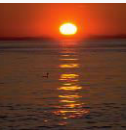




# Chapter 4: Advanced SQL

**Database System Concepts, 5th Ed.**

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# Chapter 4: Advanced SQL

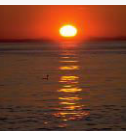
- SQL Data Types and Schemas
- Integrity Constraints
- Authorization
- Embedded SQL
- Dynamic SQL
- Functions and Procedural Constructs\*\*
- Recursive Queries\*\*
- Advanced SQL Features\*\*





# Built-in Data Types in SQL

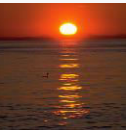
- **date:** Dates, containing a (4 digit) year, month and date
  - Example: **date** '2005-7-27'
- **time:** Time of day, in hours, minutes and seconds.
  - Example: **time** '09:00:30'      **time** '09:00:30.75'
- **timestamp:** date plus time of day
  - Example: **timestamp** '2005-7-27 09:00:30.75'
- **interval:** period of time
  - Example: **interval** '1' day
  - Subtracting a date/time/timestamp value from another gives an interval value
  - Interval values can be added to date/time/timestamp values





# Build-in Data Types in SQL (Cont.)

- Can extract values of individual fields from date/time/timestamp
  - Example: **extract (year from r.starttime)**
- Can cast string types to date/time/timestamp
  - Example: **cast <string-valued-expression> as date**
  - Example: **cast <string-valued-expression> as time**





# User-Defined Types

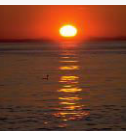
- **create type** construct in SQL creates user-defined type

**create type** *Dollars* **as numeric (12,2) final**

- **create domain** construct in SQL-92 creates user-defined domain types

**create domain** *person\_name* **char(20) not null**

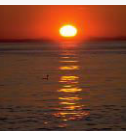
- Types and domains are similar. Domains can have constraints, such as **not null**, specified on them.





# Domain Constraints

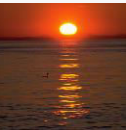
- **Domain constraints** are the most elementary form of integrity constraint. They test values inserted in the database, and test queries to ensure that the comparisons make sense.
- New domains can be created from existing data types
  - Example: **create domain Dollars numeric(12, 2)**  
**create domain Pounds numeric(12,2)**
- We cannot assign or compare a value of type Dollars to a value of type Pounds.
  - However, we can convert type as below  
(**cast** *r.A as Pounds*)  
(Should also multiply by the dollar-to-pound conversion-rate)





# Large-Object Types

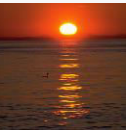
- Large objects (photos, videos, CAD files, etc.) are stored as a *large object*:
  - **blob**: binary large object -- object is a large collection of uninterpreted binary data (whose interpretation is left to an application outside of the database system)
  - **clob**: character large object -- object is a large collection of character data
  - When a query returns a large object, a pointer is returned rather than the large object itself.





# Integrity Constraints

- Integrity constraints guard against accidental damage to the database, by ensuring that authorized changes to the database do not result in a loss of data consistency.
  - A checking account must have a balance greater than \$10,000.00
  - A salary of a bank employee must be at least \$4.00 an hour
  - A customer must have a (non-null) phone number

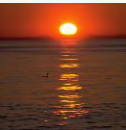






# Constraints on a Single Relation

- not null
- primary key
- unique
- **check** ( $P$ ), where  $P$  is a predicate



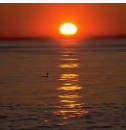


# Not Null Constraint

- Declare *branch\_name* for *branch* is **not null**  
*branch\_name* **char(15) not null**

- Declare the domain *Dollars* to be **not null**

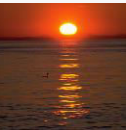
**create domain *Dollars* numeric(12,2) not null**





# The Unique Constraint

- **unique** (  $A_1, A_2, \dots, A_m$  )
- The unique specification states that the attributes  
     $A_1, A_2, \dots, A_m$   
form a candidate key.
- Candidate keys are permitted to be null (in contrast to primary keys).



