Chapter 4

Advanced SQL: Integrity Constraints

Integrity Constraints

- Ensure *Data Consistency*
- *Domain Constraints*
  - enforce valid attribute values from domain sets
  - domain set may exclude null values
- Referential Integrity (especially Foreign-Key Integrity)
  - a constraint involving two relations
  - used for specifying a relationship among tuples in two relations, the referencing relation and the referenced relation
  - (foreign-Key Constraint) tuples in the *referencing relation*, r_2, have attributes *FK* (called foreign key) that reference the primary key *PK* of the *referenced relation* r_1
  - *FK* of r_2 is a *foreign key* of r_1 with *primary key PK* if

$$\forall t_2 \in r_2, \exists t_1 \in r_1 \text{ such that } t_1[PK] = t_2[FK]$$

Integrity Constraints

- ***Updates on foreign keys:*** Let *FK* of r_2 be a *foreign key* that references the *primary key PK* of r_1. To enforce the *referential integrity*:

- ***Insert***: add t_2 to r_2. Then $t_2[FK] \in \pi_{PK}(r_1)$; otherwise, reject

- ***Delete***: remove t_1 from r_1. If $t_1[PK] \in \pi_{FK}(r_2)$, then
  - Action 1. Deny the deletion request (an *inappropriate* option), or
  - Action 2. Delete all tuples t in r_2 such that $t[FK] = t_1[PK]$

- ***Modify***:
  - **Referencing relation** - if $t_2[FK]$ in r_2 is modified to $t_2'[FK]$, then it must be the case that $t_2'[FK] \in \pi_{PK}(r_1)$; otherwise, reject
  - **Referenced relation** - if $t_1[PK]$ in r_1 is modified to $t_1'[PK]$, then use the *deletion policy* for *modification* on $t_1[PK]$
  - **Referential integrity in SQL** - indicate primary key/candidate key/foreign key during the *creation* of a table

Example.

Create table customer
(customer-name **char**(20) **not null**,
customer-street **char**(30),
customer-city **char**(30),
primary key (customer-name))

Create table branch
(branch-name **char**(15) **not null**,
branch-city **char**(30),
assets **integer**,
primary key (branch-name),
check (assets > 0))

Create table account
(account-number **char**(10) **not null**,
branch-name **char**(15),
balance **integer**,
primary key (account-number),
foreign key (branch-name) **references** branch,
check (balance >= 0))

Create table depositor
(customer-name **char**(20) **not null**,
account-number **char**(10) **not null**,
primary key (customer-name, account-number),
foreign key (customer-name) **references** customer,
foreign key (account-number) **references** account)

Integrity Constraints

Given the following relations:

Is_taking	
Student	*Course#*
Young	CS 451
Adams	EE 321
Lee	CS 451

Course	
Course#	*Title*
EE 321	Circuit Design
Eng 316	Tech Wrtg
CS 451	DBMS

where *Course#* in *Course* is the **primary key** for *Course* and *Course#* in *Is_taking* is a **foreign key**.

Discuss what actions should be taken for the following database update requests so that violations of **referential integrity** will not occur.

(a) [4 pts] Modify CS 451 in the *Course* relation to CS 353.

(b) [4 pts] Insert the tuple < Smith, Math 411 > into the *Is_taking* relation.

(c) [4 pts] Delete the tuple < EE 321, Circuit Design > from the *Course* relation.

SQL: CREATE TABLE Statements

- Basic **syntax** of the CREATE TABLE statement:

  CREATE TABLE <table name> (<table element list>)

  <table element list> ::= <table element> |
  <table element>, <table element list>

  <table element> ::= <column definition> |
  <table constraint definition>

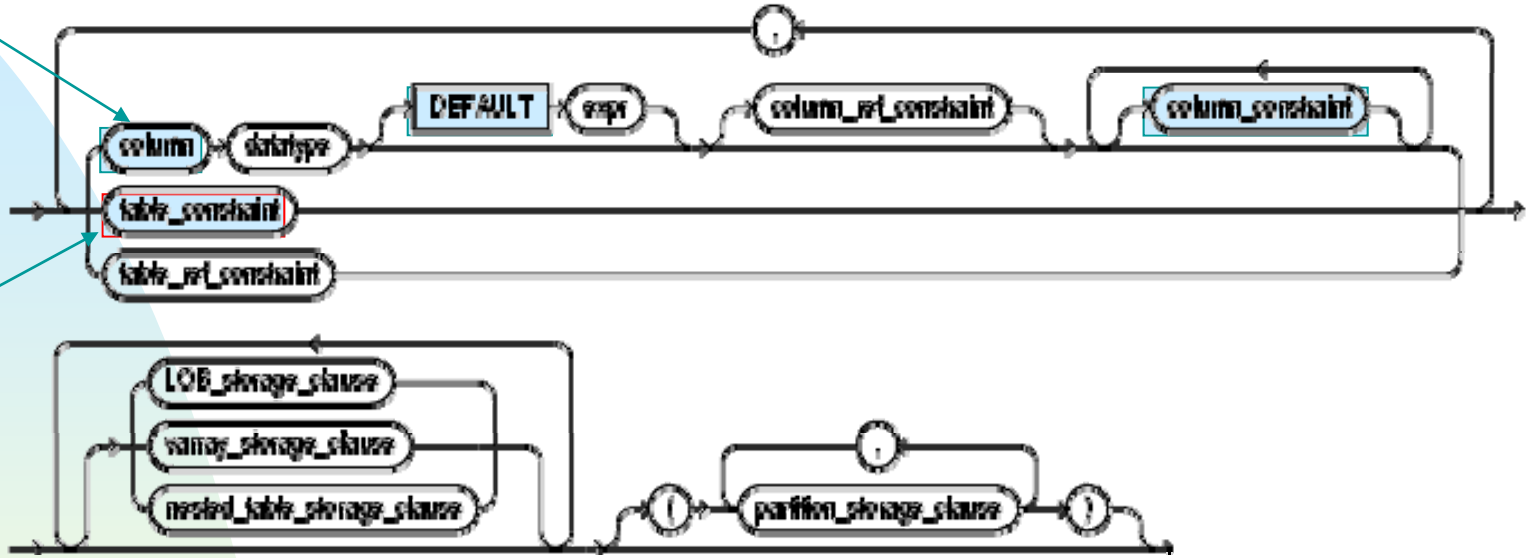
- The table definition (*relational properties* in Oracle) includes
  - *data* in the column definitions, and
  - *rules* for handling data in the table constraint definition

- A table is more like an *object* (with its data and methods) than just a simple passive file.

Relational Properties (Oracle 8i)

Column Definition

Table Constraint Definition



SQL: Column Definitions in CREATE TABLE

- Column definitions:

  <column definition> ::= <column name> <data type>
  [<default clause>]
  [<column constraint …>]

- Each column name must have a data type (e.g. numeric, char strings, *bit*), and *optional* default values and constraints.

- Each column definition can be modified by using a ALTER TABLE statement.

