



THE UNIVERSITY OF  
MELBOURNE

# Normalisation

Database Systems & Information Modelling  
INFO90002

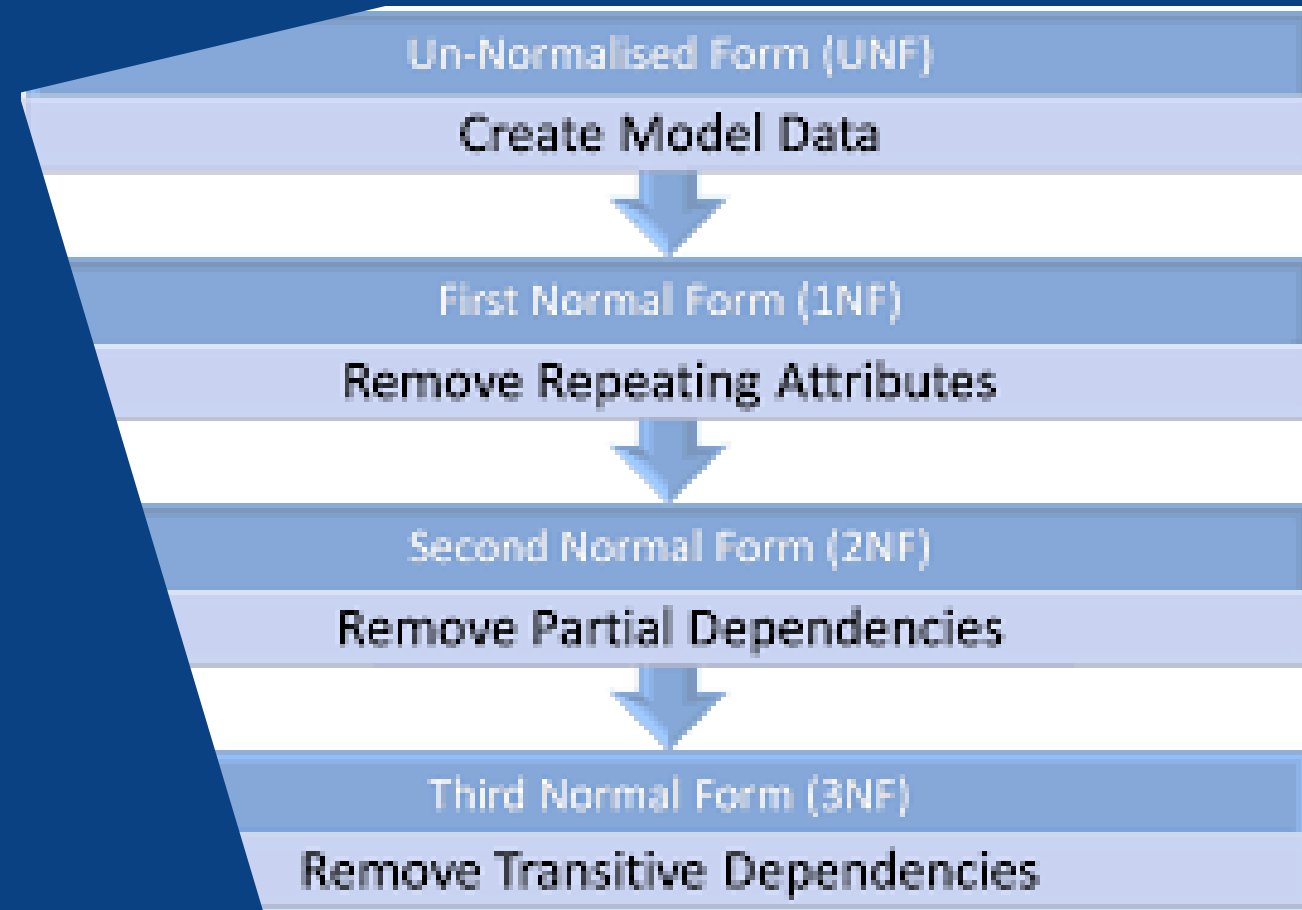
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Week 3 – Three normal forms

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# Learning Objectives

By the end of this lecture, you should be able to:

- Define normalisation
- Explain and identify database anomalies
- Define and identify functional dependencies
- Normalise relations to:
  - 1st Normal Form (1NF)
  - 2nd Normal Form (2NF)
  - 3rd Normal Form (3NF)
  - Boyce-Codd Normal Form (BCNF)



# Motivation for normalisation

What happens if we don't normalise?

