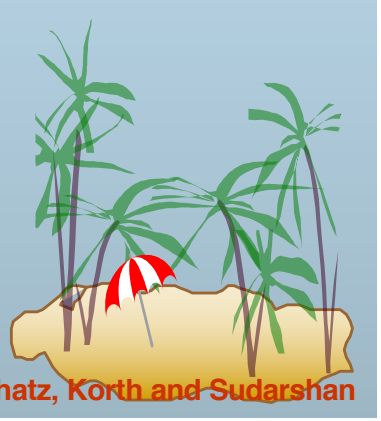
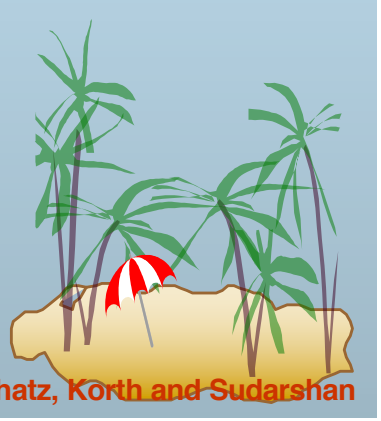
# Chapter 5: Other Relational Languages

- Query-by-Example (QBE)
- Datalog



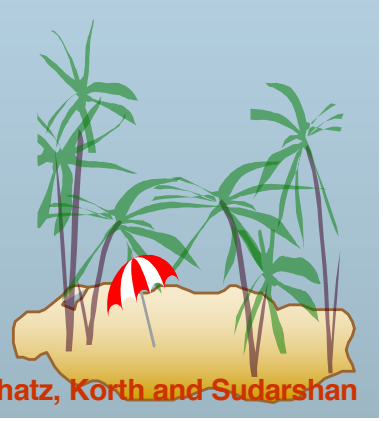
# Query-by-Example (QBE)

- Basic Structure
- Queries on One Relation
- Queries on Several Relations
- The Condition Box
- The Result Relation
- Ordering the Display of Tuples
- Aggregate Operations
- Modification of the Database



# QBE — Basic Structure

- A graphical query language which is based (roughly) on the domain relational calculus
- Two dimensional syntax – system creates templates of relations that are requested by users
- Queries are expressed “by example”



# QBE Skeleton Tables for the Bank Example

| *branch* | *branch-name* | *branch-city* | *assets* |
|---|---|---|---|
| | | | |

| *customer* | *customer-name* | *customer-street* | *customer-city* |
|---|---|---|---|
| | | | |

| *loan* | *loan-number* | *branch-name* | *amount* |
|---|---|---|---|
| | | | |

# QBE Skeleton Tables (Cont.)

| *borrower* | *customer-name* | *loan-number* |
|---|---|---|
| | | |

| *account* | *account-number* | *branch-name* | *balance* |
|---|---|---|---|
| | | | |

| *depositor* | *customer-name* | *account-number* |
|---|---|---|
| | | |

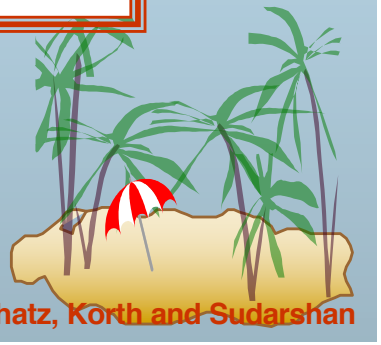
# Queries on One Relation

- Find all loan numbers at the Perryridge branch.

| *loan* | *loan-number* | *branch-name* | *amount* |
|---|---|---|---|
| | P._x | Perryridge | |

- _x is a variable (optional; can be omitted in above query)
- P. means print (display)
- duplicates are removed by default
- To retain duplicates use P.ALL

| *loan* | *loan-number* | *branch-name* | *amount* |
|---|---|---|---|
| | P.ALL. | Perryridge | |



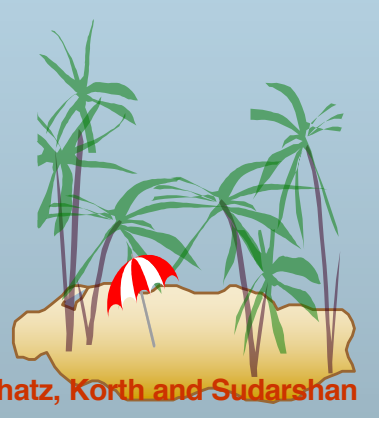
# Queries on One Relation (Cont.)

- Display full details of all loans
  - ★ Method 1:

| *loan* | *loan-number* | *branch-name* | *amount* |
|---|---|---|---|
| | P._x | P._y | P._z |

  - ★ Method 2: Shorthand notation

| *loan* | *loan-number* | *branch-name* | *amount* |
|---|---|---|---|
| P. | | | |



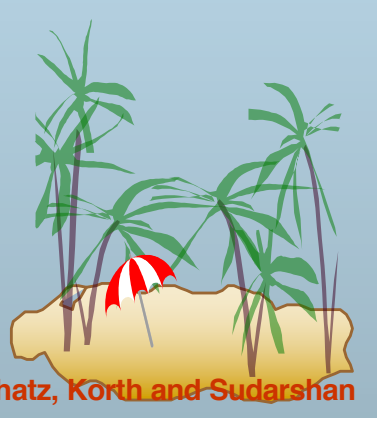
# Queries on One Relation (Cont.)

- Find the loan number of all loans with a loan amount of more than $700

| *loan* | *loan-number* | *branch-name* | *amount* |
|---|---|---|---|
| | P. | | >700 |

- Find names of all branches that are not located in Brooklyn

| *branch* | *branch-name* | *branch-city* | *assets* |
|---|---|---|---|
| | P. | ¬ Brooklyn | |



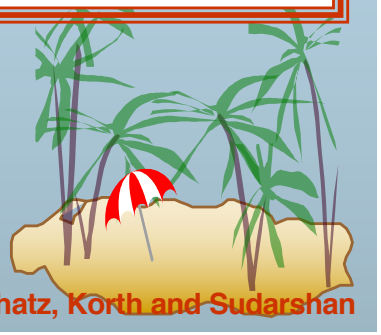
# Queries on One Relation (Cont.)

