Object-Relational Databases

User-Defined Types
Object ID's
Nested Tables

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Merging Relational and Object Models

- Object-oriented models support interesting data types --- not just flat files.
  - Maps, multimedia, etc.
- The relational model supports very-high-level queries.
- Object-relational databases are an attempt to get the best of both.

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Evolution of DBMS's

- Object-oriented DBMS's failed because they did not offer the efficiencies of well-entrenched relational DBMS's.
- Object-relational extensions to relational DBMS's capture much of the advantages of OO, yet retain the relation as the fundamental abstraction.

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SQL-99 and Oracle Features

- SQL-99 includes many of the object-relational features to be described.
- However, being so new, different DBMS's use different approaches.
  - We'll sometimes use features and syntax from Oracle.

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User Defined Types

- A *user-defined type*, or UDT, is essentially a class definition, with a structure and methods.
- Two uses:
  1. As a *rowtype*, that is, the type of a relation.
  2. As the type of an attribute of a relation.

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UDT Definition

```
CREATE TYPE <typename> AS (
    <list of elements, as in CREATE TABLE>
);
```

- Oracle syntax:
  1. Add "OBJECT" as in CREATE … AS OBJECT.
  2. Follow with / to have the type stored.

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Example: UDT Definition

```
CREATE TYPE BarType AS (
   name     CHAR(20),
   addr     CHAR(20)
);
CREATE TYPE BeerType AS (
   name     CHAR(20),
   manf     CHAR(20)
);
```

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References

- If *T* is a type, then REF *T* is the type of a reference to *T*, that is, a pointer to an object of type *T*.
- Often called an "object ID" in OO systems.
- Unlike object ID's, a REF is visible, although it is usually gibberish.

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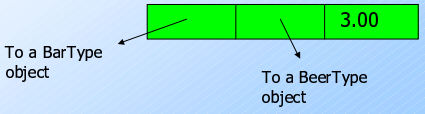
Example: REF

```
CREATE TYPE MenuType AS (
   bar      REF BarType,
   beer     REF BeerType,
   price    FLOAT
);
```

- MenuType objects look like:



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UDT's as Rowtypes

- A table may be defined to have a schema that is a rowtype, rather than by listing its elements.
- Syntax:

CREATE TABLE <table name> OF <type name>;

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Example: Creating a Relation

CREATE TABLE Bars OF BarType;

CREATE TABLE Beers OF BeerType;

CREATE TABLE Sells OF MenuType;

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Values of Relations with a Rowtype

- Technically, a relation like Bars, declared to have a rowtype BarType, is not a set of pairs --- it is a unary relation, whose tuples are objects with two components: name and addr.
- Each UDT has a *type constructor* of the same name that wraps objects of that type.

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Example: Type Constructor

- The query

  SELECT * FROM Bars;
- Produces "tuples" such as:

  BarType('Joe"s Bar', 'Maple St.')

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Accessing Values From a Rowtype

- In Oracle, the dot works as expected.
  - But it is a good idea, in Oracle, to use an alias for every relation, when O-R features are used.
- Example:

  SELECT bb.name, bb.addr
  FROM Bars bb;

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Accessing Values: SQL-99 Approach

- In SQL-99, each attribute of a UDT has *generator* (get the value) and *mutator* (change the value) methods of the same name as the attribute.
  - The generator for *A* takes no argument, as A().
  - The mutator for A takes a new value as argument, as A(v).

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Example: SQL-99 Value Access

- The same query in SQL-99 is

  SELECT bb.name(), bb.addr()
  FROM Bars bb;

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Inserting Rowtype Values

- In Oracle, we can use a standard INSERT statement, remembering that a relation with a rowtype is really unary and needs that type constructor.
- Example:

  INSERT INTO Bars VALUES(
  BarType('Joe"s Bar', 'Maple St.')
  );

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Inserting Values: SQL-99 Style

1. Create a variable *X* of the suitable type, using the constructor method for that type.
2. Use the mutator methods for the attributes to set the values of the fields of *X*.
3. Insert *X* into the relation.

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Example: SQL-99 Insert

- The following must be part of a procedure, e.g., PSM, so we have a variable newBar.

```
SET newBar = BarType();
newBar
newBar
INSERT INTO Bars VALUES(newBar);
```

Mutator methods change newBar's name and addr components.

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UDT's as Column Types

- A UDT can be the type of an attribute.
- In either another UDT definition, or in a CREATE TABLE statement, use the name of the UDT as the type of the attribute.