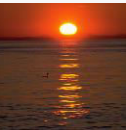


# The check clause

- **check** ( $P$ ), where  $P$  is a predicate

Example: Declare *branch\_name* as the primary key for *branch* and ensure that the values of *assets* are non-negative.

```
create table branch
  (branch_name    char(15),
   branch_city   char(30),
   assets         integer,
   primary key (branch_name),
   check (assets >= 0))
```



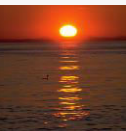


# The check clause (Cont.)

- The **check** clause in SQL-92 permits domains to be restricted:
  - Use **check** clause to ensure that an `hourly_wage` domain allows only values greater than a specified value.

```
create domain hourly_wage numeric(5,2)  
               constraint value_test check(value > = 4.00)
```

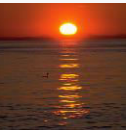
- The domain has a constraint that ensures that the `hourly_wage` is greater than 4.00
- The clause **constraint** *value\_test* is optional; useful to indicate which constraint an update violated.





# Referential Integrity

- Ensures that a value that appears in one relation for a given set of attributes also appears for a certain set of attributes in another relation.
  - Example: If “Perryridge” is a branch name appearing in one of the tuples in the *account* relation, then there exists a tuple in the *branch* relation for branch “Perryridge”.
- Primary and candidate keys and foreign keys can be specified as part of the SQL **create table** statement:
  - The **primary key** clause lists attributes that comprise the primary key.
  - The **unique key** clause lists attributes that comprise a candidate key.
  - The **foreign key** clause lists the attributes that comprise the foreign key and the name of the relation referenced by the foreign key. By default, a foreign key references the primary key attributes of the referenced table.





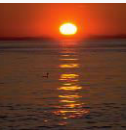
# Referential Integrity in SQL – Example

**create table** *customer*

*(customer\_name*     **char**(20),  
*customer\_street*   **char**(30),  
*customer\_city*      **char**(30),  
**primary key** (*customer\_name* ))

**create table** *branch*

*(branch\_name*        **char**(15),  
*branch\_city*        **char**(30),  
*assets*               **numeric**(12,2),  
**primary key** (*branch\_name* ))





# Referential Integrity in SQL – Example (Cont.)

**create table** *account*

*(account\_number* **char**(10),

*branch\_name* **char**(15),

*balance* **integer**,

**primary key** (*account\_number*),

**foreign key** (*branch\_name*) **references** *branch* )

**create table** *depositor*

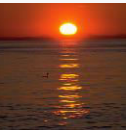
*(customer\_name* **char**(20),

*account\_number* **char**(10),

**primary key** (*customer\_name*, *account\_number*),

**foreign key** (*account\_number*) **references** *account*,

**foreign key** (*customer\_name*) **references** *customer* )

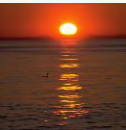






# Assertions

- An **assertion** is a predicate expressing a condition that we wish the database always to satisfy.
- An assertion in SQL takes the form  
**create assertion** <assertion-name> **check** <predicate>
- When an assertion is made, the system tests it for validity, and tests it again on every update that may violate the assertion
  - This testing may introduce a significant amount of overhead; hence assertions should be used with great care.
- Asserting  
for all  $X$ ,  $P(X)$   
is achieved in a round-about fashion using  
not exists  $X$  such that not  $P(X)$

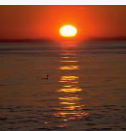




# Assertion Example

- Every loan has at least one borrower who maintains an account with a minimum balance or \$1000.00

```
create assertion balance_constraint check  
  (not exists (  
    select *  
  
  from loan  
  
  where not exists (  
    select *  
    from borrower, depositor, account  
    where loan.loan_number = borrower.loan_number  
      and borrower.customer_name = depositor.customer_name  
      and depositor.account_number = account.account_number  
      and account.balance >= 1000)))
```





# Assertion Example

- The sum of all loan amounts for each branch must be less than the sum of all account balances at the branch.

```
create assertion sum_constraint check  
  (not exists (select *  
    from branch  
    where (select sum(amount)  
      from loan  
      where loan.branch_name =  
        branch.branch_name)  
    >= (select sum (amount)  
      from account  
      where loan.branch_name =  
        branch.branch_name )))
```





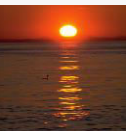
# Authorization

Forms of authorization on parts of the database:

- **Read** - allows reading, but not modification of data.
- **Insert** - allows insertion of new data, but not modification of existing data.
- **Update** - allows modification, but not deletion of data.
- **Delete** - allows deletion of data.

