An Introduction to the Database Management Systems

By
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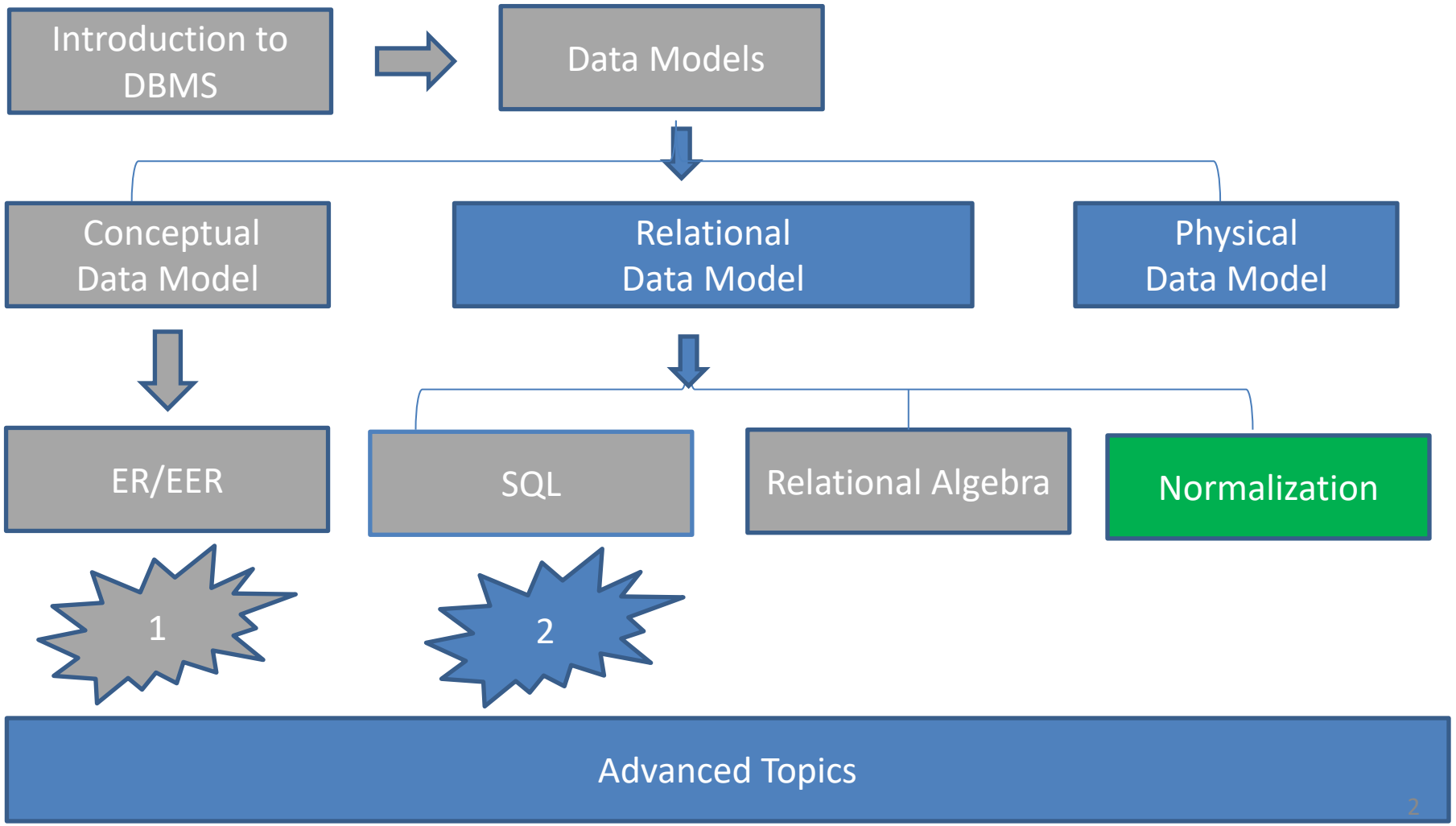
Slides originally by Book(s) Resources

Road Map

(Might change!)