- Find the loan numbers of all loans made jointly to Smith and Jones.

| *borrower* | *customer-name* | *loan-number* |
|---|---|---|
| | "Smith" | P._*x* |
| | "Jones" | _*x* |

- Find all customers who live in the same city as Jones

| *customer* | *customer-name* | *customer-street* | *customer-city* |
|---|---|---|---|
| | P._*x* | | _*y* |
| | Jones | | _*y* |

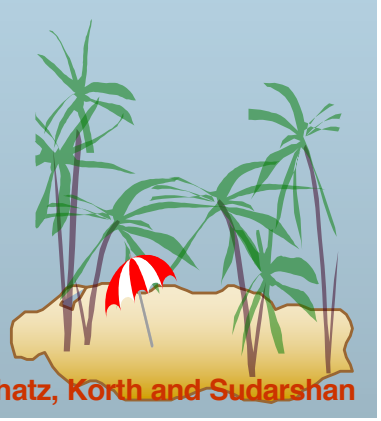


# Queries on Several Relations

- Find the names of all customers who have a loan from the Perryridge branch.

| *loan* | *loan-number* | *branch-name* | *amount* |
|---|---|---|---|
| | _x | Perryridge | |

| *borrower* | *customer-name* | *loan-number* |
|---|---|---|
| | P._y | _x |

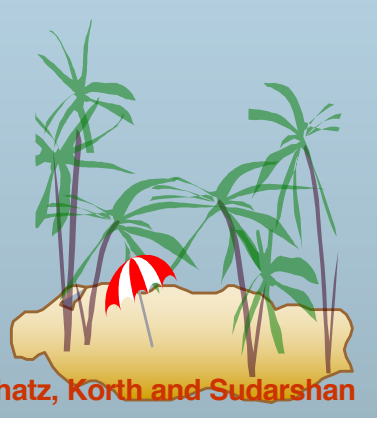


# Queries on Several Relations (Cont.)

- Find the names of all customers who have both an account and a loan at the bank.

| *depositor* | *customer-name* | *account-number* |
|---|---|---|
| | P._x | |

| *borrower* | *customer-name* | *loan-number* |
|---|---|---|
| | _x | |



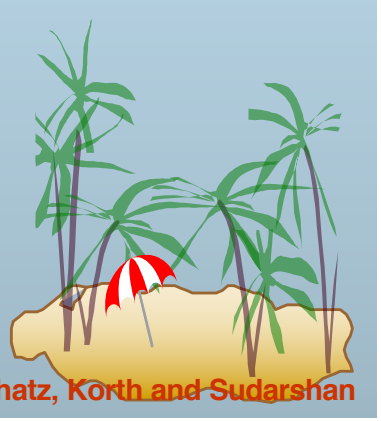
# Negation in QBE

- Find the names of all customers who have an account at the bank, but do not have a loan from the bank.

| *depositor* | *customer-name* | *account-number* |
|---|---|---|
| | P._*x* | |

| *borrower* | *customer-name* | *loan-number* |
|---|---|---|
| ¬ | _*x* | |

¬ means “there does not exist”

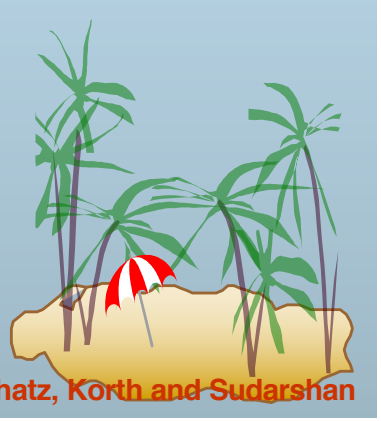


# Negation in QBE (Cont.)

- Find all customers who have at least two accounts.

| *depositor* | *customer-name* | *account-number* |
|---|---|---|
| | P._*x*<br>_*x* | _*y*<br>¬ _*y* |

¬ means “not equal to”

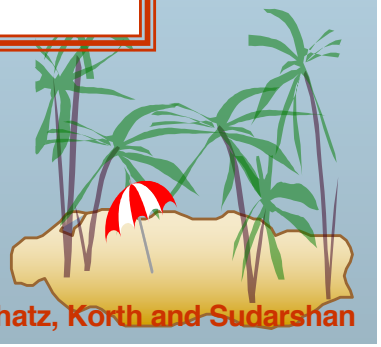


# The Condition Box

- Allows the expression of constraints on domain variables that are either inconvenient or impossible to express within the skeleton tables.
- Complex conditions can be used in condition boxes
- E.g. Find the loan numbers of all loans made to Smith, to Jones, or to both jointly

| *borrower* | *customer-name* | *loan-number* |
|---|---|---|
| | _*n* | P._*x* |

| *conditions* |
|---|
| _*n* = Smith **or** _*n* = Jones |

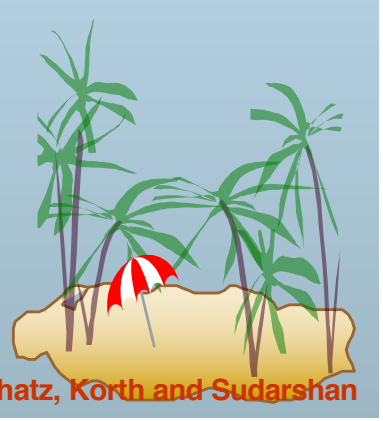


# Condition Box (Cont.)

- QBE supports an interesting syntax for expressing alternative values

| *branch* | *branch-name* | *branch-city* | *assets* |
|---|---|---|---|
| | P. | _x | |

| *conditions* |
|---|
| _x = (Brooklyn **or** Queens) |



# Condition Box (Cont.)

- Find all account numbers with a balance between \$1,300 and \$1,500

| *account* | *account-number* | *branch-name* | *balance* |
|---|---|---|---|
| | P. | | $\_x$ |

| *conditions* |
|---|
| $\_x \geq 1300$<br>$\_x \leq 1500$ |

- Find all account numbers with a balance between \$1,300 and \$2,000 but not exactly \$1,500.

| *account* | *account-number* | *branch-name* | *balance* |
|---|---|---|---|
| | P. | | $\_x$ |

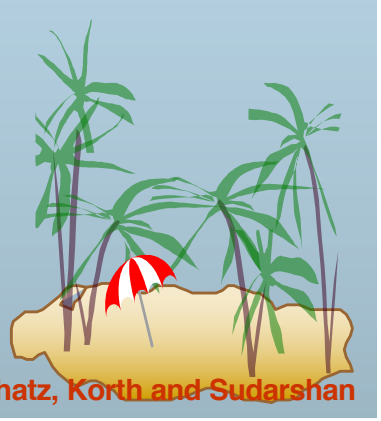
| *conditions* |
|---|
| $\_x = (\geq 1300$ **and** $\leq 2000$ **and** $\neg 1500)$ |

# Condition Box (Cont.)

- Find all branches that have assets greater than those of at least one branch located in Brooklyn

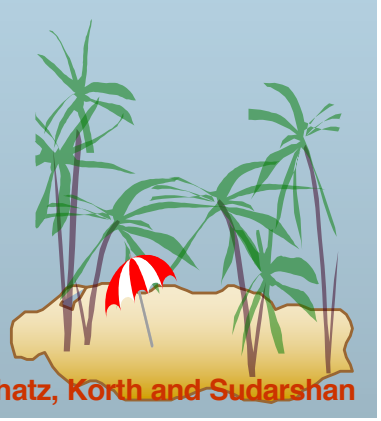
| *branch* | *branch-name* | *branch-city* | *assets* |
|---|---|---|---|
| | P._x | Brooklyn | _y<br>_z |

| *conditions* |
|---|
| _y > _z |



# The Result Relation

- Find the *customer-name*, *account-number,* and *balance* for alll customers who have an account at the Perryridge branch.
  - ★ We need to:
    - ✓ Join *depositor* and *account.*
    - ✓ Project *customer-name, account-number* and *balance.*
  - ★ To accomplish this we:
    - ✓ Create a skeleton table, called *result,* with attributes *customer-name, account-number,* and *balance.*
    - ✓ Write the query.