Forms of authorization to modify the database schema (covered in Chapter 8):

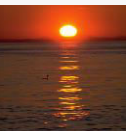
- **Index** - allows creation and deletion of indices.
- **Resources** - allows creation of new relations.
- **Alteration** - allows addition or deletion of attributes in a relation.
- **Drop** - allows deletion of relations.





# Authorization Specification in SQL

- The **grant** statement is used to confer authorization
  - grant** <privilege list>
  - on** <relation name or view name> **to** <user list>
- <user list> is:
  - a user-id
  - **public**, which allows all valid users the privilege granted
  - A role (more on this in Chapter 8)
- Granting a privilege on a view does not imply granting any privileges on the underlying relations.
- The grantor of the privilege must already hold the privilege on the specified item (or be the database administrator).



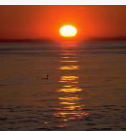


# Privileges in SQL

- **select**: allows read access to relation, or the ability to query using the view
  - Example: grant users  $U_1$ ,  $U_2$ , and  $U_3$  **select** authorization on the *branch* relation:

**grant select on *branch* to  $U_1$ ,  $U_2$ ,  $U_3$**

- **insert**: the ability to insert tuples
- **update**: the ability to update using the SQL update statement
- **delete**: the ability to delete tuples.
- **all privileges**: used as a short form for all the allowable privileges
- more in Chapter 8





# Revoking Authorization in SQL

- The **revoke** statement is used to revoke authorization.

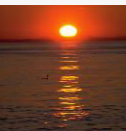
**revoke** <privilege list>

**on** <relation name or view name> **from** <user list>

- Example:

**revoke select on** *branch* **from**  $U_1, U_2, U_3$

- <privilege-list> may be **all** to revoke all privileges the revokee may hold.
- If <revokee-list> includes **public**, all users lose the privilege except those granted it explicitly.
- If the same privilege was granted twice to the same user by different grantees, the user may retain the privilege after the revocation.
- All privileges that depend on the privilege being revoked are also revoked.



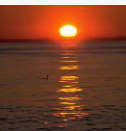


# Embedded SQL

- The SQL standard defines embeddings of SQL in a variety of programming languages such as C, Java, and Cobol.
- A language to which SQL queries are embedded is referred to as a **host language**, and the SQL structures permitted in the host language comprise *embedded SQL*.
- The basic form of these languages follows that of the System R embedding of SQL into PL/I.
- **EXEC SQL** statement is used to identify embedded SQL request to the preprocessor

EXEC SQL <embedded SQL statement > END\_EXEC

Note: this varies by language (for example, the Java embedding uses  
# SQL { .... }; )







# Example Query

- From within a host language, find the names and cities of customers with more than the variable **amount** dollars in some account.
- Specify the query in SQL and declare a *cursor* for it

EXEC SQL

**declare** *c* **cursor for**

**select** *depositor.customer\_name, customer\_city*

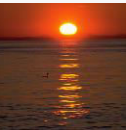
**from** *depositor, customer, account*

**where** *depositor.customer\_name = customer.customer\_name*

**and** *depositor account\_number = account.account\_number*

**and** *account.balance > :amount*

END\_EXEC





# Embedded SQL (Cont.)

- The **open** statement causes the query to be evaluated

EXEC SQL **open** *c* END\_EXEC

- The **fetch** statement causes the values of one tuple in the query result to be placed on host language variables.

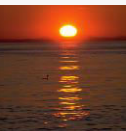
EXEC SQL **fetch** *c into* :*cn*, :*cc* END\_EXEC

Repeated calls to **fetch** get successive tuples in the query result

- A variable called SQLSTATE in the SQL communication area (SQLCA) gets set to '02000' to indicate no more data is available
- The **close** statement causes the database system to delete the temporary relation that holds the result of the query.

EXEC SQL **close** *c* END\_EXEC

Note: above details vary with language. For example, the Java embedding defines Java iterators to step through result tuples.





