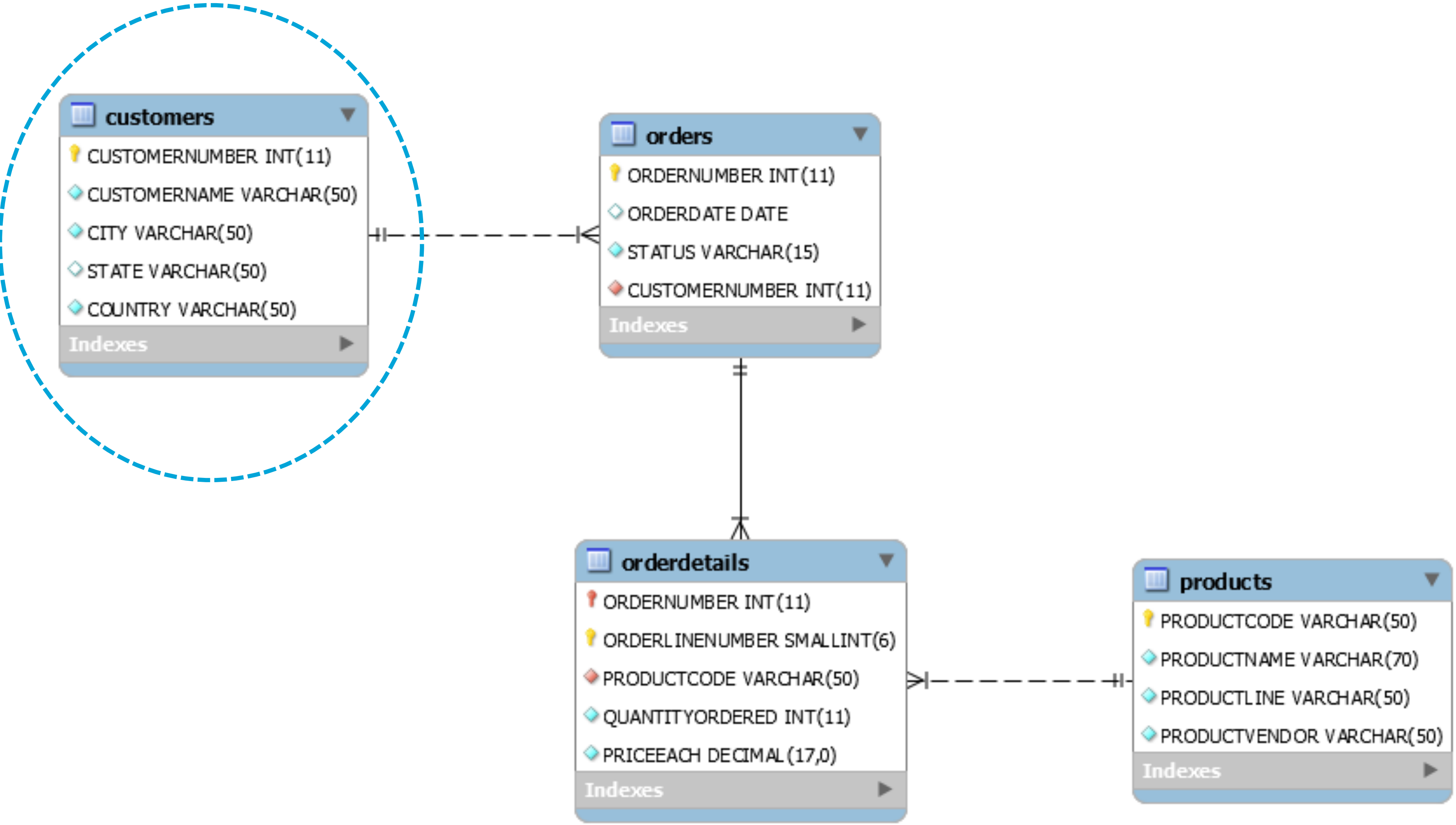
Line	Product	Quantity	Unit price	Total
1	1936 Mercedes Benz 500k Roadster	49	34	1666
2	1911 Ford Town Car	50	68	3400
3	1917 Grand Touring Sedan	30	172	5160
4	1932 Alfa Romeo 8C2300 Spider Sport	22	87	1914

Grand total: 12140

The steelwheels database



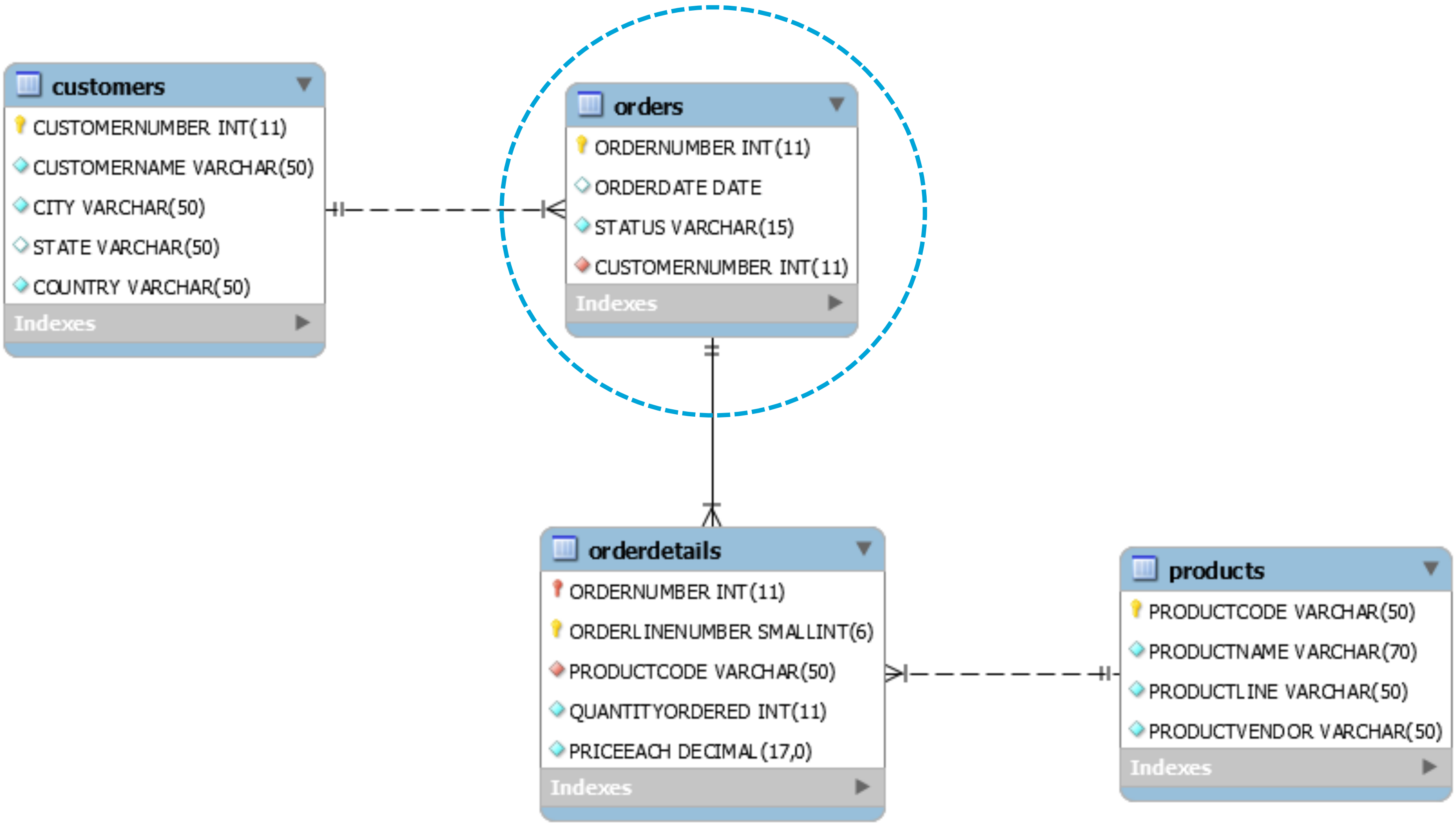
The customers table



The customers table

CUSTOMERNUMBER	CUSTOMERNAME	CITY	STATE	COUNTRY
97	Madison Inc	ST AUGUSTINE	FL	USA
98	Johnson Inc	ST Cloud	FL	USA
99	Tarallo Inc	Sanford	FL	USA
100	Audio Video 'R' Us	Orlando	FL	USA
103	Atelier graphique	Nantes	NULL	France
112	Signal Gift Stores	Las Vegas	NV	USA
114	Australian Collectors, Co.	Melbourne	Victoria	Australia
119	La Rochelle Gifts	Nantes	NULL	France
121	Baane Mini Imports	Stavern	NULL	Norway
124	Mini Gifts Distributors Ltd.	San Rafael	CA	USA
125	Havel & Zbyszek Co	Warszawa	NULL	Poland
128	Blauer See Auto, Co.	Frankfurt	NULL	Germany
129	Mini Wheels Co.	San Francisco	CA	USA
131	Land of Toys Inc.	NYC	NY	USA
141	Euro+ Shopping Channel	Madrid	NULL	Spain
144	Volvo Model Replicas, Co	Luleå	NULL	Sweden
145	Danish Wholesale Imports	Kobenhavn	NULL	Denmark
146	Saveley & Henriot, Co.	Lyon	NULL	France
148	Dragon Souveniers, Ltd.	Singapore	NULL	Singapore
151	Muscle Machine Inc	NYC	NY	USA

