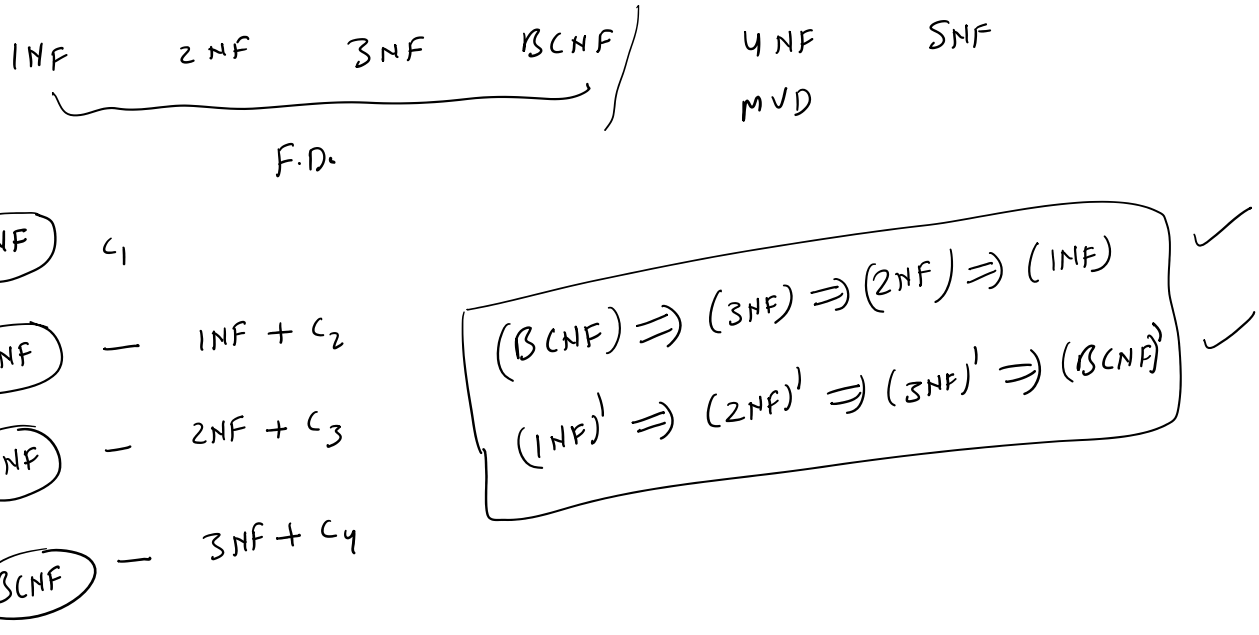
Normalization of Relations

Given a relation schema, we need to decide whether it is a good design or whether we need to decompose it into smaller relations. Such a decision must be guided by an understanding of what problems, if any, arise from the current schema. To provide such guidance, several normal forms have been proposed. If a relation schema is in one of these normal forms, we know that certain kinds of problems cannot arise.

The normal forms based on FDs are first normal form (1NF), second normal form (2NF), third normal form (3NF), and Boyce-Codd normal form (BCNF). These forms have increasingly restrictive requirements: Every relation in BCNF is also in 3NF, every relation in 3NF is also in 2NF, and every relation in 2NF is in 1NF.

All these normal forms (1NF, 2NF, 3NF, BCNF) are based on a single analytical tool: the functional dependencies among the attributes of a relation. Later, a fourth normal form (4NF) and a fifth normal form (5NF) were proposed, based on the concepts of multivalued dependencies and join dependencies, respectively