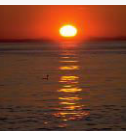
# Updates Through Cursors

- Can update tuples fetched by cursor by declaring that the cursor is for update

```
declare c cursor for  
  select *  
  from account  
  where branch_name = 'Perryridge'  
for update
```

- To update tuple at the current location of cursor *c*

```
update account  
  set balance = balance + 100  
  where current of c
```





# Dynamic SQL

- Allows programs to construct and submit SQL queries at run time.
- Example of the use of dynamic SQL from within a C program.

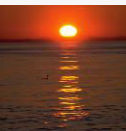
```
char * sqlprog = "update account  
                  set balance = balance * 1.05  
                  where account_number = ?"
```

```
EXEC SQL prepare dynprog from :sqlprog;
```

```
char account[10] = "A-101";
```

```
EXEC SQL execute dynprog using :account;
```

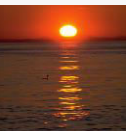
- The dynamic SQL program contains a ?, which is a place holder for a value that is provided when the SQL program is executed.





# ODBC and JDBC

- API (application-program interface) for a program to interact with a database server
- Application makes calls to
  - Connect with the database server
  - Send SQL commands to the database server
  - Fetch tuples of result one-by-one into program variables
- ODBC (Open Database Connectivity) works with C, C++, C#, and Visual Basic
- JDBC (Java Database Connectivity) works with Java





# ODBC

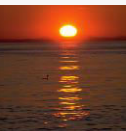
- Open DataBase Connectivity(ODBC) standard
  - standard for application program to communicate with a database server.
  - application program interface (API) to
    - ▶ open a connection with a database,
    - ▶ send queries and updates,
    - ▶ get back results.
- Applications such as GUI, spreadsheets, etc. can use ODBC





# ODBC (Cont.)

- Each database system supporting ODBC provides a "driver" library that must be linked with the client program.
- When client program makes an ODBC API call, the code in the library communicates with the server to carry out the requested action, and fetch results.
- ODBC program first allocates an SQL environment, then a database connection handle.
- Opens database connection using `SQLConnect()`. Parameters for `SQLConnect`:
  - connection handle,
  - the server to which to connect
  - the user identifier,
  - password
- Must also specify types of arguments:
  - `SQL_NTS` denotes previous argument is a null-terminated string.

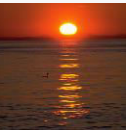




# ODBC Code

```
■ int ODBCexample()
{
    RETCODE error;
    HENV  env;   /* environment */
    HDBC  conn; /* database connection */
    SQLAllocEnv(&env);
    SQLAllocConnect(env, &conn);
    SQLConnect(conn, "aura.bell-labs.com", SQL_NTS, "avi", SQL_NTS,
        "avipasswd", SQL_NTS);
    { .... Do actual work ... }

    SQLDisconnect(conn);
    SQLFreeConnect(conn);
    SQLFreeEnv(env);
}
```

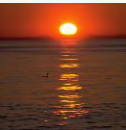






# ODBC Code (Cont.)

- Program sends SQL commands to the database by using `SQLExecDirect`
- Result tuples are fetched using `SQLFetch()`
- `SQLBindCol()` binds C language variables to attributes of the query result
  - When a tuple is fetched, its attribute values are automatically stored in corresponding C variables.
  - Arguments to `SQLBindCol()`
    - ▶ ODBC stmt variable, attribute position in query result
    - ▶ The type conversion from SQL to C.
    - ▶ The address of the variable.
    - ▶ For variable-length types like character arrays,
      - The maximum length of the variable
      - Location to store actual length when a tuple is fetched.
      - Note: A negative value returned for the length field indicates null value
- Good programming requires checking results of every function call for errors; we have omitted most checks for brevity.