# What's wrong with the *organisation* of data in this table?

| Student ID# | Student Name  | Campus Address     | Degree | Phone    | Subject ID | Subject Title | Lecturer Name | Lecturer Office | Lecturer Phone | Sem. | Grade |
|-------------|---------------|--------------------|--------|----------|------------|---------------|---------------|-----------------|----------------|------|-------|
| A121        | Joy Egbert    | 166 Grattan Street | B.Com. | 555-7771 | ACC101     | Accounting    | Davern        | T240C           | 8344-1846      | 1-11 | H1    |
| A121        | Joy Egbert    | 166 Grattan Street | B.Com. | 555-7771 | ECO101     | Economics     | Smyth         | T240F           | 8344-1868      | 1-11 | H2B   |
| A121        | Joy Egbert    | 166 Grattan Street | B.Com. | 555-7771 | ECO104     | Quant. M.     | Collier       | T240D           | 8344-5716      | 1-11 | H2B   |
| A121        | Joy Egbert    | 166 Grattan Street | B.Com. | 555-7771 | FIN101     | Finance.      | James         | T240D           | 8344-5275      | 1-11 | H2A   |
| A121        | Joy Egbert    | 166 Grattan Street | B.Com. | 555-7771 | ACC103     | Processes     | Wise          | T240E           | 8344-5309      | 1-11 | H3    |
| A123        | Larry Mueller | 302 Royal Parade   | B.Com. | 555-1235 | ACC101     | Accounting    | Davern        | T240C           | 8344-1846      | 1-11 | H1    |
| A123        | Larry Mueller | 302 Royal Parade   | B.Com. | 555-1235 | ECO101     | Economics     | Smyth         | T240F           | 8344-1868      | 1-11 | H2B   |
| A123        | Larry Mueller | 302 Royal Parade   | B.Com. | 555-1235 | ECO104     | Quant. M.     | Collier       | T240D           | 8344-5716      | 1-11 | H2A   |
| A123        | Larry Mueller | 302 Royal Parade   | B.Com. | 555-1235 | FIN101     | Finance.      | James         | T240D           | 8344-5275      | 1-11 | H3    |
| A124        | Mike Guon     | 224 Swanston St.   | B.Eco. | 555-2214 | ACC101     | Accounting    | Davern        | T240C           | 8344-1846      | 1-11 | H2A   |
| A124        | Mike Guon     | 224 Swanston St.   | B.Eco. | 555-2214 | ECO101     | Economics     | Smyth         | T240F           | 8344-1868      | 1-11 | H2A   |
| A124        | Mike Guon     | 224 Swanston St.   | B.Eco. | 555-2214 | ECO104     | Quant. M.     | Collier       | T240D           | 8344-5716      | 1-11 | H2B   |
| A124        | Mike Guon     | 224 Swanston St.   | B.Eco. | 555-2214 | ACC103     | Processes     | Wise          | T240E           | 8344-5309      | 1-11 | H2B   |
| A126        | Jackie Judson | 85 Barry Street    | B.Eco. | 555-1245 | ACC101     | Accounting    | Davern        | T240C           | 8344-1846      | 1-11 | H1    |
| A126        | Jackie Judson | 85 Barry Street    | B.Eco. | 555-1245 | ECO101     | Economics     | Smyth         | T240F           | 8344-1868      | 1-11 | H2B   |
| A126        | Jackie Judson | 85 Barry Street    | B.Eco. | 555-1245 | ECO104     | Quant. M.     | Collier       | T240D           | 8344-5716      | 1-11 | H2B   |
| A126        | Jackie Judson | 85 Barry Street    | B.Eco. | 555-1245 | ACC103     | Processes     | Wise          | T240E           | 8344-5309      | 1-11 | H2A   |
| ...         | ...           | ...                | ...    | ...      | ...        | ...           | ...           | ...             | ...            | ...  | ...   |

# Anomalies in Denormalised Data

Consider the following denormalised table (relation) :

| Student-ID | Course-ID | Fee |
|------------|-----------|-----|
| 130        | C200      | 75  |
| 200        | C300      | 100 |
| 250        | C200      | 75  |
| 425        | C400      | 150 |
| 500        | C300      | 100 |
| 575        | C500      | 50  |
| ...        | ...       | ... |

**Insertion Anomaly:** A new course cannot be added until at least one student has enrolled (which comes first student or course?)

**Deletion Anomaly:** If student 425 withdraws, we lose all record of course C400 and its fee!

**Update Anomaly:** If the fee for course C200 changes, we have to change it in multiple records (rows), else the data will be inconsistent.

# Normalisation

A technique used to remove undesired redundancy from databases (Break one large table into several smaller tables).

A relation is normalised if  
all determinants are  
candidate keys

**How do we normalise?**

# Invoice example

## Bill To

John  
Synex Inc  
128 AA Juanita Ave  
Glendora  
CA 91740 US

## Ship To

John  
Synex Inc  
128 AA Juanita Ave  
Glendora  
CA 91740 US

| Date          | 14-Aug-2009  | Order No            |       | Sales Person    | Charles Wooten |
|---------------|--|---------------------|-------|-----------------|----------------|
| Shipping Date | 13-Aug-2009  | Shipping Terms      |       | Terms           | COD            |
| ID            | SKU / Description                                    | Unit Price<br>(USD) | Qty   | Amount<br>(USD) |                |
| PS.V880.005   | AMD Athlon X2DC-7450,<br>2.4GHz/1GB/160GB/SMP-DVD/VB | 580.00              | 6.00  | 3,480.00        |                |
| PS.V880.037   | PDC-E5300 -<br>2.6GHz/1GB/320GB/SMP-DVD/FDD/VB       | 645.00              | 4.00  | 2,580.00        |                |
| LC.V890.002   | LG 18.5" WLCD  | 230.00              | 10.00 | 2,300.00        |                |
| HP.Q754.071   | HP LaserJet 5200                                     | 1,103.00            | 1.00  | 1,103.00        |                |

# Invoice example – Spreadsheet

This is not relational model

| Invoice Number | Date      | Customer Name | Customer Address    | Sales Person   | Terms | Product ID  | Product Name     | Unit Price | Quantity | Amount | Sub Total |
|----------------|-----------|---------------|---------------------|----------------|-------|-------------|------------------|------------|----------|--------|-----------|
| INV0012        | 14-Aug-09 | John / Synex  | 128 Juanita Ave...  | Charles Wooten | COD   | PSV880.006  | AMD Athlon X2DC  | 580        | 6        | 3480   | 9463      |
|                |           |               |                     |                |       | PSV880.037  | PDC E5300        | 645        | 4        | 2580   |           |
|                |           |               |                     |                |       | LC.V890.002 | LG 8.5" LCD      | 230        | 10       | 2300   |           |
|                |           |               |                     |                |       | HPQ754.071  | HP LaserJet 5200 | 1103       | 1        | 1103   |           |
|                |           |               |                     |                |       |             |                  |            |          |        |           |
|                |           |               |                     |                |       |             |                  |            |          |        |           |
| INV0013        | 15-Aug-09 | Ann / ThisCo  | 123 Smith Street... | Mary Smith     | COD   | HP Q754.071 | HP LaserJet 5200 | 1103       | 2        | 2206   | 3356      |
|                |           |               |                     |                |       | LCV890.002  | LG 8.5" LCD      | 230        | 5        | 1150   |           |