- The default clause specify the *default value* to be inserted into the column if an explicit value does not exist

SQL: Column Definitions in CREATE TABLE

- Default Clause:

  <default clause> ::= DEFAULT <default option>

  <default option> ::= <literal> | <system value> | NULL

- A *literal value* is a string of alphabetic or numeric characters.
- A *system value* can be current timestamp/date/current user ID.
- Example.

```
CREATE TABLE Account
(Acc_num INTEGER DEFAULT 1,
 Acc_type CHAR(1) DEFAULT 'A',
 Acc_descr CHAR(20) DEFAULT 'New Account');
```

Column Definitions in CREATE TABLE: Default Clause

- If a DEFAULT clause is not provided, the column definition acts as if DEFAULT NULL has been declared.
- If NULL is the default value for a column, then the NOT-NULL constraint cannot be part of the column definition.
- Most commonly used default values include
  - '0' in numeric columns
  - "Unknown" for a missing string value
  - "System timestamp" to mark a transaction, etc.
- NULL cannot be the default value for a PRIMARY KEY column, even though DEFAULT NULL PRIMARY KEY is allowed.
- Built-in functions can be specified as the default values.

Column Constraints in CREATE TABLE: Column Constraints

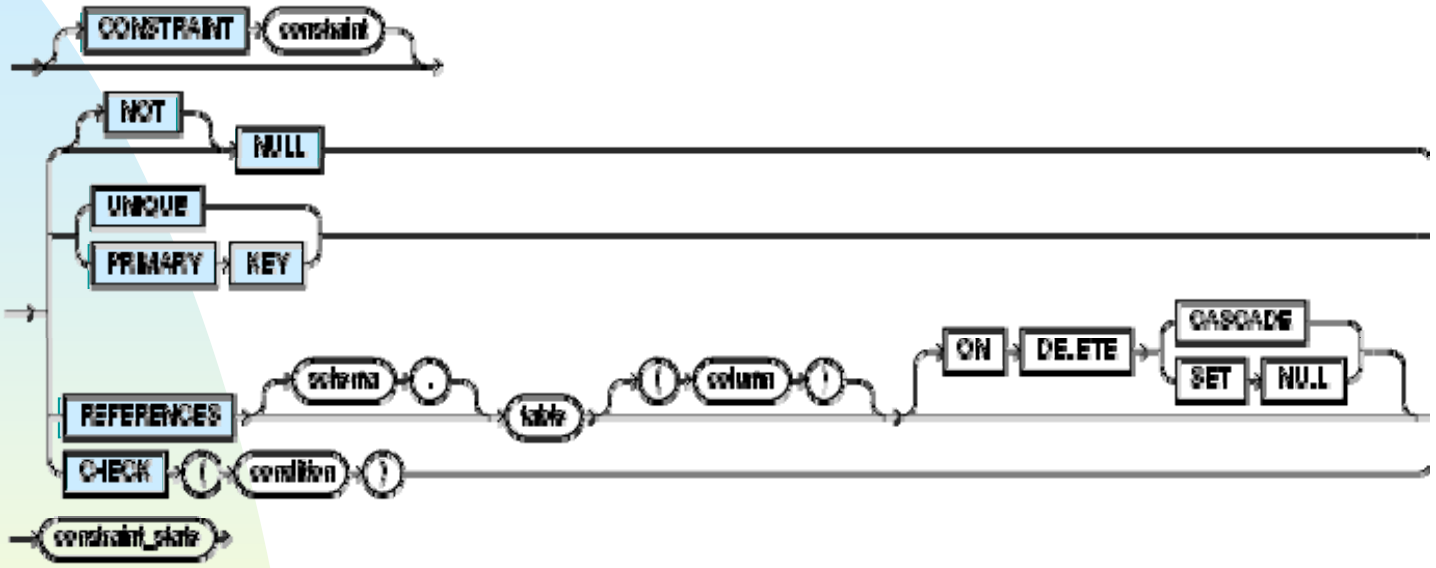
- Syntax:

<column constraint> ::= [CONSTRAINT constraint_name]
NOT NULL |
<UNIQUE/PK specification>
<REFERENCES specification> |
<CHECK constraint definition>

- Constraint rules, as defined in a table creation statement, enforce *data-integrity* constraints on columns.

- All the (new/modified) rows in the table are validated against them.

Column Constraints (Oracle 8i)

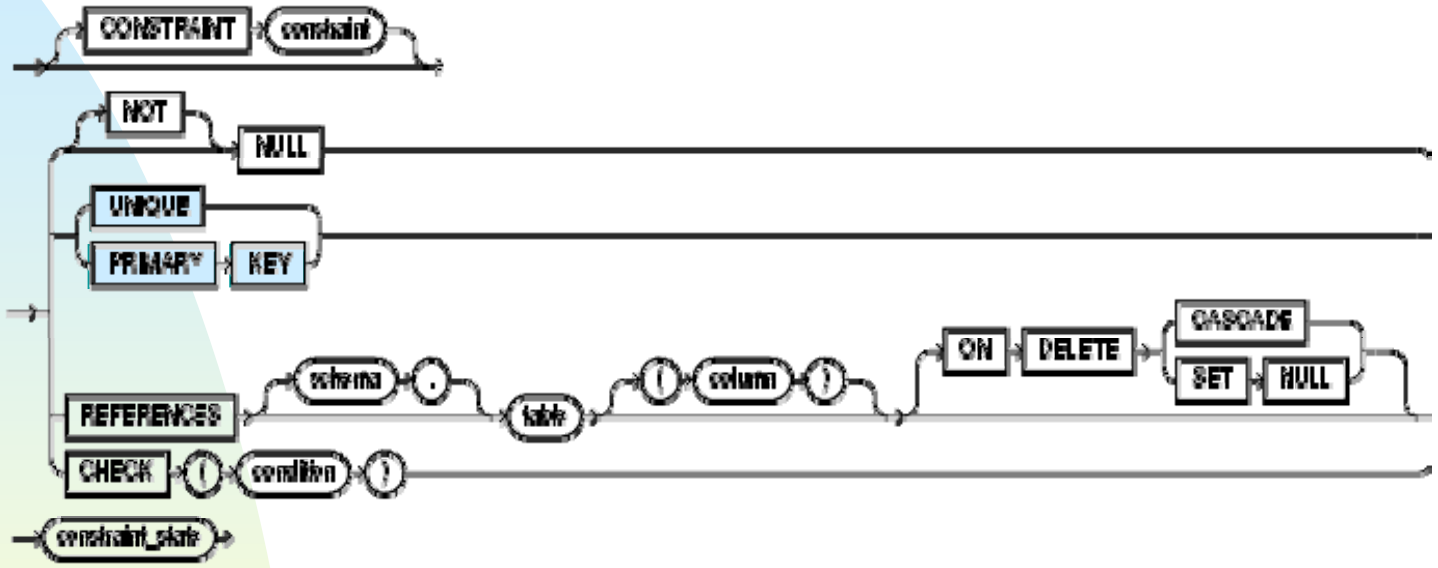


Column Constraints in CREATE TABLE - NOT NULL

- A constraint forbids the use of NULLs in a column; NOT NULL constraint requires that a column receives a value during *insert* or *update* operations
- If there is a (i) NOT NULL constraint and (ii) no default value is specified on a column, then a value must be entered into the column
- NULL is a special value in SQL that belongs to all data types.
- The interpretation of a NULL: *missing*, *unknown*, *inapplicable*, and *miscellaneous*, and NULLs cause a lot of irregular features in SQL, e.g. the strange 3-valued logic
- Example.

```
CREATE TABLE items
(Item_num INTEGER,
 Menu_code CHAR(3) NOT NULL,
 Descrip CHAR(20));
```