# ODBC Code (Cont.)

- Main body of program

```
char branchname[80];
float balance;
int lenOut1, lenOut2;
HSTMT stmt;

SQLAllocStmt(conn, &stmt);
char * sqlquery = "select branch_name, sum (balance)
                  from account
                  group by branch_name";

error = SQLExecDirect(stmt, sqlquery, SQL_NTS);
if (error == SQL_SUCCESS) {
    SQLBindCol(stmt, 1, SQL_C_CHAR, branchname, 80,
    &lenOut1);
    SQLBindCol(stmt, 2, SQL_C_FLOAT, &balance, 0,
    &lenOut2);

    while (SQLFetch(stmt) >= SQL_SUCCESS) {
        printf (" %s %g\n", branchname, balance);
    }
}
SQLFreeStmt(stmt, SQL_DROP);
```





# More ODBC Features

## ■ Prepared Statement

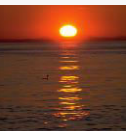
- SQL statement prepared: compiled at the database
- Can have placeholders: E.g. insert into account values(?,?,?)
- Repeatedly executed with actual values for the placeholders

## ■ Metadata features

- finding all the relations in the database and
- finding the names and types of columns of a query result or a relation in the database.

## ■ By default, each SQL statement is treated as a separate transaction that is committed automatically.

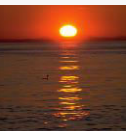
- Can turn off automatic commit on a connection
  - ▶ `SQLSetConnectOption(conn, SQL_AUTOCOMMIT, 0)`
- transactions must then be committed or rolled back explicitly by
  - ▶ `SQLTransact(conn, SQL_COMMIT)` or
  - ▶ `SQLTransact(conn, SQL_ROLLBACK)`





# ODBC Conformance Levels

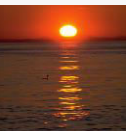
- Conformance levels specify subsets of the functionality defined by the standard.
  - Core
  - Level 1 requires support for metadata querying
  - Level 2 requires ability to send and retrieve arrays of parameter values and more detailed catalog information.
- SQL Call Level Interface (CLI) standard similar to ODBC interface, but with some minor differences.





# JDBC

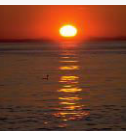
- **JDBC** is a Java API for communicating with database systems supporting SQL
- JDBC supports a variety of features for querying and updating data, and for retrieving query results
- JDBC also supports metadata retrieval, such as querying about relations present in the database and the names and types of relation attributes
- Model for communicating with the database:
  - Open a connection
  - Create a “statement” object
  - Execute queries using the Statement object to send queries and fetch results
  - Exception mechanism to handle errors





# JDBC Code

```
public static void JDBCexample(String dbid, String userid, String passwd)
{
    try {
        Class.forName ("oracle.jdbc.driver.OracleDriver");
        Connection conn = DriverManager.getConnection(
            "jdbc:oracle:thin:@aura.bell-labs.com:2000:bankdb", userid, passwd);
        Statement stmt = conn.createStatement();
        ... Do Actual Work ....
        stmt.close();
        conn.close();
    }
    catch (SQLException sqle) {
        System.out.println("SQLException : " + sqle);
    }
}
```





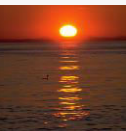
# JDBC Code (Cont.)

- Update to database

```
try {  
    stmt.executeUpdate( "insert into account values  
                        ('A-9732', 'Perryridge', 1200)");  
} catch (SQLException sqle) {  
    System.out.println("Could not insert tuple. " + sqle);  
}
```

- Execute query and fetch and print results

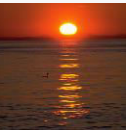
```
ResultSet rset = stmt.executeQuery( "select branch_name,  
                                     avg(balance)  
                                     from account  
                                     group by branch_name");  
  
while (rset.next()) {  
    System.out.println(  
        rset.getString("branch_name") + " " + rset.getFloat(2));  
}
```





# JDBC Code Details

- Getting result fields:
  - **rs.getString("branchname")** and **rs.getString(1)** equivalent if **branchname** is the first argument of select result.
- Dealing with Null values  
**int a = rs.getInt("a");**  
**if (rs.isNull()) Systems.out.println("Got null value");**

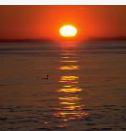






# Procedural Extensions and Stored Procedures

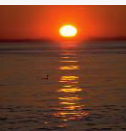
- SQL provides a **module** language
  - Permits definition of procedures in SQL, with if-then-else statements, for and while loops, etc.
  - more in Chapter 9
- Stored Procedures
  - Can store procedures in the database
  - then execute them using the **call** statement
  - permit external applications to operate on the database without knowing about internal details
- These features are covered in Chapter 9 (Object Relational Databases)