Normalization

- Informal Design Guidelines for Relation Schemas
- Functional Dependencies
- Normal Forms 

Normal forms

- Invented by Codd as a test on relational database schemas
  - The tests ('normal forms') grow more severe. The more severe the test, the higher the normal form, the more robust the database
  - If a schema does not pass the test, it is decomposed in partial schemas that do pass the test
  - It is not always necessary to reach the highest possible normal form

1NF - First Normal Form

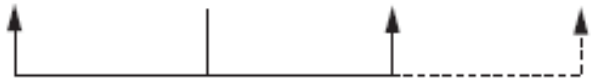
- Attributes can only be single-valued
  - Is a basic demand of most relational databases
- Example of a non-1NF relation (see next slide). This normally is already ruled out by the definition of a relation (so using the relational database model automatically ensures 1NF)

Non-1NF - example

(a)

DEPARTMENT

Dname	Dnumber	Dmgr_ssn	Dlocations



(b)

DEPARTMENT

Dname	Dnumber	Dmgr_ssn	Dlocations
Research	5	333445555	{Bellaire, Sugarland, Houston}
Administration	4	987654321	{Stafford}
Headquarters	1	888665555	{Houston}

(c)

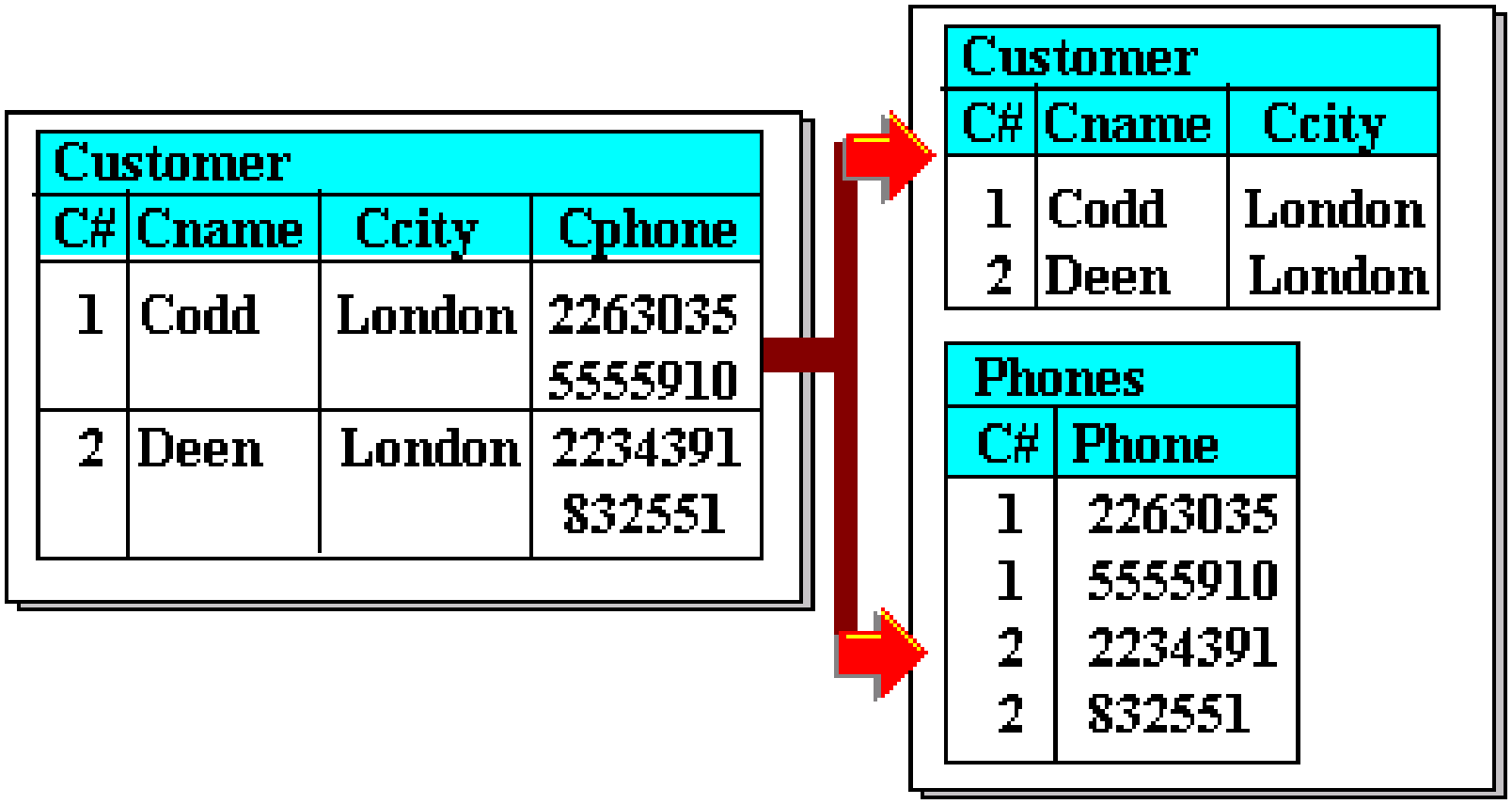
DEPARTMENT

Dname	Dnumber	Dmgr_ssn	Dlocation
Research	5	333445555	Bellaire
Research	5	333445555	Sugarland
Research	5	333445555	Houston
Administration	4	987654321	Stafford
Headquarters	1	888665555	Houston

1NF - First Normal Form

- Solutions for a multi-valued attribute A in R:
  1. Preferred: create new relation S with A and a foreign key to R
  2. Extend the key of R with an index number for the values of A (redundancy!); e.g. department has no. 5A, or 5B, or 5C
  3. Determine the maximum number of values per tuple for A (say *k*) and replace attribute by *k* attributes (say, loc1, loc2, and loc3). This introduces null-values!

1NF - First Normal Form



2NF - Second Normal form

- Definition: $X \rightarrow Y$ is a *partial* functional dependency if there is an attribute A in X s.t. $X\text{-}\{A\} \rightarrow Y$

- $X \rightarrow Y$ is *total* if it is not partial

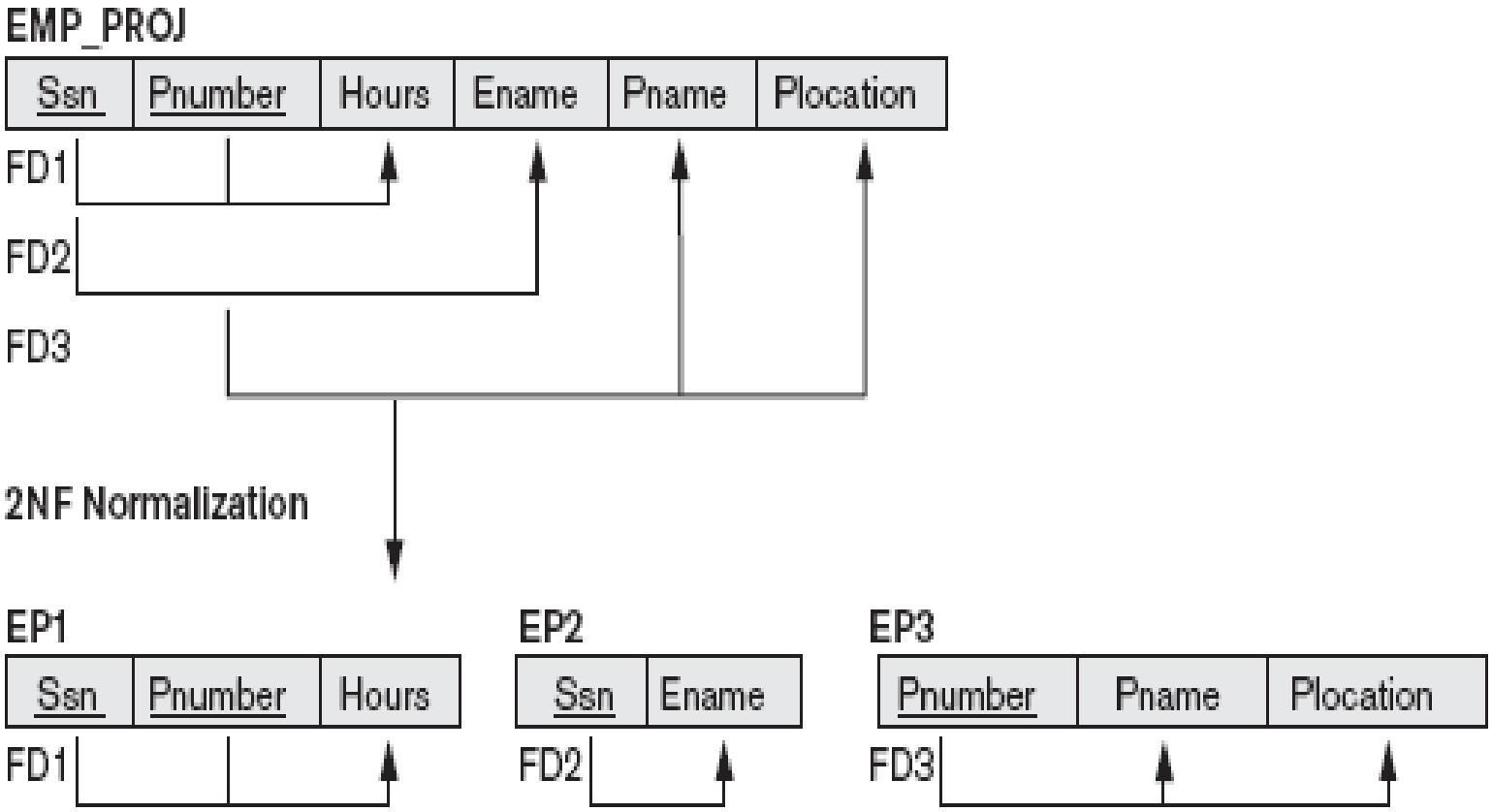
- 2NF: each non-primary attribute is totally dependent on primary key (and not on parts of the primary key)