# The Result Relation (Cont.)

- The resulting query is:

| *account* | *account-number* | *branch-name* | *balance* |
|---|---|---|---|
| | _y | Perryridge | _z |

| *depositor* | *customer-name* | *account-number* |
|---|---|---|
| | _x | _y |

| *result* | *customer-name* | *account-number* | *balance* |
|---|---|---|---|
| P. | _x | _y | _z |

# Ordering the Display of Tuples

- AO = ascending order; DO = descending order.
- E.g. list in ascending alphabetical order all customers who have an account at the bank

| *depositor* | *customer-name* | *account-number* |
|---|---|---|
| | P.AO. | |

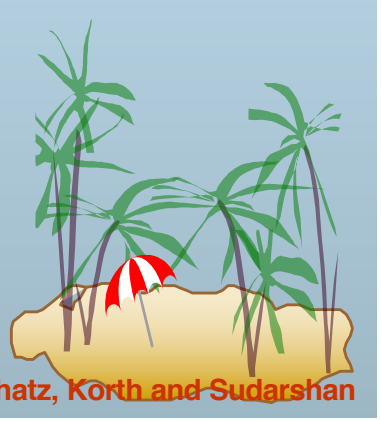
- When sorting on multiple attributes, the sorting order is specified by including with each sort operator (AO or DO) an integer surrounded by parentheses.
- E.g. List all account numbers at the Perryridge branch in ascending alphabetic order with their respective account balances in descending order.

| *account* | *account-number* | *branch-name* | *balance* |
|---|---|---|---|
| | P.AO(1). | Perryridge | P.DO(2). |

# Aggregate Operations

- The aggregate operators are AVG, MAX, MIN, SUM, and CNT
- The above operators must be postfixed with “ALL” (e.g., SUM.ALL.or AVG.ALL._x) to ensure that duplicates are not eliminated.
- E.g. Find the total balance of all the accounts maintained at the Perryridge branch.

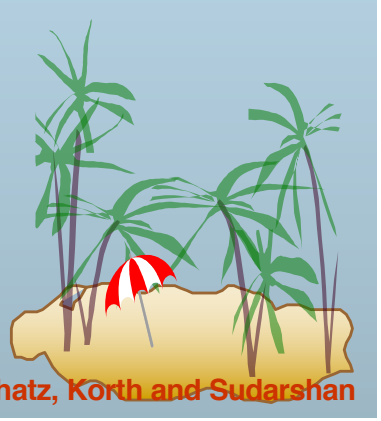
| *account* | *account-number* | *branch-name* | *balance* |
|---|---|---|---|
| | | Perryridge | P.SUM.ALL. |



# Aggregate Operations (Cont.)

- UNQ is used to specify that we want to eliminate duplicates
- Find the total number of customers having an account at the bank.

| *depositor* | *customer-name* | *account-number* |
|---|---|---|
| | P.CNT.UNQ. | |



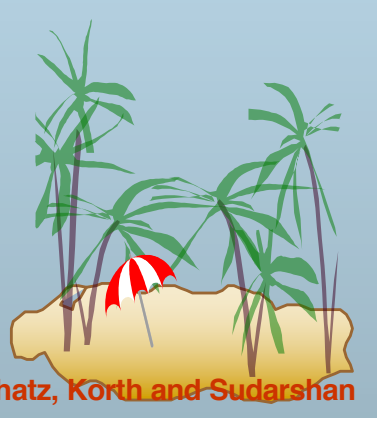
# Query Examples

- Find the average balance at each branch.

| *account* | *account-number* | *branch-name* | *balance* |
|---|---|---|---|
| | | P.G. | P.AVG.ALL._x |

- The “G” in “P.G” is analogous to SQL’s **group by** construct
- The “ALL” in the “P.AVG.ALL” entry in the *balance* column ensures that all balances are considered
- To find the average account balance at only those branches where the average account balance is more than $1,200, we simply add the condition box:

| *conditions* |
|---|
| AVG.ALL._x > 1200 |



# Query Example

- Find all customers who have an account at all branches located in Brooklyn.
  - ★ Approach: for each customer, find the number of branches in Brooklyn at which they have accounts, and compare with total number of branches in Brooklyn
  - ★ QBE does not provide subquery functionality, so both above tasks have to be combined in a single query.
    - ✓ Can be done for this query, but there are queries that require subqueries and cannot be expressed in QBE always be done.
- In the query on the next page
  - CNT.UNQ.ALL._*w* specifies the number of distinct branches in Brooklyn. Note: The variable _*w* is not connected to other variables in the query
  - CNT.UNQ.ALL._*z* specifies the number of distinct branches in Brooklyn at which customer *x* has an account.

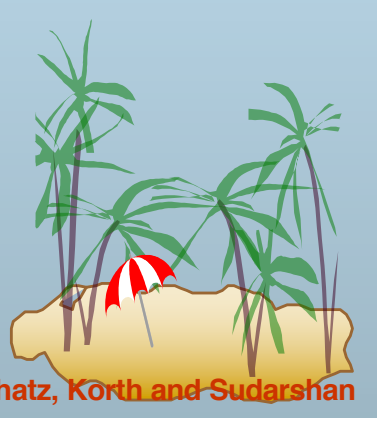
# Query Example (Cont.)

| *depositor* | *customer-name* | *account-number* |
|---|---|---|
| | P.G._*x* | _*y* |

| *account* | *account-number* | *branch-name* | *balance* |
|---|---|---|---|
| | _*y* | _*z* | |

| *branch* | *branch-name* | *branch-city* | *assets* |
|---|---|---|---|
| | _*z* | Brooklyn | |
| | _*w* | Brooklyn | |

| *conditions* |
|---|
| CNT.UNQ._*z* = CNT.UNQ._*w* |



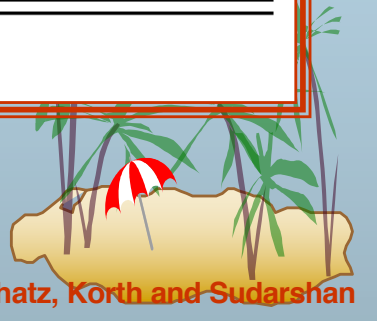
# Modification of the Database – Deletion

- Deletion of tuples from a relation is expressed by use of a D. command. In the case where we delete information in only some of the columns, null values, specified by –, are inserted.
- Delete customer Smith

| *customer* | *customer-name* | *customer-street* | *customer-city* |
|---|---|---|---|
| D. | Smith | | |

- Delete the *branch-city* value of the branch whose name is "Perryridge".

| *branch* | *branch-name* | *branch-city* | *assets* |
|---|---|---|---|
| | Perryridge | D. | |