# Functions and Procedures

- SQL:1999 supports functions and procedures
  - Functions/procedures can be written in SQL itself, or in an external programming language
  - Functions are particularly useful with specialized data types such as images and geometric objects
    - ▶ Example: functions to check if polygons overlap, or to compare images for similarity
  - Some database systems support **table-valued functions**, which can return a relation as a result
- SQL:1999 also supports a rich set of imperative constructs, including
  - Loops, if-then-else, assignment
- Many databases have proprietary procedural extensions to SQL that differ from SQL:1999





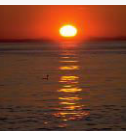
# SQL Functions

- Define a function that, given the name of a customer, returns the count of the number of accounts owned by the customer.

```
create function account_count (customer_name varchar(20))  
returns integer  
begin  
  declare a_count integer;  
  select count ( * ) into a_count  
  from depositor  
  where depositor.customer_name = customer_name  
  return a_count;  
end
```

- Find the name and address of each customer that has more than one account.

```
select customer_name, customer_street, customer_city  
from customer  
where account_count (customer_name) > 1
```





# Table Functions

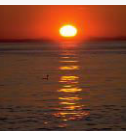
- SQL:2003 added functions that return a relation as a result
- Example: Return all accounts owned by a given customer

**create function** *accounts\_of* (*customer\_name* **char**(20)

**returns table** ( *account\_number* **char**(10),  
*branch\_name* **char**(15)  
*balance* **numeric**(12,2))

**return table**

(**select** *account\_number*, *branch\_name*, *balance*  
**from** *account* *A*  
**where exists** (  
    **select** \*  
    **from** *depositor* *D*  
    **where** *D.customer\_name* = *accounts\_of.customer\_name*  
        **and** *D.account\_number* = *A.account\_number* ))





# Table Functions (cont'd)

- Usage

```
select *  
from table (accounts_of ('Smith'))
```





# SQL Procedures

- The *author\_count* function could instead be written as procedure:

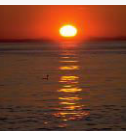
```
create procedure account_count_proc (in title varchar(20),  
                                     out a_count integer)  
begin  
    select count(author) into a_count  
    from depositor  
    where depositor.customer_name = account_count_proc.customer_name  
end
```

- Procedures can be invoked either from an SQL procedure or from embedded SQL, using the **call** statement.

```
declare a_count integer;  
call account_count_proc( 'Smith', a_count);
```

Procedures and functions can be invoked also from dynamic SQL

- SQL:1999 allows more than one function/procedure of the same name (called name **overloading**), as long as the number of arguments differ, or at least the types of the arguments differ





# Procedural Constructs

- Compound statement: **begin ... end**,
  - May contain multiple SQL statements between **begin** and **end**.
  - Local variables can be declared within a compound statements
- **While** and **repeat** statements:

```
declare  $n$  integer default 0;
```

```
while  $n < 10$  do
```

```
    set  $n = n + 1$ 
```

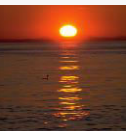
```
end while
```

```
repeat
```

```
    set  $n = n - 1$ 
```

```
until  $n = 0$ 
```

```
end repeat
```



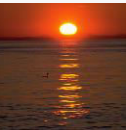


# Procedural Constructs (Cont.)

## ■ For loop

- Permits iteration over all results of a query
- Example: find total of all balances at the Perryridge branch

```
declare n integer default 0;  
for r as  
    select balance from account  
    where branch_name = 'Perryridge'  
do  
    set n = n + r.balance  
end for
```







# Procedural Constructs (cont.)

- Conditional statements (**if-then-else**)

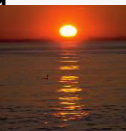
E.g. To find sum of balances for each of three categories of accounts (with balance <1000, >=1000 and <5000, >= 5000)

```
if r.balance < 1000
  then set l = l + r.balance
elseif r.balance < 5000
  then set m = m + r.balance
else set h = h + r.balance
end if
```

- SQL:1999 also supports a **case** statement similar to C case statement
- Signaling of exception conditions, and declaring handlers for exceptions

```
declare out_of_stock condition
declare exit handler for out_of_stock
begin
...
.. signal out-of-stock
end
```