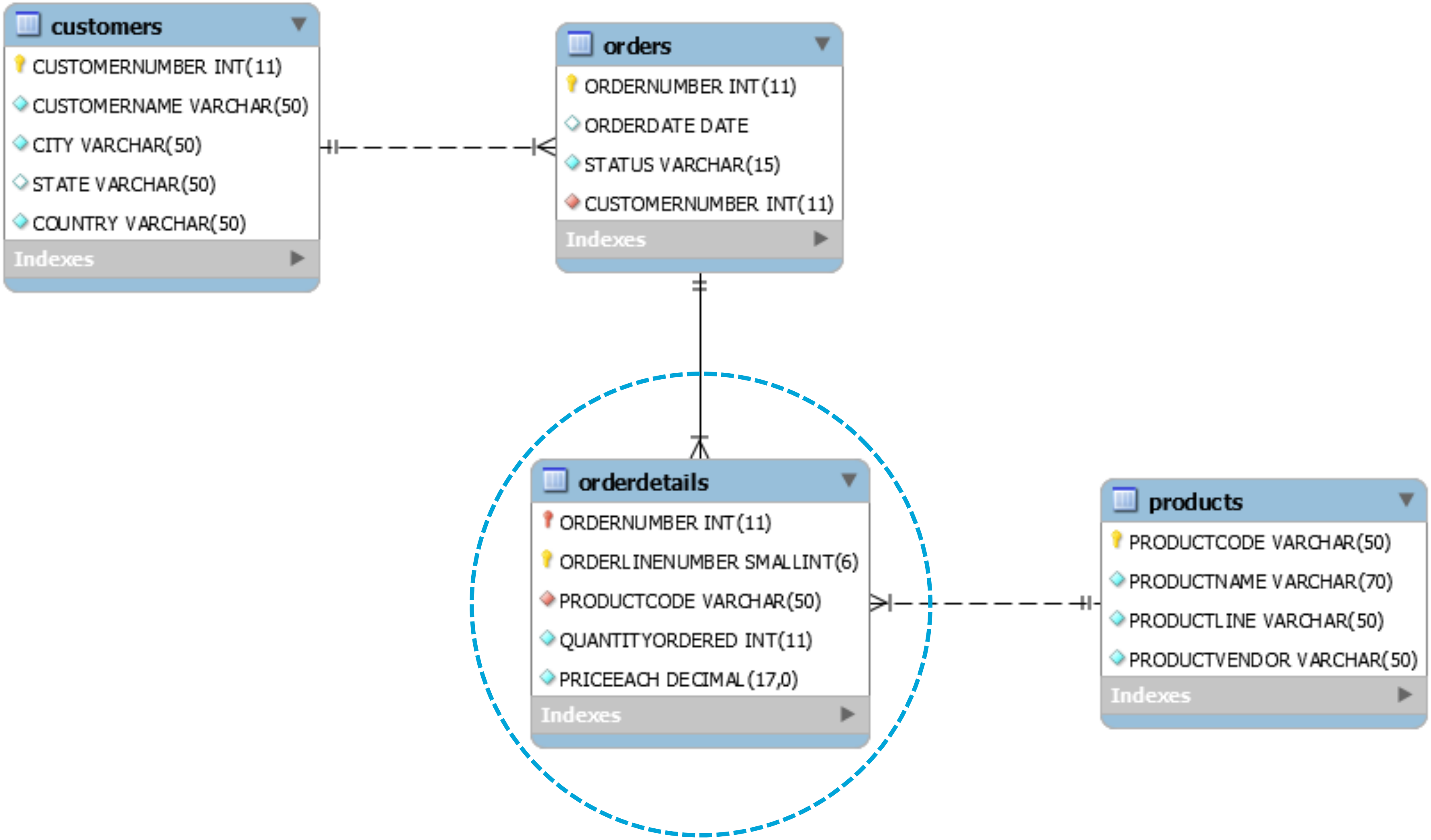
The orders table



The orders table

ORDERNUMBER	ORDERDATE	STATUS	CUSTOMERNUMBER
10100	2003-01-06	Shipped	363
10101	2003-01-09	Shipped	128
10102	2003-01-10	Shipped	181
10103	2003-01-29	Shipped	121
10104	2003-01-31	Shipped	141
10105	2003-02-11	Shipped	145
10106	2003-02-17	Shipped	278
10107	2003-02-24	Shipped	131
10108	2003-03-03	Shipped	385
10109	2003-03-10	Shipped	486
10110	2003-03-18	Shipped	187
10111	2003-03-25	Shipped	129
10112	2003-03-24	Shipped	144
10113	2003-03-26	Shipped	124
10114	2003-04-01	Shipped	172
10115	2003-04-04	Shipped	424
10116	2003-04-11	Shipped	381
10117	2003-04-16	Shipped	148
10118	2003-04-21	Shipped	216
10119	2003-04-28	Shipped	382

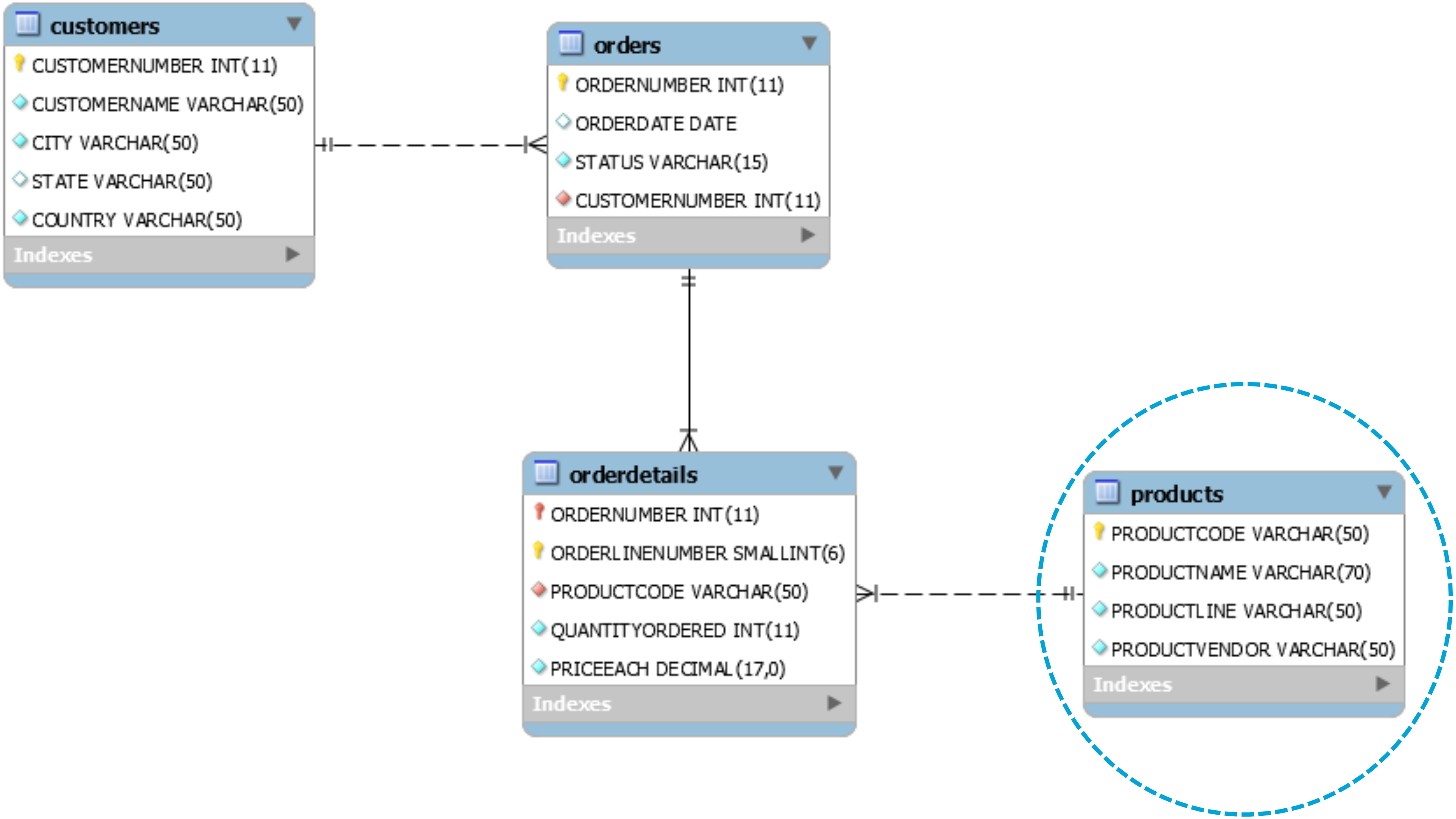
The orderdetails table



The orderdetails table

```
+-------------+-----------------+-------------+-----------------+-----------+
| ORDERNUMBER | ORDERLINENUMBER | PRODUCTCODE | QUANTITYORDERED | PRICEEACH |
+-------------+-----------------+-------------+-----------------+-----------+
|       10100 |               1 | S24_3969    |              49 |        34 |
|       10100 |               2 | S18_2248    |              50 |        68 |
|       10100 |               3 | S18_1749    |              30 |       172 |
|       10100 |               4 | S18_4409    |              22 |        87 |
|       10101 |               1 | S18_2795    |              26 |       145 |
|       10101 |               2 | S24_2022    |              46 |        54 |
|       10101 |               3 | S24_1937    |              45 |        31 |
|       10101 |               4 | S18_2325    |              25 |       151 |
|       10102 |               1 | S18_1367    |              41 |        50 |
|       10102 |               2 | S18_1342    |              39 |       123 |
|       10103 |               1 | S24_2300    |              36 |       102 |
|       10103 |               2 | S18_2432    |              22 |        54 |
|       10103 |               3 | S32_1268    |              31 |       104 |
|       10103 |               4 | S10_4962    |              42 |       129 |
|       10103 |               5 | S18_4600    |              36 |       117 |
|       10103 |               6 | S700_2824   |              42 |       106 |
|       10103 |               7 | S32_3522    |              45 |        76 |
|       10103 |               8 | S12_1666    |              27 |       126 |
|       10103 |               9 | S18_4668    |              41 |        47 |
|       10103 |              10 | S18_1097    |              35 |       112 |
+-------------+-----------------+-------------+-----------------+-----------+
```