# Invoice example – Spreadsheet Format

| Invoice Number | Date      | Customer Name | Customer Address    | Sales Person   | Terms | Sub Total | Discount | Sales Tax | Shipping |
|----------------|-----------|---------------|---------------------|----------------|-------|-----------|----------|-----------|----------|
| INV0012        | 14-Aug-09 | John / Synex  | 128 Juanita Ave...  | Charles Wooten | COD   | 9463      | 0        | 780.70    | 0        |
| INV0013        | 15-Aug-09 | Ann / ThisCo  | 123 Smith Street... | Mary Smith     | COD   | 3356      | 0        | 100       | 0        |

| Product ID  | Product Name     | Unit Price | Quantity | Amount |
|-------------|------------------|------------|----------|--------|
| PSV880.006  | AMD Athlon X2DC  | 580        | 6        | 3480   |
| PSV880.037  | PDC E5300        | 645        | 4        | 2580   |
| LC.V890.002 | LG 8.5" LCD      | 230        | 10       | 2300   |
| HPQ754.071  | HP LaserJet 5200 | 1103       | 1        | 1103   |
| HPQ754.071  | HP LaserJet 5200 | 1103       | 2        | 2206   |
| LCV890.002  | LG 8.5" LCD      | 230        | 5        | 1150   |

Break into two  
But...  
How do we connect?

# Invoice example – Spreadsheet Format

| Invoice Number | Date      | Customer Name | Customer Address    | Sales Person   | Terms | Sub Total | Discount | Sales Tax | Shipping |
|----------------|-----------|---------------|---------------------|----------------|-------|-----------|----------|-----------|----------|
| INV0012        | 14-Aug-09 | John / Synex  | 128 Juanita Ave...  | Charles Wooten | COD   | 9463      | 0        | 780.70    | 0        |
| INV0013        | 15-Aug-09 | Ann/This Co   | 123 Smith Street... | Mary Smith     | COD   | 3356      | 0        | 100       | 0        |

| Product ID  | Product Name     | Unit Price | Quantity | Amount | Invoice Number |
|-------------|------------------|------------|----------|--------|----------------|
| PSV880.006  | AMD Athlon X2DC  | 580        | 6        | 3480   | INV0012        |
| PSV880.037  | PDC E5300        | 645        | 4        | 2580   | INV0012        |
| LC.V890.002 | LG 8.5" LCD      | 230        | 10       | 2300   | INV0012        |
| HPQ754.071  | HP LaserJet 5200 | 1103       | 1        | 1103   | INV0012        |
| HPQ754.071  | HP LaserJet 5200 | 1103       | 2        | 2206   | INV0013        |
| LCV890.002  | LG 8.5" LCD      | 230        | 5        | 1150   | INV0013        |

Add FK

# Invoice example – keep fixing

| Invoice Number | Date      | Customer Name | Customer Address    | Sales Person   | Terms | Sub Total | Discount | Sales Tax | Shipping |
|----------------|-----------|---------------|---------------------|----------------|-------|-----------|----------|-----------|----------|
| INV0012        | 14-Aug-09 | John / Synex  | 128 Juanita Ave...  | Charles Wooten | COD   | 9463      | 0        | 780.70    | 0        |
| INV0013        | 15-Aug-09 | Ann / ThisCo  | 123 Smith Street... | Mary Smith     | COD   | 3356      | 0        | 100       | 0        |

| Product ID  | Product Name     | Unit Price | Quantity | Amount | Invoice Number |
|-------------|------------------|------------|----------|--------|----------------|
| PSV880.006  | AMD Athlon X2DC  | 580        | 6        | 3480   | INV0012        |
| PSV880.037  | PDC E5300        | 645        | 4        | 2580   | INV0012        |
| LC.V890.002 | LG 8.5" LCD      | 230        | 10       | 2300   | INV0012        |
| HPQ754.071  | HP LaserJet 5200 | 1103       | 1        | 1103   | INV0012        |
| HPQ754.071  | HP LaserJet 5200 | 1103       | 2        | 2206   | INV0013        |
| LCV890.002  | LG 8.5" LCD      | 230        | 5        | 1150   | INV0013        |

This is about  
product

This is about  
Order (invoice)

# Invoice example – keep fixing

| Invoice Number | Date      | Customer Name | Customer Address    | Sales Person   | Terms | Sub Total | Discount | Sales Tax | Shipping |
|----------------|-----------|---------------|---------------------|----------------|-------|-----------|----------|-----------|----------|
| INV0012        | 14-Aug-09 | John / Synex  | 128 Juanita Ave...  | Charles Wooten | COD   | 9463      | 0        | 780.70    | 0        |
| INV0013        | 15-Aug-09 | Ann / ThisCo  | 123 Smith Street... | Mary Smith     | COD   | 3356      | 0        | 100       | 0        |

| <i>Product ID</i> | <i>Quantity</i> | <i>Amount</i> | <i>Invoice Number</i> |
|-------------------|-----------------|---------------|-----------------------|
| PSV880.006        | 6               | 3480          | INV0012               |
| PSV880.037        | 4               | 2580          | INV0012               |
| LC.V890.002       | 10              | 2300          | INV0012               |
| HPQ754.071        | 1               | 1103          | INV0012               |
| HPQ754.071        | 2               | 2206          | INV0013               |
| LCV890.00         | 5               | 1150          | INV0013               |

Break into two

| Product ID  | Product Name     | Unit Price |
|-------------|------------------|------------|
| PSV880.006  | AMD Athlon X2DC  | 580        |
| PSV880.037  | PDC E5300        | 645        |
| LC.V890.002 | LG 8.5" LCD      | 230        |
| HPQ754.071  | HP LaserJet 5200 | 1103       |