Column Constraints (Oracle 8i)



Column Constraints in CREATE TABLE: Unique & Primary Key

- **Syntax:**

  <unique specification> ::= UNIQUE | PRIMARY KEY

- UNIQUE constraint states that no duplicate values are allowed in the column

- Differences between UNIQUE and PRIMARY KEY:

  1) There can be only one PRIMARY KEY but many UNIQUE columns
  2) PRIMARY KEY is automatically declared to have a NOT NULL constraint, but a UNIQUE column can have NULL value

  Example.

```
CREATE TABLE Account
    (Acct_num INTEGER PRIMARY KEY,
     Acct_code INTEGER UNIQUE);
```

Column Constraints in CREATE TABLE: Unique & Primary Key

- When a PRIMARY KEY constraint is created, the DBS automatically creates an *internal index* on the column(s).

- Multiple-column of the form <unique specification>, which means that the combination of a number of columns is unique, is allowed, e.g.,

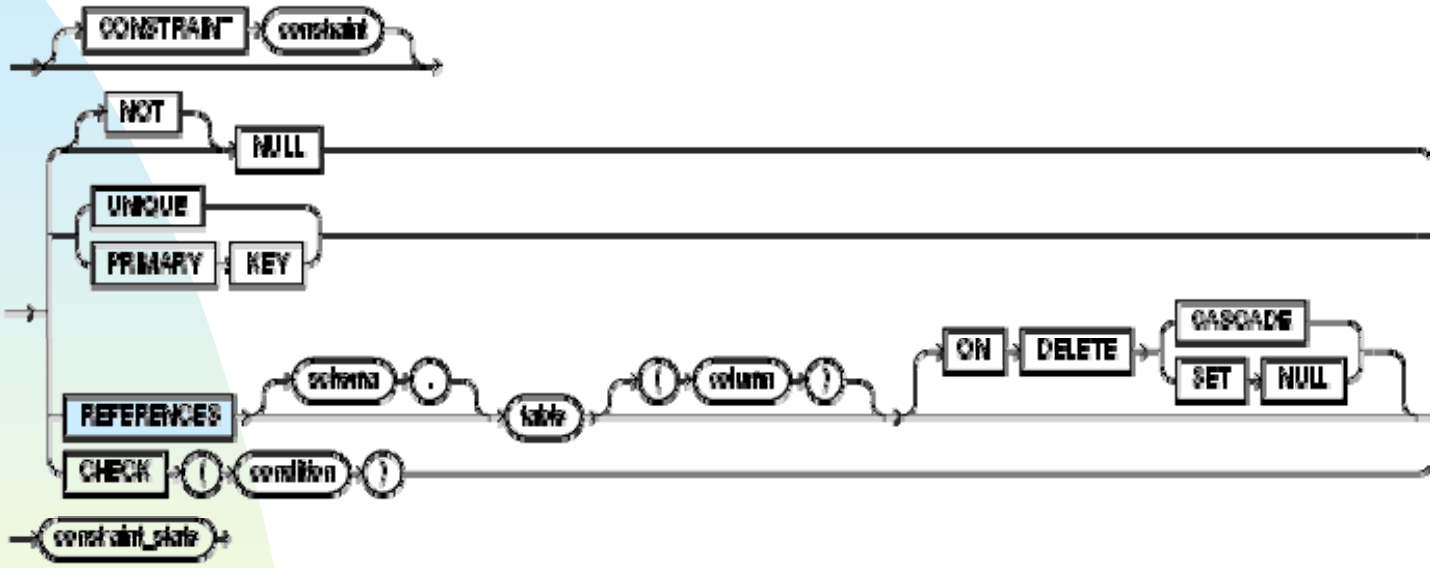
```
PRIMARY KEY(Account_Number, Customer_Name)
```

Example.

```
CREATE TABLE depositor
      (Acct  num char(10),
       Customer_name char(15),
       PRIMARY KEY(Acct_num, Customer_name));
```

A Table-definition constraint, not a *Column-definition* constraint

Column Constraints (Oracle 8i)



Column Constraints in CREATE TABLE: REFERENCE

- Syntax:

  <reference specification> ::= REFERENCES <referenced table name>
  [(<reference column>)]

  - If no <reference column> is specified, then the PRIMARY KEY column of the referenced table is assumed to be the target.

- Specify *referential integrity* (*foreign key integrity*)
- Example.

```
CREATE TABLE account
 (Account# char(10),
  Branch_Name char(15) REFERENCES branch),
  Balance number(4, 2),
  PRIMARY KEY(Account#));
```

OR

```
CREATE TABLE account
    (Account# char(10),
     Branch_Name char(15),
     Balance number(4, 2),
     PIMARY KEY(Account#),
     FOREIGN KEY (Branch_Name)
          REFERENCES branch);
```

- Several columns can reference the same target column.
- A PRIMARY KEY value cannot be deleted from the referenced table if it is referenced in a referencing table (without cascading).

Column Constraints in CREATE TABLE: REFERENCE

- REFERENCE Clauses with ON DELETE CASCADE
- Use the ON DELETE CASCADE option to specify the *deletion* from the referencing table when the corresponding referenced rows are deleted from the referenced table.
- *Reduces* the quantity of SQL statements that are required for performing the delete operations.
- Example.

```
CREATE TABLE depositor
        (Acct_num CHAR(10) REFERENCES account
                                ON DELETE CASCADE,
         Customer_name CHAR(15),
         Bname CHAR(15) REFERENCES branch (Branch_name)
                                ON DELETE SET NULL,
         PRIMARY KEY(Acct_num, Customer_name);
```

Column Constraints in CREATE TABLE: REFERENCE

- Default values for the Referenced Column:
  - If the referenced table is different from the referencing table, then by default, the referenced column is the *primary-key* column of the referenced table.
  - If the referenced and referencing tables are the same, then the referenced column must be specified.
- Referential Relationships within a Table
  - A referential relationship between two columns of the same table can be established, e.g.,

```
CREATE TABLE Employee
      (Emp_num INTEGER,
       Mgr_num INTEGER REFERENCES Employee (Emp_num),
       PRIMARY KEY(Emp_num));
```

Column Constraints in CREATE TABLE: References

- The column referenced by a FOREIGN KEY can be either a PRIMARY KEY or a column with a UNIQUE constraint.