- The handler here is **exit** -- causes enclosing **begin..end** to be exited
- Other actions possible on exception





# External Language Functions/Procedures

- SQL:1999 permits the use of functions and procedures written in other languages such as C or C++
- Declaring external language procedures and functions

```
create procedure account_count_proc(in customer_name varchar(20),  
                                     out count integer)
```

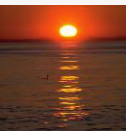
```
language C
```

```
external name ' /usr/avi/bin/account_count_proc'
```

```
create function account_count(customer_name varchar(20))  
returns integer
```

```
language C
```

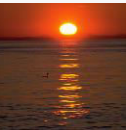
```
external name ' /usr/avi/bin/author_count'
```





# External Language Routines (Cont.)

- Benefits of external language functions/procedures:
  - more efficient for many operations, and more expressive power
- Drawbacks
  - Code to implement function may need to be loaded into database system and executed in the database system's address space
    - ▶ risk of accidental corruption of database structures
    - ▶ security risk, allowing users access to unauthorized data
  - There are alternatives, which give good security at the cost of potentially worse performance
  - Direct execution in the database system's space is used when efficiency is more important than security





# Security with External Language Routines

- To deal with security problems
  - Use **sandbox** techniques
    - ▶ that is use a safe language like Java, which cannot be used to access/damage other parts of the database code
  - Or, run external language functions/procedures in a separate process, with no access to the database process' memory
    - ▶ Parameters and results communicated via inter-process communication
- Both have performance overheads
- Many database systems support both above approaches as well as direct executing in database system address space



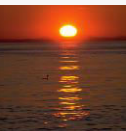


# Recursion in SQL

- SQL:1999 permits recursive view definition
- Example: find all employee-manager pairs, where the employee reports to the manager directly or indirectly (that is manager's manager, manager's manager's manager, etc.)

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

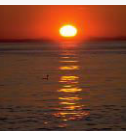
This example view, *empl*, is called the *transitive closure* of the *manager* relation





# 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
- Computing transitive closure
  - The next slide shows a *manager* relation
  - Each step of the iterative process constructs an extended version of *empl* from its recursive definition.
  - The final result is called the *fixed point* of the recursive view definition.
- Recursive views are required to be *monotonic*. That is, if we add tuples to *manger* the view contains all of the tuples it contained before, plus possibly more

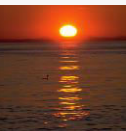




# Example of Fixed-Point Computation

<i>employee_name</i>	<i>manager_name</i>
Alon	Barinsky
Barinsky	Estovar
Corbin	Duarte
Duarte	Jones
Estovar	Jones
Jones	Klinger
Rensal	Klinger

<i>Iteration number</i>	<i>Tuples in empl</i>
0	
1	(Duarte), (Estovar)
2	(Duarte), (Estovar), (Barinsky), (Corbin)
3	(Duarte), (Estovar), (Barinsky), (Corbin), (Alon)
4	(Duarte), (Estovar), (Barinsky), (Corbin), (Alon)

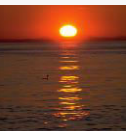




# Advanced SQL Features\*\*

- Create a table with the same schema as an existing table:  
**create table** *temp\_account* **like** *account*
- SQL:2003 allows subqueries to occur *anywhere* a value is required provided the subquery returns only one value. This applies to updates as well
- SQL:2003 allows subqueries in the **from** clause to access attributes of other relations in the **from** clause using the **lateral** construct:

```
select C.customer_name, num_accounts
from customer C,
      lateral (select count(*)
               from account A
               where A.customer_name = C.customer_name )
as this_customer (num_accounts )
```



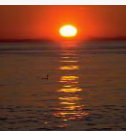




# Advanced SQL Features (cont'd)

- Merge construct allows batch processing of updates.
- Example: relation *funds\_received* (*account\_number*, *amount*) has batch of deposits to be added to the proper account in the *account* relation

```
merge into account as A  
  using (select *  
          from funds_received as F)  
  on (A.account_number = F.account_number)  
  when matched then  
    update set balance = balance + F.amount
```





# End of Chapter

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