# Invoice example – keep fixing

| Invoice Number | Date      | Customer Name | Customer Address    | Sales Person   | Terms | Sub Total | Discount | Sales Tax | Shipping |
|----------------|-----------|---------------|---------------------|----------------|-------|-----------|----------|-----------|----------|
| INV0012        | 14-Aug-09 | John / Synex  | 128 Juanita Ave...  | Charles Wooten | COD   | 9463      | 0        | 780.70    | 0        |
| INV0013        | 15-Aug-09 | Ann / ThisCo  | 123 Smith Street... | Mary Smith     | COD   | 3356      | 0        | 100       | 0        |

| Product ID  | Quantity | Amount | Invoice Number |
|-------------|----------|--------|----------------|
| PSV880.006  | 6        | 3480   | INV0012        |
| PSV880.037  | 4        | 2580   | INV0012        |
| LC.V890.002 | 10       | 2300   | INV0012        |
| HPQ754.071  | 1        | 1103   | INV0012        |
| HPQ754.071  | 2        | 2206   | INV0013        |
| LCV890.00   | 5        | 1150   | INV0013        |

What about amount?

| Product ID  | Product Name     | Unit Price |
|-------------|------------------|------------|
| PSV880.006  | AMD Athlon X2DC  | 580        |
| PSV880.037  | PDC E5300        | 645        |
| LC.V890.002 | LG 8.5" LCD      | 230        |
| HPQ754.071  | HP LaserJet 5200 | 1103       |

# Invoice example – keep fixing

| Invoice Number | Date      | Customer Name | Customer Address    | Sales Person   | Terms | Sub Total | Discount | Sales Tax | Shipping |
|----------------|-----------|---------------|---------------------|----------------|-------|-----------|----------|-----------|----------|
| INV0012        | 14-Aug-09 | John / Synex  | 128 Juanita Ave...  | Charles Wooten | COD   | 9463      | 0        | 780.70    | 0        |
| INV0013        | 15-Aug-09 | Ann / ThisCo  | 123 Smith Street... | Mary Smith     | COD   | 3356      | 0        | 100       | 0        |

| Product ID  | Quantity | Invoice Number |
|-------------|----------|----------------|
| PSV880.006  | 6        | INV0012        |
| PSV880.037  | 4        | INV0012        |
| LC.V890.002 | 10       | INV0012        |
| HPQ754.071  | 1        | INV0012        |
| HPQ754.071  | 2        | INV0013        |
| LCV890.00   | 5        | INV0013        |

Could be derived

| Product ID  | Product Name     | Unit Price |
|-------------|------------------|------------|
| PSV880.006  | AMD Athlon X2DC  | 580        |
| PSV880.037  | PDC E5300        | 645        |
| LC.V890.002 | LG 8.5" LCD      | 230        |
| HPQ754.071  | HP LaserJet 5200 | 1103       |

# Invoice example – keep fixing

| Invoice Number | Date      | Customer Name | Customer Address    | Sales Person   | Terms | Sub Total | Discount | Sales Tax | Shipping |
|----------------|-----------|---------------|---------------------|----------------|-------|-----------|----------|-----------|----------|
| INV0012        | 14-Aug-09 | John / Synex  | 128 Juanita Ave...  | Charles Wooten | COD   | 9463      | 0        | 780.70    | 0        |
| INV0013        | 15-Aug-09 | Ann / ThisCo  | 123 Smith Street... | Mary Smith     | COD   | 3356      | 0        | 100       | 0        |

| Product ID  | Quantity | Invoice Number |
|-------------|----------|----------------|
| PSV880.006  | 6        | INV0012        |
| PSV880.037  | 4        | INV0012        |
| LC.V890.002 | 10       | INV0012        |
| HPQ754.071  | 1        | INV0012        |
| HPQ754.071  | 2        | INV0013        |
| LCV890.00   | 5        | INV0013        |

What about sales person?

| Product ID  | Product Name     | Unit Price |
|-------------|------------------|------------|
| PSV880.006  | AMD Athlon X2DC  | 580        |
| PSV880.037  | PDC E5300        | 645        |
| LC.V890.002 | LG 8.5" LCD      | 230        |
| HPQ754.071  | HP LaserJet 5200 | 1103       |

# Invoice example – keep fixing

| Invoice Number | Date      | Customer Name | Customer Address    | Sales Person ID | Terms | Sub Total | Discount | Sales Tax | Shipping |
|----------------|-----------|---------------|---------------------|-----------------|-------|-----------|----------|-----------|----------|
| INV0012        | 14-Aug-09 | John / Synex  | 128 Juanita Ave...  | 1               | COD   | 9463      | 0        | 780.70    | 0        |
| INV0013        | 15-Aug-09 | Ann / This co | 123 Smith Street... | 2               | COD   | 3356      | 0        | 100       | 0        |

| Product ID  | Quantity | Invoice Number |
|-------------|----------|----------------|
| PSV880.006  | 6        | INV0012        |
| PSV880.037  | 4        | INV0012        |
| LC.V890.002 | 10       | INV0012        |
| HPQ754.071  | 1        | INV0012        |
| HPQ754.071  | 2        | INV0013        |
| LCV890.00   | 5        | INV0013        |

What about customer?

| Sales Person ID | Sales Person   |
|-----------------|----------------|
| 1               | Charles Wooten |
| 2               | Mary Smith     |

| Product ID  | Product Name     | Unit Price |
|-------------|------------------|------------|
| PSV880.006  | AMD Athlon X2DC  | 580        |
| PSV880.037  | PDC E5300        | 645        |
| LC.V890.002 | LG 8.5" LCD      | 230        |
| HPQ754.071  | HP LaserJet 5200 | 1103       |