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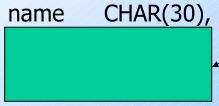
Example: Column Type

```
CREATE TYPE AddrType AS (
   street     CHAR(30),
   city       CHAR(20),
   zip        INT
);
CREATE TABLE Drinkers (
   name       CHAR(30),
```



```
);
```

Values of addr and favBeer components are objects with 3 and 2 fields, respectively.

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Oracle Problem With Field Access

- You can access a field *F* of an object that is the value of an attribute *A* by *A.F*.
- However, you must use an alias, say *rr*, for the relation *R* with attribute *A*, as *rr.A.F*.

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Example: Field Access in Oracle

- Wrong:

```
SELECT favBeer.name
FROM Drinkers;
```

- Wrong:

```
SELECT Drinkers.favBeer.name
FROM Drinkers;
```

- Right:

```
SELECT dd.favBeer.name
FROM Drinkers dd;
```

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Following REF's

- *A* -> *B* makes sense if:
  1. *A* is of type REF *T*.
  2. *B* is an attribute (field) of objects of type *T*.
- Denotes the value of the *B* component of the object pointed to by *A*.

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Example: Following REF's

- Remember Sells is a relation with a rowtype MenuType(bar, beer, price), where bar and beer are REF's to objects of types BarType and BeerType.
- Find the beers served by Joe:

```
SELECT beer->name
FROM Sells
WHERE bar->name = 'Joe''s Bar';
```

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Following REF's: Oracle Style

- REF-following is implicit in the dot.
- Just follow a REF by a dot and a field of the object referred to.
- Example:

```
SELECT ss.beer.name
FROM Sells ss
WHERE ss.bar.name = 'Joe''s Bar';
```

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Oracle's DEREF Operator -- Motivation

- If we want the set of beer objects for the beers sold by Joe, we might try:

```
SELECT ss.beer
FROM Sells ss
WHERE ss.bar.name = 'Joe''s Bar';
```

- Legal, but ss.beer is a REF, hence gibberish.

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Using DEREF

- To see the BeerType objects, use:

```
SELECT DEREF(ss.beer)
FROM Sells ss
WHERE ss.bar.name = 'Joe''s Bar';
```

- Produces values like:

```
BeerType('Bud', 'Anheuser-Busch')
```

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Methods --- Oracle Syntax

- Classes are more than structures; they provide methods.
- We'll study the Oracle syntax for methods.
  - Declare in CREATE TYPE, and define methods in a CREATE TYPE BODY statement.
  - Use PL/SQL syntax for methods.
  - Use variable SELF to refer to the object to which the method is applied.

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Example: Method Declaration

- Let's add method priceInYen to MenuType.

```
CREATE TYPE MenuType AS OBJECT (
    bar         REF BarType,
    beer        REF BeerType,
    price       FLOAT,
    [redacted]priceInYen(rate IN FLOAT)
        RETURN FLOAT,
    PRAGMA RESTRICT_REFERENCES(priceInYen, [redacted])
);
/
```

What Oracle calls methods.

"Write no database state." That is, whatever priceInYen does it won't modify the database.

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Method Definition – Oracle Style

- Form of create-body statement:

```
CREATE TYPE BODY <type name> AS
  <method definitions = PL/SQL
     procedure definitions, using
     "MEMBER FUNCTION" in place of
     "PROCEDURE">
END;
/
```

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Example: Method Definition

```
CREATE TYPE BODY MenuType AS
  MEMBER FUNCTION
     priceInYen(rate FLOAT) RETURN FLOAT IS
        BEGIN
           RETURN rate * SELF.price;
        END;
END;
/
```

No mode (IN) in body, just in declaration

Use parentheses *only* when there is at least one argument

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Method Use

- Follow a name for an object by a dot and the name of the method, with arguments if any.
- Example:

```
SELECT ss.beer.name,
       ss.priceInYen(120.0)
FROM Sells ss
WHERE ss.bar.name = 'Joe"s Bar';
```

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Order Methods: SQL-99

- Each UDT *T* may define two methods called EQUAL and LESSTHAN.
  - Each takes an argument of type *T* and is applied to another object of type *T*.
  - Returns TRUE if and only if the target object is = (resp. <) the argument object.
- Allows objects of type T to be compared by =, <, etc. in WHERE clauses and for sorting (ORDER BY).