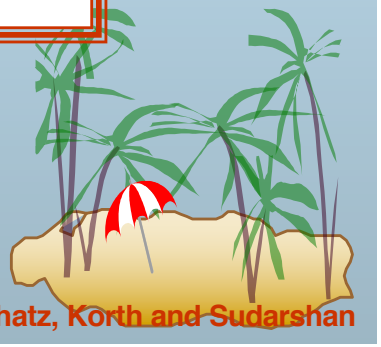
# Deletion Query Examples

- Delete all loans with a loan amount between $1300 and $1500.
  - ★ For consistency, we have to delete information from loan and borrower tables

| *loan* | *loan-number* | *branch-name* | *amount* |
|---|---|---|---|
| D. | $_y$ | | $_x$ |

| *borrower* | *customer-name* | *loan-number* |
|---|---|---|
| D. | | $_y$ |

| *conditions* |
|---|
| $_x = (\geq 1300$ **and** $\leq 1500)$ |



# Deletion Query Examples (Cont.)

- Delete all accounts at branches located in Brooklyn.

| *account* | *account-number* | *branch-name* | *balance* |
|---|---|---|---|
| D. | _y | _x | |

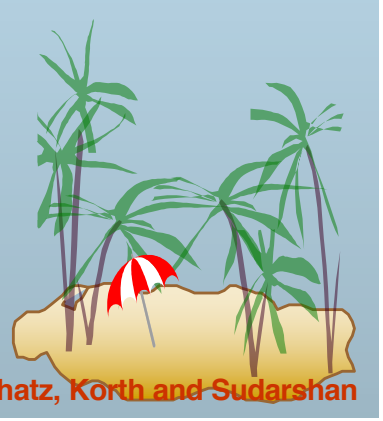
| *depositor* | *customer-name* | *account-number* |
|---|---|---|
| D. | | _y |

| *branch* | *branch-name* | *branch-city* | *assets* |
|---|---|---|---|
| | _x | Brooklyn | |

# Modification of the Database – Insertion

- Insertion is done by placing the I. operator in the query expression.
- Insert the fact that account A-9732 at the Perryridge branch has a balance of $700.

| *account* | *account-number* | *branch-name* | *balance* |
|---|---|---|---|
| I. | A-9732 | Perryridge | 700 |



# Modification of the Database – Insertion (Cont.)

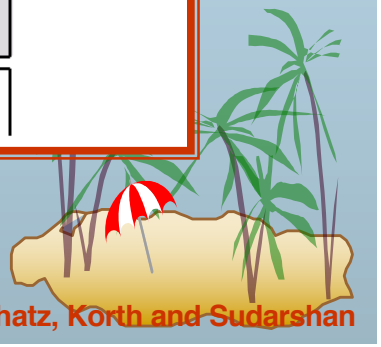
- Provide as a gift for all loan customers of the Perryridge branch, a new $200 savings account for every loan account they have, with the loan number serving as the account number for the new savings account.

| *account* | *account-number* | *branch-name* | *balance* |
|---|---|---|---|
| I. | _x | Perryridge | 200 |

| *depositor* | *customer-name* | *account-number* |
|---|---|---|
| I. | _y | _x |

| *loan* | *loan-number* | *branch-name* | *amount* |
|---|---|---|---|
| | _x | Perryridge | |

| *borrower* | *customer-name* | *loan-number* |
|---|---|---|
| | _y | _x |



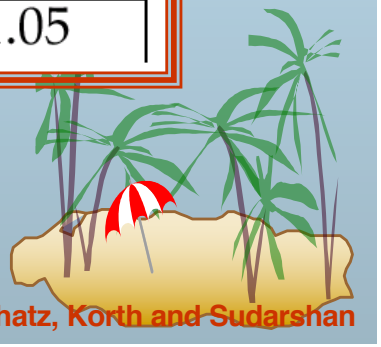
# Modification of the Database – Updates

- Use the U. operator to change a value in a tuple without changing *all* values in the tuple. QBE does not allow users to update the primary key fields.
- Update the asset value of the Perryridge branch to $10,000,000.

| *branch* | *branch-name* | *branch-city* | *assets* |
|---|---|---|---|
| | Perryridge | | U.10000000 |

- Increase all balances by 5 percent.

| *account* | *account-number* | *branch-name* | *balance* |
|---|---|---|---|
| | | | U._*x* * 1.05 |