The products table



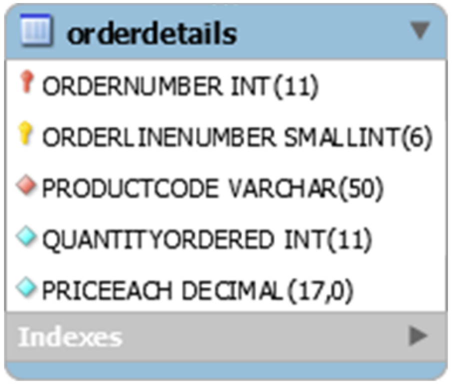
The products table

PRODUCTCODE	PRODUCTNAME	PRODUCTLINE	PRODUCTVENDOR
S10_1678	1969 Harley Davidson Ultimate Chopper	Motorcycles	Min Lin
S10_1949	1952 Alpine Renault 1300	Classic Cars	Classic Metal
S10_2016	1996 Moto Guzzi 1100i	Motorcycles	Highway 66
S10_4698	2003 Harley-Davidson Eagle Drag Bike	Motorcycles	Red Start
S10_4757	1972 Alfa Romeo GTA	Classic Cars	Motor City
S10_4962	1962 LanciaA Delta 16V	Classic Cars	Second Gear
S12_1099	1968 Ford Mustang	Classic Cars	Autoart Studio
S12_1108	2001 Ferrari Enzo	Classic Cars	Second Gear
S12_1666	1958 Setra Bus	Trucks and Buses	Welly Diecast
S12_2823	2002 Suzuki XREO	Motorcycles	Unimax Art
S12_3148	1969 Corvair Monza	Classic Cars	Welly Diecast
S12_3380	1968 Dodge Charger	Classic Cars	Welly Diecast
S12_3891	1969 Ford Falcon	Classic Cars	Second Gear
S12_3990	1970 Plymouth Hemi Cuda	Classic Cars	Studio M
S12_4473	1957 Chevy Pickup	Trucks and Buses	Exoto Designs
S12_4675	1969 Dodge Charger	Classic Cars	Welly Diecast
S18_1097	1940 Ford Pickup Truck	Trucks and Buses	Studio M
S18_1129	1993 Mazda RX-7	Classic Cars	Highway 66
S18_1342	1937 Lincoln Berline	Vintage Cars	Motor City
S18_1367	1936 Mercedes-Benz 500K Special Roadster	Vintage Cars	Studio M

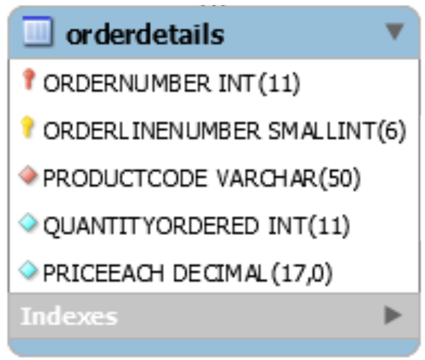
Analytical Queries

Analytical queries

- Calculating sales
  - **table**: orderdetails
  - **column**: quantityordered
  - **column**: priceeach
  - **multiply**: quantityordered*priceeach
  - **sum**: sum(quantityordered*priceeach)



Total sales



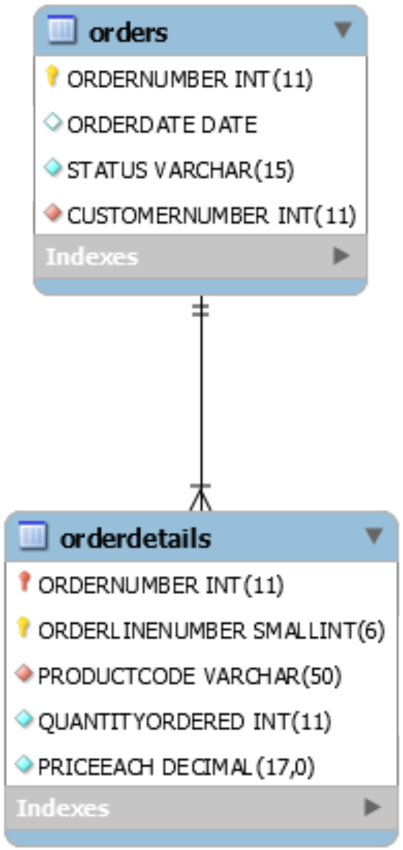

```
select sum(a.quantityordered*a.priceeach) as sales
from orderdetails as a;
```

```
+----------+
| sales    |
+----------+
| 11581065 |
+----------+
1 row in set (0.01 sec)
```

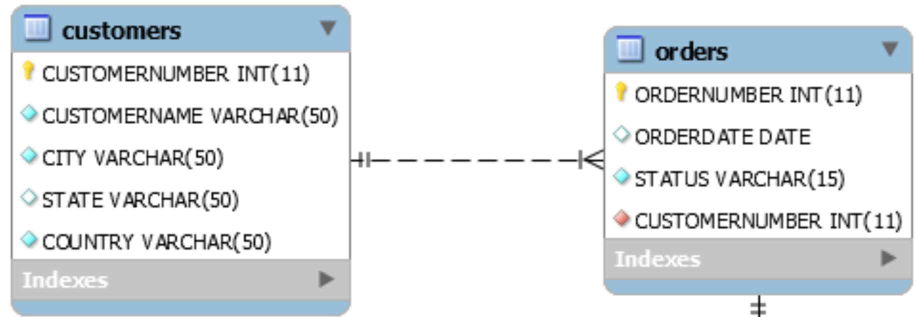
Sales by customer

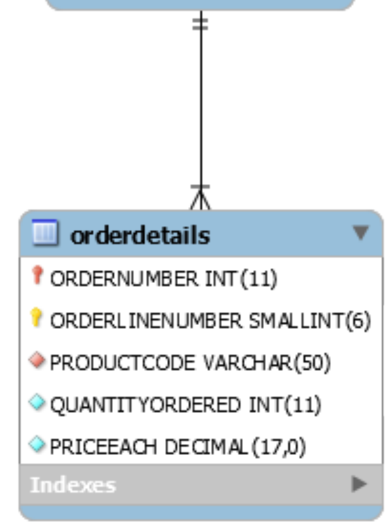
```
select b.customernumber,
        sum(a.quantityordered*a.priceeach) as sales
from orderdetails as a,
        orders as b
where a.ordernumber = b.ordernumber
group by b.customernumber;
```

```
+----------------+---------+
| customernumber | sales   |
+----------------+---------+
|             97 | 300000  |
|             98 | 300000  |
|             99 |  30000  |
|            100 |   5160  |
|            103 |  24160  |
|            ... |    ...  |
+----------------+---------+
102 rows in set (0.01 sec)
```



Sales by Customer Country

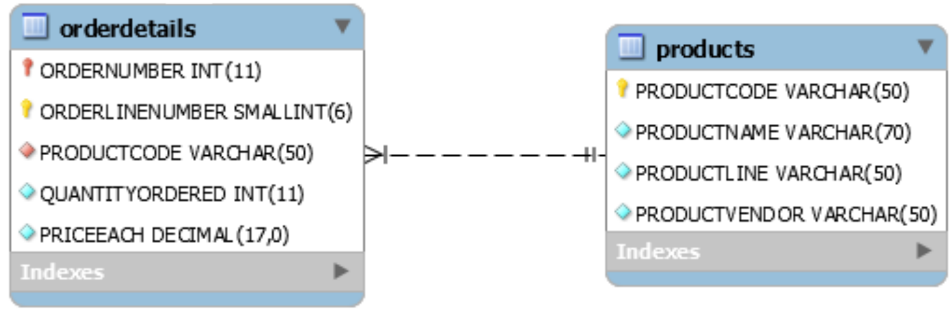





```
select c.country,
       sum(a.quantityordered*a.priceeach) as sales
from orderdetails as a,
       orders as b,
       customers as c
where a.ordernumber = b.ordernumber
   and b.customernumber = c.customernumber
group by c.country;
```

```
+-------------+---------+
| country     | sales   |
+-------------+---------+
| Australia   |  630638 |
| Austria     |  202089 |
| Belgium     |  108485 |
| Canada      |  224085 |
| ...         |     ... |
+-------------+---------+
21 rows in set (0.02 sec)
```

Sales by product line



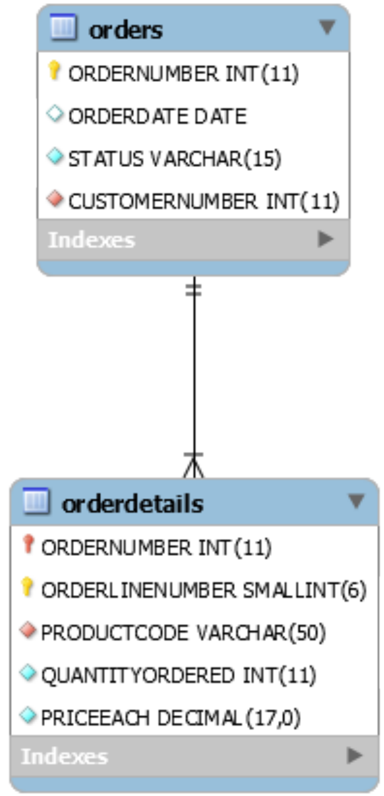

```
select b.productline,
        sum(a.quantityordered*a.priceeach) as sales
from orderdetails as a,
      products as b
where a.productcode = b.productcode
group by b.productline;
```

```
+------------------+---------+
| productline      | sales   |
+------------------+---------+
| Classic Cars     | 4090489 |
| Motorcycles      | 1274351 |
| Planes           | 1077130 |
| Ships            |  748369 |
| Trains           |  234662 |
| Trucks and Buses | 1154450 |
| Vintage Cars     | 3001614 |
+------------------+---------+
7 rows in set (0.02 sec)
```

Sales by year

```
select year(b.orderdate) as year,
        sum(a.quantityordered*a.priceeach) as sales
from orderdetails as a,
        orders as b
where a.ordernumber = b.ordernumber
group by year(b.orderdate);
```

```
+------+---------+
| year | sales   |
+------+---------+
| 2003 | 4312435 |
| 2004 | 4987780 |
| 2005 | 1980850 |
+------+---------+
3 rows in set (0.02 sec)
```

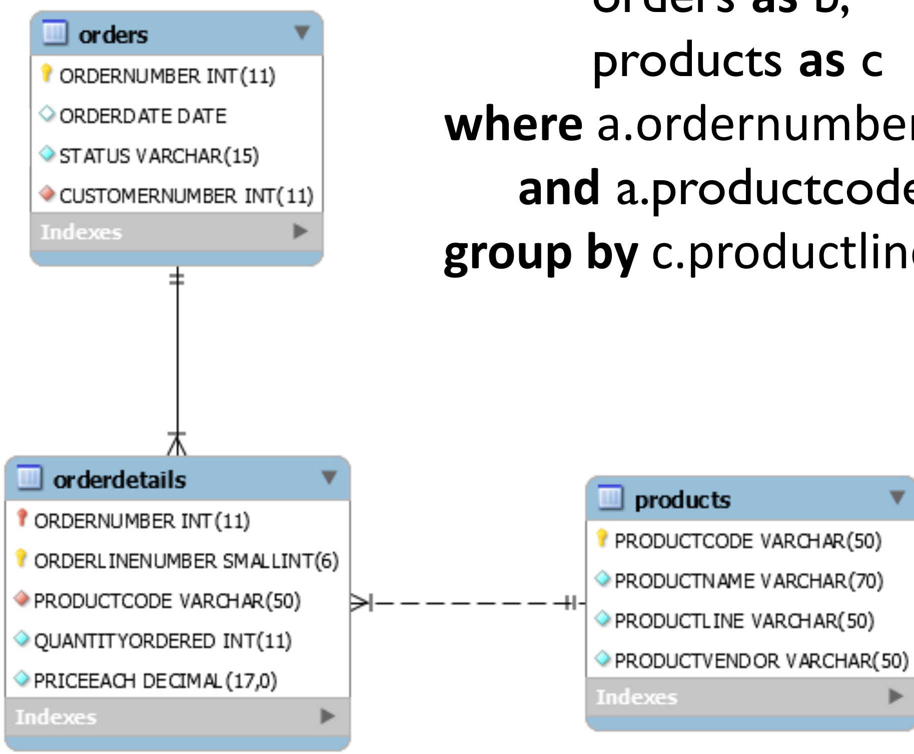


Multi-dimensional model

- Data can be analyzed according to different **dimensions**
  - in this example
    - customer country
    - product line
    - year
  - what about combining multiple dimensions?