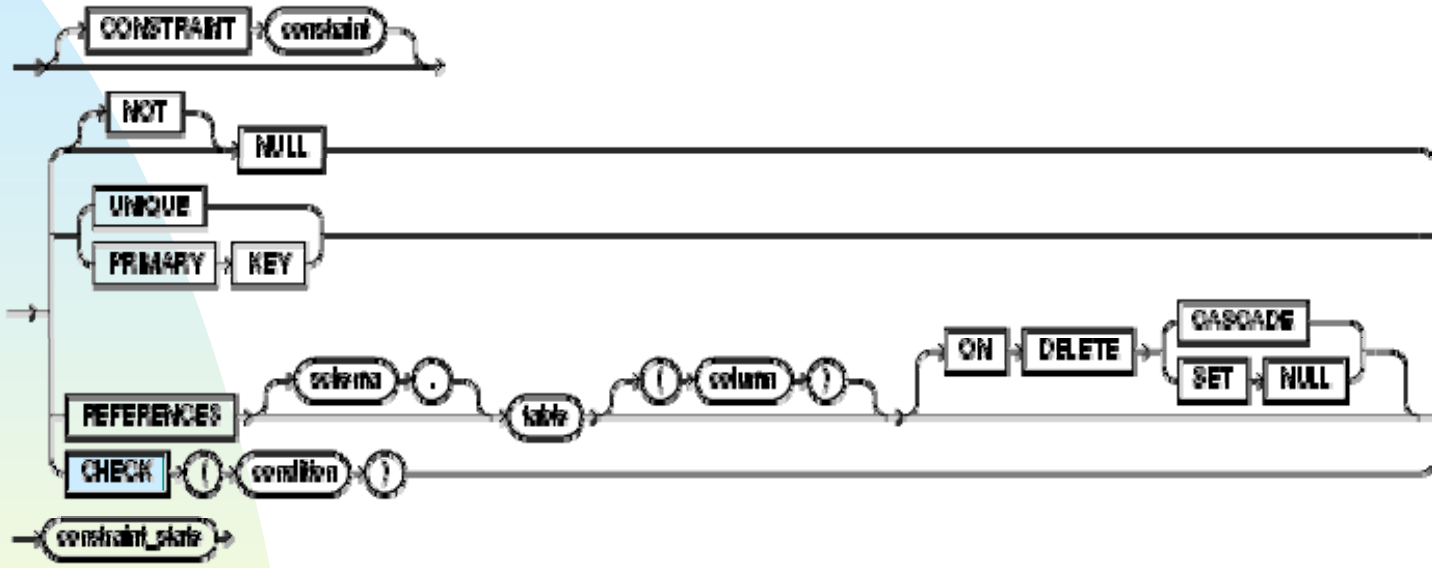
- In SQL-92, the following constraints are *equivalent*:

PRIMARY KEY ≡
CHECK (UNIQUE (SELECT <key columns>
FROM <table>))
AND (<key columns> IS NOT NULL)

UNIQUE ≡ CHECK(UNIQUE (SELECT <key column>
FROM <table>))

NOT NULL ≡ CHECK(<column> IS NOT NULL)

Column Constraints (Oracle 8i)



Column Constraints in CREATE TABLE: Check Constraint

- **Syntax**:

  <check constraint constraint> ::= CHECK <search condition>

- Tests the rows of a table against a *logical expression*, which is called *search condition*
  - *Rejects* rows whose search condition returns FALSE.
  - *Accepts* rows when the search condition returns TRUE (or in other implementations, UNKNOWN, a “benefit-of-the doubt" feature).
- Range checking, e.g., CHECK(rating BETWEEN 1 AND 10)
- Checking on values in enumerated sets, e.g., CHECK(Color IN (‘Red’, ‘Blue’, ‘Orange’, ‘Green’, ‘Yellow’))
- Subqueries cannot be specified in a CHECK clause (in Oracle 8i)

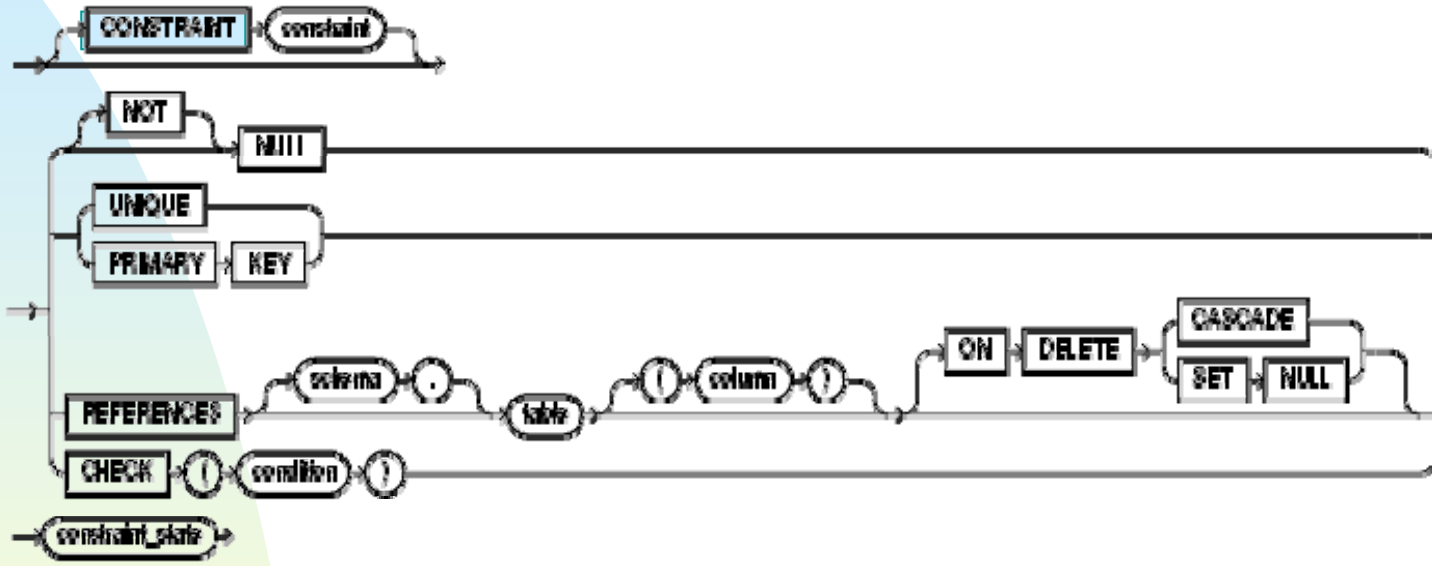
Column Constraints in CREATE TABLE: Multiple-Column

- Usage: associate one or more columns in a table with a constraint.
  - Example.

```
CREATE TABLE Multi-Ref
            (Acct_Id      CHAR(10),
             Loan_Amt     INTEGER,
             Credit       INTEGER,
             CHECK (Credit > 0 AND Loan_Amt < 9999),
             CHECK (Credit > Loan_Amt));
```

- (In some DBMSs) When the constraint is created on a number of columns
  - the columns *cannot* be assigned any default values, and
  - referential relationships *cannot* be established between them

Column Constraints (Oracle 8i)



Constraint Names in CREATE TABLE

- *Optional* in a *check constraint* clause, but is a good idea to use it.
- Constraint names *appear* in error messages when corresponding constraint violations occur.