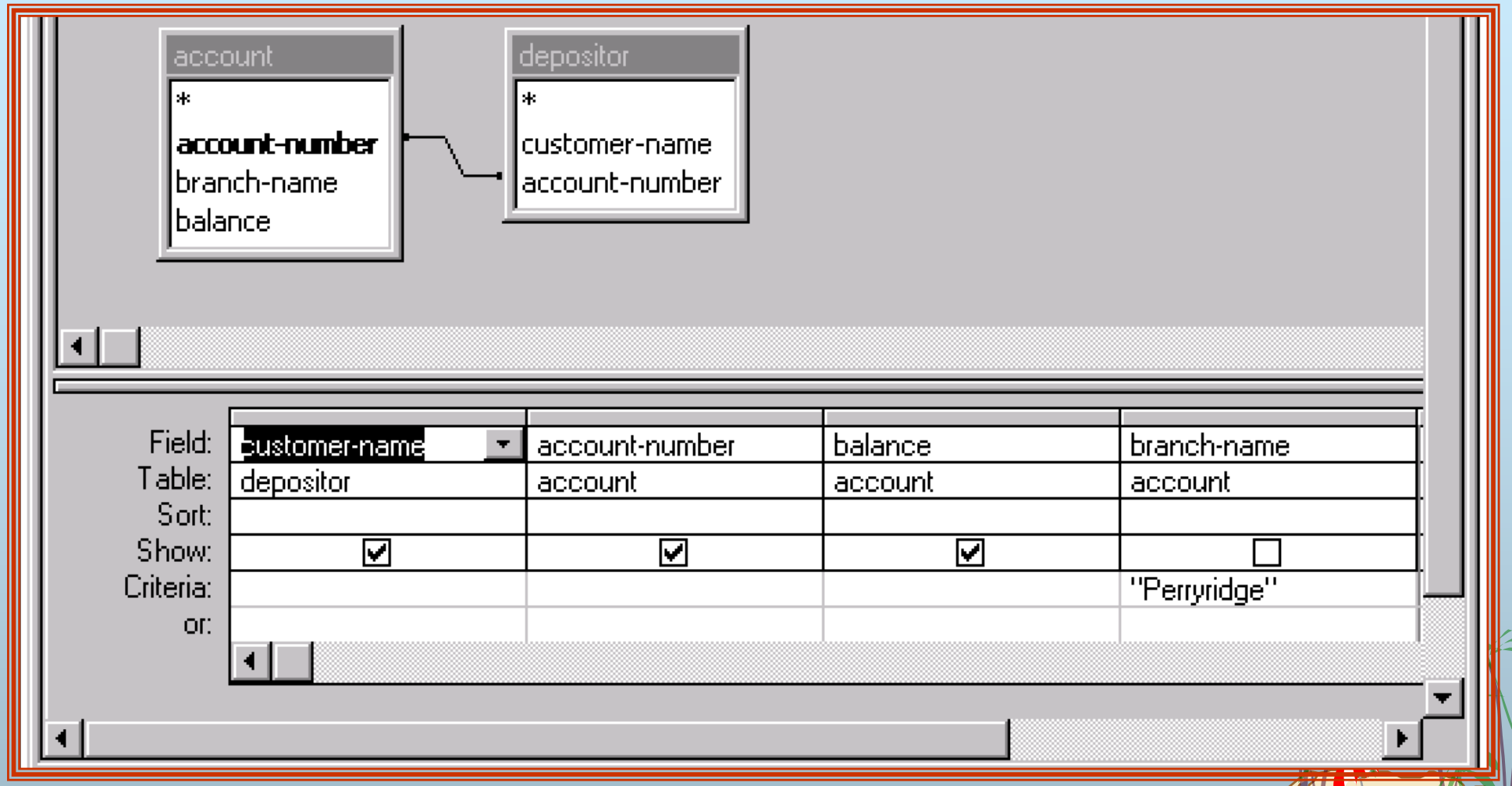


# Microsoft Access QBE

- Microsoft Access supports a variant of QBE called Graphical Query By Example (GQBE)
- GQBE differs from QBE in the following ways
  - ★ Attributes of relations are listed vertically, one below the other, instead of horizontally
  - ★ Instead of using variables, lines (links) between attributes are used to specify that their values should be the same.
    - ✓ Links are added automatically on the basis of attribute name, and the user can then add or delete links
    - ✓ By default, a link specifies an inner join, but can be modified to specify outer joins.
  - ★ Conditions, values to be printed, as well as group by attributes are all specified together in a box called the **design grid**

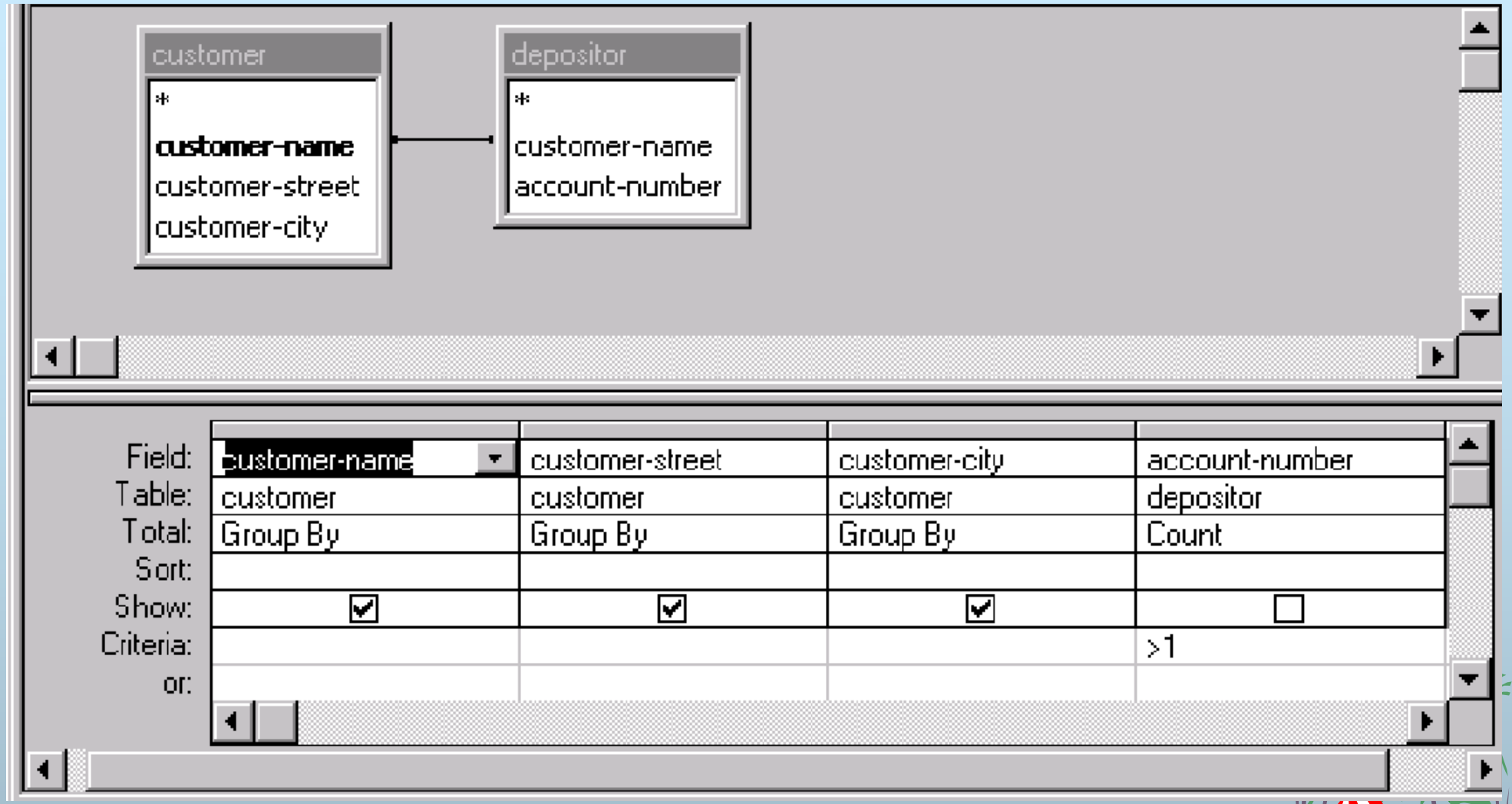
# An Example Query in Microsoft Access QBE

- Example query: Find the *customer-name*, *account-number* and *balance* for all accounts at the Perryridge branch



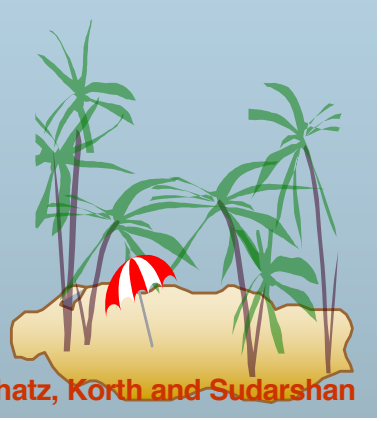
# An Aggregation Query in Access QBE

- Find the *name, street* and *city* of all customers who have more than one account at the bank