# Invoice example – Done!

| Invoice Number | Date      | Customer ID | Sales Person ID | Terms | Sub Total | Discount | Sales Tax | Shipping |
|----------------|-----------|-------------|-----------------|-------|-----------|----------|-----------|----------|
| INV0012        | 14-Aug-09 | 1           | 1               | COD   | 9463      | 0        | 780.70    | 0        |
| INV0013        | 15-Aug-09 | 2           | 2               | COD   | 3356      | 0        | 100       | 0        |

| Product ID  | Quantity | Invoice Number |
|-------------|----------|----------------|
| PSV880.006  | 6        | INV0012        |
| PSV880.037  | 4        | INV0012        |
| LC.V890.002 | 10       | INV0012        |
| HPQ754.071  | 1        | INV0012        |
| HPQ754.071  | 2        | INV0013        |
| LCV890.00   | 5        | INV0013        |

| Sales Person ID | Sales Person   |
|-----------------|----------------|
| 1               | Charles Wooten |
| 2               | Mary James     |

| Customer ID | Customer Name | Customer Address    |
|-------------|---------------|---------------------|
| 1           | John / Synex  | 128 Juanita Ave...  |
| 2           | Ann / ThisCo  | 123 Smith Street... |

| Product ID  | Product Name     | Unit Price |
|-------------|------------------|------------|
| PSV880.006  | AMD Athlon X2DC  | 580        |
| PSV880.037  | PDC E5300        | 645        |
| LC.V890.002 | LG 8.5" LCD      | 230        |
| HPQ754.071  | HP LaserJet 5200 | 1103       |

# Normalised Relations and ER Diagram

We can name the relations now

Customer (CustomerNumber, CustomerName, CustomerAddress)

Clerk (ClerkNumber, ClerkName)

Product (ProductNumber, ProductDescription)

Invoice (InvoiceNumber, Date, *CustomerNumber*, *ClerkNumber*)

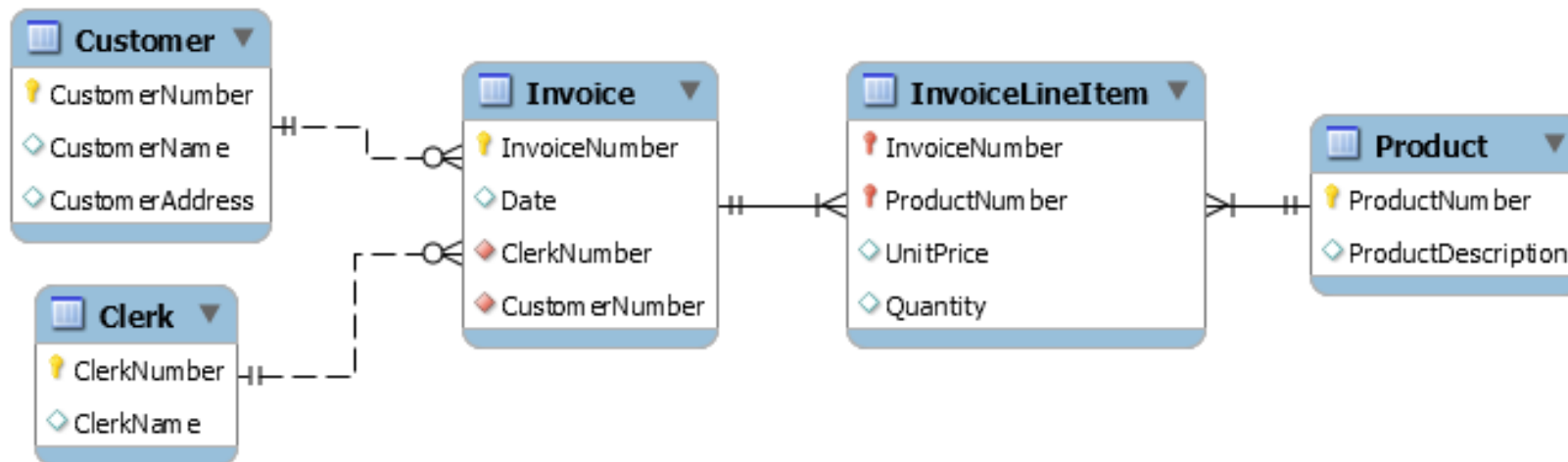
InvoiceLineItem (InvoiceNumber, ProductNumber, UnitPrice, Quantity)

KEY:

PK = Underline

FK = Italic

PFK Underline + Italic





Un-Normalised Form (UNF)

Create Model Data



First Normal Form (1NF)

Remove Repeating Attributes



Second Normal Form (2NF)

Remove Partial Dependencies



Third Normal Form (3NF)

Remove Transitive Dependencies

# Normalisation and Associated Concepts

# Functional Dependency

- A functional dependency concerns values of attributes in a relation
- The attribute Y is **fully functionally dependent** on the attribute X if each value of X determines one and only value of Y

Notation:  $X \rightarrow Y$

- X determines Y (If I know X then I also know Y)

StudentID  $\longrightarrow$  Student-name

StudentID  $\longrightarrow$  Student-email



# Functional Dependency:

- Determinants ( $X, Y \rightarrow Z$ )
  - the attribute(s) on the left hand side of the arrow
- Key and Non-Key attributes
  - each attribute is either part of the primary key or it is not
- Partial functional dependency ( $Y \twoheadrightarrow Z$ )
  - a functional dependency of one or more non-key attributes upon part (but not all) of the primary key, e.g. (StudentID, SubjectCode)  $\rightarrow$  StudentName
- Transitive dependency ( $Z \rightarrow D$ )
  - a functional dependency between 2 (or more) non-key attributes, e.g. SubjCode | SubjectName | LecturerID | LecturerName results in SubjCode  $\rightarrow$  LecturerName