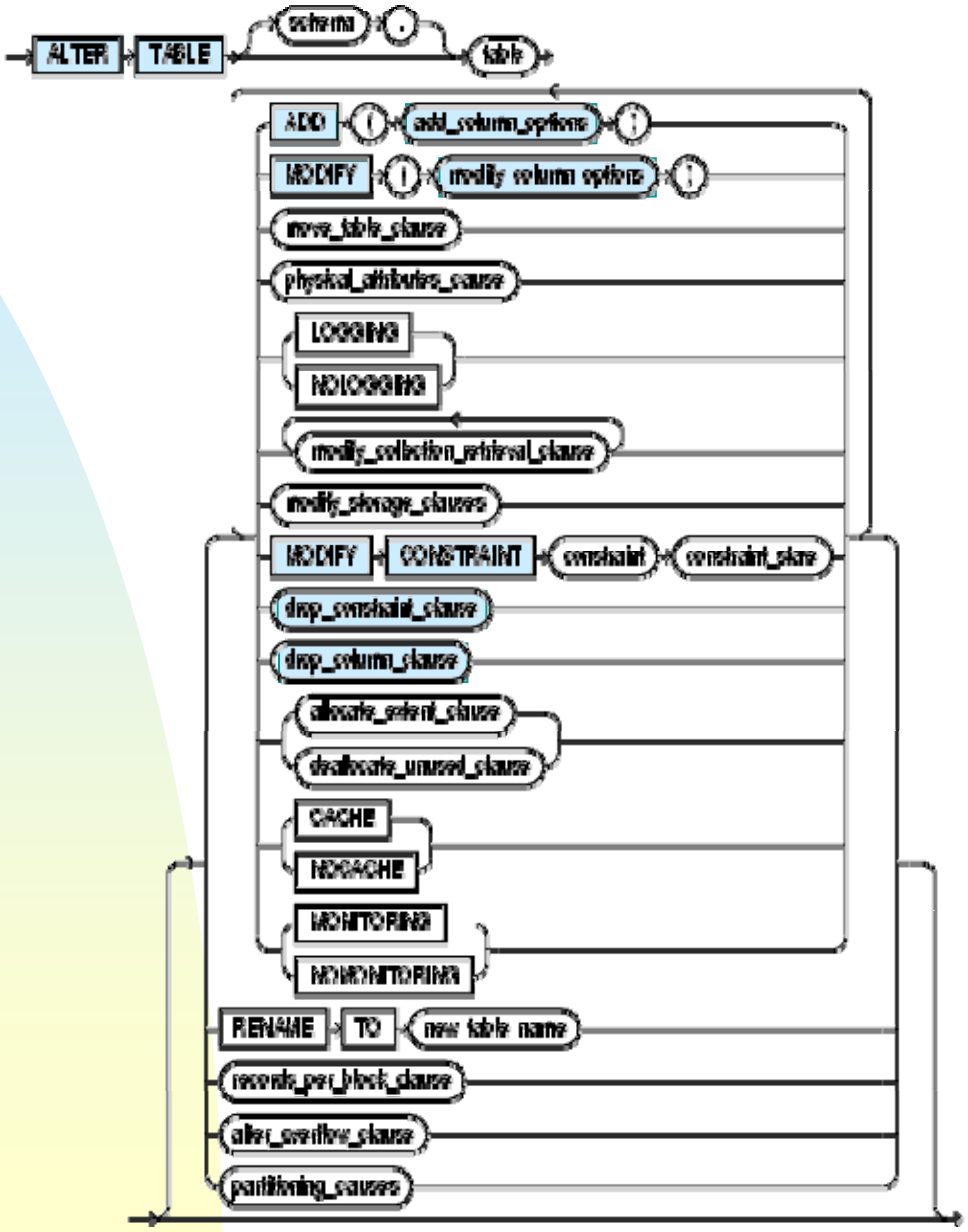
Examples.

```
CREATE TABLE account
   (Account# char(10),
    Branch_Name char(15),
    Balance number(4, 2),
    CONSTRAINT Min_Balance
          CHECK (balance >= 0));
```

```
CREATE TABLE depositor
    (Account# char(10),
     Customer_Name char(15),
     CONSTRAINT Acct_Verification
       CHECK To_NUMBER(Account#)
            BETWEEN 1 AND 9999));
```

- When a constraint is created, the DBS adds a row for that constraint to the *system catalog table*.
- CHECK() clause allows complex expressions to be specified that verify relationships among rows/tables/constants.

SQL: ALTER TABLE



SQL: ALTER TABLE

- Use the ALTER TABLE statement to *update* (add, delete, modify) the *definition* of (columns in) a table.

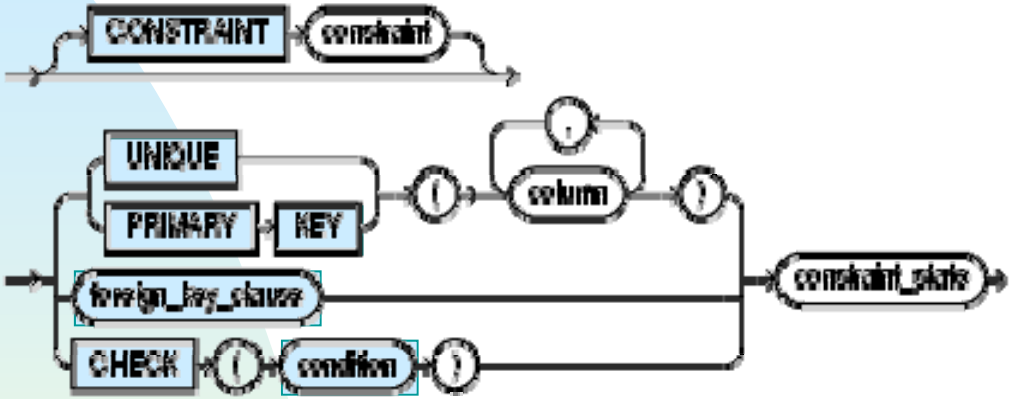
ALTER TABLE <table name> <ALTER TABLE Action>

<ALTER TABLE Action> **::=**
ADD (<Column Definition>) |
DROP COLUMN <Column Name> [CASCADE CONSTRAINTS] |
DROP CONSTRAINT
MODIFY (<Column Definition>) |
MODIFY CONSTRAINT <Constraint Name><Constraint_State> | …

- **Add Column**
  - Extends the existing table by putting a new, unique column on it.
  - Example.