2NF - Normalizing

- Break up the relation such that every partial key with their dependent attributes is in a separate relation. Only keep those attributes that depend totally on the primary key

- Example (see next slide)

2NF - example


EMP_PROJ
Ssn
Pnumber
Hours
Ename
Pname
Plocation
FD1
FD2
FD3
2NF Normalization
EP1
Ssn
Pnumber
Hours
FD1
EP2
Ssn
Ename
FD2
EP3
Pnumber
Pname
Plocation
FD3

3NF - Third Normal Form

- Definition: $X \rightarrow Y$ is a *transitive* dependency if there is a Z that is not (part of) a candidate key s.t. $X \rightarrow Z$ and $Z \rightarrow Y$

- 3NF: no non-primary attribute is transitively depending on the primary key

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3NF - Normalizing

- Break up the relation such that the attributes that are depending on not-key attributes appear in a separate table (together with the attributes on which they depend)

- Example (see next slide)

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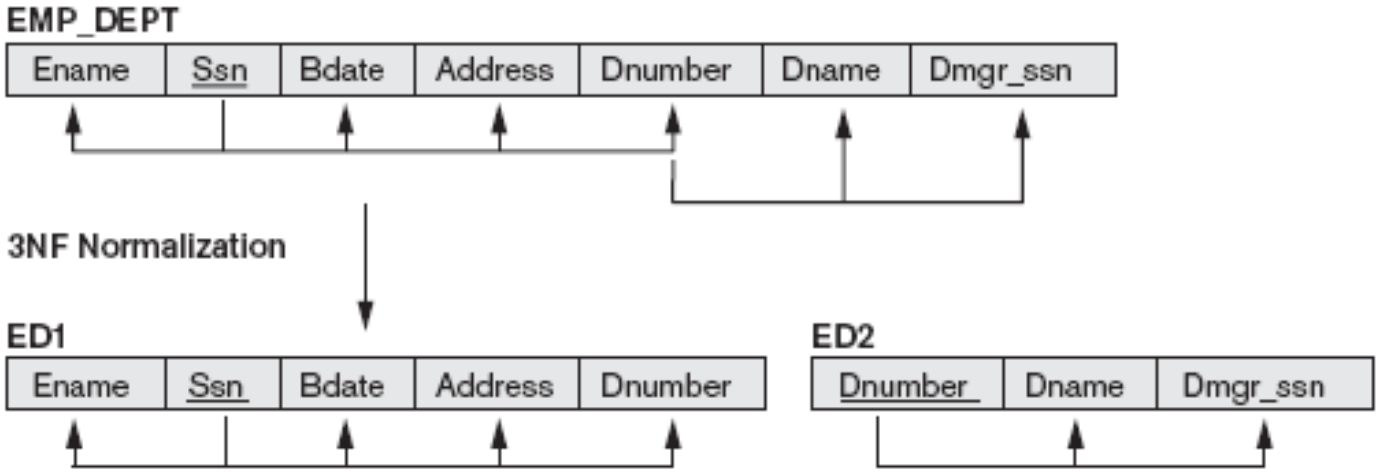
3NF - example