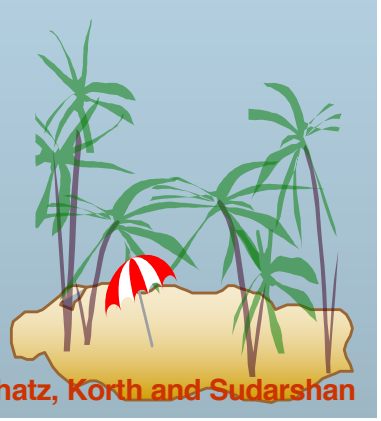
# Aggregation in Access QBE

- The row labeled **Total** specifies
  - ★ which attributes are group by attributes
  - ★ which attributes are to be aggregated upon (and the aggregate function).
  - ★ For attributes that are neither group by nor aggregated, we can still specify conditions by selecting **where** in the Total row and listing the conditions below
- As in SQL, if group by is used, only group by attributes and aggregate results can be output



# Datalog

- Basic Structure
- Syntax of Datalog Rules
- Semantics of Nonrecursive Datalog
- Safety
- Relational Operations in Datalog
- Recursion in Datalog
- The Power of Recursion



# Basic Structure

- Prolog-like logic-based language that allows recursive queries; based on first-order logic.
- A Datalog program consists of a set of *rules* that define views.
- Example: define a view relation *v1* containing account numbers and balances for accounts at the Perryridge branch with a balance of over $700.

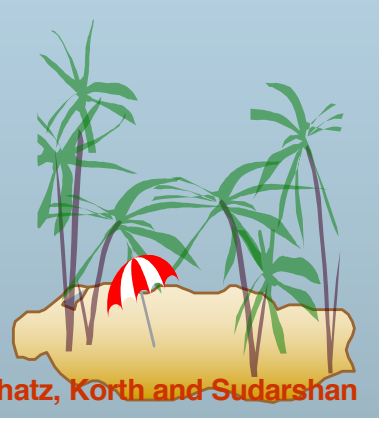
$$v1(A, B) :- account(A, \text{“Perryridge”}, B), B > 700.$$

- Retrieve the balance of account number “A-217” in the view relation *v1.*

$$? \; v1(\text{“A-217”}, B).$$

- To find account number and balance of all accounts in *v1* that have a balance greater than 800

$$? \; v1(A,B), B > 800$$



# Example Queries

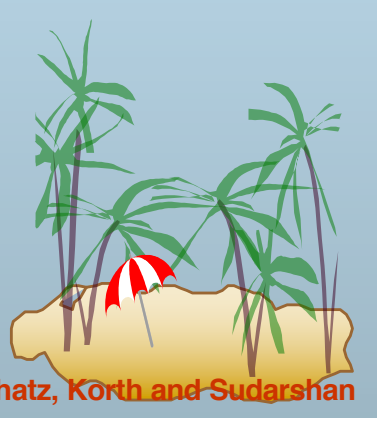
- Each rule defines a set of tuples that a view relation must contain.
  - ★ E.g. *v1(A, B) :– account(A, "*Perryridge", *B), B* > 700 is read as

    **for all** *A, B*

    **if** (*A*, "Perryridge", *B*) ∈ *account* **and** *B* > 700

    **then** (*A, B*) ∈ *v1*
- The set of tuples in a view relation is then defined as the union of all the sets of tuples defined by the rules for the view relation.
- Example:

  *interest-rate(A*, 5*) :– account(A, N, B), B* < 10000
  *interest-rate(A*, 6*) :– account(A, N, B), B* >= 10000

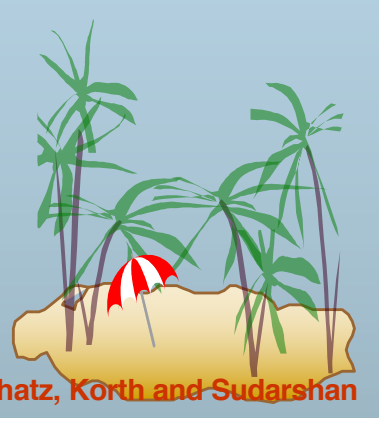


# Negation in Datalog

- Define a view relation *c* that contains the names of all customers who have a deposit but no loan at the bank:

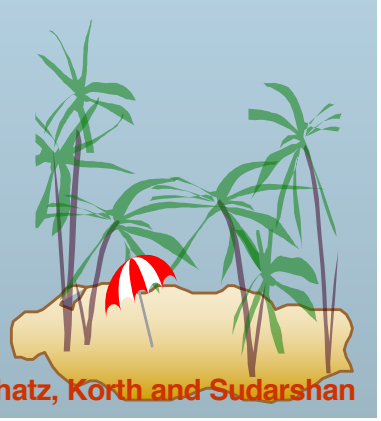
  *c(N)* :– *depositor(N, A),* **not** *is-borrower(N).*
  *is-borrower(N)* :–*borrower (N,L).*

- NOTE: using **not** *borrower (N, L)* in the first rule results in a different meaning, namely there is some loan L for which N is not a borrower.
  - ★ To prevent such confusion, we require all variables in negated "predicate" to also be present in non-negated predicates



# Formal Syntax and Semantics of Datalog

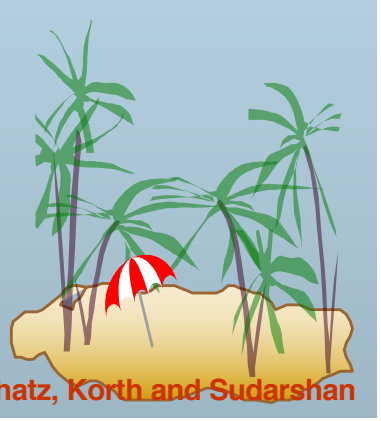
- We formally define the syntax and semantics (meaning) of Datalog programs, in the following steps
  1. We define the syntax of predicates, and then the syntax of rules
  2. We define the semantics of individual rules
  3. We define the semantics of non-recursive programs, based on a layering of rules
  4. It is possible to write rules that can generate an infinite number of tuples in the view relation. To prevent this, we define what rules are "safe". Non-recursive programs containing only safe rules can only generate a finite number of answers.
  5. It is possible to write recursive programs whose meaning is unclear. We define what recursive programs are acceptable, and define their meaning.



# Semantics of a Rule (Cont.)

- *Each rule defines a mapping from the relations in the body to the derived relations in the head: if I are the relations in the body then infer($R_1$, I) denotes the mapping for rule $R_1$*
- *This mapping is easily expressed in relational algebra (but rules must be safe!)*
- *Given an set of rules* $\mathfrak{R} = \{R_1, R_2, ..., R_n\}$, we define

$$infer(\mathfrak{R}, I) = infer(R_1, I) \cup infer(R_2, I) \cup ... \cup infer(R_n, I)$$