ALTER TABLE Account
ADD Customer_ID CHAR(5) DEFAULT '00000' NOT NULL;

ADD Table-Constraint Option (Oracle 8i)

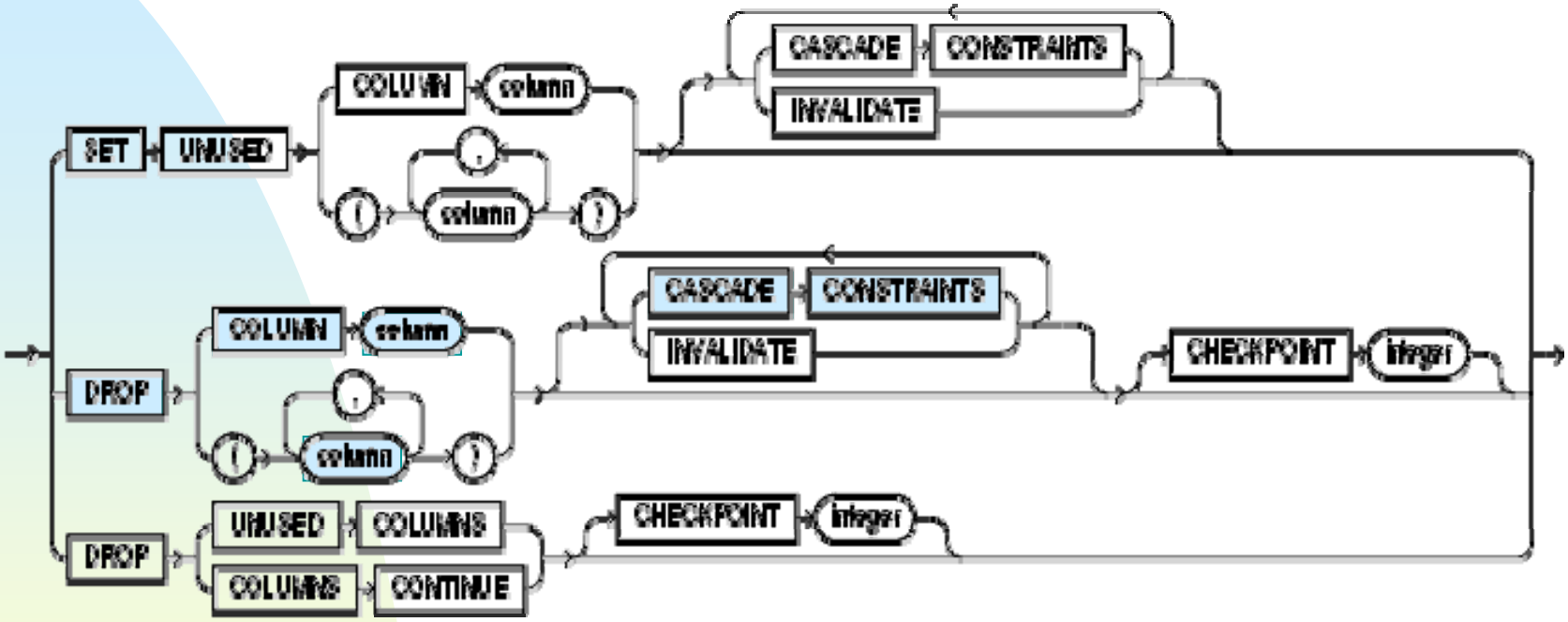


ALTER TABLE: Add Table Constraints

- Specify a new constraint in a table
- Some DBMS requires the usage of ALTER TABLE statements to add *referential integrity constraints* to a table, rather than allowing the declaration be made at schema creation time.
- Example.

```
ALTER TABLE Account
ADD FOREIGN KEY(Branch_name) REFERENCES Branch
ADD PRIMARY KEY(Account_number)
ADD CONSTRAINT Pos_Bal CHECK (Balance > 0);
```

Drop-Column **Option (Oracle 8i)**



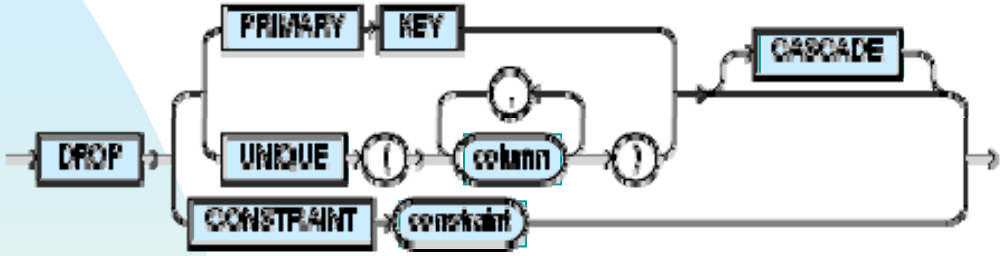
ALTER TABLE: Drop Column

- Removes an existing column from a table.
- CASCADE CONSTRAINTS drops all *referential integrity* constraints defined on the dropped columns that are either *primary* or *unique keys*.
- Without the CASCADE CONSTRAINTS clause, if any constraint is referenced by
  - columns from other tables, or
  - remaining columns in the same table,

  the DROP COLUMN statement *aborts* and an *error* is returned.
- Example.

```
ALTER TABLE Account
DROP COLUMN Customer_ID CASCADE CONSTRAINTS;
```

Drop-Constraint Clause **(Oracle 8i)**



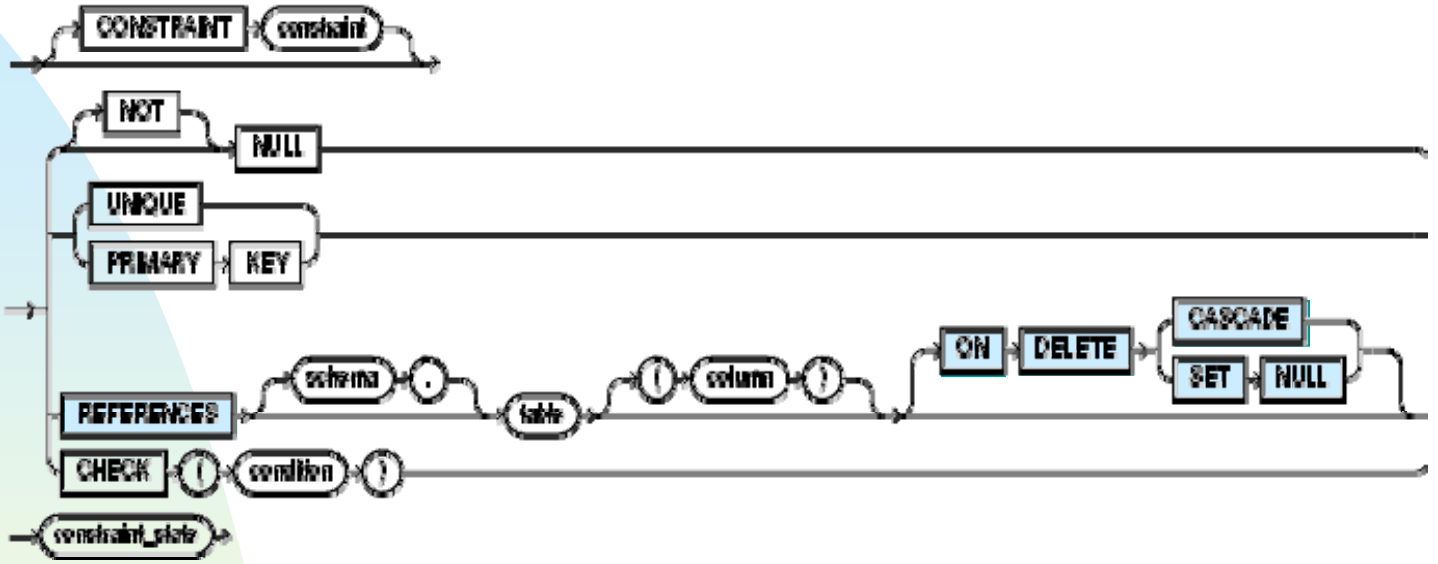
ALTER TABLE: Drop Constraint

- Drop an existing constraint in a table:
  - Default values, (NOT-)NULLs, Primary Key, Unique, etc.
- If the modified column is referenced by other tables, then those referential constraints could not be dropped, unless the CASCADE clause is specified.
  - To restore the constraints to the referencing tables again, e.g., foreign key, use the Alter Table statement.
- Example.