Sales by product line and year

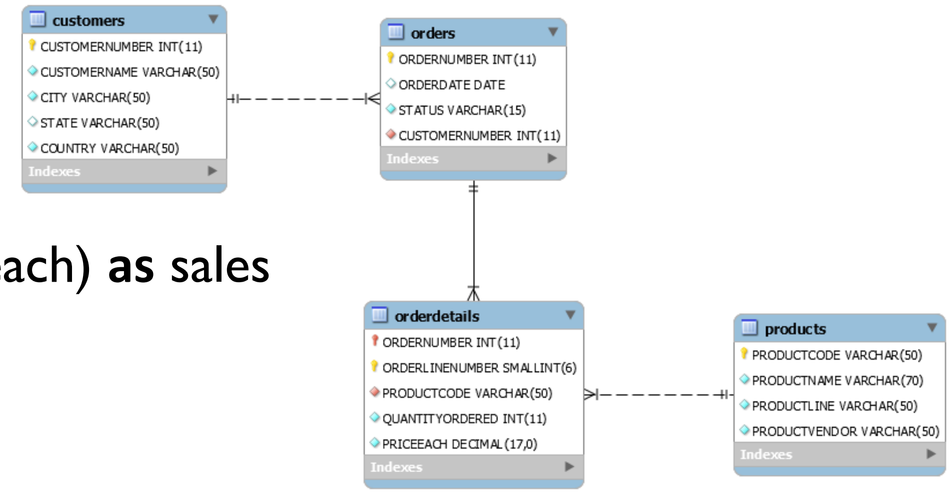
```
select c.productline,
        year(b.orderdate) as year,
        sum(a.quantityordered*a.priceeach) as sales
from orderdetails as a,
      orders as b,
      products as c
where a.ordernumber = b.ordernumber
   and a.productcode = c.productcode
group by c.productline, year(b.orderdate);
```




```
+-----------------+------+---------+
| productline     | year | sales   |
+-----------------+------+---------+
| Classic Cars    | 2003 | 1513998 |
| Classic Cars    | 2004 | 1837904 |
| Classic Cars    | 2005 |  738587 |
| Motorcycles     | 2003 |  397392 |
| Motorcycles     | 2004 |  590632 |
| ...             |  ... |     ... |
+-----------------+------+---------+
21 rows in set (0.03 sec)
```

Sales by customer country, product line and year

```
select d.country,
        c.productline,
        year(b.orderdate) as year,
        sum(a.quantityordered*a.priceeach) as sales
from orderdetails as a,
      orders as b,
      products as c,
      customers as d
where a.ordernumber = b.ordernumber
   and a.productcode = c.productcode
   and b.customernumber = d.customernumber
group by d.country,
            c.productline,
          year(b.orderdate);
```



country	productline	year	sales
Australia	Classic Cars	2003	85355
Australia	Classic Cars	2004	76198
Australia	Classic Cars	2005	31460
Australia	Motorcycles	2003	42337
Australia	Motorcycles	2004	33077
...	...	...	...

245 rows in set (0.04 sec)

Limitations of the Operational Database Table Model

Multi-dimensional model

- Analytical queries over the database
  - non-uniform treatment of dimensions
    - e.g. use of special functions for the time dimension
  - complex aggregates to calculate measures
    - e.g. sum(quantityordered*priceeach)
  - some calculations are done over and over again
    - e.g. quantityordered*priceeach
  - all of this running in parallel with transactional queries
    - impacts performance

Limitations of the Operational Table Model

- Example 1: *In which costumers bought most products last month?*
- Example 2: I*n which weeks and products, and cities do we observe the largest variation of sales?*
- Example 3: *How many customers brought products of product line A in the first week of 2017?*

Analytic processing is very **inefficient** due to the need to navigate in the model (many joins)

Limitations of the Operational Table Model

- Queries with many joins navigating across the data model
- Is it possible to optimise this processing?

Views?

Pre-aggregated data?

(Materialized Views)

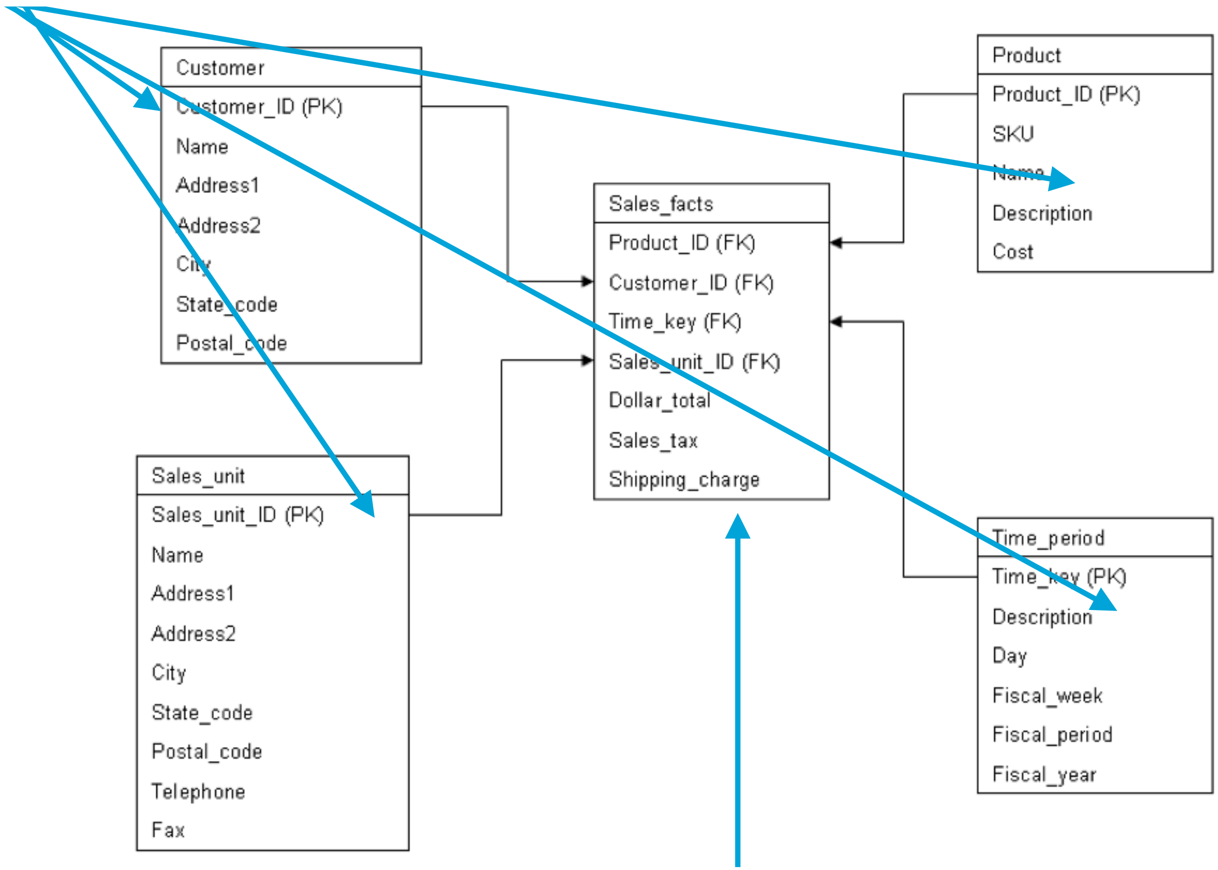
Indexes?

Another data model?

```
SELECT COUNT(DISTINCT Customer_ID)
FROM Sales_Facts
  INNER JOIN Time_Period
WHERE Fiscal_year = 2017
  AND Fiscal_week = 1
```

Multi-Dimensional Data Model (schema)