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Order Methods: Oracle

- We may declare any one method for any UDT to be an *order method*.
- The order method returns a value <0, =0, or >0, as the value of object SELF is <, =, or > the argument object.

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Example: Order Method Declaration

- Order BarType objects by name:

```
CREATE TYPE BarType AS OBJECT (
   name      CHAR(20),
   addr      CHAR(20),
   ORDER MEMBER FUNCTION before(
        bar2 IN BarType) RETURN INT,
   PRAGMA RESTRICT_REFERENCES(before,
                              )
);
/
```

Read/write no database state/package state. A "package" is a collection of procedures and variables that can communicate values among them.

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Example: Order Method Definition

```
CREATE TYPE BODY BarType AS
   ORDER MEMBER FUNCTION
        before(bar2 BarType) RETURN INT IS
   BEGIN
        IF SELF.name < bar2.name THEN RETURN –1;
        ELSIF SELF.name = bar2.name THEN RETURN 0;
        ELSE RETURN 1;
        END IF;
   END;
END;
/
```

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Oracle Nested Tables

- Allows values of tuple components to be whole relations.
- If *T* is a UDT, we can create a type *S* whose values are relations with rowtype *T*, by:

  CREATE TYPE *S* AS TABLE OF *T*;

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Example: Nested Table Type

```
CREATE TYPE BeerType AS OBJECT (
   name      CHAR(20),
   kind      CHAR(10),
   color     CHAR(10)
);
/
CREATE TYPE BeerTableType AS
   TABLE OF BeerType;
/
```

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Example --- Continued

- Use BeerTableType in a Manfs relation that stores the set of beers by each manufacturer in one tuple for that manufacturer.

```
CREATE TABLE Manfs (
        name      CHAR(30),
        addr      CHAR(50),
        beers     beerTableType
);
```

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Storing Nested Relations

- Oracle doesn't really store each nested table as a separate relation --- it just makes it look that way.
- Rather, there is one relation *R* in which all the tuples of all the nested tables for one attribute *A* are stored.
- Declare in CREATE TABLE by:

  NESTED TABLE *A* STORE AS *R*

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Example: Storing Nested Tables

```
CREATE TABLE Manfs (
        name      CHAR(30),
        addr      CHAR(50),
        beers     beerTableType

NESTED TABLE beers STORE AS BeerTable
```

Note where the semicolon goes and doesn't go.

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Querying a Nested Table

- We can print the value of a nested table like any other value.
- But these values have two type constructors:
  1. For the table.
  2. For the type of tuples in the table.

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Example: Query a Nested Table

- Find the beers by Anheuser-Busch:

```
SELECT beers FROM Manfs
WHERE name = 'Anheuser-Busch';
```

- Produces one value like:

```
BeerTableType(
  BeerType('Bud', 'lager', 'yellow'),
  Beertype('Lite', 'malt', 'pale'),...
)
```

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Querying Within a Nested Table

- A nested table can be converted to an ordinary relation by applying THE(…).
- This relation can be used in FROM clauses like any other relation.

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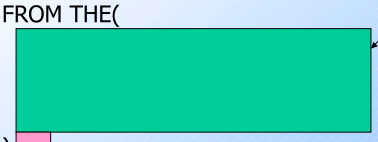
Example: Use of THE

- Find the ales made by Anheuser-Busch:

```
SELECT bb.name
FROM THE(
```




```
)
WHERE bb.kind = 'ale';
```

An alias for the nested table, which has no name

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Turning Relations Into Nested Tables

- Any relation with the proper number and types of attributes can become the value of a nested table.
- Use CAST(MULTISET(…) AS <type>) on the relation to turn it into the value with the proper type for a nested table.

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Example: CAST --- 1

- Suppose we have a relation Beers(beer, manf), where beer is a BeerType object and manf a string --- the manufacturer of the beer.
- We want to insert into Manfs a new tuple, with Pete's Brewing Co. as the name and a set of beers that are whatever Beers has for Pete's.

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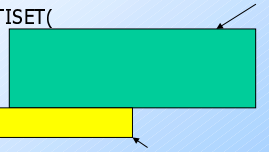
Example: CAST --- 2

```
INSERT INTO Manfs VALUES (
   'Pete"s', 'Palo Alto',
   CAST(
        MULTISET(
        )
   )
);
```



The set of BeerType objects for Pete's

Turn the set of objects into a nested relation

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