1NF: no more than one value per attribute per tuple at a time

~~2NF~~

3NF

4NF

5NF

BCNF

guarantee:
- no redundancy
- no update or del anomalies
- lossless

Use the closure algorithm and the normal-form criteria (for BCNF or 3NF) in our decomposition

- we will need to
  - find superkeys
  - find keys
  - find FDs in a projection of a relation

Decomposition that is not lossless:

R:

A	B	C	D
1	2	3	4
5	6	7	8

R1:

A	B
1	2
5	6

R2:

C	D
3	4
7	8

Criterion for a relation being in BCNF (Boyce Codd):

A relation is in BCNF if

- all its FDs have a superkey of the relation on the left-hand side (LHS)

R(ABCD)

	4NF
$AB \to C$	✓
$C \to D$	—
$D \to A$	—

$AB^+ = ABCD$

$C^+ = ACD$

$D^+ = AD$

[When you start (step one) - it is sufficient to check just the given FD]

If not in BCNF: iterate:

(a) split using a noncompliant FD

(b) check if the results are all in BCNF (using all the FDs)

Ri R is not in BCNF

- picking C→D for the decomposition

The attributes in the closure of the LHS of C→D:

R1(ACD)

The remaining attrs plus the LHS of C→D:

R2(BC)

A 2-attr rel is always in BCNF [(& 3NF)]

Is R1(ACD) in BCNF?

for ACD only ⇓ LHS a superkey?

$C \to D$	$C^+ = ACD$	✓
$D \to A$	$D^+ = AD$	—
$C \to A$	$C^+ = ACD$	✓
$AC \to D$	$AC^+ = ACD$	✓
$CD \to A$	$CD^+ = ACD$	

$\Rightarrow$ R1 is not in BCNF because of $D \to A$

R1(ACD) - decomposing into BCNF using $D \to A$

R3(AD) R4(CD)

A decomposition of R(ABCD) with $AB \to C$, $C \to D$, $D \to A$ into BCNF is {R2(BC), R3(AD), R4(CD)}

Apply(SSN, college, name, HSCode, HSCity, sports)

SSN → name

HSCode → HSCity

Applications(SSN, college, HSCode, sports)

Applicants(SSN, name)

HSchools(HSCode, HSCity)

R(ABC)

$AB \to C$

$C \to B$ // BCNF violation

R1(BC)

R2(AC)

$AB \to C$ can no longer be enforced

3NF decomposition

- use the same BCNF-decomposition algorithm
= but with a different stopping criterion (BCNF + additional condition)

3NF criteria:

A relation satisfies 3NF if, for each of its FDs,

- either the BCNF criterion is satisfied
- or the RHS of the FD is part of a key

Students (ID, addr, landlph)

ID → addr

addr → landlph

ID+ is ok (BCNF)
addr+ is not ok (BCNF)

R(ABC)	LHS is a superkey	RHS is part of key
A → B	✓	(don't look)
B → C	—	—

Decomposition: same for BCNF & 3NF: R1(AB), R2(BC)

R(ABCD)

	LHS is a superkey	RHS is part of key
$AB \to C$	✓	✓
$C \to D$	—	✓
$D \to A$	—	✓

Keys: AB, BC, BD

$\Rightarrow$ R(ABCD) with $AB \to C$, $C \to D$, $D \to A$ is in 3NF

R(ABCD)

$B \to C$

$B \to D$

(a) provide a BCNF decomposition of R

R1(AB), R2(BCD)

(b) provide a 3NF decomposition of R

R1(AB), R2(BCD)

Keys: AB