EMP_DEPT
Ename
Ssn
Bdate
Address
Dnumber
Dname
Dmgr_ssn
3NF Normalization
ED1
Ename
Ssn
Bdate
Address
Dnumber
ED2
Dnumber
Dname
Dmgr_ssn

General form 2NF and 3NF

- Put the same demands on **all candidate keys** (super keys) – which is more severe
  - 2NF: every non-key attribute is totally dependent on all keys
  - 3NF: no non-key attribute is transitively dependent on any key
    Other formulation:
    if $X \rightarrow A$ then A is prime or X is a super key
- Example (see next slide)

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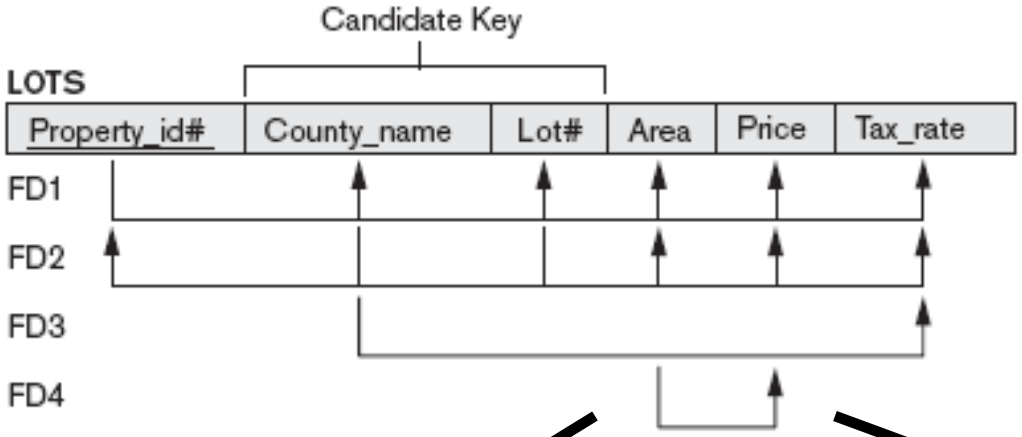
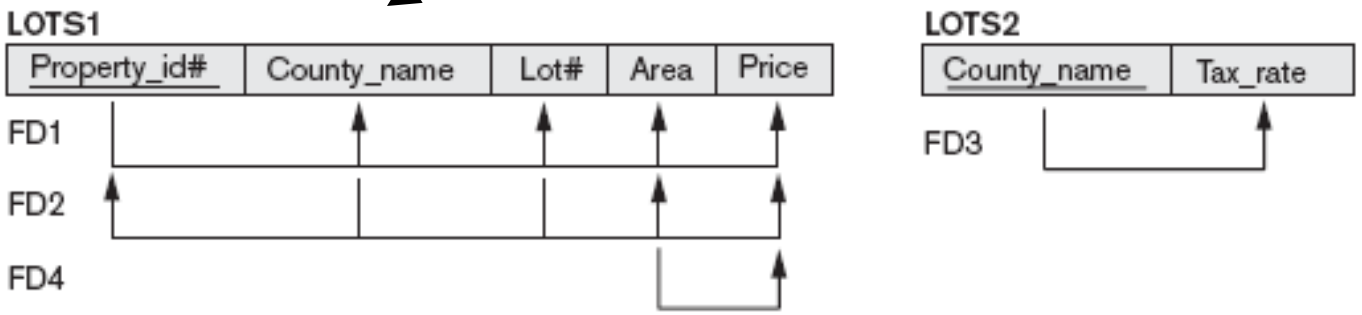
General form 2NF and 3NF - example