Dimensions / Axis

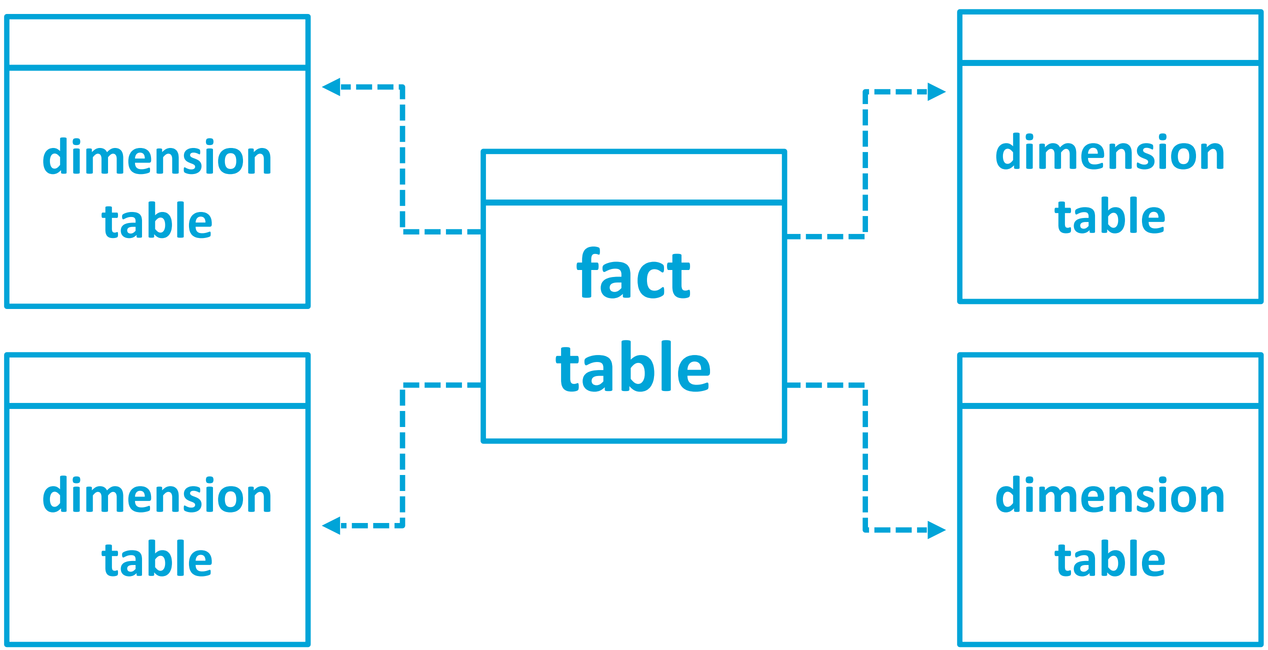


Measures / Facts / Observations / Occurrences

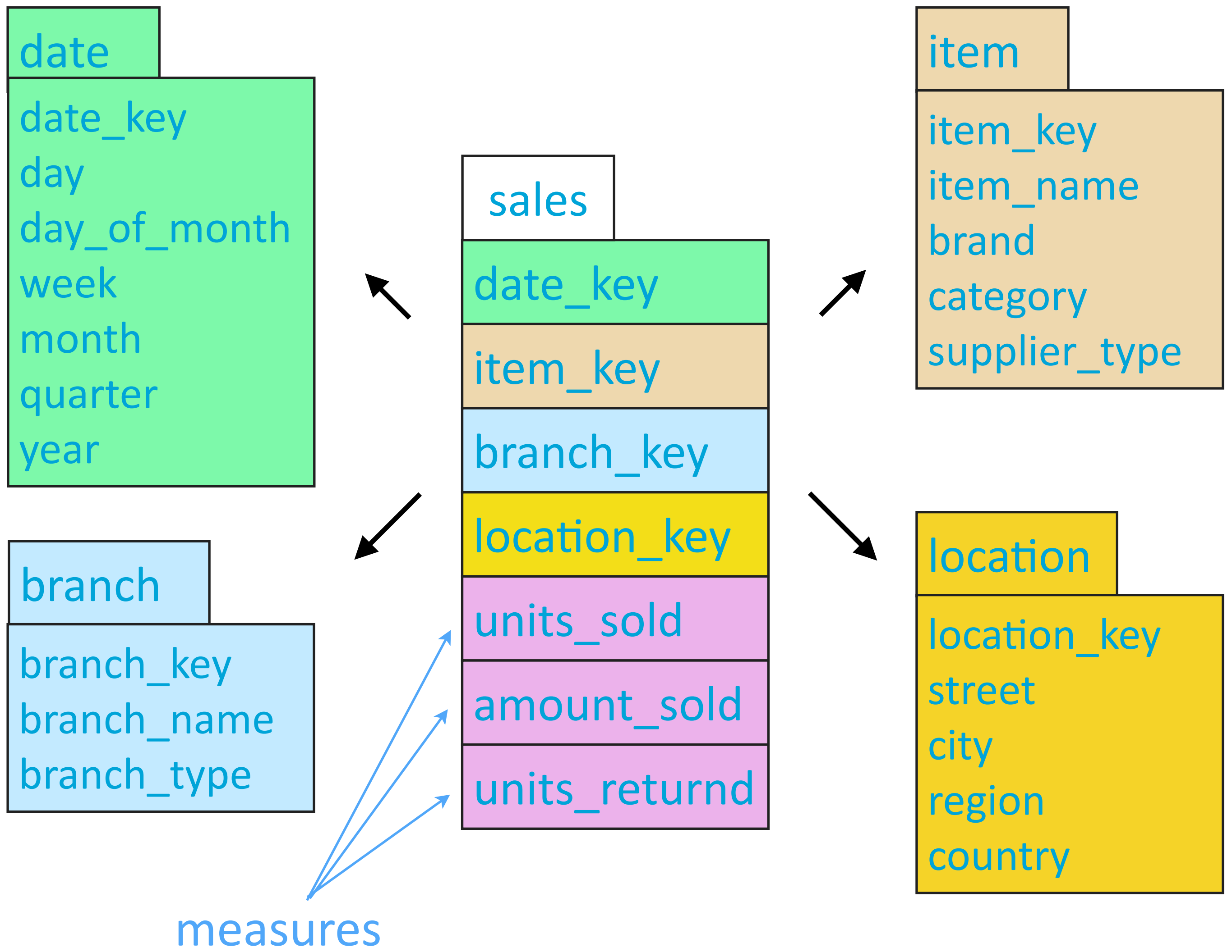
Data Warehousing

Data Warehousing

- Advantages of having a separate data warehouse
  - Separate OLTP and OLAP operations
  - Design a suitable schema for analytical queries
    - The star schema

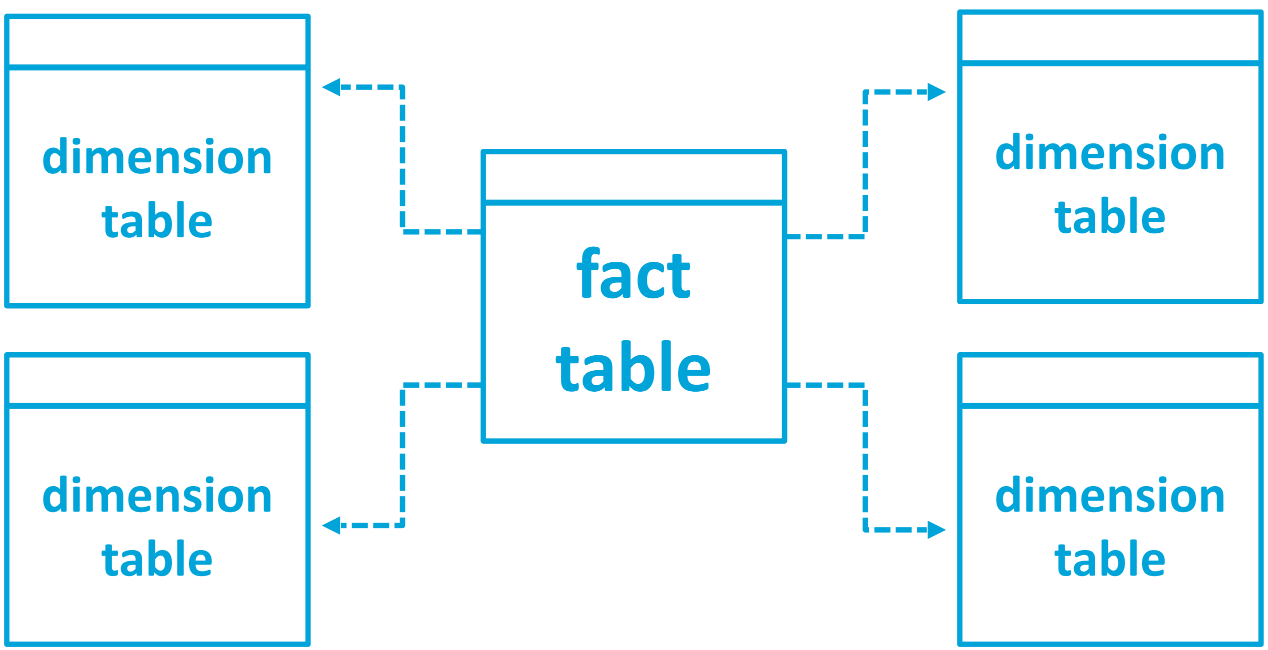


A Star Schema



Data Warehousing

- Analytical queries over a star schema
  - Join fact table with the desired dimension tables
  - Group by some level of those dimensions
  - Aggregate some measure in the fact table



Typical Dimensions of a Star Schema

- Who?
- What?
- Where?
- Facts
- How?
- When?