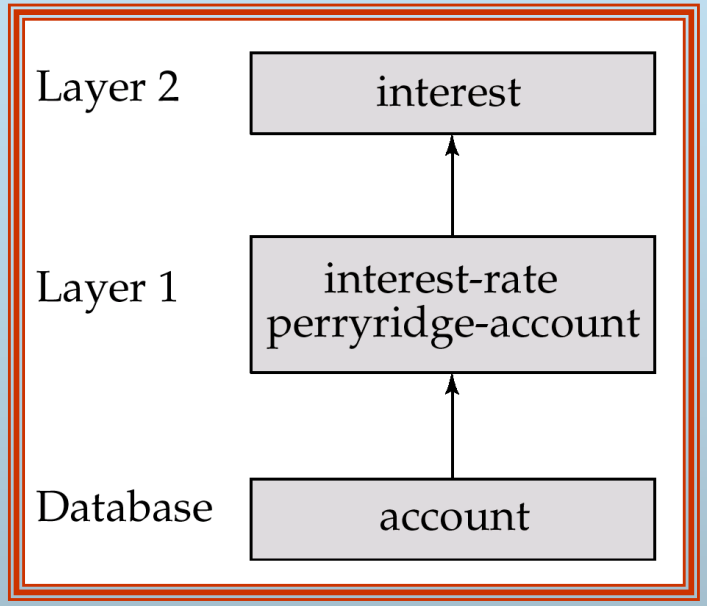


# Layering of Rules

- Define the interest on each account in Perryridge

  *interest(A, I)* :– *perryridge-account*(*A,B*),
  *interest-rate(A,R), I = B * R*/100.
  *perryridge-account(A,B)* :–*account*(*A,* “Perryridge”, *B).*
  *interest-rate(A*,0) :–account(*N, A, B), B* < 2000.
  interest-rate(*A*,5) :–account(N, A, B), *B* > 2000.

- Layering of the view relations

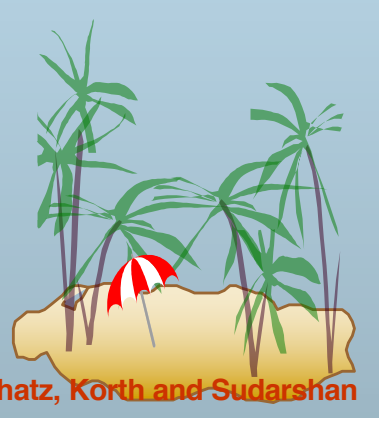


# Recursion in Datalog

- Suppose we are given a relation
  *manager(X, Y)*
  containing pairs of names X, Y such that Y is a manager of X (or equivalently, X is a direct employee of Y).
- Each manager may have direct employees, as well as indirect employees
  - ★ Indirect employees of a manager, say Jones, are employees of people who are direct employees of Jones, or recursively, employees of people who are indirect employees of Jones
- Suppose we wish to find all (direct and indirect) employees of manager Jones. We can write a recursive Datalog program.

  *empl-jones (X) :- manager (X, Jones).*

  *empl-jones (X) :- manager (X, Y), empl-jones(Y).*



# Semantics of Recursion in Datalog

- *I = infer($\mathcal{R}$, I) Is the meaning of a recursive program $\mathcal{R}$ .*
- This is known as a **fixed point** equation---actually we want the least solution of this fixpoint equation.
- This is computed by the iterative procedure *Datalog-Fixpoint*

```
procedure Datalog-Fixpoint
        I = set of facts in the database
        repeat
                Old_I = I
                I = I ∪ infer(ℛ, I)
        until I = Old_I
```

- But this only works for rules defining a monotonic mapping: I.e., rules without negation and aggregates
- Negation and aggregates are nonmonotonic.

# Example of Datalog-FixPoint Iteration

| *employee-name* | *manager-name* |
|---|---|
| Alon | Barinsky |
| Barinsky | Estovar |
| Corbin | Duarte |
| Duarte | Jones |
| Estovar | Jones |
| Jones | Klinger |
| Rensal | Klinger |

| Iteration number | Tuples in *empl-jones* |
|---|---|
| 0 | |
| 1 | (Duarte), (Estovar) |
| 2 | (Duarte), (Estovar), (Barinsky), (Corbin) |
| 3 | (Duarte), (Estovar), (Barinsky), (Corbin), (Alon) |
| 4 | (Duarte), (Estovar), (Barinsky), (Corbin), (Alon) |

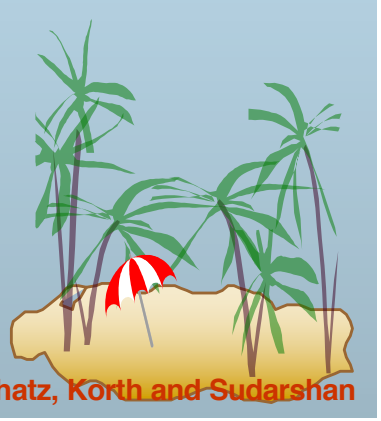
# Another Example

- Create a view relation *empl* that contains every tuple *(X, Y)* such that *X* is directly or indirectly managed by *Y.*

  *empl(X, Y)* :–*manager(X, Y).*
  *empl(X, Y)* :–*manager(X, Y), empl(Z, Y)*

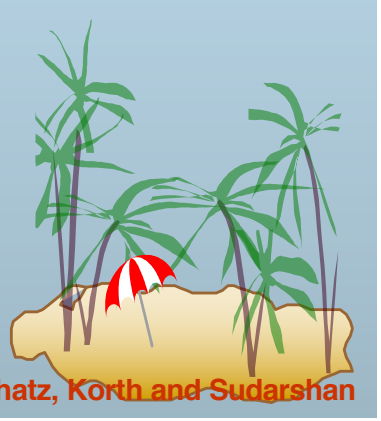
- Find the direct and indirect employees of Jones.

  *? empl(X,* “Jones”).



# The Power of Recursion

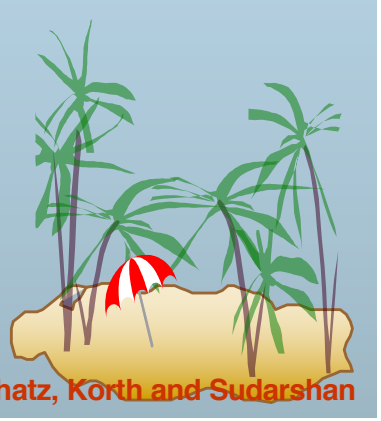
- Recursive views make it possible to write queries, such as transitive closure queries, that cannot be written without recursion or iteration.
  - ★ Intuition: Without recursion, a non-recursive non-iterative program can perform only a fixed number of joins of manager with itself
    - ✓ This can give only a fixed number of levels of managers
    - ✓ Given a program we can construct a database with a greater number of levels of managers on which the program will not work



# Recursion in SQL

- SQL:1999 permits recursive view definition
- E.g. query to find all employee-manager pairs

```
with recursive empl (emp, mgr ) as (
        select emp, mgr
        from   manager
    union
        select emp, empl.mgr
        from   manager, empl
        where manager.mgr = empl.emp      )
select *
from   empl
```

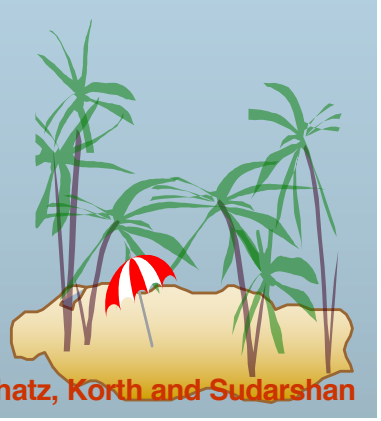


# Monotonicity

- Relational operators: $\Pi$, $\sigma$, $\times$, $\cup$, ,$\cap$, and $\rho$ (as well as expressions of this operators) are monotonic.
- Set difference and division are nonmonotonic and so are updates
- Relational algebra expression containing negation, or division, or aggregates, or updates may be nonmonotonic.
- Similarly, Datalog programs without negation are monotonic, but Datalog programs with negation (or aggregates) may not be monotonic
- Semantics and efficient computation of programs with negation is a major research challenge—e.g., nonmonotonic reasoning in AI.