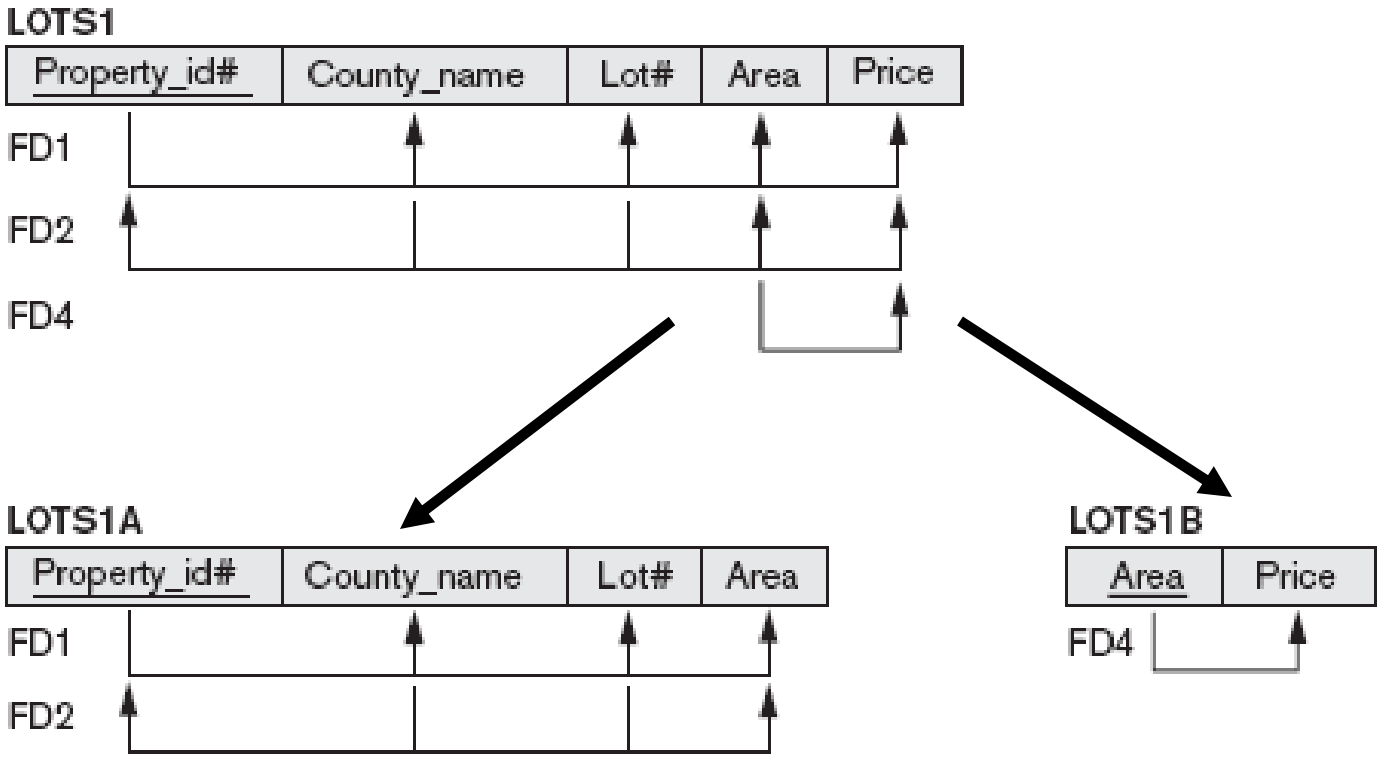


1NF



2NF

General form 2NF and 3NF - example



2NF

3NF

Boyce-Codd Normal Form

- Simpler, but stronger than 3NF
- BCNF: for each *non-trivial* dependency $X \rightarrow A$ holds that X is a super key

- Difference: in 3NF if A is a prime attribute, X does not have to be super key
- In many cases a 3NF schema is also BCNF