Dimensions are the explanation of facts

Typical Dimensions of a Star Schema

Customer Dimension

Product Dimension

Location Dimension

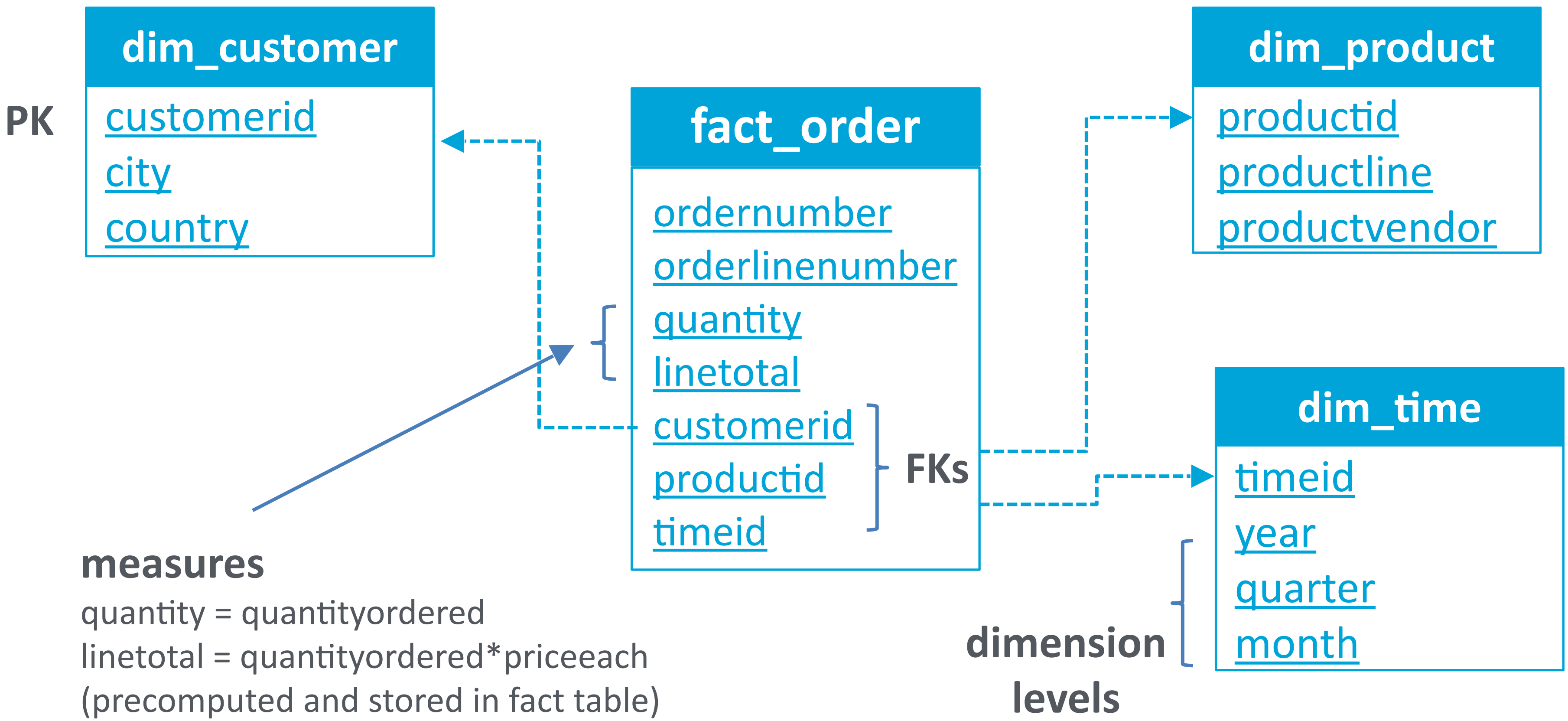
Facts

Time Dimension

Date Dimension

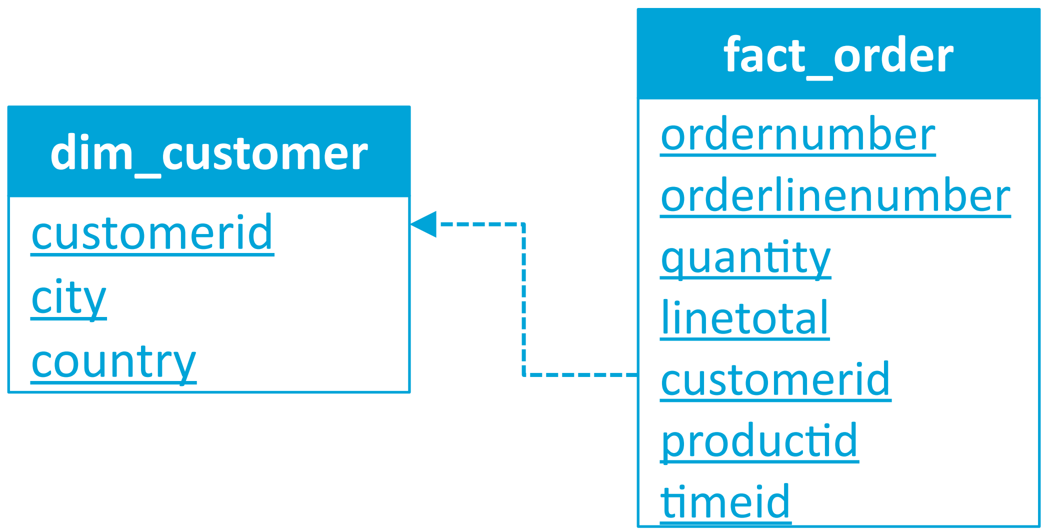
Data Warehousing

- Example of a star schema



Data Warehousing

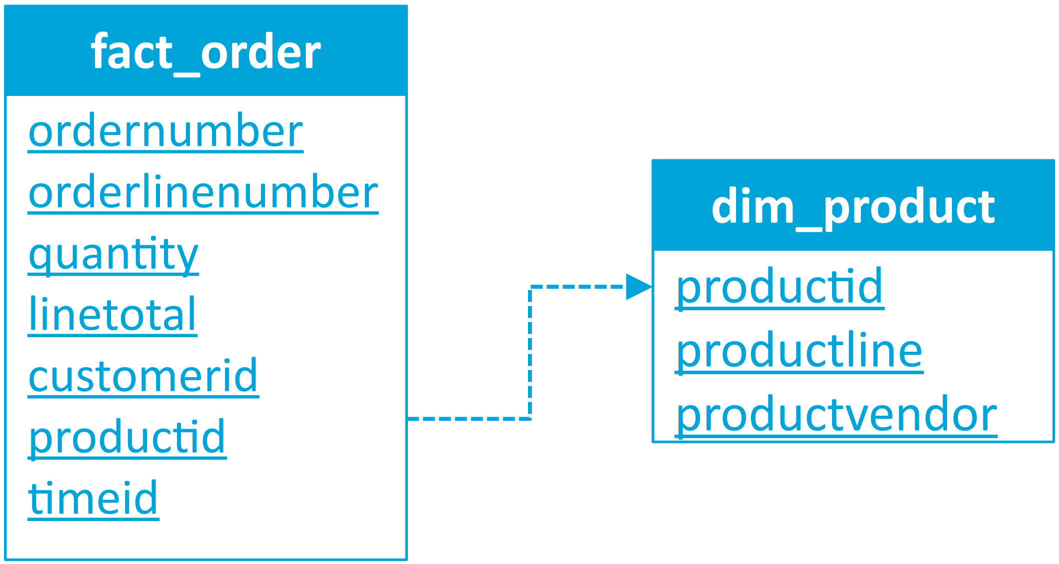
- Sales by customer country




```
select b.country, sum(a.linetotal) as sales
from fact_order as a, dim_customer as b
where a.customerid = b.customerid
group by b.country;
```

Data Warehousing

- Sales by product line

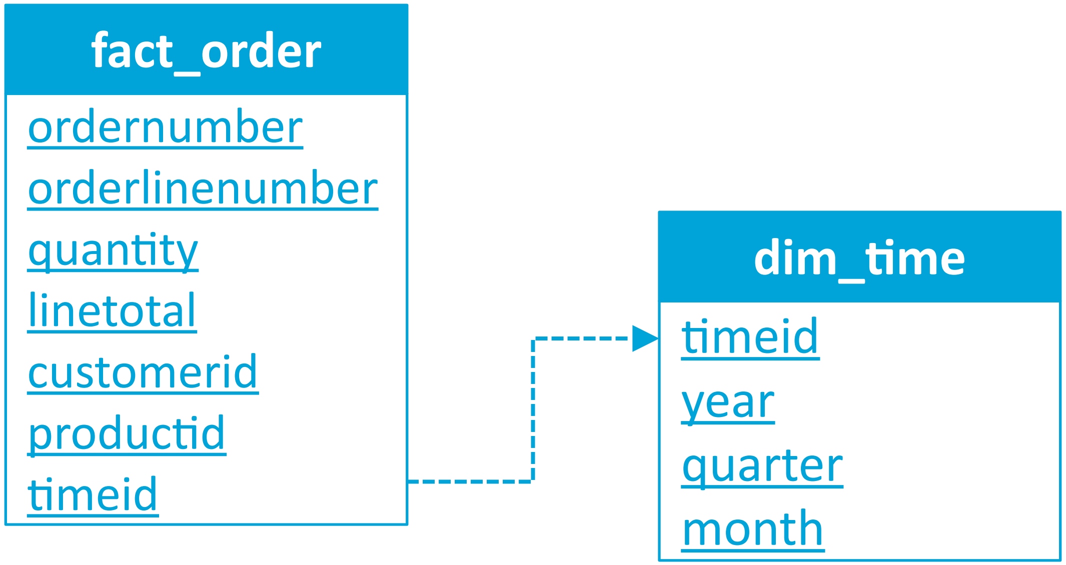


select b.productline, **sum**(a.linetotal) **as** sales
from fact_order **as** a, dim_product **as** b
where a.productid = b.productid
group by b.productline;

Data Warehousing

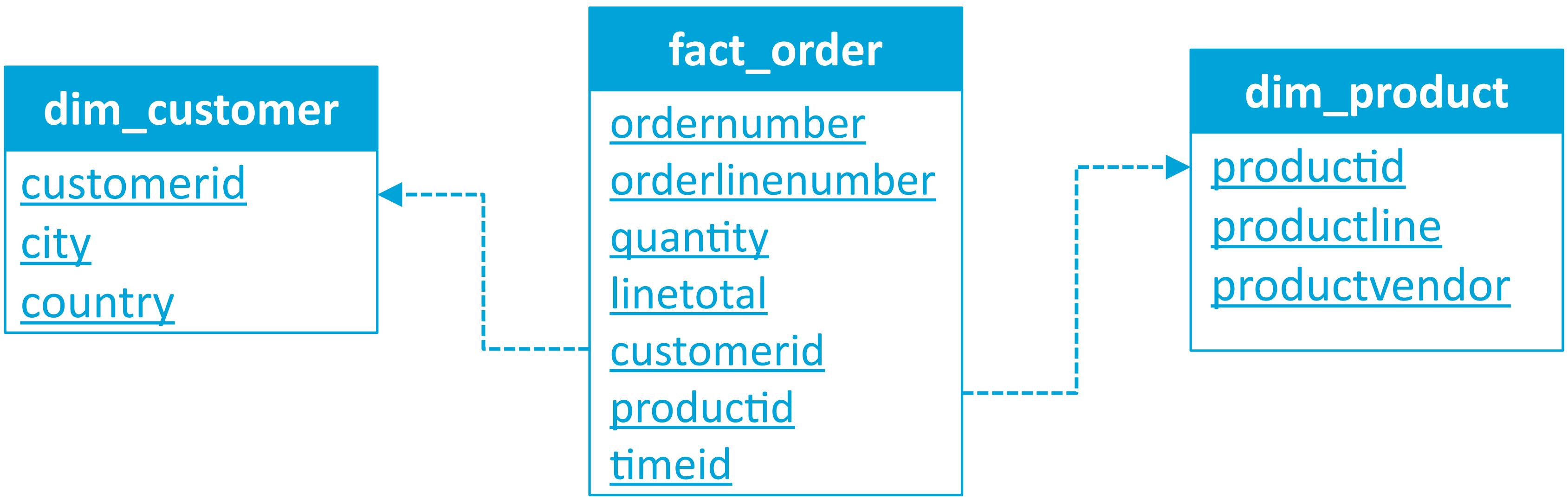
- Sales by year

```
select b.year, sum(a.linetotal) as sales
from fact_order as a, dim_time as b
where a.timeid = b.timeid
group by b.year;
```