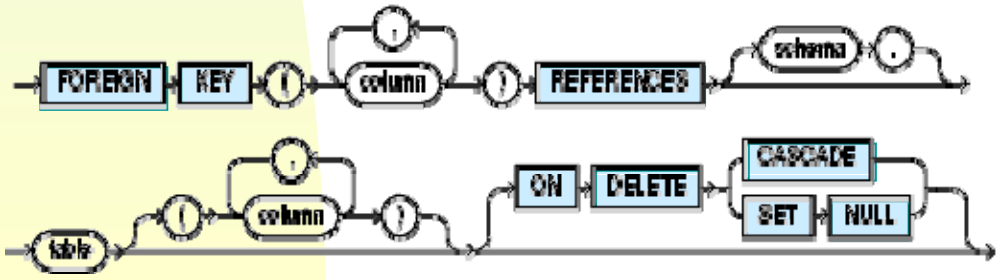
```
ALTER TABLE Branch
DROP PRIMARY KEY CASCADE;
```

Column Constraints **(Oracle 8i)**

Column_constraints:



Foreign_Key Clause:



Cascading Actions **in SQL**

- If there is a chain of foreign-key dependencies across multiple relations, with **on delete cascade** specified for each dependency, a *deletion* or *update* at one end of the chain can propagate across the entire chain.
- If a *cascading update to delete* causes a constraint violation that cannot be handled by a further cascading operation, the system aborts the transaction.
  - As a result, all the changes caused by the transaction and its cascading actions are undone.
- Referential integrity is only checked at the end of a transaction
  - Intermediate steps are allowed to violate referential integrity provided later steps remove the violation
  - Otherwise, it would be impossible to create some database states, e.g., insert two tuples whose foreign keys point to each other (e.g., *spouse* attribute of relation *married-person*)

Cascading Actions **in SQL**

- An example on specifying cascading actions in SQL:

  CREATE TABLE *account*
  . . .
  FOREIGN KEY(*branch-name*) REFERENCES *branch*
  ON DELETE CASCADE
  ON UPDATE CASCADE
  . . .)

- Due to the ON DELETE CASCADE clauses, if a deletion of a tuple in *branch* results in referential-integrity constraint violation, the delete "cascades" to the *account* relation will *delete* the tuple that refers to the branch.

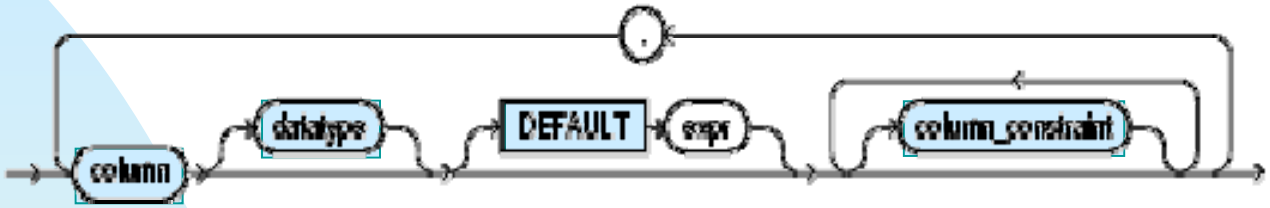
- **Cascading updates** are similar.

Cascading Actions **in SQL**

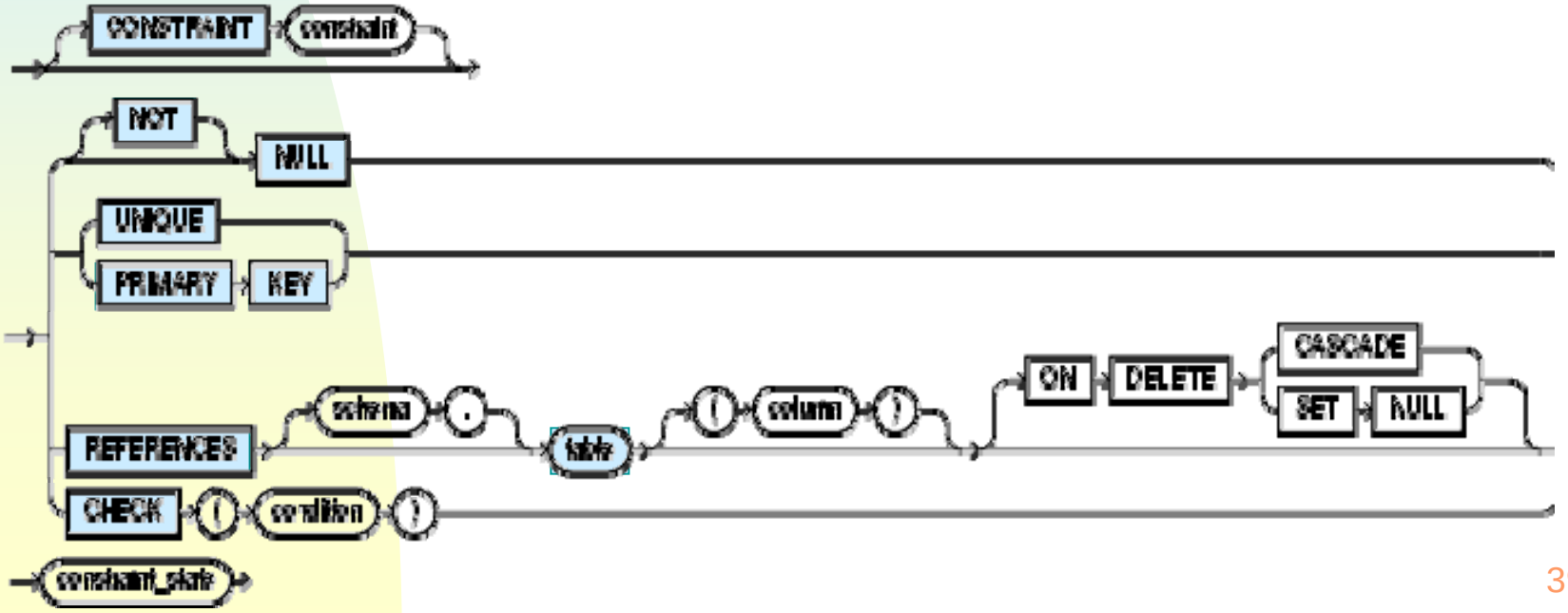
- Alternative to cascading:
  - on delete set null
  - on delete set default
- Null values in foreign key attributes complicate SQL referential integrity semantics, and are best prevented using **not null**

Modify-Column Option (Oracle 8i)

Column Definition:



Column_Constraint:



ALTER TABLE: Modify Column

- Changes an existing column and its definition
- Exactly what can be modified vary from DBMS to DBMS
- Some of the updates that can be made in Oracle 8i:
  - modify a data type to a compatible data type, e.g., INTEGER to REAL
  - allow NULL by changing NOT NULL (or DEFAULT) to NULL
  - add NOT NULL constraint clause
- Example.

```
ALTER TABLE Account
Modify (Balance number(5,2) DEFAULT 0,
        Branch_name NOT NULL);
```

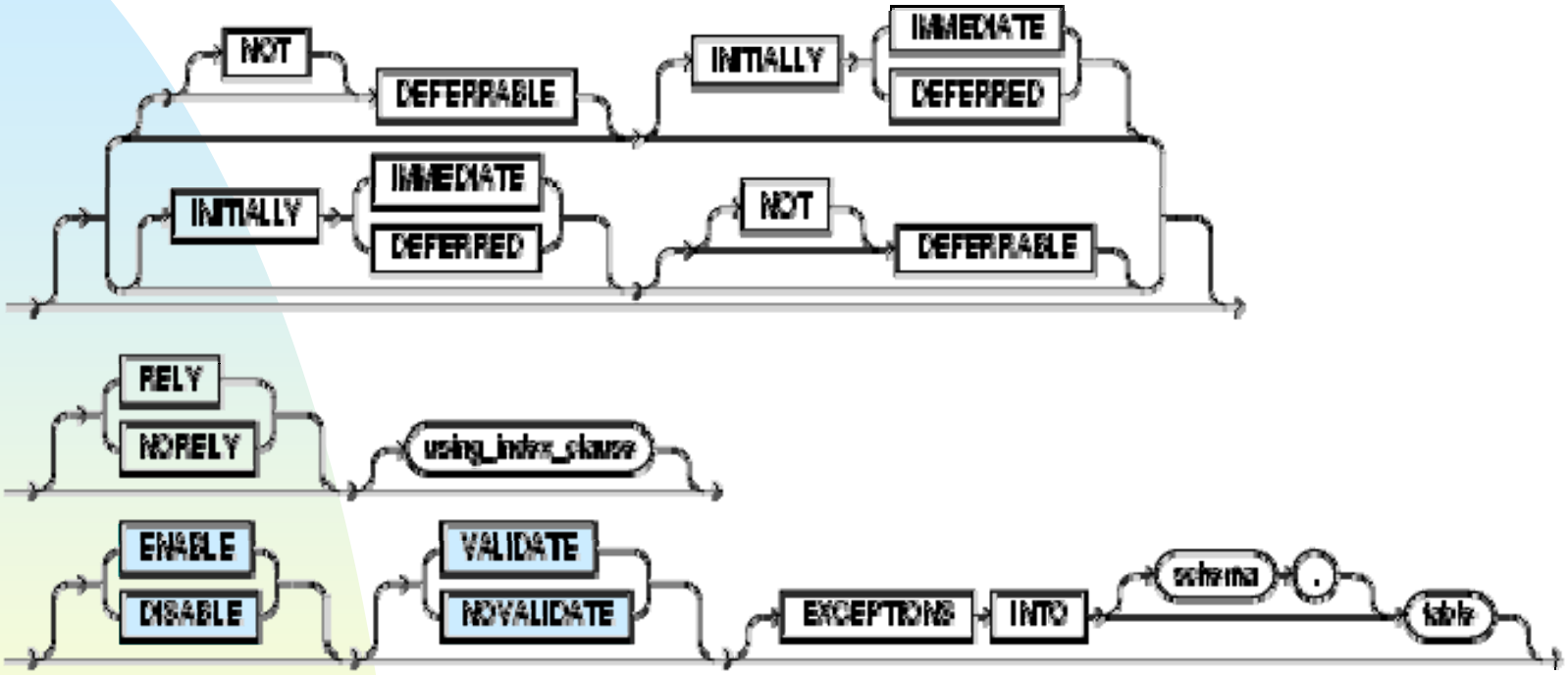
ALTER TABLE: NULL Values

- One can modify an existing column that did *not* permit NULLs to permit NULLs.
  - Example.

```
ALTER TABLE Account
MODIFY Customer_ID CHAR(6) NULL;
```

- One can change a column from "allows NULL values" to "disallow NULL values," provided that the column contains no NULL values.
  - Example. See example on previous slides. ▶
- *Alternative*: one can permit a non-NULL column to allow NULLs by using the DROP CONSTRINT clause to drop the NOT-NULL constraint on the column.

Modify Constraint State Option (Oracle 8i)



ALTER TABLE: Modify Constraint State

- **Modify Constraint** *constraint_name* ***Constraint_State***
- Modify an existing constraint named *constraint* in a table to a new constraint state.
  - Possible *constraint states*:
    - Enable/Disable
    - Validate/No Validate
    - Initially Immediate/Deferred
  - Example.

```
ALTER TABLE Depositor
MODIFY CONSTRAINT Acct_verification ENABLE;
```

SQL: Char Functions

- **Substr(*String*, *m*, [, *n*])**
- Extract a substring of *String*, beginning at position *m*.
  - The extracted substring is of length *n*.
  - If *n* is omitted, then the default is the substring from position *m* to the end of *String*.
  - Example.

Let *String* = 'ABCDE'. Then

substr(*String*, 2, 3) = 'BCD', and
substr(*String*, 4) = 'DE'

SQL: Inserting Null Values

- Inserting a null value in a column, which allows NULL values, by entering the word NULL.
  - Example.

```
INSERT INTO EMP
        VALUES (7955, 'Wilson', '22-Apr-99', NULL, 30000);
```

- Instead of explicitly specifying NULL for each blank column, list only the columns, not necessary in the *order* as defined in the table, and values that are not NULL.
  - A new tuple is inserted by placing the values into the attributes in the *order* the columns were specified in the INSERT statement and making the remaining fields NULL.
  - Example.

```
INSERT INTO EMP (ENO, Ename, HireDate, Sal)
        VALUES (7955, 'Wilson', '22-Apr-99', 30000);
```

Triggers

- A trigger is a statement that is executed *automatically* by the system as a side effect of a modification to the DB.
- To design a trigger mechanism, we must:
  - Specify the conditions under which the trigger is to be executed.
  - Specify the actions to be taken when the trigger executes.
- Triggers introduced to SQL standard in SQL:1999, but supported even earlier using non-standard syntax by most databases.

Triggers

- Example. Suppose that instead of allowing negative account balances, the bank deals with overdrafts by
  - setting the account balance to zero
  - creating a loan in the amount of the overdraft
  - giving this loan a loan number identical to the account number of the overdrawn account

  The *condition* for executing the trigger is an update to the *account* relation that results in a negative *balance* value.

Trigger

Example (in SQL:1999)

depositor(Customer-name, Account-number)
borrower(Customer-name, Loan-number)
account(Account-number, Branch-name, Balance)
loan(Loan-number, Branch-name, Amount)

```
create trigger overdraft-trigger after update on account
referencing new row as nrow
for each row
when nrow.balance < 0
begin atomic
        insert into borrower
           (select customer-name, depositor.account-number
            from depositor
            where nrow.account-number = depositor.account-number);
           insert into loan values
           (nrow.account-number, nrow.branch-name, –nrow.balance);
        update account set balance = 0
           where account.account-number = nrow.account-number
end
```