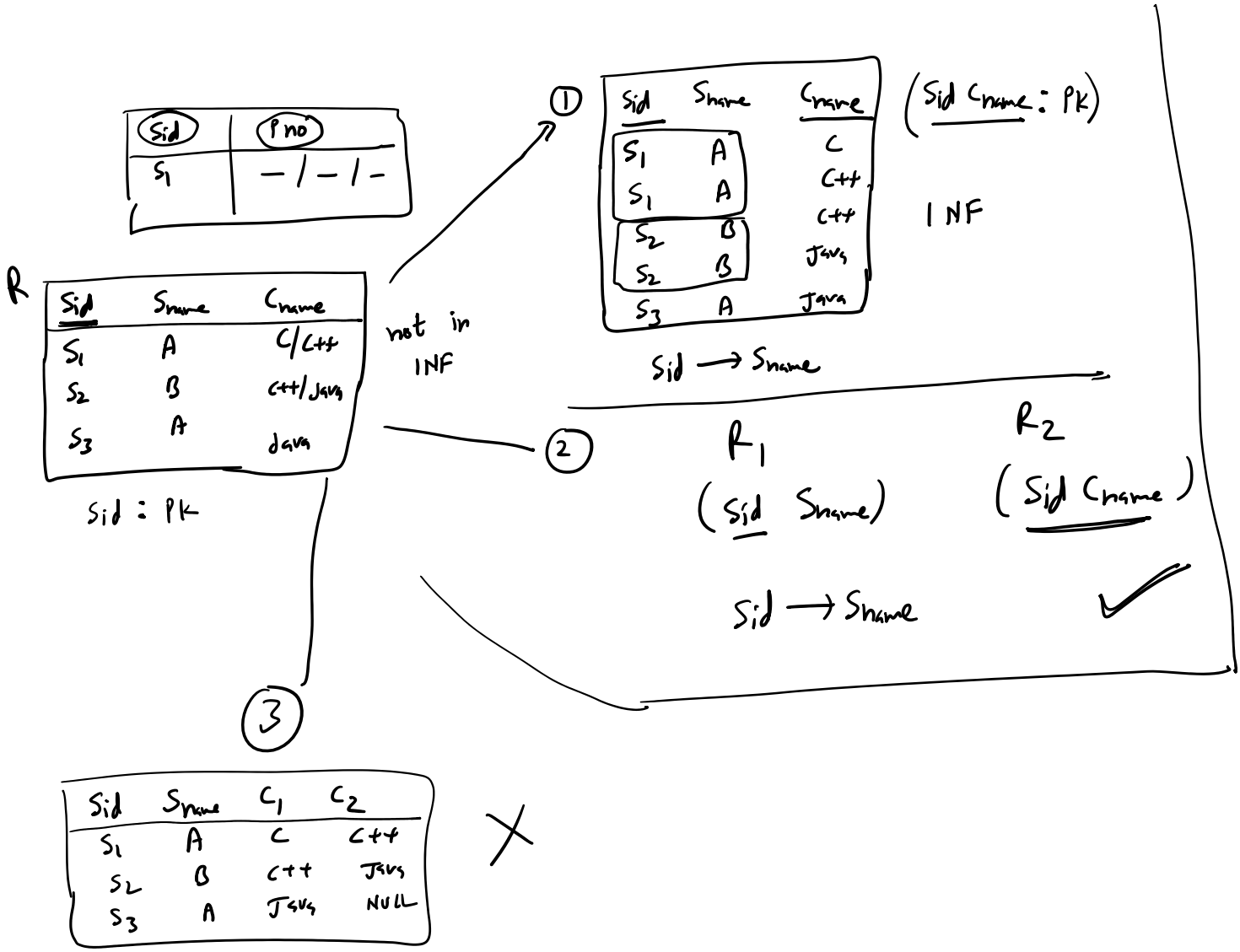
Definition: The normal form of a relation refers to the highest normal form condition that it meets, and hence indicates the degree to which it has been normalized.



First Normal Form

First normal form (1NF)is now considered to be part of the formal definition of a relation in the basic (flat) relational model; historically, it was defined to disallow multivalued attributes, composite attributes, and their combinations. It states that the domain of an attribute must include only *atomic* (simple, indivisible) *values* and that the value of any attribute in a tuple must be a *single value* from the domain of that attribute. Hence, 1NF disallows having a set of values, a tuple of values, or a combination of both as an attribute value for a *single tuple.* In other words, 1NF disallows *relations within relations* or *relations as attribute values within tuples.* The only attribute values permitted by 1NF are single **atomic** (or **indivisible**) **values.**

A relation schema R is in first normal form (1NF) if the domains of all attributes of R are atomic.



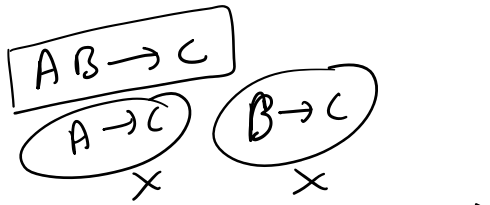
Second normal form (2NF)

Prime attribute: an attribute that is part of any **candidate key** will be considered as prime.

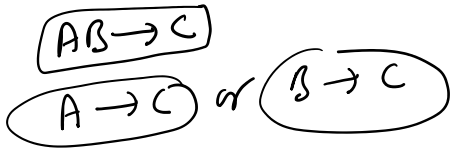
Definition. An attribute of relation schema R is called a **prime attribute** of R if it is a member of *some candidate key* of R. An attribute is called **nonprime** if it is not a prime attribute—that is, if it is not a member of any candidate key.

Second normal form (2NF) is based on the concept of full functional dependency.