Data Warehousing

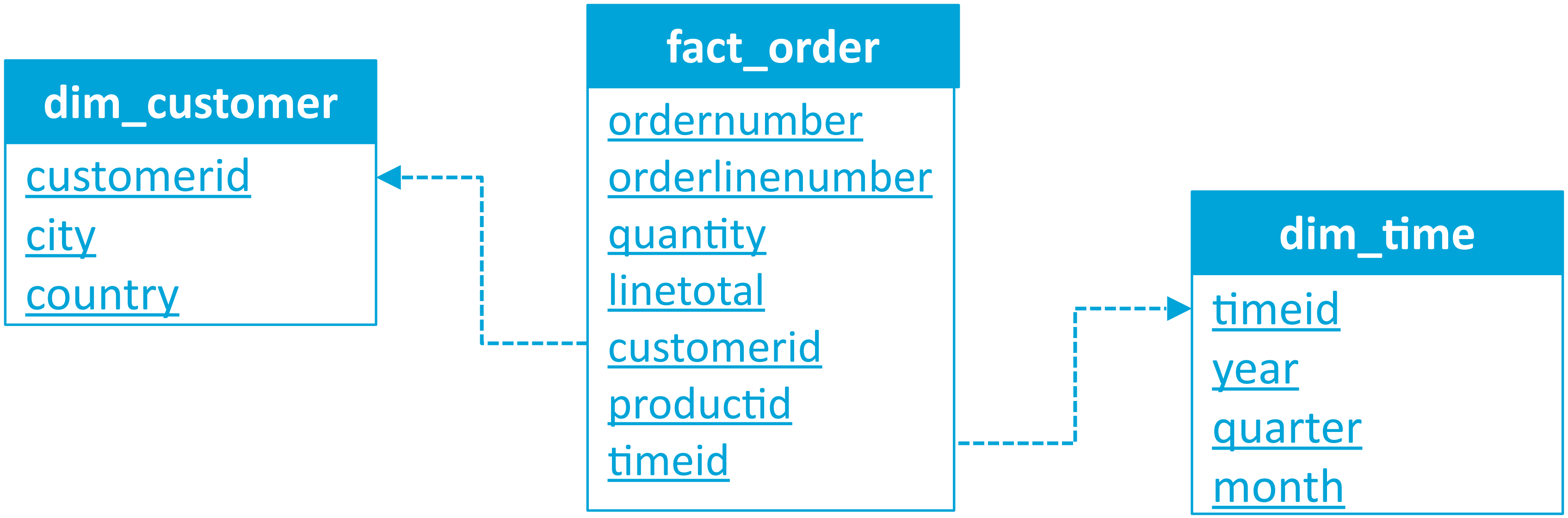
- Sales by customer country and product line




```
select c.country, b.productline, sum(a.linetotal) as sales
from fact_order as a, dim_product as b, dim_customer as c
where a.productid = b.productid
   and a.customerid = c.customerid
group by c.country, b.productline;
```

Data Warehousing

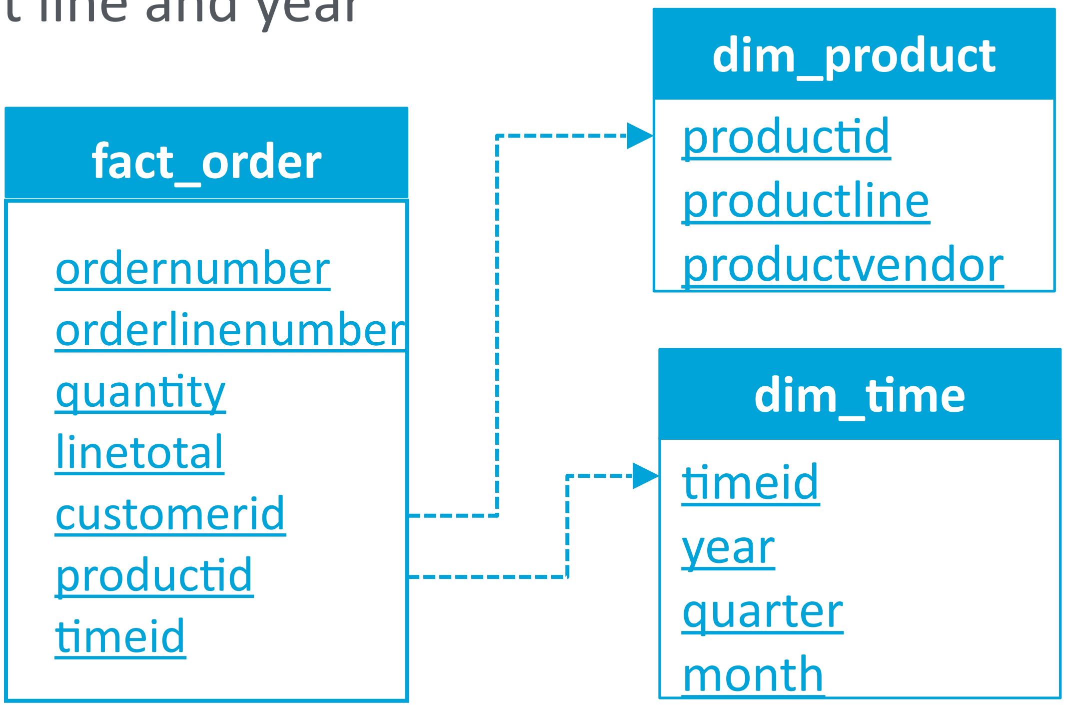
- Sales by customer country and year




```sql
select c.country, b.year, sum(a.linetotal) as sales
from fact_order as a, dim_time as b, dim_customer as c
where a.timeid = b.timeid
  and a.customerid = c.customerid
group by c.country, b.year;
```

Data Warehousing

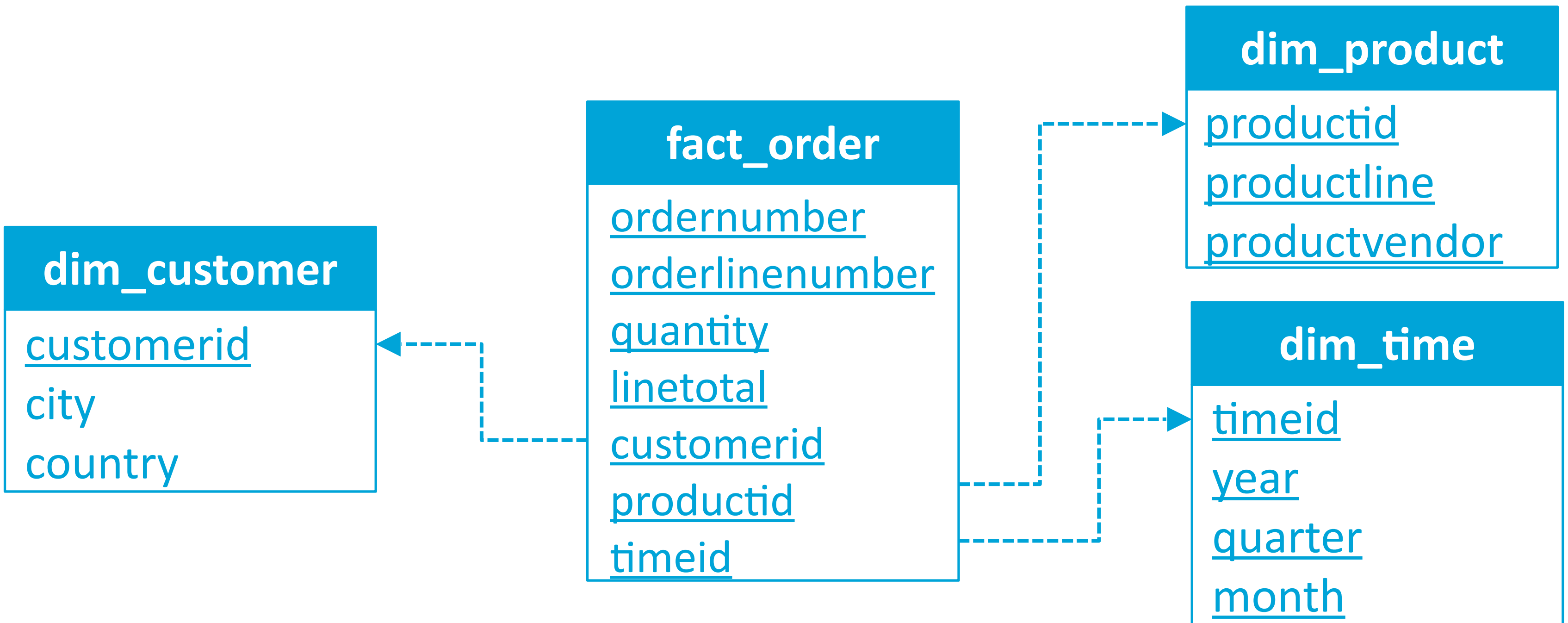
- Sales by product line and year



select c.productline, b.year, **sum**(a.linetotal) **as** sales
from fact_order **as** a, dim_time **as** b, dim_product **as** c
where a.timeid = b.timeid **and** a.productid =
c.productid
group by c.productline, b.year;

Data Warehousing

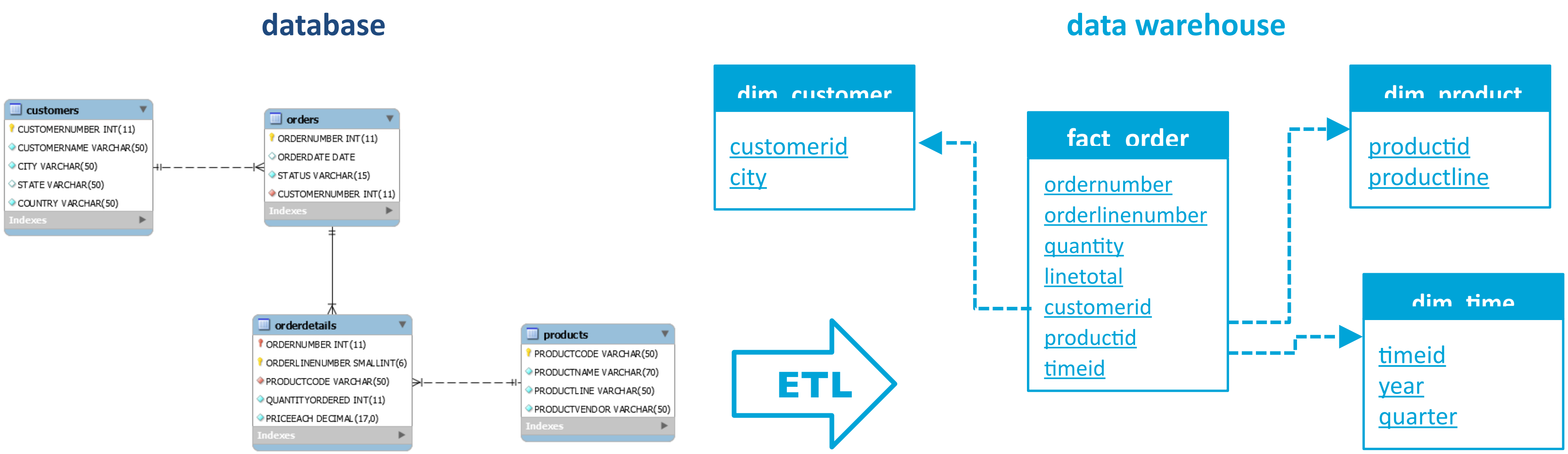
- Sales by customer country, product line and year



select d.country, c.productline, b.year, **sum**(a.linetotal) **as** sales
from fact_order **as** a, dim_time **as** b, dim_product **as** c, dim_customer **as** d
where a.timeid = b.timeid **and** a.productid = c.productid **and**
a.customerid = d.customerid
group by d.country, c.productline, b.year;