$A(\underline{X}, \underline{Y}, Z, D)$

# Armstrong's Axioms

Functional dependencies can be identified using Armstrong's Axioms

$A = (X_1, X_2, \dots, X_n)$  and  $B = (Y_1, Y_2, \dots, Y_n)$

1. Reflexivity:  $B \subseteq A \implies A \rightarrow B$

**Example:** Student\_ID, name  $\rightarrow$  name

2. Augmentation:  $A \rightarrow B \implies AC \rightarrow BC$

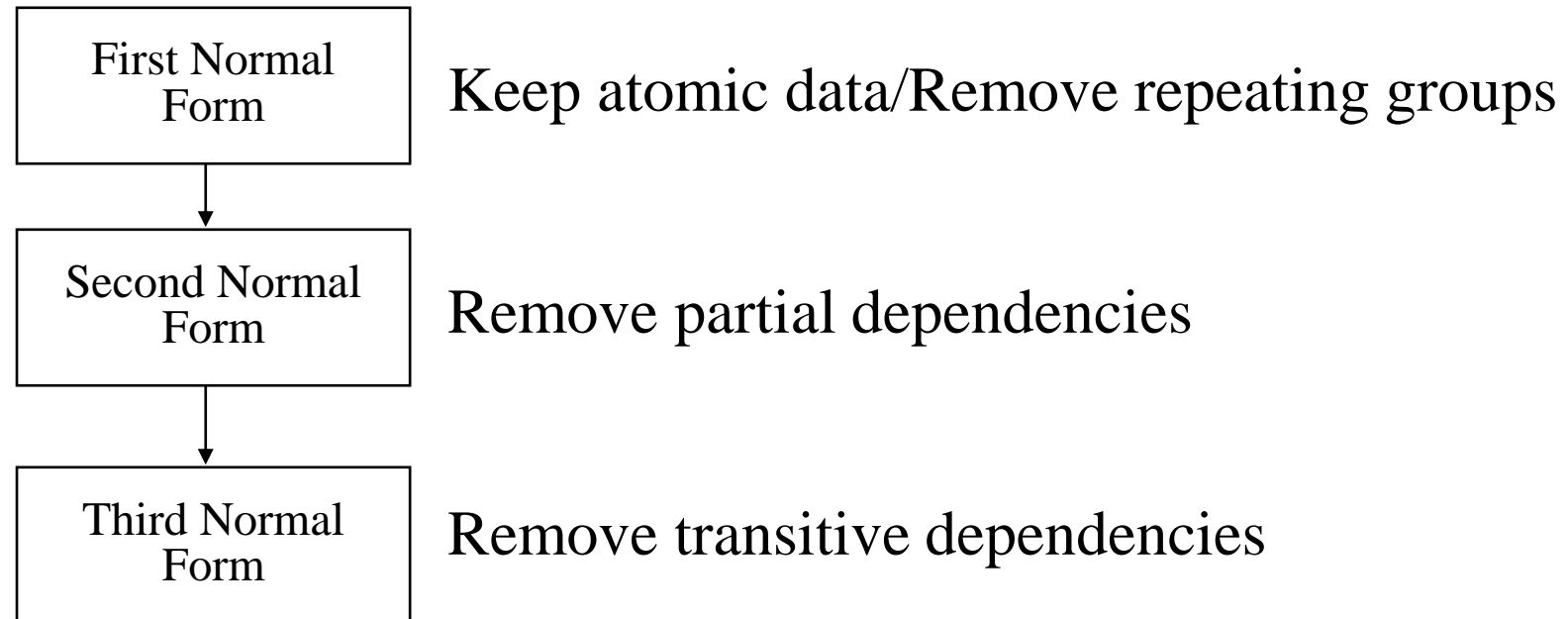
**Example:** Student\_ID  $\rightarrow$  name  $\implies$  Student\_ID, surname  $\rightarrow$  name, surname

3. Transitivity:  $A \rightarrow B$  and  $B \rightarrow C \implies A \rightarrow C$

**Example:** ID  $\rightarrow$  birthdate, and birthdate  $\rightarrow$  age then ID  $\rightarrow$  age

# Steps in Normalisation

Normal form - the state of a relation resulting from applying rules about the functional dependency of some attributes upon others



# Example: UNF (unnormalised form)

| Order# | Customer# | Item# | Description                                       | Qty |
|--------|-----------|-------|---|-----|
| 1234-5 | 789912    | L236  | Lenovo Q27q 27" QHD Monitor with Built-in Speaker | 1   |
|        |           | D722  | Dell KM5221W Pro Wireless Keyboard and Mouse      | 1   |
| 2577-1 | 321154    | B614  | Belkin High Speed HDMI Cable with Ethernet (5M)   | 2   |
|        |           | A343  | ALOGIC Ultra USB-C to HDMI Cable (2m)             | 1   |
|        |           | M766  | Microsoft Surface Dock 2                          | 1   |



# First Normal Form (1NF)

## Remove Repeating Groups/Keep Atomic Data

- repeating groups of attributes cannot be represented in a flat, two-dimensional table
  - removing cells with multiple values (keep atomic data)
  - eliminate nulls

### OrderItem

| Order# | Customer# | Item# | Description                                       | Qty |
|--------|-----------|-------|---|-----|
| 1234-5 | 789912    | L236  | Lenovo Q27q 27" QHD Monitor with Built-in Speaker | 1   |
| 1234-5 | 789912    | D722  | Dell KM5221W Pro Wireless Keyboard and Mouse      | 1   |
| 2577-1 | 321154    | B614  | Belkin High Speed HDMI Cable with Ethernet (5M)   | 2   |
| 2577-1 | 321154    | A343  | ALOGIC Ultra USB-C to HDMI Cable (2m)             | 1   |
| 2577-1 | 321154    | M766  | Microsoft Surface Dock 2                          | 1   |



# First Normal Form (1NF) - cont

Identify PK

Example: Order-Item (Order#, Customer#, (Item#, Desc, Qty))

Identify all dependencies

The obvious dependency:

Order#, Item#  $\rightarrow$  Customer#, Desc, Qty

Additional dependencies:

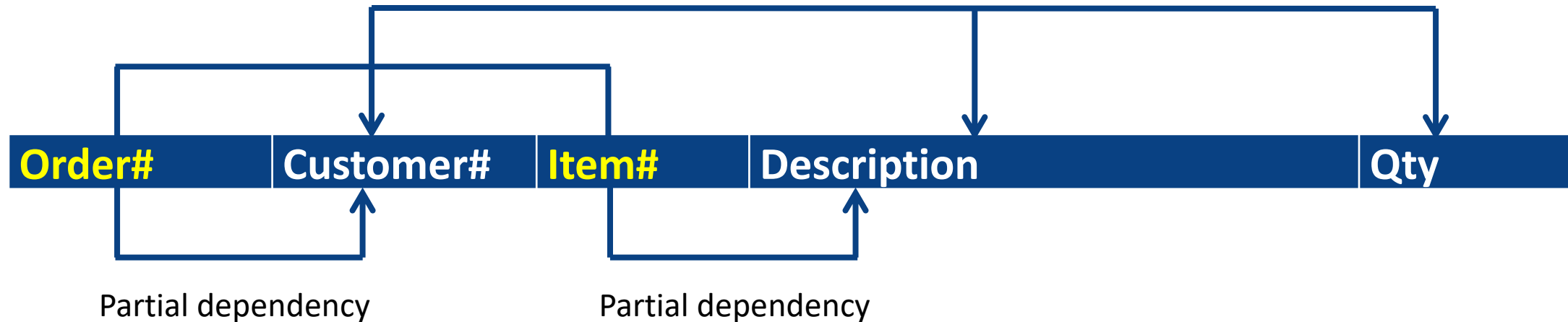
Order#  $\rightarrow$  Customer#

Order#, Item#  $\rightarrow$  Desc, Qty

Partial dependency:

Item#  $\rightarrow$  Desc

# First Normal Form Dependency Diagram



- The arrows above the attributes indicate all desirable dependencies, i.e. dependencies based on PK **Order#** and **Item#**
- The arrows below the attributes indicate partial dependencies

# Partial Dependency Anomalies

Order-Item (Order#, Item#, Desc, Qty)

## OrderItem

| Order# | Item# | Desc  | Qty |
|--------|-------|---|-----|
| 1234-5 | L236  | Lenovo Q27q 27" QHD Monitor with Built-in Speaker | 1   |
| 1234-5 | D722  | Dell KM5221W Pro Wireless Keyboard and Mouse      | 1   |
| 2577-1 | B614  | Belkin High Speed HDMI Cable with Ethernet (5M)   | 2   |
| 2577-1 | A343  | ALOGIC Ultra USB-C to HDMI Cable (2m)             | 1   |
| 2577-1 | M766  | Microsoft Surface Dock 2                          | 1   |

- *UPDATE*      change item desc in many places
- *DELETE*      data for last item lost when last order for that item is deleted
- *INSERT*      cannot add new item until it is ordered

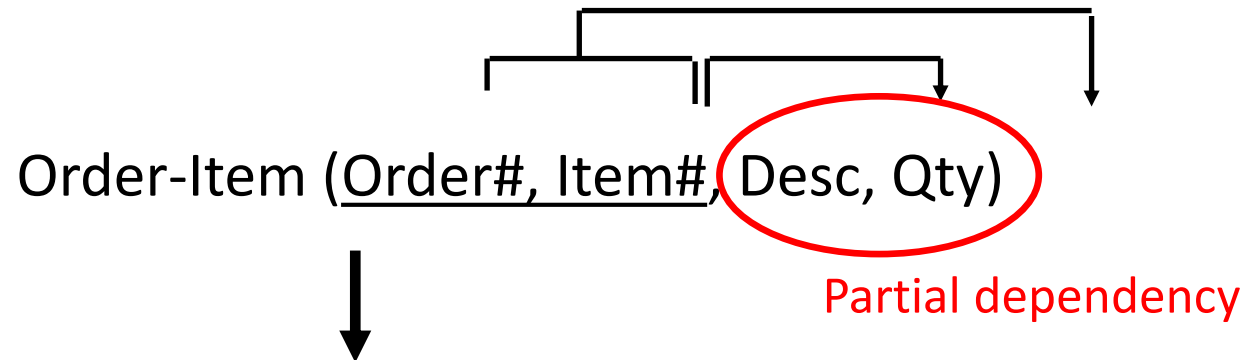
# Second Normal Form (2NF)

2NF occurs only when the 1NF has a composite PK

If a table has a single-attribute PK, it's already in 2NF

*Eliminate Partial Dependencies - create new tables*

Example: Order-Item (Order#, Item#, Desc, Qty)



Item (Item#, Desc)

Order-Item (Order#, Item#, Qty)

# Solution to these Anomalies

## OrderItem

| Order# | Item# | Qty |
|--------|-------|-----|
| 1234-5 | L236  | 1   |
| 1234-5 | D722  | 1   |
| 2577-1 | B614  | 2   |
| 2577-1 | A343  | 1   |
| 2577-1 | M766  | 1   |

*delete last order for  
item, but item remains*

## Item

| Item# | Description                                       |
|-------|---|
| L236  | Lenovo Q27q 27" QHD Monitor with Built-in Speaker |
| D722  | Dell KM5221W Pro Wireless Keyboard and Mouse      |
| B614  | Belkin High Speed HDMI Cable with Ethernet (5M)   |
| A343  | ALOGIC Ultra USB-C to HDMI Cable (2m)             |
| M766  | Microsoft Surface Dock 2                          |