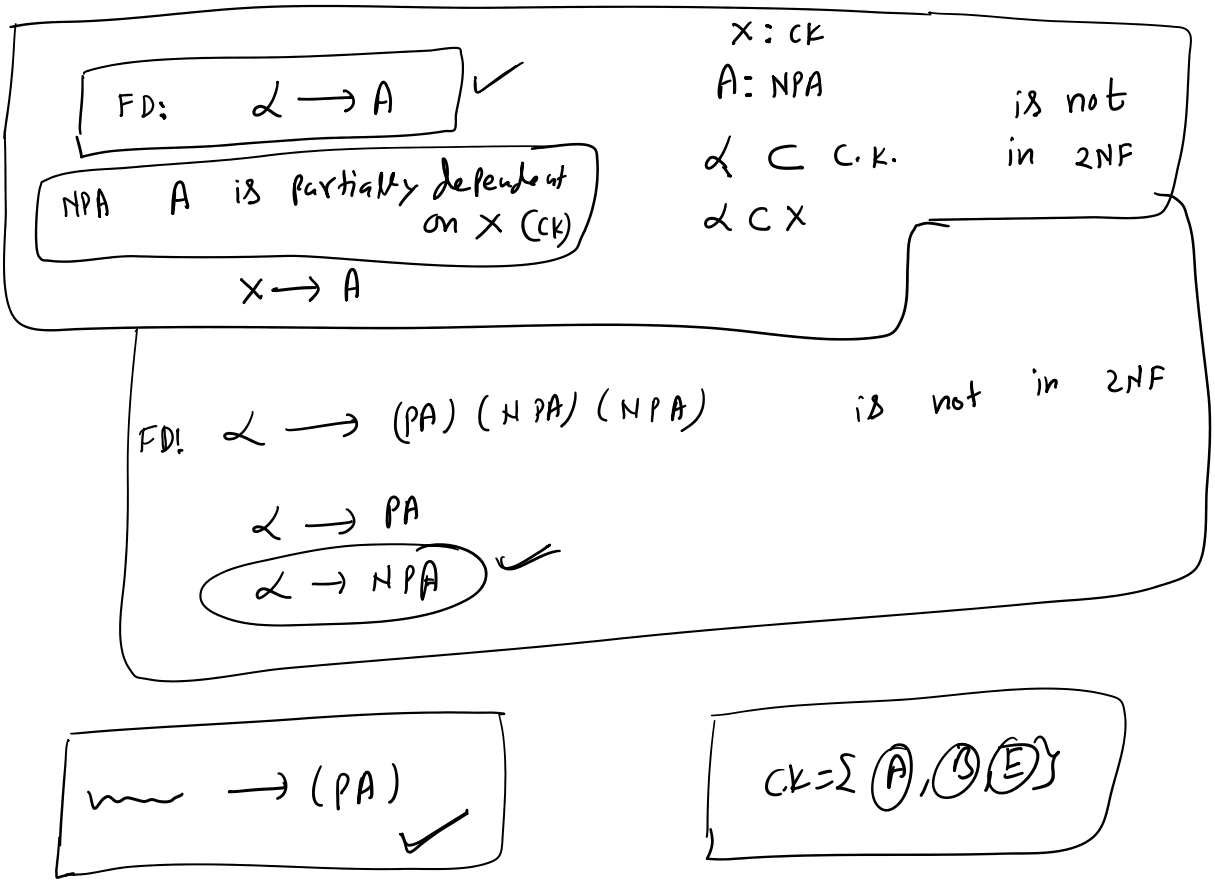
Definition (Full Functional Dependency)
A functional dependency $X \rightarrow Y$ is a full functional dependency if removal of any attribute A from X means that the dependency does not hold any more; that is, for any attribute $A \in X, (X - \{A\})$ does not functionally determine Y.



Definition (Partial Functional Dependency)
A functional dependency $X \rightarrow Y$ is a partial dependency if some attribute $A \in X$ can be removed from X and the dependency still holds; that is, for some $A \in X, (X - \{A\}) \rightarrow Y$.



Definition: A relation schema R is in second normal form (2NF) if every nonprime attribute A in R is not partially dependent on any candidate key of R.
This definition can be restated as follows: A relation schema R is in 2NF if every nonprime attribute A in R is fully functionally dependent on every candidate key of R.



R(A B C D E)

1NF ✓

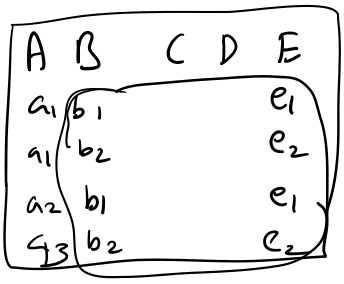
F : { AB → C, C → D, B → E }
✓ ✓ X

CK: AB

PA: { A, B }

NPA : { C, D, E }

not in 2NF



B → E

R

R1 R2

R1(ABCD)

AB → C

C → D

CK: AB

in 2NF

R2(BE)

B → E ✓

CK: B

in 2NF

A B C D