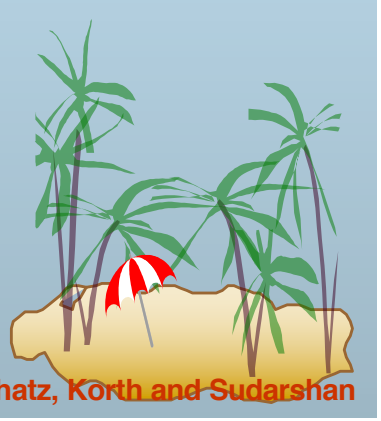
# Forms and Graphical User Interfaces

- Most naive users interact with databases using form interfaces with graphical interaction facilities
  - ★ Web interfaces are the most common kind, but there are many others
  - ★ Forms interfaces usually provide mechanisms to check for correctness of user input, and automatically fill in fields given key values
  - ★ Most database vendors provide convenient mechanisms to create forms interfaces, and to link form actions to database actions performed using SQL



# Report Generators

- Report generators are tools to generate human-readable summary reports from a database
  - ★ They integrate database querying with creation of formatted text and graphical charts
  - ★ Reports can be defined once and executed periodically to get current information from the database.
  - ★ Example of report (next page)
  - ★ Microsoft's Object Linking and Embedding (OLE) provides a convenient way of embedding objects such as charts and tables generated from the database into other objects such as Word documents.

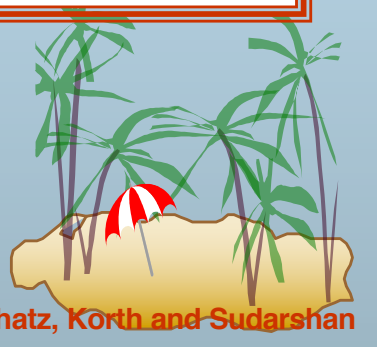


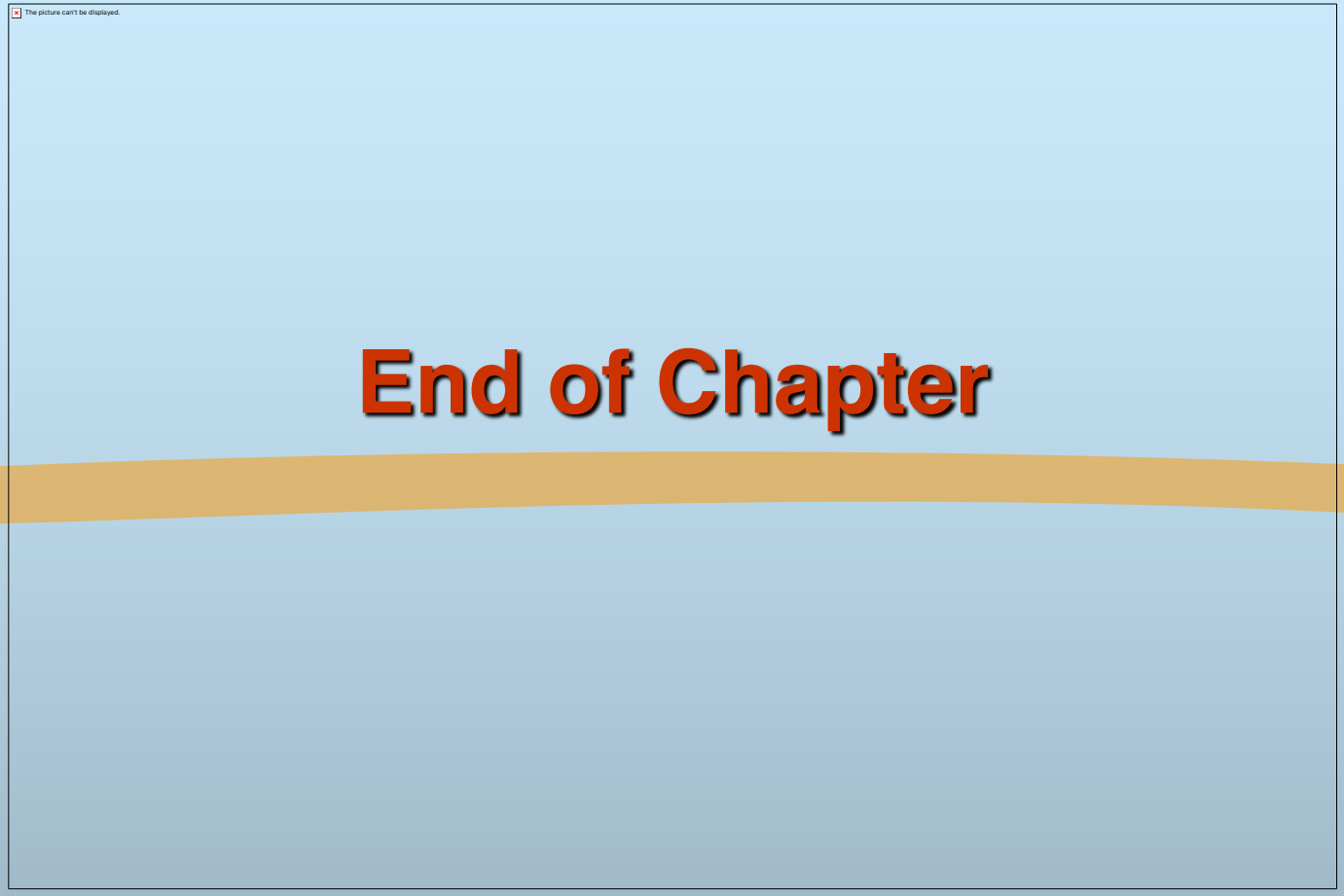
# A Formatted Report

**Acme Supply Company Inc.**
**Quarterly Sales Report**

Period: Jan. 1 to March 31, 2001

| Region | Category | Sales | Subtotal |
|---|---|---|---|
| North | Computer Hardware | 1,000,000 | |
| | Computer Software | 500,000 | |
| | All categories | | 1,500,000 |
| South | Computer Hardware | 200,000 | |
| | Computer Software | 400,000 | |
| | All categories | | 600,000 |
| | | **Total Sales** | 2,100,000 |






# End of Chapter