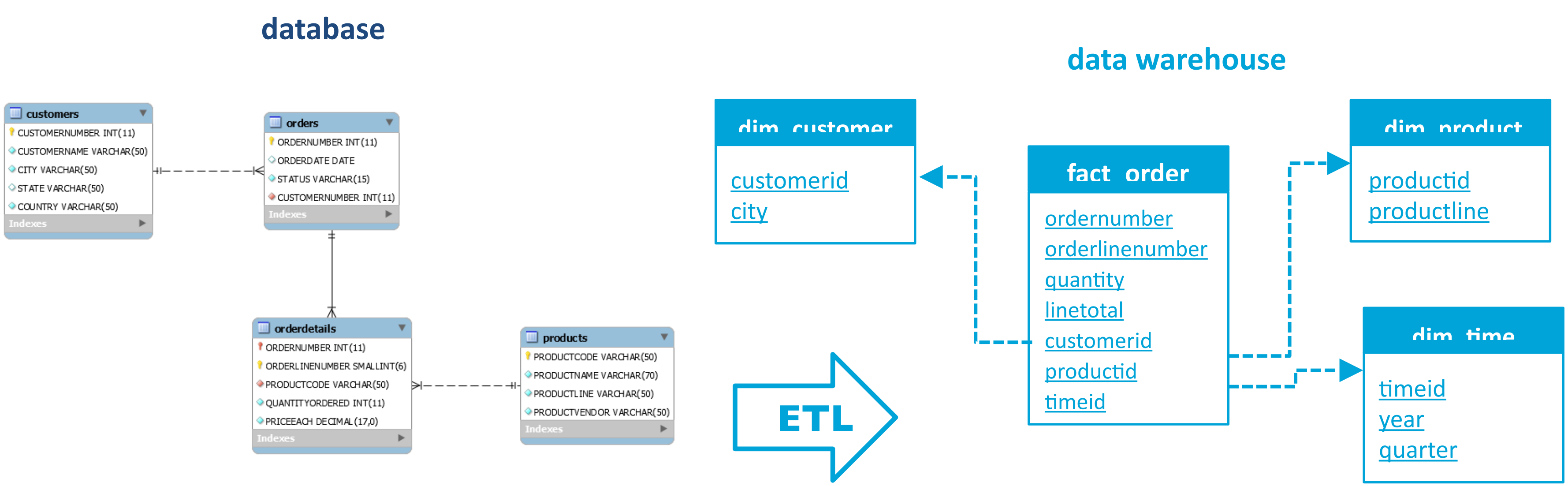
Data Warehousing

- How to build a data warehouse
  - ETL process
    - extract data from original database
    - transform data to fit star schema
    - load data onto data warehouse

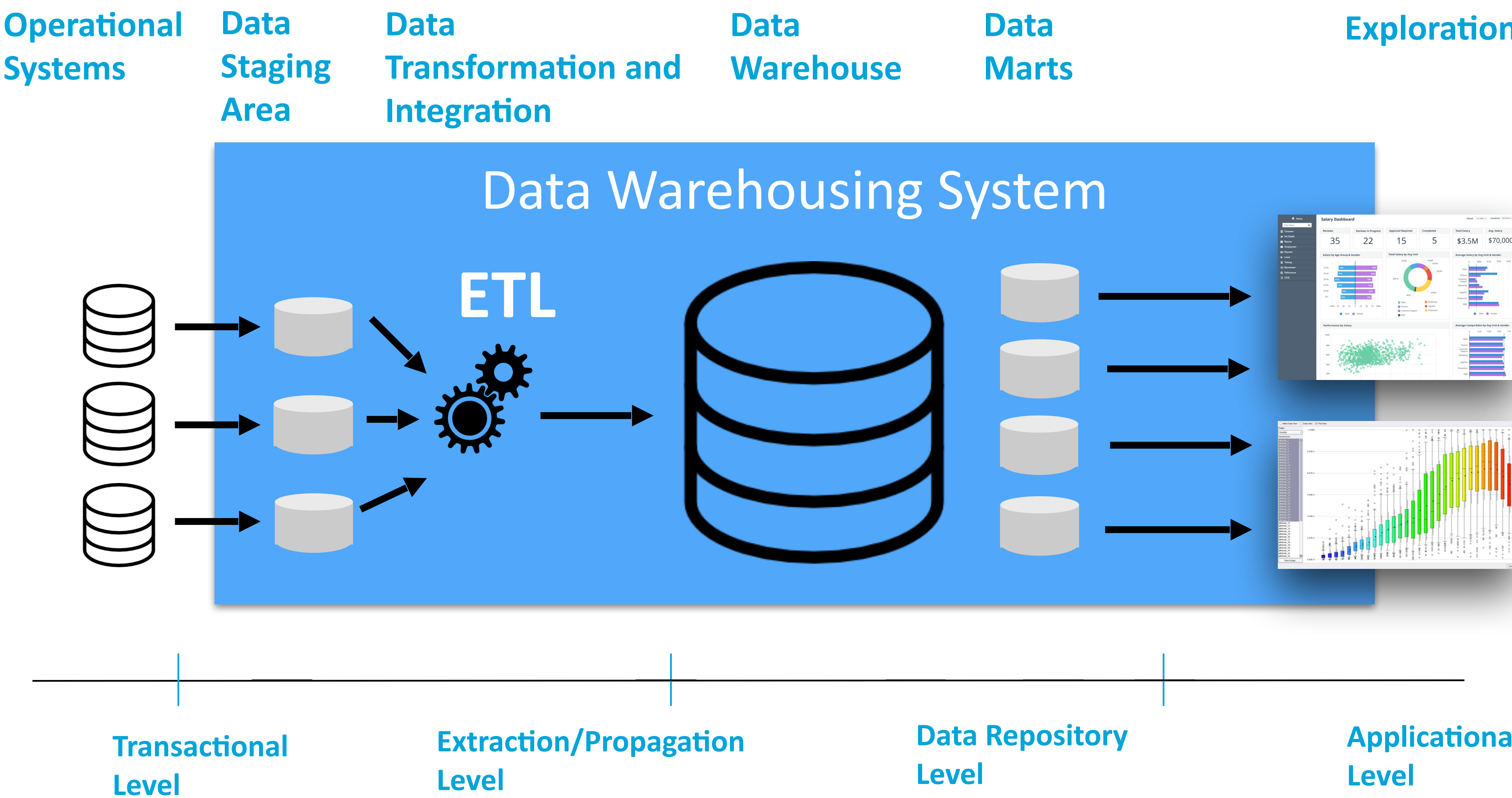


Data Warehousing

- How to build a data warehouse
  - this usually involves
    - one transformation for each dimension table
    - one transformation for the fact table
    - a job that runs all transformations in the correct sequence

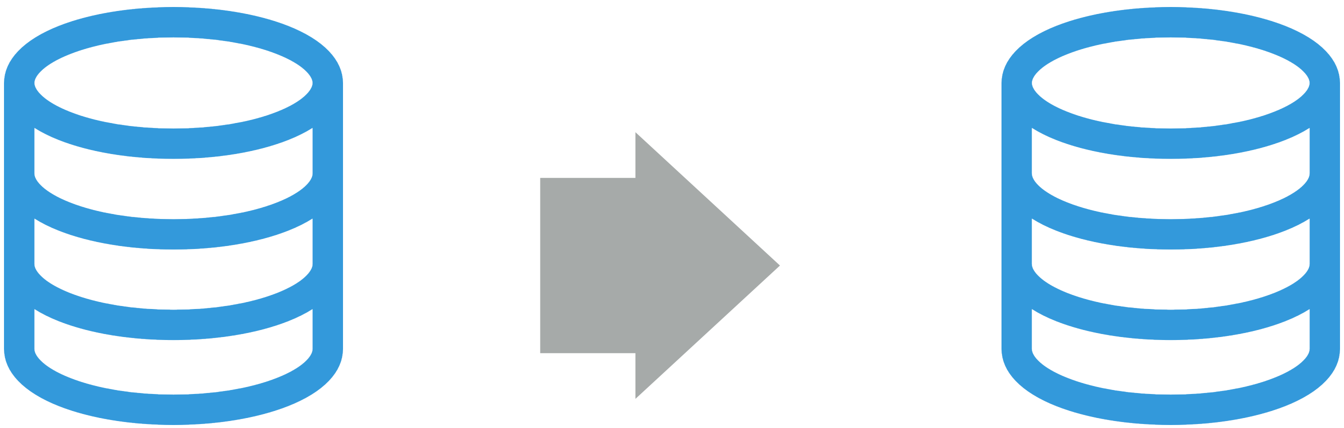


Architecture of a Data Warehousing System



OLAP *vs.* OLTP

Relationship of OLAP *with* OLTP



Online Transaction Processing (OLTP)

Online Analytical Processing OLAP

Transactional vs. Analytical Processing

- Transactional processing (OLTP)
  - create a new order
  - add products to an order
  - change the status of an order
  - etc.

- Analytical processing (OLAP)
  - sales by customer country
  - sales by product line
  - sales by year
  - etc.

OLTP vs. OLAP

- **OLTP**
  - Focus on the operation of a system
  - Large number of short transactions
  - Very fast query response
  - Performance metric is ‘Transactions per second’
- **OLAP**
  - Focus on analysis of historical data
  - Low number of long data load transactions
  - Slow response to very complex queries involve aggregations
  - Performance metric is ‘Query response time’