*add new item at any time*

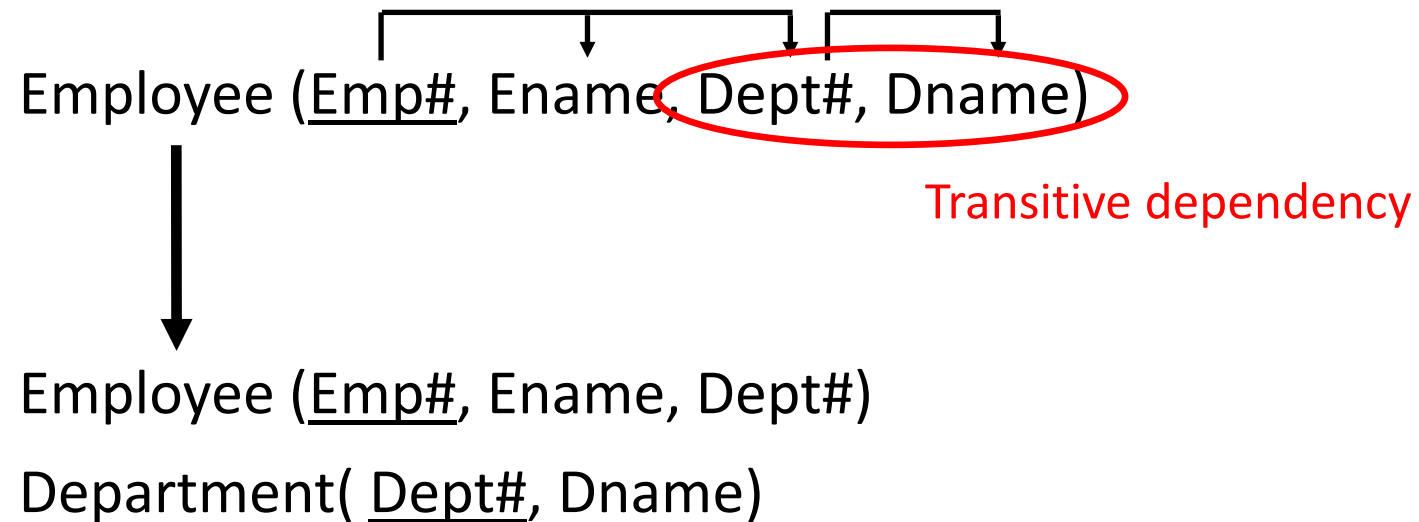
*change item description  
in one place*

# Third Normal Form

## Eliminate Transitive Dependencies

a non-key attribute **cannot be identified** by another non-key attribute

Example: Employee (Emp#, Ename, Dept#, Dname)



# Transitive Dependency Anomalies

Example: Employee (Emp#, Ename, Dept#, Dname)

| Emp# | EName       | Dept# | DName |
|------|-------------|-------|-------|
| 101  | Emma Smith  | D3    | IT    |
| 203  | Aron Lee    | D4    | Sales |
| 251  | Sizan Black | D4    | Sales |
| 304  | June Chen   | D1    | HR    |
| 341  | Nick Russo  | D3    | IT    |

- *UPDATE* change dept name in many places
- *DELETE* data for dept lost when last employee for that dept is deleted
- *INSERT* cannot add new dept until an employee is allocated to it



# Solution to these Anomalies

## Employee

| Emp# | EName       | Dept# |
|------|-------------|-------|
| 101  | Emma Smith  | D3    |
| 203  | Aron Lee    | D4    |
| 251  | Sizan Black | D4    |
| 304  | June Chen   | D1    |
| 341  | Nick Russo  | D3    |

*delete last employee in  
dept, but dept remains*

*add new department at any time*

*change department  
name in one place*

| Dept# | DName |
|-------|-------|
| D3    | IT    |
| D4    | Sales |
| D4    | Sales |
| D1    | HR    |
| D3    | IT    |

## Department

# Boyce-Codd Normal Form

Every determinant must be a candidate key

"Every non-key attribute must provide a fact about the key, the whole key, and nothing but the key. (So help me Codd)"

Example: Allocation (Student#, Teacher, Subject, Grade)

| Student# | Teacher | Subject   | Grade |
|----------|---------|-----------|-------|
| 123344   | Darwin  | Biology   | D     |
| 123344   | Curie   | Chemistry | C     |
| 455667   | Curie   | Chemistry | HD    |
| 788994   | Curie   | Physics   | C     |
| 877995   | Darwin  | Biology   | HD    |

Student#+Teacher → Subject, Grade

Subject → Teacher



# Boyce-Codd Anomalies

## Allocation

| Student# | Teacher | Subject   | Grade |
|----------|---------|-----------|-------|
| 123344   | Darwin  | Biology   | D     |
| 123344   | Curie   | Chemistry | C     |
| 455667   | Curie   | Chemistry | HD    |
| 788994   | Curie   | Physics   | C     |
| 877995   | Darwin  | Biology   | HD    |

*UPDATE*

*DELETE*


*CREATE*

student changing subject may lose teacher for that subject

deleting student may lose subject allocated to that teacher


cannot assign a subject to a teacher until a student takes it

# Solution to these Anomalies




| Student# | Subject   | Grade |
|----------|-----------|-------|
| 123344   | Biology   | D     |
| 123344   | Chemistry | C     |
| 455667   | Chemistry | HD    |
| 788994   | Physics   | C     |
| 877995   | Biology   | HD    |

*Change enrolment without  
losing teacher/subject*



*delete student but subject remains*

| Subject   | Teacher |
|-----------|---------|
| Biology   | Darwin  |
| Chemistry | Curie   |
| Chemistry | Curie   |
| Physics   | Curie   |
| Biology   | Darwin  |

*add a subject and assign a teacher to it*



Boyce-Codd is taught for completeness but is **not examinable**



# What's examinable

- **Normalisation Process (1NF -> 2NF -> 3NF)**
- **Anomalies**
- **Functional dependencies**
- **Denormalisation**



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# Thank you

Subtitle

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**Identifier first line**

Second line