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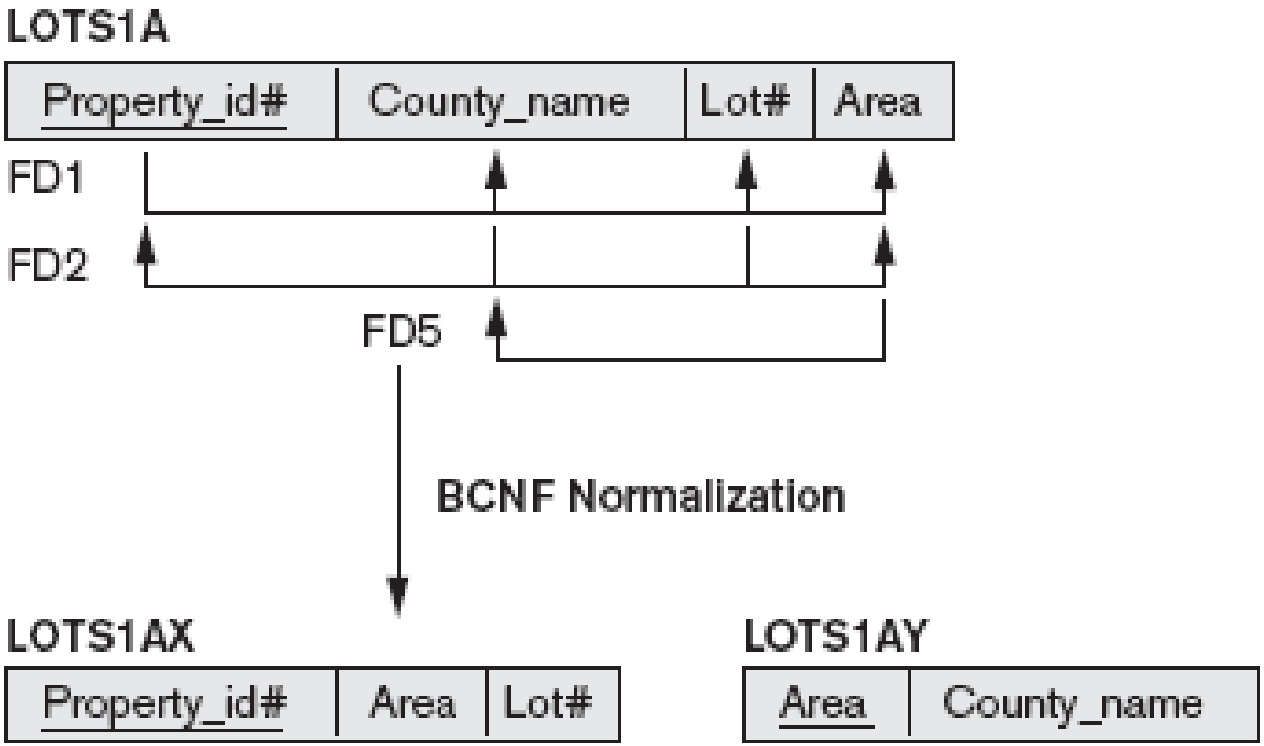
BCNF example



Decompositions

- Only adhering to a normal form is not enough
- We must not lose attributes in the process!
- Non-additive Join-property:
  - a natural join of the result of a decomposition should result in the original table, without spurious tuples
- There exist algorithms to automatically find good decompositions

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ER-schema to relational schemas

- A relational database schema that is mapped from an ER-schema is often in BCNF, but always in 3NF (so, check if BCNF is applicable and useful)

- Many CASE-tools can map an ER-schema automatically into a good relational schema (e.g., SQL create-table commands)

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Summary

- Informal guidelines for good design
- Functional dependency
  - Basic tool for analyzing relational schemas
- Normalization:
  - 1NF, 2NF, 3NF, BCNF

Quiz 4

- Suppose you are given a relation *R* with four attributes *ABCD*. For each of the following sets of FDs, assuming those are the only dependencies that hold for *R*, do the following:
- (a) Identify the candidate key(s) for *R*.
- (b) Identify the best normal form that *R* satisfies (1NF, 2NF, 3NF, or BCNF).
- (c) If *R* is not in BCNF, decompose it into a set of BCNF relations that preserve the dependencies.

Quiz 4

- 1. $C \rightarrow D$, $C \rightarrow A$, $B \rightarrow C$
- 2. $B \rightarrow C$, $D \rightarrow A$
- 3. $ABC \rightarrow D$, $D \rightarrow A$
- 4. $A \rightarrow B$, $BC \rightarrow D$, $A \rightarrow C$
- 5. $AB \rightarrow C$, $AB \rightarrow D$, $C \rightarrow A$, $D \rightarrow B$